Cereal Systems Initiative for South Asia
Phase III

Annual Report
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Acronyms and Abbreviations

Acronym	Full Name
AAS	Agricultural Advisory Services
ADS	Agriculture Development Strategy
AIP	Agricultural Inputs Project
AIRN	Agriculture Inputs Retailers' Network
AMTRC	Agricultural Machinery Testing and Research Center
BARI	Bangladesh Agriculture Research Institute
BRRI	Bangladesh Rice Research Institute
BWMRI	Bangladesh Wheat and Maize Research Institute
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
CSISA-MI	Cereal Systems Initiative for South Asia-Mechanization and Irrigation
DAE	Department of Agricultural Extension
DFTQC	Department of Food Technology and Quality Control
DoA	Department of Agriculture
DSR	Direct-seeded rice
FAW	Fall armyworm
fb	Followed by
FtF	Feed the Future
GIS	Geographic information systems
HRS	Healthy rice seedlings
HW	Hand-weeding
iDE	International Development Enterprises
IFPRI	International Food Policy Research Institute
IRRI	International Rice Research Institute
KISAN	Knowledge-based Integrated Sustainable Agriculture and Nutrition
MoA	Ministry of Agriculture
NAMEA	Nepal Agricultural Machinery Entrepreneurs' Association
NARC	Nepal Agricultural Research Council
NARES	National Agriculture Research and Extension System
NGO	Non-governmental organization
NSAF	Nepal Seed and Fertilizer project
PERSUAP	Pesticide evaluation report and safer use action plan
PMAMP	Prime Minister's Agriculture Modernization Project
PQR	Premium quality rice
RVC	Rice Value Chain
UN-CSAM	United Nations Center for Sustainable Agricultural Mechanization
USAID	United States Agency for International Development

CSISA Phase III

Context, Approach, and Theory of Change

Following the food price crisis of 2007–8, agricultural research and development efforts in South Asia have received considerable public, private sector, and donor investment, particularly in the relatively impoverished areas of the Eastern Indo-Gangetic Plains. Nevertheless, re-investments in agriculture have been less adept at supporting transformative change than was originally envisaged. While progress has been made in addressing some of the systemic weaknesses that contribute to low rates of rural growth, many persist:

- **Research organizations** narrowly construe their mandates and are only partially oriented towards the clients of research outputs;
- **Extension** primarily focuses on single technologies or generalized 'packages of practices' that are not underpinned by rigorous field evaluations that lead towards better targeting;
- **Livelihoods** initiatives do a commendable job of reaching underserved communities, including women farmers, but rarely have the technical competence to match their reach;
- The **private sector** – although learning quickly – lacks deep experience in the emerging markets in the region along with the types of location intelligence that can steer engagement;
- **Small entrepreneurs** generally lack access to support services, both business development and technical;
- Progressive **policies** ostensibly support farmers, but just as often impede private investment;
- **Cooperation across organizations** in the agricultural research-for-development space is, in most cases, limited.

Layered onto these dynamics are the risks inherent in cropping in areas where weather patterns are erratic, water resources are poorly developed, heat stress is a binding constraint, and timely field operations are often compromised by a diminishing supply of rural labor. Despite these shortcomings and production challenges, there is considerable promise that the many individual strengths within the innovation system[1] in South Asia can be marshaled and coordinated to spur and sustain transformative change.

With support from the Bill & Melinda Gates Foundation and U.S. Agency for International Development, the Cereal Systems Initiative for South Asia (CSISA) has worked as an eco-regional initiative to support agricultural development in South Asia since 2009. **CSISA's aim is to use sustainable intensification technologies and management practices to enhance the productivity of cereal-based cropping systems, increase farm incomes, and reduce agriculture's environmental footprint**[2]. As a science-driven and impacts-oriented initiative, we reside at the intersection of a diverse set of partners in the public and private sectors, occupying the 'messy middle' where research meets development. By engaging with a network of partners,

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[1] The World Bank (2012) defines innovation systems as '…. a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance.

[2] Pretty and Bahrucha (2014) define sustainable intensification '….as a process or system where agricultural yields are increased without adverse environmental impact and without the conversion of additional non-agricultural land. The concept does not articulate or privilege any particular vision or method of agricultural production. Rather, it emphasizes ends rather than means…. The combination of the terms 'sustainable' and 'intensification' is an attempt to indicate that desirable out comes around both more food and improved environmental goods and services could be achieved by a variety of means.'

CSISA is built on the premise that transformative development typically requires not one single change, but the orchestration of several.

In **Phase III** (2015–20), CSISA places emphasizes ensuring that partners in the public and private sectors are better poised to contribute to change on a sustaining basis by addressing areas of systemic weakness (as listed above). By addressing these areas and fostering new connections and collaborative efforts across the innovation system, CSISA will seek to mainstream elements of our approach and to ensure a successful exit at the termination of Phase III.

CSISA Phase III pursues four **inter-linked primary outcomes**:

1. Widespread adoption of sustainable intensification technologies and management practices in South Asian cereal systems
2. Mainstreaming innovation processes into the programming of national, state, and district-level government institutions in order to improve the impacts achieved with current and future investments in agricultural R&D
3. Generating critical knowledge and research-based products that will support technology scaling and impact generation
4. Improving the policy environment to support sustainable intensification, prioritizing scaling up work with national partners to address policy constraints and improve the policy environment for realizing sustainable intensification futures in CSISA's target geographies.

Major Activities and Accomplishments

As conveyed in the mid-term report, significant funding delays and associated uncertainties about the level of planned support from USAID hampered CSISA activities in FY18. Several partner organization subagreements and a large number of staff contracts were terminated. Despite these challenges, several core research for development activities were maintained as were strategic partnerships for achieving scale.

BANGLADESH

- Promising initial results from field trials conducted in collaboration with the Bangladesh Rice Research Institute have identified key agronomic constraints and methods to overcome these constraints in spring-sown (*aus*) **directly sown rice** crops. CSISA has been instrumental in conducting research on directly sown rice and working with national research and extension partners to spark farmers' initial interest in this new but potentially advantageous technique that saves energy and labor.
- Although favorable weather this year resulted in limited **wheat blast** disease problems, CSISA continues to pioneer techniques for disease control in partnership with national research partners. Key outcomes have included CSISA's support for BARI for the release and multiplication of blast-resistant and zinc enriched wheat variety 'BARI Gom 333.'
- CSISA's interventions to encourage farmers to grow **healthy rice seedlings** continue to yield results. An estimated 51% of the 17,736 farmers who engaged in video shows and trainings have gone on to continue use of better-bet agronomic management techniques to grow healthy rice seedlings on 4,700 hectares in the winter *boro* season. Many of these farmers also carried these practices forward into the 2018 monsoon (*aman*) season, with 9,616 hectares benefiting from healthy rice seedling practices. These results are underscore the simple yet impactful work that can be done to orient

farmers in easy-to-implement better-bet agronomic techniques that can be adopted and sustained over multiple seasons.

- **Fall armyworm** (FAW), *Spodoptera frugiperda*, has been identified for the first time on the Indian subcontinent. To formulate an emergency response plan, CSISA convened a workshop with senior officials from USAID, Ministry of Agriculture, Department of Agriculture Extension, Bangladesh Rice Research Institute, Bangladesh Agricultural Research Centre, the Bangladesh Agricultural Research Institute and the Bangladesh Wheat and Maize Research Institute. A national-level follow-up workshop will be convened in late 2018 or early 2019 to develop collaborative plans for pest monitoring and rapid action responses to the threat of FAW in Asia.
- CSISA continued **integrated weed management** research focused on rice by leveraging partnerships with the Bangladesh Rice Research Institute (BRRI). Two promising control options incorporating new classes of safe and effective herbicides reduced weed control costs by \$66 – 73 ha^{-1} in the *aman* season and US \$ 57 – 58 ha^{-1} in the *boro* season. Labor requirements were also reduced by 18 person-days per hectare in the summer monsoon *aman* season and by 16 person-days in the winter season. These data that will be used in the next year to make these herbicide molecules (mefecenat + bensulfuron methyl, bispyribac sodium, and penoxsulam) available to farmers through commercial pathways following verification and approval of PERSUAP status.

NEPAL

- At the national level, CSISA has retained a strong focus on providing **strategic support for the government-led Prime Minister's Agriculture Modernization Project (PMAMP)**, the national flagship for spurring sector growth, to help them meet their ambitious agricultural development goals by strengthening evidence-based programming for intervention prioritization, targeting, and developing integrative technology scaling strategies. During the reporting period, CSISA assisted the PMAMP leadership convene the first national forums for maize, wheat, rice, and mechanization that united public, private, and civil society organizations towards common goals and enhanced the types of collaborations required to reach them.
- At regional PMAMP offices, CSISA has provided **technical guidance** on seasonal activity planning and facilitated cross-learning events and 'trainings of trainers' on how to correctly implement and to scale sustainable intensification technologies. As part of this approach, CSISA has equipped PMAMP staff with a host of training and extension materials, including simple 'tips' guides, training videos, and key messaging for social marketing platforms such as FM radio. CSISA recently expanded its collaboration to include the Rice Super Zone in eastern Nepal.
- Data from CSISA's household survey indicates that **for rice production in the western Terai, there is about a 3 t/ha achievable yield gap and >US\$ 500/ha profit gap** in current production systems. The major yield limiting factors to rice intensification are the lack of irrigation facilities, paucity of N and P fertilizer, and late transplanting dates. By documenting 'base of the pyramid' investments, CSISA is helping the PMAMP and other partners set the right investment priorities for extension and technology scaling.
- CSISA's yield and production practice survey for rice confirms the importance of supplemental irrigation for **reducing risks and achieving high and stable crop yields**. Across the Terai districts where the survey was implemented (total of more than > 1,050 households), farmers who irrigated three or four times had rice yields that averaged approximately 4.5 t/ha, whereas farmers who did not irrigate achieved yields of 3.0 t/ha, indicating that water stress in even a 'good' monsoon year reduces rice yield

potential by 33%. Past and ongoing efforts to expand the use of irrigation in Nepal for staple crop production have focused primary on assuring supply by supporting the expansion of infrastructure such as tube wells for groundwater pumping.

- CSISA has been evaluating and promoting drill-sown **direct seeded rice** for the last seven years in select western Terai districts of Nepal. CSISA used survey-based assessment techniques to explore individual farmers perceptions' of DSR, including 21 reasons why farmers do not adopt and nine reasons why farmers adopt. Factors strongly correlated with the non-adoption of DSR as compared to transplanted rice included increased weed pressure and the unavailability of herbicides, seeding machinery and skilled service providers. Additional factors expressed were a low level of confidence in the technology, a poor success rate in crop establishment, a need for assured irrigation and a well-leveled field, the need for intensive knowledge and frequent field monitoring. Despite many constraints to DSR adoption, farmers still continue to use the technology because it eliminates the need for seedling raising and transplanting, as well as lowers the cost of field preparation and crop establishment, increases the opportunities for timely crop establishment, reduces drudgery and labor requirements, increases profit and does not reduce yields compared to the transplanted rice. With the Rice Super Zone program, CSISA is working aggressively to ensure that more farmers and service providers fully understand the benefits of DSR along with management methods to reduced down-side risks.
- In collaboration with the government-led Maize Super Zone program and machinery traders, CSISA provided hands on-training on the operation of the seed drill and power weeder for potential service providers and technicians from the Super Zone and traders in order to help increase mechanization in maize production. The use of a seed drill for seeding and a weeder for earthing up and weed management reduces cultivation costs by 50% compared to current farmers' practice. **With CSISA's facilitation, more than 200 ha of maize were seeded using a seed drill and service provision in new areas in this reporting period.**
- Aflatoxin contamination of food staples is widespread in Nepal, posing both long-term health threats and near-term harm to nutritional outcomes. Although many efforts have been made to characterize the problem, few have offered practical solutions on how to mitigate this issue at the agriculture and nutrition interface. CSISA and the Department of Food Technology and Quality Center (DFTQC) assessed aflatoxin levels in maize and how these levels change with improved agronomy and post-harvest management. Research found that the **pre-harvest aflatoxin level can be minimized through better fertilizer management and post-harvest aflatoxin levels can be dramatically reduced by taking maize grain off the cob and sun drying the grain before storage**. These interventions also align with CSISA's emphasis on scale-appropriate mechanization solutions for smallholders.
- By programming across the value chain and supporting service providers, machinery importers, and government partners by encouraging public-private partnerships, CSISA's ongoing support for reaper-harvester sales has led to over **2,877 machines purchased that are providing harvesting services on over 14,385 hectares of rice and wheat on an annual basis**. In 2014, this technology was not present in Nepal and has only emerged with the support of CSISA.
- Through strengthened markets for zero-tillage drills, CSISA's collaborative effort with partners enabled **1,545 farmers to adopt mechanized wheat sowing on 887 hectares**. Most encouragingly, mechanized seeding adoption has been achieved through the

increased private sector provision of seed drills with more than 70 drills sold for the 2 and 4-wheel tractor platforms during the reporting period.

- CSISA investigated the impacts associated with mini-tiller (5 to 9 horsepower) adoption for land preparation on smallholder rice productivity and technical efficiency in the mid-hills of Nepal. Findings demonstrate that rising on-farm rural wage rates and an emerging decline in draft animal availability are driving adoption of the mini-tiller. Among users, the **mini-tiller increased rice productivity by 1,110 kg/ha and technical efficiency by 12%. Moreover, the analysis revealed that very small farms (≤0.25 ha) that adopt mini-tillers are likely to benefit the most both in terms of gains in rice productivity and technical efficiency.** These findings support policies that favor the expansion of small-scale mechanization in the hill production ecologies of South Asia and highlight the need to foster the emergence of an associated service economy that will permit smallholders access to capital-intensive machinery such as the mini-tiller.

POLICY

- CSISA has been able to generate evidence to support efforts for **increasing the scope and reach of agricultural risk management** throughout the region. In particular, CSISA generated the first field-level evidence on the efficacy of an innovative risk management tool that bundles a novel index insurance product with a yield-enhancing (specifically, reducing yield variability) stress-tolerant rice variety. Additionally, CSISA demonstrated how having insurance generates both ex ante risk mitigation effects as well as ex post income effects, resulting in an expansion in area under higher-value crops and increased investments in modern agricultural inputs during the monsoon season, and more intensive rice production and higher rice productivity during the subsequent dry season.
- CSISA co-organized a high-level **regional stakeholder engagement** to discuss country- and state-level experiences with crop insurance. The goal of the workshop was to provide a platform whereby experiences and ideas can be shared among various stakeholders and across disciplinary and geographic boundaries, all for the enhancement of rural livelihoods in South Asia.
- CSISA partnered with the Nepal Seed and Fertilizer project (NSAF) to jointly determine the **policy roadmap for the fertilizer sector in Nepal** by gathering evidence and synthesizing evidence on the 'true' demand for fertilizers.
- Many activities were suspended during the current reporting period as a result of uncertainty in project funding. In particular, activities around seed systems and markets and agricultural insurance have effectively been reduced to nil, though activities around mechanization and fertility management have been reinvigorated with renewed funding to support these activities.

***Note**: This report reflects a 12-month period when the project's funding became both uncertain and delayed. At one point, it appeared that funding would be dramatically reduced and possibly eliminated. As a result, most of the activities were thereafter suspended or shrunk as we waited to see if funding for FY18 became available. FY18 funding did arrive in August 2018. This report reflects those conditions.*

A. Innovation Toward Impact

A.1 Reducing Risk to Facilitate Uptake of Sustainable Intensification Practices

A.1.1 Directly-sown rice to address labor and energy constraints to precision rice establishment

Dry direct-seeded rice (DSR) is an innovative approach to establish rice crops that has the potential to reduce production cost by saving labor and economizing scarce irrigation water resources. Mechanized DSR can help farmers to establish crops within recommended planting dates by reducing time requirements for crop establishment. When established using farm machinery and seed drills, DSR can also create employment opportunities through service provision – a key plank of the CSISA program. Although DSR is becoming popular in many Asian countries, adoption in Bangladesh has remained limited. CSISA conducts applied research and facilitates extension activities to address the slow adoption rate, which are caused by the following factors:

- Risk of seedling emergence and damage due to cold in the winter *boro* season. This more or less eliminates farmer's ability to sow DSR during this period, despite the ability to better control water in the field because *boro* is primarily irrigated. Late sowing (early to mid-February) is an option to overcome these risks, but early monsoon storms usually begin from mid-April. Such storms can cause severe yield losses.

- In the summer monsoon *aman* season, crop establishment through DSR is at high risk of seed mortality due to excess water and flooding. Soils may also be too wet or flooded to permit mechanical seeding.

- The spring *aus* season is comparatively suitable for DSR; however, *aus* is cultivated on only 6% of land in Bangladesh. Despite this comparatively small area, *aus* provides an opportunity to encourage the expansion of DSR within an appropriate agronomic and environmental niche, while also benefiting a very large number of farmers who practice *aus* rice production.

- Appropriate machinery is also important for DSR. Machinery scale-out and commercialization efforts by CSISA's synergistic Mechanization and Irrigation (CSISA-MI) project have expanded the availability of two-wheel tractor and attachable sowing equipment that can be used to prepare fields and directly sow rice in a single operation. DSR can now be practiced in *aus* growing areas where the appropriate machines are available.

Aus area coverage is slowly increasing in Bangladesh because *boro* rice production is becoming less profitable. This is largely due to the high costs of irrigation for *boro*, while *aus* is predominantly rainfed. Farmers in some areas are also diversifying away from jute cultivation to *aus* rice because of the low availability of surface water required for jute fiber retting, in addition to the generally high labor costs required to harvest and ret the crop. It is also a priority of the government of Bangladesh to expand the *aus* area to reduce pressure on farmers' wallets and groundwater from *boro* production.

In partnership with the Department of Extension, CSISA worked to target the *aus* season for DSR. This initiative aligns with Ministry of Agriculture (MoA) policy to expand *aus* rice production, including DSR crop establishment and farm mechanization. CSISA began testing mechanized DSR during the 2016 *aus* season in USAID's Feed the Future Zone in southern Bangladesh. Based on the successful DSR results from the first season of experimentation (see the previous CSISA annual report), CSISA facilitated an awareness campaign for farmers, stakeholders, and policymakers to encourage farmers to try out DSR *aus* 2017. Additional activities included (i) exploring the most high-potential areas for *aus* DSR through expert consultation, (ii) coordination meetings with seed drill service providers, farmers, and local DAE officers, in addition to machinery traders and input dealers (particularly herbicide dealers). In addition, CSISA conducted (iii) trainings for seed drill service providers on DSR technologies (seeder calibration, precision sowing, safe herbicide use, and weed management) to demonstrate DSR sowing and management to farmers. Finally, (iv) on-farm verification trials on improved weed management practices in DSR were implemented in collaboration with the Bangladesh Rice Research Institute (BRRI). Data from this work can be found in Figure 1. Visits for high-level officials and scientists from BRRI and officers from the DAE were organized to observe the performance and exchange ideas with farmers about DSR. CSISA also worked to facilitate market linkages between dealers and farmers to ensure quality inputs, particularly seeds and low-environmental impact and PERSUAP-approved herbicides, as well as with rice millers and traders interested in marketing DSR rice.

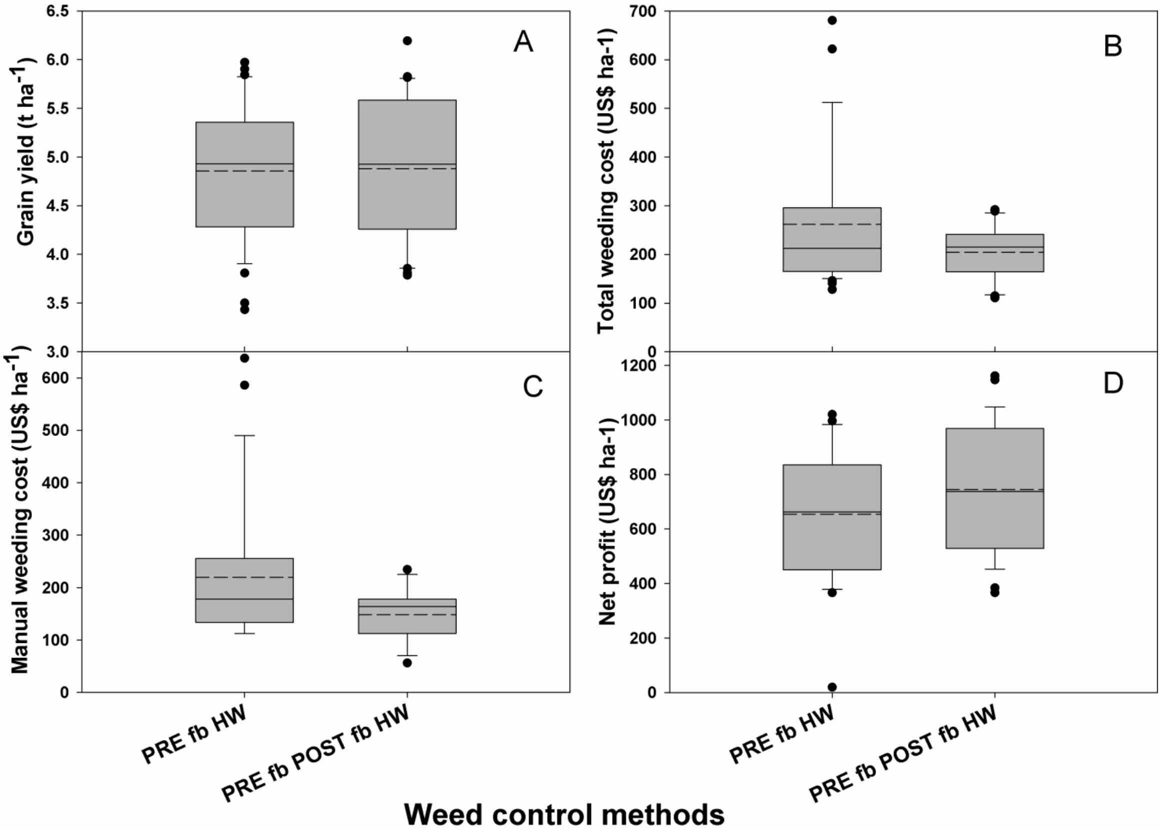


FIG 1. GRAIN YIELD (A), TOTAL WEED CONTROL COSTS (B), MANUAL WEEDING COST (C) AND NET RETURN IN DSR CROPS DURING AUS 2018 SEASON AS AFFECTED BY WEED CONTROL METHODS. THE HORIZONTAL SOLID LINE WITHIN THE BOX REPRESENTS THE MEDIAN, AND HORIZONTAL DASH LINE REPRESENTS THE MEAN, THE BOUNDARY OF THE BOX CLOSEST TO ZERO INDICATES THE 25TH PERCENTILE, THE BOUNDARY OF THE BOX FARTHEST FROM ZERO INDICATES 75TH PERCENTILE. PRE FB HW: PRE-EMERGENCE HERBICIDE FOLLOWED BY HAND WEEDING; PRE FB POST FB HW: PRE-EMERGENCE HERBICIDE FOLLOWED BY POST-EMERGENCE HERBICIDE FOLLOWED BY HAND WEEDING.

CSISA also provided technical support to extension agent staff from DAE, who in turn implemented a subsidy program for *aus* cultivation on around of 200 ha *aus* DSR in the union Goshaidanga, Shailkupa, under Jhenaidah district. Farmers in this area were interested in DSR since it required less water and resulted in lower establishment costs and was a better alternative to jute; however, their major concern with sustaining DSR is weed management.

In comparison to flooded and transplanted rice, weed management is a considerable challenge in DSR. If weeds are not managed properly, rice yield can be significantly reduced. High weed pressure, unavailability of safe and effective herbicides and farmers' limited knowledge about DSR are some of the main reasons for low uptake and lower yields in DSR in the early stages of adoption. Most farmers control weeds in DSR by using herbicides, but knowledge of the most effective, least environmentally damaging, and most affordable herbicides for weed flora encountered in DSR fields in Bangladesh is limited. The on-farm evaluation of weed management options that CSISA conducted in partnership with BRRI showed that farmers could easily manage weeds if they applied integrated weed management principles. The results of weed management trials conducted in *aus* 2017 indicated that the best economic weed management practices are pre-emergence herbicide pendimethalin applied immediately after sowing and irrigation followed by post-emergence herbicide bispyribac at 15–20 days after sowing followed by one hand weeding at 40–45 days after sowing (mentioned in previous reports). These management techniques however require careful implementation and a willingness among farmers to actively manage water.

When implemented outside of the experimental setting and in farmers' own fields, we observed similar patterns: pre-emergence herbicide applied immediately after sowing and irrigation followed by post-emergence herbicide at 15–20 days after sowing followed by one hand weeding performed better than when farmers used only pre-emergence herbicide followed by one hand weeding. Farmers' yield in DSR (mean 4.8 t ha^{-1}) was similar when the following weed management practices were implemented: 1) pre-emergence followed by one-hand weeding and 2) pre-emergence followed by post-emergence followed by one hand weeding. Weed management costs and net profit however varied greatly among these practices. The mean total weed management cost for pre-emergence followed by one hand weeding was US$ 280 ha^{-1}, although it was just \$200 $^{-1}$ for pre-emergence followed by post-emergence followed by one hand weeding. This was due mainly to the higher labor requirement for the pre-emergence followed by one hand weeding practice, indicating that the former is a more beneficial practice.

DAE OFFICIALS AND FARMERS VISIT FIELD PLOTS WITH PARTICULARLY WELL-PERFORMING WHEAT CROPS IN FARIDPUR. PHOTO: M. A. ARAFAT.

Further DSR activities were not undertaken in 2018 due to funding uncertainty. CSISA however plans to implement further work on DSR in the 2019 *aus* season, including expanded technology targeting research using spatial information and GIS-based analysis, in addition to additional low-cost integrated weed management methods that, once validated, can be extended to farmers by DAE and other development partners.

A.1.3 Agronomy and varieties to reduce the threat of wheat blast

After the 2016 outbreak of wheat blast, adoption of crop management and a variety of recommendation packages given through factsheets and different awareness-raising activities were conducted by CSISA and other agricultural development partners. Compared to the initial outbreak observed in 2016, comparatively cooler and drier weather conditions around the flowering stage in 2017 and 2018 resulted in a less extensive wheat blast infection. Affected areas declined from 15,000 ha in 2016 to just 22 and 16 ha in 2017 and 2018 respectively. However, trace infection was found in 3 new farms in 2017 and 2 new farms in 2018 compared to the districts infected in the previous years. This indicates the ongoing spread of the disease and its adaptability to new environments, underscoring the potential for its spread. Environmental modeling work conducted by CIMMYT also indicates the potential for re-emergence of wheat blast when and where weather conditions are favorable.

CIMMYT continues collaborative research with the newly instituted Bangladesh Wheat and Maize Research Institute (BWMRI) to develop resistant varieties of germplasm, forecasting model and management technologies to mitigate the disease. In late 2017, a blast-resistant, zinc-enriched variety (BARI Gom 33), with good agronomic characters was been released by BWMRI with the assistance of several bilateral initiatives led by CIMMYT, including CSISA. Other major CSISA activities in collaboration with BWMRI during the reporting period were as follows:

Wheat blast disease response in new wheat varieties as a function of different seeding dates: Previous experience showed that wheat blast attacks were more severe in older, more widely cultivated varieties and when the crop was sown late in the season. Working with BWMRI, CSISA tested six new varieties including the known blast-susceptible BARI Gom 26 across five seeding dates (25 November; 5, 15 and 25 December, 2017 and 5 January 2018) at research stations in three different agro-ecological zones across Bangladesh, including Dinajpur, Jessore and Rajshahi. The trial was surrounded by mixture of disease-susceptible varieties where blast spores were sprayed to enhance infection in the tested varieties. No blast infection was observed for the early sown crops, e.g. those established on 25 November and 5 December, irrespective of varieties including the susceptible check BARI Gom 26. Blast infections however started in to be noticed in the 15 December seeded crop, with pressure increasing in later-sown stands. The highest disease severity was found in when wheat was sown on 5 January with BARI Gom 26 (85.9% infection) whereas, BARI Gom 33 had only 0.96% infection followed by BARI Gom 32 (8.2%) and BARI Gom 30 (10.3%). The highest yield was found with sowing during the 25 November seeding in Dinajpur, however in Jessore and Rajshahi, statistically similar high yields were recorded with the 5 and 15 December seeding dates. These preliminary results indicate the importance of region-specific recommendations and the use of less disease-susceptible varieties. Experiments are being continued in the 2018–19 wheat season to reconfirm these results, which will later be disseminated to farmers via DAE, development partners, and through mass media campaigns.

Wheat blast surveillance: Wheat blast surveillance continued in 2018 but in a slightly different form. Surveillance was conducted in seven wheat growing districts including Meherpur, Jessore, Faridpur, Dinajpur, Rajshahi, Pabna and Barisal in 24 km diameter areas around automatic weather stations. These data will be useful for validation of wheat blast forecasting models developed in partnership with Universidad de Passo Fundu, Brazil and through CSISA's synergies with the Climate Services for Resilient Development project, also supported by USAID. Wheat samples and data were collected from 616 fields across Bangladesh in three phenological stages. Infection was found in all locations except Dinajpur, although severity tended to be low. From the Meherpur location, 462 weed symptomatic samples of 12 weed species were also collected and observed under a microscope after spore isolation at BWMRI laboratory, Dinajpur, but no spores of the pathogen were found. Other methods of identifying what weed species might be alternative hosts for wheat blast are being considered for the upcoming season.

WHEAT BLAST SAMPLE COLLECTION
PHOTO: ALANUZZAMAN KURISHI

Efficacy of foliar fungicides: Tests were continued to identify low-cost and effective fungicides for wheat blast under highly controlled research station conditions as they had been in the previous year, with all fungicide applications managed by trained professionals (see the 2017 CSISA annual report). The following fungicide combinations appeared to be inexpensive and good candidates for reducing blast infection under natural conditions.

Table 1. 2017–18 wheat season results of foliar applied fungicide trials to control wheat blast in southern Bangladesh

		Infection level or severity (%)			PERSUAP status[1]
Trade name	**Common name**	**Infected spike (%)**	**Head area (%)**	**Severity**	
Nativo 75 WG	Tebuconazole 50% + Trifloxystrobin 25%	8.3	56.7	5.3	Tebuconazole restricted, Trifloxystrobin unrestricted
Trooper 75 WP	Tricyclazole 75%	4.0	53.3	2.3	Banned
Folicur 250 EC	Tebuconazole 25%	11.0	60.0	6.7	Restricted
Opponent 75 WG	Tebuconazole 50% + Trifloxystrobin 25%	3.3	56.7	2.0	Tebuconazole restricted, Trifloxystrobin unrestricted
Filia 525 SE	Propiconazole 12.5% + Tricyclazole 40%	3.67	60.0	2.3	Propiconazole restricted Tricyclazole Banned
Amistar Top 325 SC	Azoxystrobin 20%+ Difenoconazole 12.5%	9.0	63.3	6.00	Both unrestricted
Control	Unsprayed	96.0	96.7	93.0	

[1.] *CSISA in Bangladesh follows the country-wide Programmatic Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP) for all non-research and on-farm activities.*

All the selected fungicides including Nativo 75 WG, Amistar Top 325 SC, Folicur 250 EW, Opponent 75 WG, Filia 525 SE and Trooper 75 WP were found effective in controlling wheat blast infection. Trooper is however not permitted for extension among farmers through the USAID PERSUAP, and therefore cannot be recommended. All the other fungicides are commercially available in Bangladesh and therefore promising for disease mitigation. Among them, Nativo 75 WG (Tebunaconazole 50% + Trifloxystrobin 25%) was found to be the most useful due to the highest yield (38%) and net profit ($223 ha^{-1}) increase over controlled plots. Any extension advisories deployed by CSISA or the project's partners for farmers regarding these fungicides must also be accompanied by personal and environmental safety messaging regarding responsible fungicide use.

A.2 Adding value to extension and agro-advisory systems

A.2.2 Building precision nutrient management approaches around scaling pathways

As indicated in the 2017–18 semi-annual report, research under this activity was suspended temporarily due to funding constraints. CSISA field staff however continued to advise farmers, Department of Agricultural Extension and agricultural input dealers on appropriate crop and nutrient management strategies through one to one interactions, in meetings, and farmer field days.

B. Systemic Change Toward Impact

B.1 Partnerships for inclusive growth around commercial pockets and neglected niches

B.1.1 Deployment of better-bet agronomic messaging through input dealer networks and development partners

Scaling-out information on better-bet agronomy

CSISA continued in 2017–18 to develop accessible guides for better-bet maize, rice, wheat and legume crop agronomy, which are disseminated through development partners and state extension networks. This simple but effective activity works to increase agricultural productivity by deploying recommendations for easy-to-implement, inexpensive (and hence inclusive) agronomic management practices for smallholder farmers, relying on the project's vast assortment of private and public sector partners to scale-out technical information. Key informational guides, trainings, and advice deployed in the 2017–18 winter cropping season focused on healthy rice seedlings to boost yield, and on improving mungbean cultivation practices. As a rapidly expanding, profitable and nutritious legume crop, farmers are increasingly replacing fallow land with mungbean in CSISA's working areas in Barisal Hub under the FtF zone. Although funding uncertainty caused considerable setbacks in activities in the last fiscal year, CSISA was still able to mobilize some limited and strategic activities. Monitoring efforts were also continued to gauge the ongoing impact of extension and training efforts well after initial interventions.

Healthy Rice Seedlings: Funding uncertainty forced the suspension of awareness-raising activities among farmers of the benefits of transplanting healthy rice seedlings (HRS) since the beginning of the winter boro season during 2017/18. CSISA nonetheless conducted a follow-up survey with farmers who had been previously exposed to HRS awareness-raising activities, particularly those who had attended HRS video showings in public places and who engaged in light trainings conducted by Agricultural Advisory Society (AAS) and other partners in Bangladesh. The objective of the survey was to assess if and how many farmers who learned about HRS raising practices in 2017 aman season continued to use HRS raising practices in aman 2018 without intervention by CSISA.

Ninety farmers who viewed HRS video and who are growing aman rice in aman 2018 were interviewed in the survey. Survey results indicated sustained adoption of simple to implement but effective and productivity-enhancing healthy rice seedling techniques that can be practiced individually or as part of a package. At least 99% of the farmers surveyed continued to make use of at least one practice (Table 2), while others continued to practice a suite of new healthy rice seedling practices. The results indicated that adoption of HRS practices sustained even without CSISA intervention on 9,616 hectares across the surveyed areas of the FtF zone.

Table 2. Results from farmer surveys on the sustained adoption of new healthy rice seedling practices. Farmers were surveyed two seasons after having been exposed to extension messaging on HRS practices. Data indicate ongoing sustained adoption of new practices without CSISA intervention.

Practices to raise HRS	Percent of farmers who continue to practice each healthy rice seedling practice two seasons following extension exposure
Adoption and sustained use of certified seeds	60
Seedbed moved to a new location free of shade	99
Seedbed now placed in a location with irrigation	70
Seedbeds now prepared with drainage facilities	87

Adoption and sustained use of the recommended seed rate (</= 4.0 kg per decimal seedbed)	70
Adoption and sustained use of recommended seedling age (35-40 days) in *aman* rice	100
Adoption and sustained use of seed fungicide treatment	49
Adoption and sustained use of flotation techniques to screen-out poor quality seeds before seeding	32
Adoption and ongoing use of seed germination tests	42

B.1.3 Rabi fallows development in coastal Bangladesh

Farmers' preference for cropping intensification in polder and non-polder environments of coastal south-central Bangladesh

Large tracts of coastal Bangladesh within the Feed the Future Zone have low levels of crop intensification. Farmers are either fallowing their fields or growing low-input and relatively low-output rainfed crops during the drier winter season. Identification of suitable land area and crop options, as well as mechanisms for interventions to overcome farmers' low risk-bearing capacity for crop intensification, have been a focus of CSISA Phase III. In partnership with Wageningen University, CSISA undertook applied research to understand the trajectories of agricultural change in these areas over the last twenty years. Such research is important to inform development planners and policy makers about appropriate interventions given the ways in which farming systems are changing, thereby helping to increase the efficiency of development investments by tuning them to regionally relevant conditions.

Using twenty year panel data from 502 households in two diverse environments in coastal Bangladesh, we studied farm trajectories of change and the influences of multiple drivers/factors influencing agricultural change. Our approach, which can be adapted to other farming systems and geographies, showed that coastal farming systems exhibit complex dynamics that are spatially and temporally diverse. With rapid economic changes, farming systems in this portion of the FtF zone have gradually moved from heterogeneous, rice–livestock based farm types into more homogenous farming systems with less livestock and increased emphasis on income generated from pulses and off-farm employment. Evidence also suggest that farm typological diversity has decreased within and outside of polders. Marginal- and small-sized farms now dominate compared to a more diverse mix of marginal to large farm types twenty years before. So, agricultural intensification in coastal Bangladesh is likely to be successful only if they are specifically designed for different farm types by scaling to the level of structural and functional characteristics of farm households.

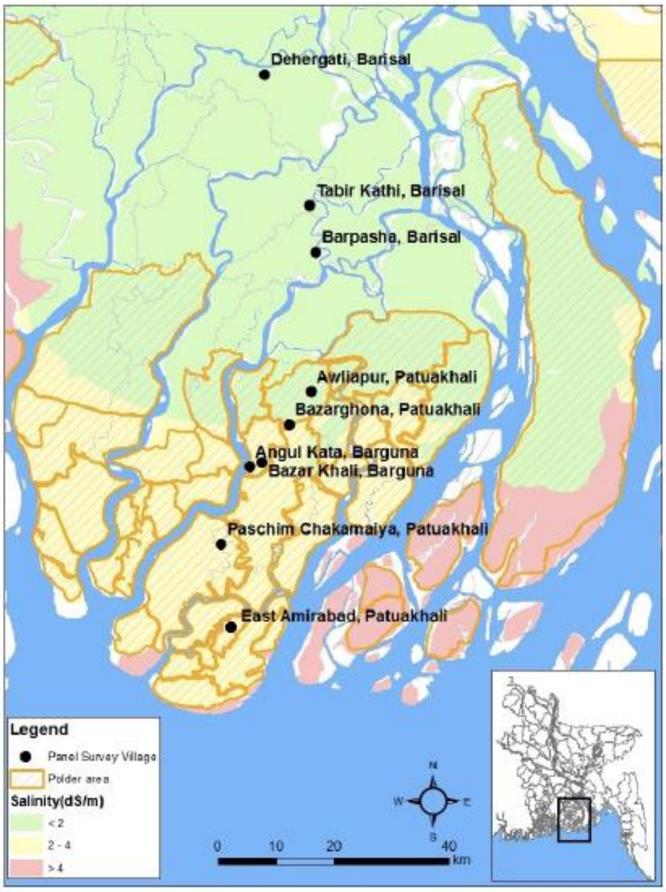


Fig 2. Map of the study area showing study districts. Black spots indicate the study villages. Salinity data refers to soil and water salinity.

Variability in cropping intensity, landholding size and off-farm income strongly influence farming system change outside polders. Within polders, variables strongly contributing to farm type dynamics are similar, though livestock holdings contribute more than farm size. We have shown the influence of both micro- and meso-level factors other than macro-level drivers (e.g. population and cyclone intensity) in driving changes in cropping intensity. Micro-level factors including perceived soil fertility, and degree of farm plot fragmentation influenced cropping intensity among the samples in coastal systems. Our data indicate that most cropping in the central coast has historically depended on indigenous soil fertility with little application of inorganic or organic amendments, aligned with concerns of declining soil fertility in Bangladesh. Integrated and precision approaches to nutrient management are therefore likely to be beneficial, although extension services on nutrient management tend to be much more successful in irrigated areas that have homogenous farm households. In diverse, complex and risk-prone-rainfed coastal farming systems of Bangladesh broad fertilizer recommendations are implausible. Private and public extension systems should respond to this diversity and complexity while recommending fertilizer management.

The landscape elevation class to which the farmland belongs had a positive influence on cropping intensities of the studied areas, reinforcing the requirement for both infield drainage and clearing existing drainage channels in the watershed. Finally, the environmental risk posed by cyclones had a negative influence on both cropping intensities and off-farm income activities in the area. These, however, have not been dealt with thought policy instruments by the government, instead the planning focus is on promoting Boro rice cultivation, which seems less appealing to farmers. Rather, farmers and the communities seem to deal with them by fallowing the land. This suggests for climate services and crop insurance that increase farmers' resilience to cope and adapt to natural hazards and extreme events. Services including development of abiotic stress-tolerant rice and mungbean varieties and extension support on fertilization and flood management are required.

The increasing importance of off-farm income (remittances and off-farm employment), particularly for small and marginally sized farms could be seen as '*stepping out*' of farming. Conversely, almost 12% and 22% of farms outside and within polders, respectively, tended to continuously fallow land during the winter between 2005–15. This indicates a '*hanging in*' strategy for farms less reliant on off-farm income. Increasing income from intensified cropping and reduced land fallowing in coastal Bangladesh is likely to require considerable changes in cropping patterns through inclusion and intensification of high value crops supported by requisite irrigation infrastructure, market access, and supportive policies. This study also indicates that secured tenure rights can instill confidence in farmers that multiple cropping could be beneficial. Sharecroppers in the study area have been reported to be averse to investment in land management or irrigation in the absence of land tenure rights. At the current rates, the cost of securing tenure rights through land registration is roughly around 10% of the total value of land. Most of the small and marginal farmers cannot afford this, which indicates the need to strengthen formal land management systems alongside the better management of existing informal land sharing arrangements.

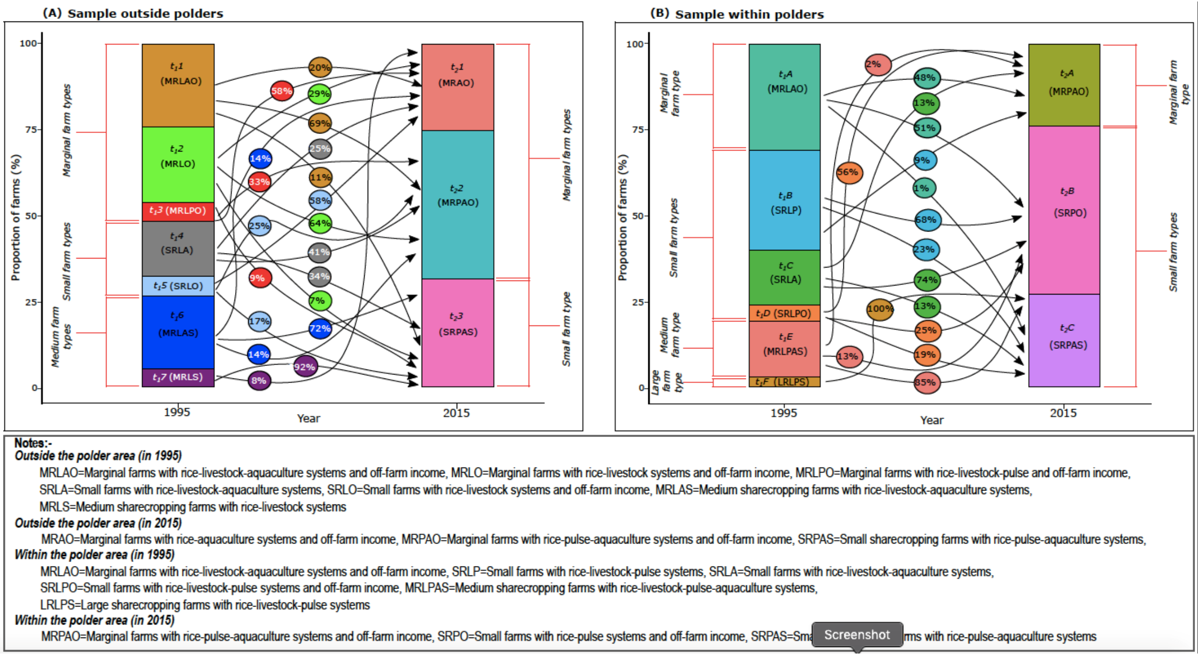


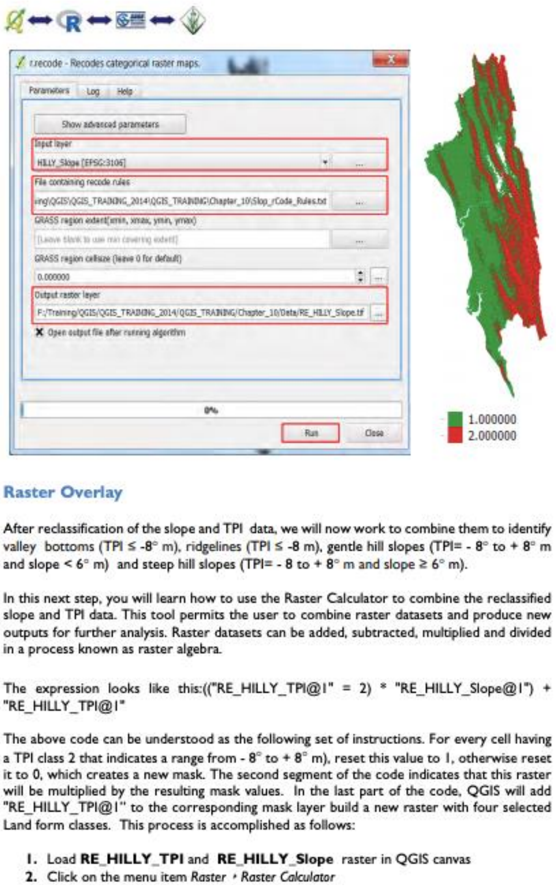
Fig 3. Agricultural change in Bangladesh's south-central coast over twenty years. Farm type dynamics in areas outside (panel A) and within polders (panel B) between 1995 and 2015. Arrows represent the trajectory of change from one farm type in 1995 to another in 2015. Values within circles show the percentage of farms transitioning.

The conceptual model and the analysis provided here illustrates, how it is meaningful to consider a wide range of socioecological system properties potentially influencing agricultural intensification—rather than singling out macro-drivers such as population pressure as the metric of agrarian change and intensification. The Government of Bangladesh has aligned the 7th Five Year Plan in line with the sustainable development goals of the United Nations aimed at ending hunger, achieve food security and improve nutrition and promote sustainable agriculture. Many of these goals also align with that of the FtF program – not only in Bangladesh, but globally. As outlined in current government of Bangladesh documents, the focus has however been largely on increasing the productivity of *Boro* rice production in the *rabi* season. As shown by our data, dry season cultivation of mungbean or other pulses and aquaculture could however result in intensified agriculture, with implications for food security and household income. Policy failures in drainage and flood management within and outside polders have been critiqued for less-intensive farming systems in coastal Bangladesh. Setting these issues aside, as discussed above, the pathways to catalyze Sustainable Development Goals in these systems is through ameliorating the environmental risks from cyclones, improving sharecropping arrangements and tenure security, alongside farming systems re-design that incorporates household's development aspirations and the factors affecting their choices. In sum, these results underscore the importance of accounting for multiple levels of socioecological drivers of change when developing appropriate policy options for sustainable development in South Asia's coastal farming systems.

B.1.4 High-value, premium quality rice expansion Bangladesh

CSISA initiated popularization of premium quality rice (PQR) varieties in the Feed the Future Zone through several activities in second phase and continued in early third phase. These activities were however discontinued in the winter season of 2017–18 due to funding delays and shortfalls. As indicated in the mid-term report for fiscal year 2017–18, CSISA did source information from the Department of Agricultural Extension on area coverage of PQR over this season. This was done to assess the ongoing impact of CSISA's activities despite the lack of formal intervention and engagement. The PQR variety BRRI Dhan 50 and BRRI Dhan 63, both of which were introduced and popularized with support from CSISA in the project's second and early third phase, were planted on over 29,000 hectares across Barisal, Faridpur and Jessore hubs. This indicates strongly that PQR has matured as an intervention, and that value chains have emerged to sustain rice farmers' continued cultivation of these varieties, both for home consumption as well as for the market. Although CSISA cannot claim full responsibility for these results, the project's pioneering efforts to expand the use of these varieties, as well as early efforts in the third phase of the project, have had a clear and lasting impact.

B.2 Bringing participatory science and technology evaluations to the landscape and back again



Raster Overlay

After reclassification of the slope and TPI data, we will now work to combine them to identify valley bottoms (TPI ≤ -8° m), ridgelines (TPI ≤ -8 m), gentle hill slopes (TPI= - 8° to + 8° m and slope < 6° m) and steep hill slopes (TPI= - 8 to + 8° m and slope ≥ 6° m).

In this next step, you will learn how to use the Raster Calculator to combine the reclassified slope and TPI data. This tool permits the user to combine raster datasets and produce new outputs for further analysis. Raster datasets can be added, subtracted, multiplied and divided in a process known as raster algebra.

The expression looks like this:(("RE_HILLY_TPI@1" = 2) * "RE_HILLY_Slope@1") + "RE_HILLY_TPI@1"

The above code can be understood as the following set of instructions. For every cell having a TPI class 2 that indicates a range from - 8° to + 8° m), reset this value to 1, otherwise reset it to 0, which creates a new mask. The second segment of the code indicates that this raster will be multiplied by the resulting mask values. In the last part of the code, QGIS will add "RE_HILLY_TPI@1" to the corresponding mask layer build a new raster with four selected Land form classes. This process is accomplished as follows:

1. Load **RE_HILLY_TPI** and **RE_HILLY_Slope** raster in QGIS canvas
2. Click on the menu item *Raster* › *Raster Calculator*

Fig 4. An example single page detail from the book 'Introduction to basic GIS and spatial analysis using QGIS: Applications in Bangladesh' that was produced by CSISA in 2018, which has accompanying data available on the CSISA Data Verse Website that can be used for guided or self GIS learning.

B.2.1 Increasing the capacity of NARES to conduct participatory science and technology evaluations

Delayed funding in the 2017–18 fiscal year resulted in the suspension of CSISA activities to increase the capacity of NARES to conduct participatory science and technology evaluations. As indicated in the mid-term report for the 2017–18 fiscal year, the CSISA team did complete work on 13 learning modules for Bangladeshi scientists that were assembled into a compendium book entitled 'Introduction to basic GIS and spatial analysis using QGIS: Applications in Bangladesh.' This book provides series of learning modules introducing young scientists and researchers to GIS and spatial analysis using the open-source QGIS platform, and complementary R, SAGA and GRASS Platforms. The book can be used for self-learning and/or as part of guided and interactive exercises. With the resumption of funding in September of 2018, the CSISA team is now working on plans to expand institutional use of the book and to offer training courses at NARES and Bangladeshi universities working in agricultural, climate and environmental sciences.

In addition to the above work, CSISA also convened an emergency meeting of Government of Bangladesh officials in late September of 2018 to discuss the potential threat posed by the emergence of fall army worm in India.

CSISA convened an orientation meeting on the potential threat of fall army worm in Bangladesh in late September of 2018.

The fall armyworm (FAW), *Spodoptera frugiperda*, a devastating insect-pest, has been identified for the first time on the Indian subcontinent. Native to the Americas, the pest is known to eat over 80 plant species, with a particular preference for maize, a main staple crop around the world. The fall armyworm was first officially reported in Nigeria in West Africa in 2016, and rapidly spread across 44 countries in sub-Saharan Africa. Sightings of damage to maize crops in India due to fall armyworm mark the first report of the pest in Asia. Scientists from the College of Agriculture, University of Agricultural and Horticultural Sciences confirmed the arrival of the pest in maize fields within campus grounds in Shivamogga, in the state of Karnataka, southern India. Both morphological and molecular techniques confirmed the identity as FAW.

In response, CSISA organized an orientation meeting on FAW and its implications for Bangladesh. The meeting was jointly organized by the Bangladesh Wheat and Maize Research Institute (BWMRI), Bangladesh Agricultural Research Institute (BARI) and CIMMYT. Senior officials from Ministry of Agriculture (MoA), Department of Agriculture Extension, Bangladesh Rice Research Institute, Bangladesh Agricultural Research Centre (BARC), BARI, BWMRI and CIMMYT participated in the meeting. Marian Parsons, Acting FtF Team Leader, EG Office and Mohammad Shibly, Agriculture Specialist of USAID and Dr. B. M. Prasanna, CIMMYT's Global Maize Program Director were present in the meeting. A national-level follow-up workshop will be convened in late 2018 or early 2019 to develop collaborative plans for pest monitoring and rapid action responses to the threat of FAW in Asia.

C. Achieving Impact at Scale

C.1 Growing the input and service economy for sustainable intensification technologies

C.1.1 Integrated weed management to facilitate sustainable intensification transitions in rice

Despite funding uncertainty in the 2017–18 fiscal year, CSISA continued integrated weed management research focused on rice by leveraging partnerships with the Bangladesh Rice Research Institute. BRRI scientists with technical assistance of CSISA conducted on-farm trials on different weed control options for transplanted rice across Jessore and Faridpur hubs during the monsoon *aman* season of 2016 (prior to large budget shortfalls), and the winter *boro* season of 2016–17 and subsequent *aman* 2017 season (the latter two seasons). CSISA also conducted farmer surveys during *boro* 2016-17 and *aman* 2017 to generate information on farmers' weed management practices and their knowledge gaps, perceptions on predominant problematic weed species and weed control costs. Since the *boro* season of 2017–18, on-farm activities on integrated weed management were however suspended due to funding uncertainty. CSISA scientists nonetheless continued further analysis of data gathered since the *aman* season in 2016. Key results are presented below.

Valuation of weed control options: The weed control options evaluated include a combination of new classes of herbicides – pendimethalin and mefenacet + bensulfuron methyl (pre-emergence herbicide), bispyribac sodium or penoxsulam (post-emergence herbicide), mechanical and hand weeding compared to farmers' typical management practices (pretilachlor pre-emergence herbicide followed by two-hands weeding) in transplanted rice. These weed control options were compared with farmers' standard average weed management practices.

Two weed control options involving the use of mefecenat + bensulfuron methyl followed by either bispyribac sodium or penuxsulam and then followed by one hand weeding produced the highest grain yields. Use of these new weed control options reduced weed control costs by US$ 66 – 73 ha^{-1} in the *aman* season and US$ 57 – 58 ha^{-1} in the *boro* season. Compared with farmers' conventional practices, these new weed control options increased gross income by US$ 121 – 151 ha^{-1} in the *aman* season and by US$ 143 – 145 ha^{-1} in the winter *boro* season across a series of locations in which trials were established. Use of the these new classes of herbicides also reduced labor use by 18 person-days (8 hour days) ha^{-1} in the summer monsoon *aman* season and by 16 person-days ha^{-1} in the winter season (see tables below).

Table 3a. Effect of weed control methods on rice grain yield, total weed control cost, labor use for manual weeding, and gross income over conventional practice in transplanted rice during the summer *aman* seasons in 2016 and 2017

Variation source		Grain yield (t ha^{-1})	Total weed control cost (US$ ha^{-1})	Labor used in manual weeding (man-day ha^{-1})	Gross income (US$ ha^{-1}) over CP
Site					
	Jessore	4.56 ^{a}	108 ^{a}	24 a	59
	Faridpur	4.04 ^{b}	84 ^{b}	18 ^{b}	79
Season					
	Aman 2016	3.91 ^{b}	89 ^{b}	24 ^{a}	34 ^{b}
	Aman 2017	4.70 ^{a}	103 ^{a}	18 ^{b}	104 ^{a}
Weed control methods (WCM)					
	CP	4.25 ^{ab}	141 ^{b}	32 ^{b}	-
	Pendi fb 1 HW	4.22 ^{ab}	104 ^{c}	22 ^{cd}	33 ^{bcd}
	Mefena+Bensul fb 1 HW	4.27 ^{ab}	78 ^{e}	17 ^{ef}	71 ^{abcd}
	Mefena+Bensul fb 1 MW	4.28 ^{ab}	57 ^{f}	12 ^{g}	95 ^{abc}
	Bispyribac fb 1 HW	4.02 ^{b}	80 ^{de}	18 ^{de}	8 ^{cd}
	Penoxsulam fb 1 HW	3.98 ^{b}	95 ^{cd}	20 ^{cde}	-16 ^{d}
	Mefena+Bensul fb Bispyri 1 HW	4.54 ^{a}	68 ^{ef}	14 ^{fg}	151 ^{a}
	Mefena+Bensul fb Penox fb 1 HW	4.45 ^{ab}	75 ^{e}	14 ^{fg}	121 ^{ab}
	MW fb 1 HW	4.41 ^{b}	97 ^{c}	23 ^{c}	88 ^{abc}
	Weed-free	4.60 ^{a}	165 ^{a}	38 ^{a}	68 ^{abcd}
F-Ratio					
Site		59.2***	122.7***	125.4***	2.1^{ns}

Season	108.2***	40.6***	114.9***	22.2***
WCM	3.7**	103.1***	85.8***	6.7***
Site × Season	2.5ns	45.3***	49.4***	8.8**
Site × WCM	0.18ns	9.0***	6.1***	0.29ns
Season × WCM	0.13ns	9.1***	6.2***	0.41ns
Site × Season × WCM	0.27ns	1.47ns	1.1ns	0.38ns

*CP refers to conventional practice [pre-emergence herbicide (pretilachlor) broadcast with the mix of urea fertilizer at xx DAT followed by manual hand weeding at 20-25 days after transplanting (DAT) and 40-45 DAT]; HW refers to hand weeding; fb refers to followed by; MW refers to mechanical weeding using Bangladesh Rice Research Institute developed rice weeder. Means in a columns (for site, season, and weed control methods) followed by the same small letter are not significantly different according to Tukey's HSD at alpha = 0.05. ***, ** and * indicates significance at P < 0.001, 0.01 and 0.05; ns indicates non-significance.*

Table 3b. Effect of weed control methods on grain yield, total weed control cost, and labor use for manual weeding, and gross income over conventional practice in transplanted rice during the *boro* season of 2016–17

Variation source		Grain yield (t ha^{-1})	Total weed control cost (US$ ha^{-1})	Labor used for manual weeding (man-day ha^{-1})	Gross income (US$ ha^{-1}) over CP
Site					
	Jessore	6.4 a	135 a	36 a	24 b
	Faridpur	6.2 b	108 b	30 b	36 a
Weed control methods (WCM)					
	CP	6.3 abc	146 b	39 b	-
	Pendi fb 1 HW	6.4 abc	126 bc	33 bc	42 ab
	Mefena+Bensul fb 1 HW	6.4 abc	118 bcd	32 bcd	54 ab
	Mefena+Bensul fb 1 MW	6.0 abc	93 cd	28 cd	-8 ab
	Bispyribac fb 1 HW	5.8 bc	132 b	35 bc	-116 b
	Penoxsulam fb 1 HW	5.7 c	123 bcd	36 bc	-118 b
	Mefena+Bensul fb Bispyri 1 HW	6.6 a	88 d	23 d	145 a
	Mefena+Bensul fb Penox fb 1 HW	6.6 a	89 d	23 d	143 a
	MW fb 1 HW	6.4 ab	123 bcd	32 bcd	63 ab
	Weed-free	6.7 a	183 a	52 a	66 ab
F-Ratio					
Site		5.46***	30.2***	20.3***	5.1***
WCM		5.34***	14.1***	15.9***	0.16ns
Site × WCM		0.42ns	1.2ns	2.1*	0.31ns

*Means in columns not sharing the same letter are not significantly different according to Tukey's HSD at alpha = 0.05. ***, ** and * indicates significance at P < 0.001, 0.01 and 0.05; ns indicates non-significance.*

This research conducted in partnership with BRRI, generated data that will be used in the next year to work with herbicide companies/dealers to investigate the potential for making these herbicide molecules (mefecenat + bensulfuron methyl, bispyribac sodium, and penoxsulam) available to farmers through commercial pathways following verification and approval of PERSUAP status.

A survey of farmers' weed management practices and their knowledge gaps, predominant problematic weed species and weed control costs: A sound understanding of the weed diversity crucial to improve weed management and guide weed control tactics. The weed vegetation of a particular area is determined not only by the environment but also edaphic and biological factors that include soil texture and structure, pH, nutrients and moisture status, associated crops and crop rotations, weed control measures and field history.

To explore the effect of sites and cropping systems (nominal variables) on weed species composition, weed species data (60 samples and from 23 species) were subjected to canonical correspondence analysis separately for farmers practicing herbicide application field and for those not using herbicide. The environmental variables used in the analysis are land type (ordinal scale of 1–3), soil type (ordinal scale of 1–3) and water stagnancy ranked (1-6). The figure legend below provides more detail on these scales. Ordinations were plotted as species-environment by plots with scaling focused on inter-species distances.

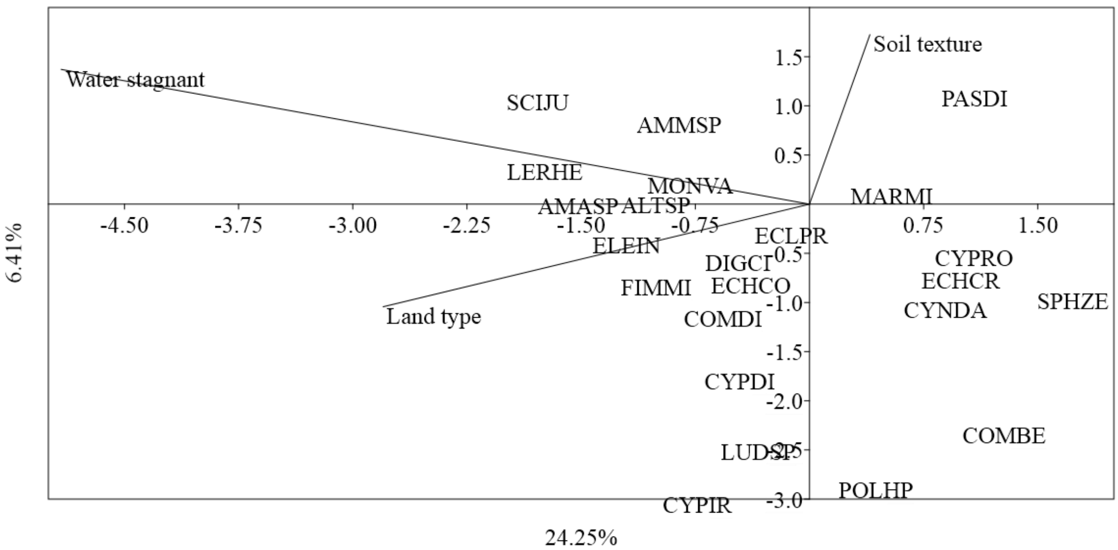


Fig 5a. Canonical correspondence analysis of weed species data from herbicide applied fields. *Nominal environmental variables are land type (1=high, 2=medium, 3=low), soil texture (1=sand, 2=silt, 3= clay, 4=clay loam), water stagnant (1=0-10 cm, 2=10-20 cm, 3=20-30 cm, 4=30-40 cm, 5=40-50 cm, 6= >50 cm). Eigenvalues for first and second axes are 0.24 and 0.06, respectively. Weed species: CYNDA= Cynodon dactylon, ECHCR= Echinochloa crusgalli, ECHCO= Echinochloa colona, ELEIN= Elusine indica, PASSP= Paspalum sp, DIGCL= Digitaria ciliaris, LERHE= Leersia hexandra, ALRSP= Alternanthera sp, AMASP= Amaranthus spinosus, ECLPR= Eclipta prostrate, LUDSP= Ludwigia sp, MARMI= Marsilea minuta, COMBE= Commelina benghalensis, COMDI= Commelina diffusa, SPHZE= Sphenoclea zeylanica, MONVA= Monochoria vaginalis, CYPDI= Cyperus difformis, CYPIR= Cyperus irria, CYPRO= Cyperus rotundus, FIMMI= Fimbristylis miliacea, SCRMA= Scripus maritimus, POLHY= Polygonum hydropiper.*

Weed density with herbicide applied: The first axis explains 24.3% of the variation and the second axis explains just 6.4%. The positioning of the environmental variables show that the main explainable variation in the weed species composition is positively correlated with the soil texture, and negatively correlated with water stagnancy and land type. The species associated with the soil texture are: PASDS, MARMI, CYPRO, ECHCR, CYNDA, SPHZE, and COMBE. The species associated with the water stagnant are MNOVA, AMNSP, AMASP, ALTSP, and LERHE. The species associated with the land type are ELESIN, ECLPR, DIGCI, FIMMI, ECHCO, COMDI, ALRSP, CYPDI, CYPIR, and LUDSP.

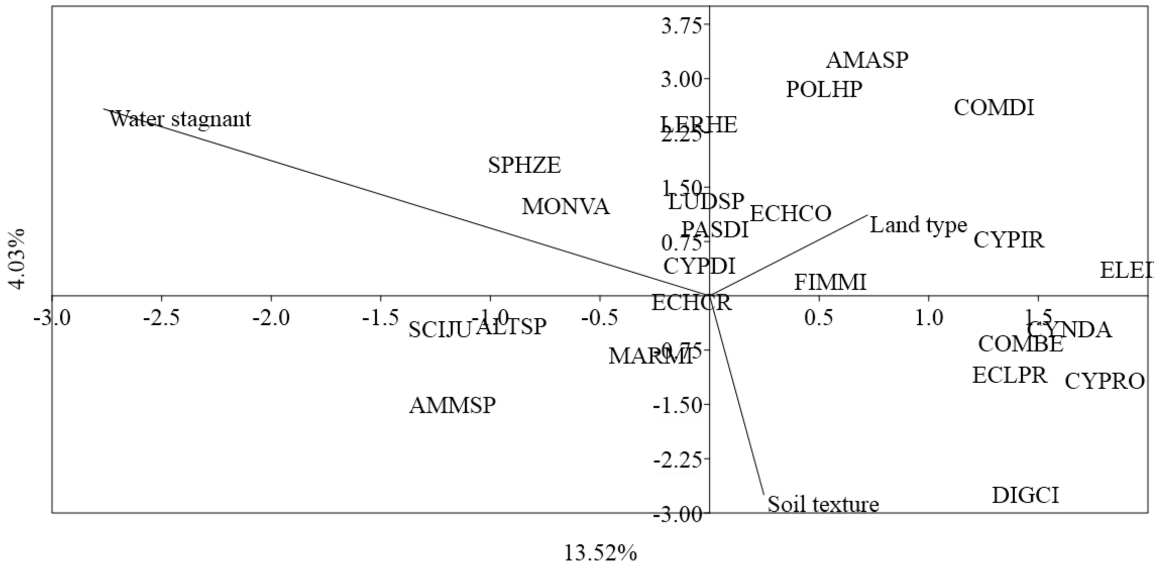


Fig 5b. Canonical correspondence analysis of weed species data of the without herbicide field. *Nominal environmental variables are land type (1=high, 2=medium, 3=low), soil texture (1=sand, 2=silt, 3= clay, 4=clay loam), water stagnant (1=0-10 cm, 2=10-20 cm, 3=20-30 cm, 4=30-40 cm, 5=40-50 cm, 6= >50 cm). Eigenvalues for first and second axes are 0, 14 and 0.04, respectively. Weed species: CYNDA= Cynodon dactylon, ECHCR= Echinochloa crusgalli, ECHCO= Echinochloa colona, ELEIN= Elusine indica, PASSP= Paspalum sp, DIGCL= Digitaria ciliaris, LERHE= Leersia hexandra, ALRSP= Alternanthera sp, AMASP= Amaranthus spinosus, ECLPR= Eclipta prostrate, LUDSP= Ludwigia sp, MARMI= Marsilea minuta, COMBE= Commelina benghalensis, COMDI= Commelina diffusa, SPHZE= Sphenoclea zeylanica, MONVA= Monochoria vaginalis, CYPDI= Cyperus difformis, CYPIR= Cyperus irria, CYPRO= Cyperus rotundus, FIMMI= Fimbristylis miliacea, SCRMA= Scripus maritimus, POLHY= Polygonum hydropiper.*

Weed density without herbicide applied: The first axis explains 13.5% of the variation and the second axis explains only 4.03%. The positioning of the environmental variables shows that the main explainable variation in the weed species composition is positively correlated with the land type and soil texture, and negatively correlated with water stagnancy. The species associated with the soil texture are: ECLPR, MARMI, CYPRO, ECHCR, CYNDA, COMBE, and DIGCI. The species associated with the water stagnancy are MNOVA, SPHZE, AMNSP, ALTSP, and LERHE. The species associated with the land type are CYPIR, ELESIN, FIMMI, ECHCO, ECHCO, POLHP, AMASP, PASDI, COMDI, CYPDI, and LUDSP. The low explanatory values found on each axis however indicate that further analysis need to be conducted in order to better understand patterns in the collected data and to derive weed management advice from the survey results.

Dominant and most problematic weeds: Based on abundance, the ten most dominant weed species in fields where farmers both did and did not apply herbicide and non-herbicide are shown below, alongside data on key problematic weed species that have some level of tolerance to herbicides.

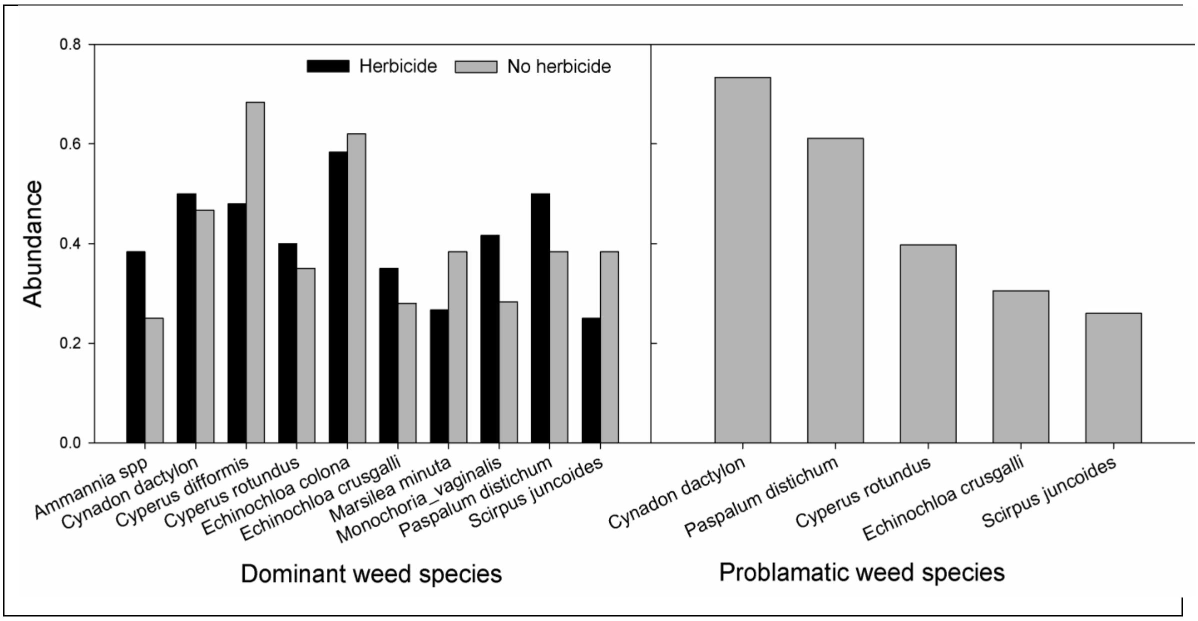


Fig 6. Abundance of ten dominant weeds, and five most problematic weed species in Jashore and Faridpur sites

These data and resulting analyses are preliminary; additional analysis is underway to better understand survey results and derive actionable recommendations for weed management that can be incorporated into CSISA's integrated weed management programs for rice in Bangladesh. In the coming six months, the complete results of this work will be shown at a national level workshop planned to involve both governmental research and private sector partners, convened with support from CSISA.

C.2 Managing risk by coping with climate extremes

C.2.2 Early wheat for combatting heat stress

The climate of Bangladesh is warm and humid. Although suitable for crops like rice, farmers wishing to grow wheat face a number of climatic challenges. Key among these is the effect of late sowing date: yield can decline precipitously when seeding goes beyond November 30. The optimum time of wheat seeding as per recommendation of the Wheat Research Center, Bangladesh Agriculture Research Institute, is 15–30 November. After 30 November, wheat yield can decline at a rate of 1.3% or 43 kg per ha per day for each day that seeding is delayed.

CSISA is conducting an experiment on wheat sowing dates in partnership with BARI to develop improved and more specific sowing date recommendations for different regions of Bangladesh, and to generate data on the performance of new wheat varieties under different sowing dates. The newly developed varieties need to be evaluated for their agronomic performance under different environmental conditions. In this context, an experiment was conducted in three locations of Bangladesh i.e., Dinajpur, Rajshahi, Jessore, during the wheat growing season of 2017–18 to evaluate the performance of newly released wheat varieties under different sowing dates, to find out the optimum sowing time for a specific variety and to identify heat tolerant and heat susceptible varieties. Under the environmental conditions of Dinajpur, it was observed that all of the wheat varieties sown under optimum sowing conditions (25 Nov) produced the maximum yield, while yield of all varieties were decreased significantly when sown later. Under the environmental conditions of Rajshahi and Jessore, wheat sown between the first week of December (5 Dec) and mid-December (15 Dec) performed better than wheat sown on 25 November. Considering the varieties, BARI Gom 30 (4,092 kg ha^{-1}) performed the best under all sowing conditions, including the late-sown, heat stressed conditions of Dinajpur, which was statistically similar to BARI Gom 32 (4,022 kg ha^{-1}) and BARI Gom 33 (4,061 kg ha^{-1}). Whereas, under the environmental conditions of Rajshahi, BARI Gom 33 produced the maximum grain yield (3,538 kg/ha) under the conditions of the Dec 15 sowing, followed by BARI Gom 31 (3,355 kg ha^{-1}) and BARI Gom 28. Considering the yield performance of all varieties under all sowing conditions of Jessore, BARI Gom 32 and BARI Gom 30 produced statistically similar and maximum grain yield under all sowing conditions, followed by BARI Gom 31. At a sowing date of Dec 5, BARI Gom 32 also produced the maximum yield. This variety also produced the second highest and third highest yield under the sowing conditions of Dec 15 and Dec 25 under the environmental conditions of Jessore. After one year of observation, it was also noticed that location specific environmental/sowing conditions are very important to the potential of a specific variety.

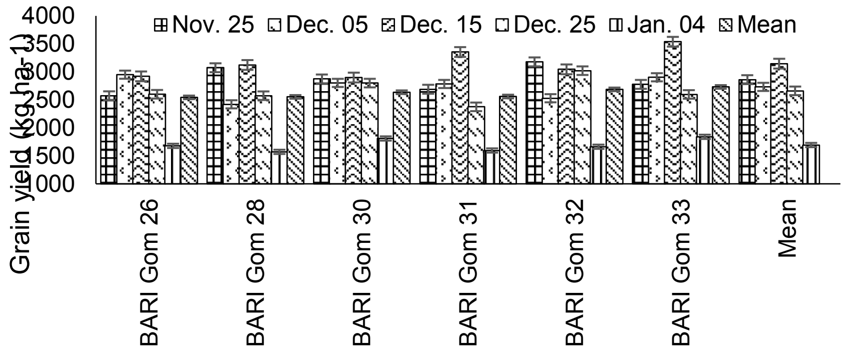


Fig 7a. Yield of wheat varieties as affected by sowing date in Rajshahi. Bars for yield of different wheat varieties are significantly different at $P \leq 0.05$ (LSD test). Mean ±SE in each bar was calculated from three replications for each treatment.

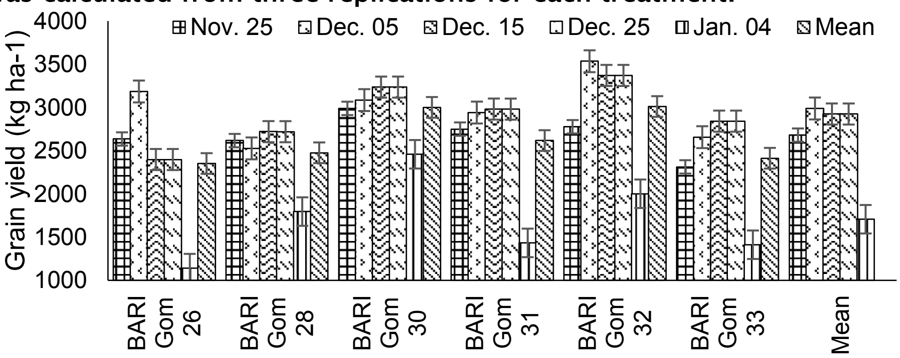


Fig 7b. Yield of wheat varieties is affected by sowing dates in Jessore. For details of the graph, see above.

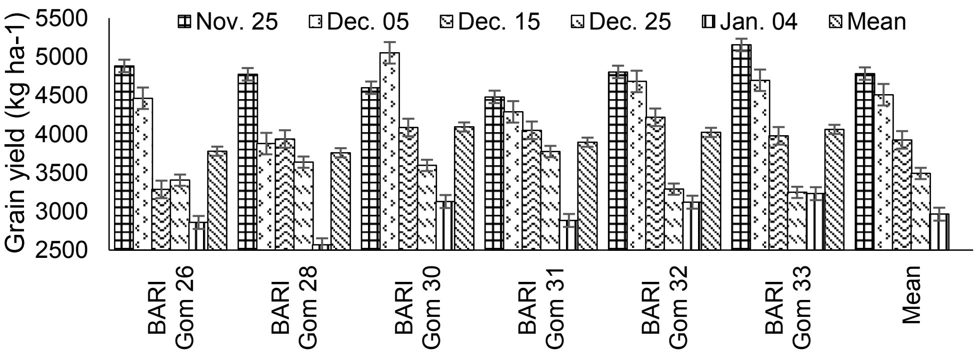


Fig 7c. Yield of wheat varieties as a function of sowing dates in Dinajpur. For details of the graph, see above.

Outside the research station and in farmers' fields previous focus groups with farmers revealed that excessive soil moisture at seeding time is the main cause of late wheat seeding followed by the farmers' knowledge gap of the benefits of early seeding. Despite funding uncertainty during 2017–18, 80,000 leaflets on early wheat sowing were distributed to farmers through public and private sector partners to raise farmers' awareness of this crucial issue. Farmers and others now realized the benefits of early seeding. Early wheat seeding was however not easily achieved in the last year due to very unseasonable and heavy rains during the pre-seeding and seeding times in wheat growing regions. Average rainfall in Dinajpur, Faridpur, Ashore and Bhola regions were 130, 246, 664 and 216 mm, respectively, during October, November and December of 2017. Due to these rains, farmers reacted and choose to sow less wheat, resulting in a 16% reduction in acreage over last year's area. Wheat blast infection in 2017 was conversely very low, only appeared sporadically on around 22 ha in contrast to 1,500 ha in 2016. Blast affected areas in 2018 only appeared on 16 ha.

Yet because such rainfall was highly unusual, similar setbacks are not anticipated in the 2018–19 wheat season. The CSISA team is therefore working to reinvigorate early wheat sowing media and messaging campaigns. A short video on early wheat seeding was prepared which will be show in village video shows to around 65,000 farmers of major wheat growing areas of Dinajpur, Ashore, Faridpur and Barisal. Similar to last years' activity, early wheat seeding leaflets will also be distributed to farmers through public and private sector partners. Early wheat seeding benefits and adoption policies will also be discussed in field days, workshops, seminars etc. in different CSISA events, with reports of the successfulness of these activities detailed in the April 2019 mid-term report.

CSISA III Linkages with Livestock

Assessment of alternative feeding options to enhance dairy farm sustainability in Bangladesh's Feed the Future Zone

Mixed crop-livestock (dairy) farming systems are relatively common in Bangladesh. Dairy production is however characterized by low productivity that largely result from feeding and breed (genetic) constraints. Limited fodder quantity and poor quality are important problems that limit dairy profitability. Few smallholder farmers can afford the labor required to cut and carry collected and high-quality fodder to their farms. Nor are the able to afford purchase of quality fodder in sufficient quantities, despite indications of a growing fodder market in parts of the Feed the Future zone (FtF). In collaboration with the Farming Systems Ecology group at Wageningen University, CSISA undertook preliminary research in 2018 to explore potential alternative fodder production and feeding systems in two districts of the FtF zone. In addition to assessing the potential for fodder production and strategic use of external feed items, trade-offs with environmental outcomes were considered. The following key research questions were considered, including (1) How do different crop-dairy farming systems in the FtF zone perform in terms of profitability, resource use efficiency and environmental impact? (2) Which synergies and trade-offs exist between economic (dairy and crop production) and environmental indicators of sustainability?

In an effort to respond to these research questions, a detailed farm survey of 18 farmers in Meherpur and Jhenaidha Districts in Bangladesh was conducted. We categorized farmers in into three dairy resource-endowment groupings including small (≤ 3 cows), medium (4-10 cows) and large (≥ 10 cows). Detailed data on farm, crop, and livestock practices were conducted through farmer surveys and farm observations. Data were then analysed the using the FarmDESIGN modelling tool. The former model includes routines for a multi-objective optimization algorithm employing Pareto-based Differential Evolution to allow exploration of trade-offs and synergies between model indicators such as dairy production, profitability and improvement in soil organic matter balances.

Based on field research results, alternative feed and crop production options were explored by altering and replaced different land, crop and animal management parameters until the model selected Pareto-optimal solutions for the mix of crops and livestock components, in consideration of a suite of sustainability indicators.

Original and model-optimized farm performance of large, medium and small sized farms over a year by using Pareto optimum solutions for five objectives at Meherpur and Jhenaidha districts in Bangladesh's Feed the Future Zone. The optimized performance is the average of solutions from the optimization that perform better in all objectives compared to the original farm configuration.

Table 4. Multi-criteria optimization of integrated crop-livestock systems in Bangladesh

Objectives	**Indicators**	**Farm location and size considering dairy livestock holdings**					
		Jessore			Meherpur		
		Large	Medium	Small	Large	Medium	Small
Self-reliance in farm energy use (%)	Original performance	17	26	47	27	57	52
	Optimized performance	20	33	54	29	69	55
	Potential change (%)	18	25	16	8	21	7
Total farm profit ($/ha)	Original performance	5,148	5,012	8,757	1,310	-216	4,071
	Optimized performance	5,880	5,636	9,623	1,801	667	4,978
	Potential change (%)	14	12	10	37	209	22
Feed cost ($/kg dry matter feed)	Original performance	0.30	0.26	0.22	0.19	0.17	0.18
	Optimized performance	0.29	0.22	0.21	0.17	0.15	0.16
	Potential change (%)	-3	-16	-6	-10	-15	-7
Soil nitrogen losses (kg N/ha)	Original performance	298	342	189	193	74	111
	Optimized performance	247	330	169	178	62	86
	Potential change (%)	-17	-4	-10	-8	-16	-22
Soil organic matter balance (kg/ha)	Original performance	21	163	295	387	243	952
	Optimized performance	82	223	344	402	275	992
	Potential change (%)	286	37	17	4	13	4

Summarizing and interpreting these data, the following farm redesign options may be considered:

- Lower use of external feed and higher use of on-farm feed can increase operating profit, despite the need to shift portion of farmers' fields from rice production to feed production.
- Across farm sizes, copping patterns will need to be re-organized to accommodate production of fodder, which may include Napier grass (that can be grown on field margins and next to pathways), wheat fodder (the production of which is already increasing in Jessore District).
- Several new processed feed items (maize silage, urea treated rice straw) can be introduced to farmers collaborating with CSISA to

GOPAL MOHANTA AND HIS WIFE WORK TO PREPARE FEED FOR THEIR LIVESTOCK. PHOTO CREDIT: S. MOJUMDER/DRIK/CIMMYT

sustainably intensify dairy production.
- Increasing the cultivation of leguminous crops can result in dual-purpose results, including quality feed production alongside a decrease in soil nitrogen losses and hence pollution
- Despite the high cost of hybrid seed, use of maize as fodder, as well as the cultivation of Napier grass can increase farm feed and energy self-reliance, while also contributing to more positive soil organic matter balances.

The results of this preliminary modelling study are being presented to farmers in an effort to validate them and generate discussion on the utility of the results. Where farmers are particularly positive about viable alternative feed options, CSISA may consider deployment of awareness-raising and training materials to inform mixed crop-livestock farmers of the numerous options that can be employed to realize the triplicate objectives of increased dairy and crop production, profitability, and reduced environmental trade-offs.

Challenges faced during the reporting period

As indicated in the semi-annual report, the key challenge faced in the 2017–18 reporting period was the uncertainty of funding from USAID. In consultation with CSISA's Activity Manager at USAID, alternative plans were put into place and we reacted to the delay and budget reduction by de-emphasizing scaling activities and refocusing our work on strategic research. Yet as indicated in the proceeding text of this annual report, all of the activities on CSISA's work plans were heavily impacted. For example, most of the CSISA staff from both CIMMYT and IRRI had to be terminated, retrenched, or transferred into other projects. In CIMMYT, a total of 15 full-time equivalent staff were transferred to other projects. Two CIMMYT staff were terminated. At IRRI, eight full-time staff were terminated. In addition, all partner sub-contracts were terminated (including those with iDE on scale-appropriate mechanization commercialization and with Bangabandhu Sheikh Mujibur Rahman Agricultural University on precision nutrient management. Key remaining staff and partners' scenarios are detailed in tabular form in both Appendix 1 and Appendix 2. Now that funding has been restored, we are in the process of rebuilding our staff, reorganizing work plans, and restarting activities. This however requires considerable effort following such significant setbacks.

A. Innovation Toward Impact

A.1 Reducing Risk to Facilitate Uptake of Sustainable Intensification Practices

A.1.1 Directly-sown rice (DSR) to address labor and energy constraints to precision rice establishment

Due to outmigration and an aging rural workforce, seasonal scarcity of agricultural labor is one of the biggest challenges to the viability and profitability of Nepalese agriculture. Traditional rice establishment practices of manually transplanting rice seedlings into puddled fields cost farmers time, labor, energy and money. Machine-sown direct seeded rice is a cost-effective technology that avoids the costs of raising rice nurseries and transplanting seedlings in the main field. In this context, DSR can be a suitable alternative to conventional transplanted puddled rice.

Despite these benefits, DSR can be riskier than transplanted puddled rice due to higher weed pressure and the possibility of stand mortality with early rains. The selection of suitable land, deployment of trained service providers, timely crop establishment, along with the utilization of integrated weed management practices are pivotal for reliably obtaining good yields with DSR.

DSR seven years on: Who continues and why?

CSISA has been evaluating and promoting drill-sown direct seeded rice for the last seven years in select western Terai districts of Nepal. Despite these efforts, adoption rates of DSR are not advancing as quickly as expected but use continues among a core group of farmers. This presents a learning opportunity to characterize enabling factors for DSR adoption in the Nepal context.

Among a sub-set farmers who are using the technology (n=143), we characterized perceptions of DSR on a Likert scale ranging from 5 (factors strongly favoring adoption) to -5 (factors strongly disfavoring adoption) in seven western Terai districts (Chitwan, Nawalparrasi, Rupandehi, Banke, Bardiya, Kailali and Kanchanpur) where CSISA is working to scale DSR technology.

Challenges to DSR use as compared to transplanted rice included increased weed pressure and the unavailability of herbicides, seeding machinery and skilled service providers. Additional factors expressed were a low level of confidence in the technology, a poor success rate in crop establishment, a need for assured irrigation and a well-leveled field, and the perceived need for frequent field monitoring. CSISA's experience indicates that these problems are manageable through awareness raising, training, strengthening private service providers and improving market development for machinery and herbicides. Despite many constraints to DSR adoption, farmers still continue to use the technology because it eliminates the need for seedling raising and transplanting, as well as lowers the cost of field preparation and crop establishment, increases the opportunities for timely crop establishment, reduces drudgery and labor requirements, increases profit and does not reduce yields compared to the transplanted rice (Figure 9).

With partners such as the PMAMP and the Rice Super Zone program, CSISA is working aggressively to ensure that more farmers and service providers fully understand the benefits of DSR along with management methods to reduced down-side risks.

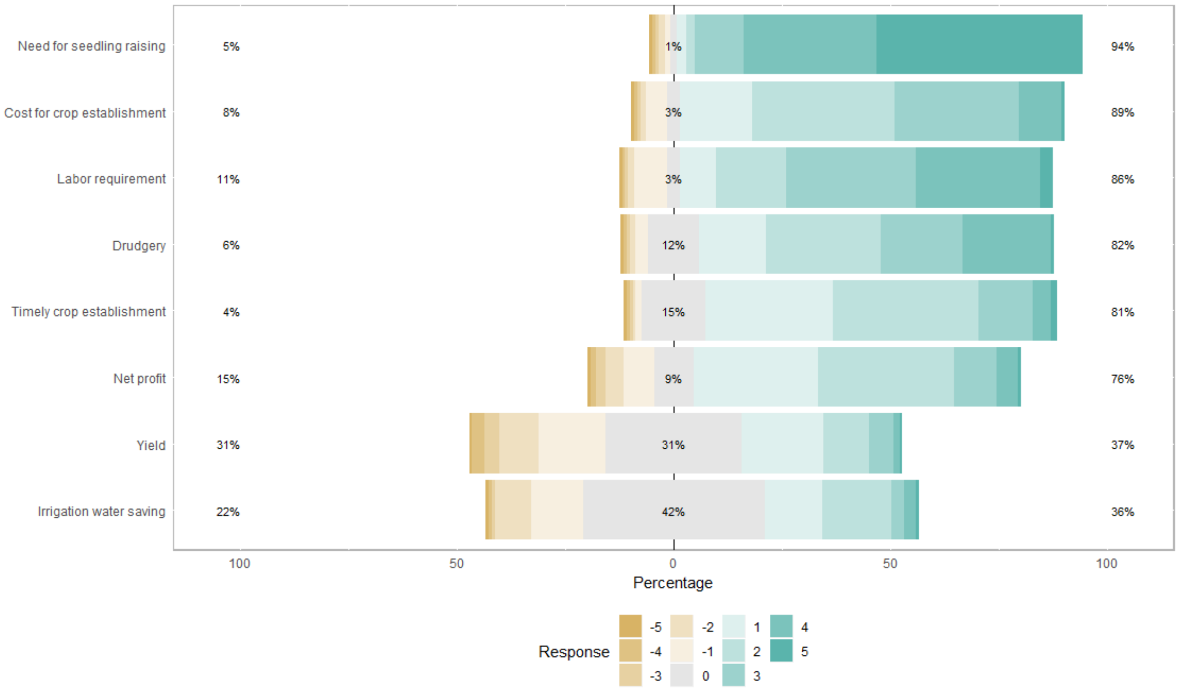


FIGURE 8. PROPENSITY SCORES ESTIMATED ON A LIKERT SCALE (+5 HIGHLY PREFERRED <---- > -5 HIGHLY NOT PREFERRED) FROM THE PERSPECTIVE OF DSR ADOPTERS IN FOUR WESTERN TERAI DISTRICTS.

Simulating optimum sowing dates for DSR

The benefits of adopting DSR may not be sufficient incentives for farmers to adopt DSR if they perceive that the yield potential is lower compared to alternative establishment methods.

Given the sensitivity of rice to temperature and rainfall variability, optimizing the seeding date and using adapted varieties are of central importance to enhancing DSR yields. We conducted a simulation study using the rice growth model ORYZA-3 to assess the yield potential of varieties from three different maturity classes: Radha-4 (120 days), Sabitri (135 days) and Sworna (150 days)) across a range of seeding dates starting from the end of April to the end of July.

The attainable yield potential for all three maturity classes (short-, medium- and long-duration) is more than 8 t/ha under optimum sowing dates and irrigated conditions (Figure 9). Averaged across the districts, the best simulated sowing date for short-, medium- and long-duration varieties varied from 1–15 July, 20 June to 5 July, and 10–25 June, respectively. For the short-duration variety, yield decline starts after 15 July, while it declines after 10 July in medium- and after 25 June in long-duration varieties. Under irrigated conditions, DSR can theoretically be seeded from the beginning of May to the end of July. However, field access by the

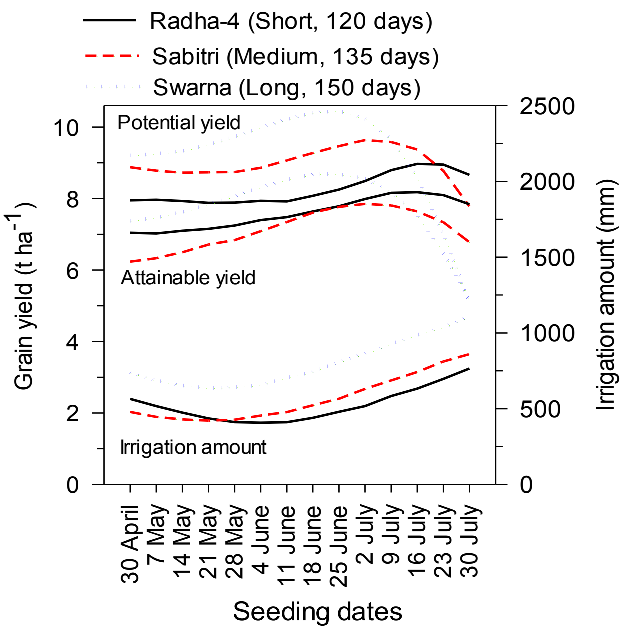


FIGURE 9. YIELDS UNDER SIMULATED SOWING DATES FOR SHORT-, MEDIUM-, AND LONG-DURATION RICE VARIETIES

seed drill machines for seed sowing typically poses a binding constraint that prevents sowing after June in most years.

During the optimum seeding period, the irrigation requirement varies across the variety, with the short-duration variety requiring 559 mm irrigation water, the medium-duration variety requiring 554 mm and the long-duration variety requiring 724 mm. Seeding before or after these optimum dates increases the irrigation requirement.

B. Systemic Change Towards Impact

B.1 Partnerships for inclusive growth around commercial pockets and neglected niches

B.1.1 Deployment of better-bet agronomic messaging through input dealer networks and development partners

Big data insights for development priority setting

Rice yield and profit gaps

Slow productivity growth rates (low yield growth rate in Nepal compared to India and Bangladesh) and the increasing volume of rice imports (~US$ 300 million in 2017) provide incentives for closing the rice yield gap in Nepal. CSISA's household survey and crop cut experiments were conducted across 1,052 households in 2016 and were re-analyzed to calculate yield and profitability gaps associated with current farmer practices across the western Terai districts in the FtF Zone. The top 10% of farmers obtained a yield of 6.8 t/ha whereas the mean yield was 3.8 t/ha, showing an attainable yield gap of 3.0 t/ha. Also, the top 10% of farmers obtained a net profit of US$ 760/ha whereas mean profitability was US$ 252/ha, indicating an attainable profit gap of more than US$ 508/ha (Figure 10). These results demonstrate the considerable gains that can be achieved through improved staple crop management with practices that are currently adapted and implemented by farmers in Nepal.

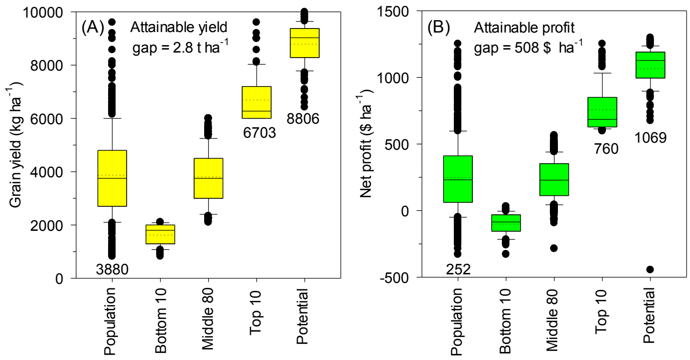


FIGURE 10. YIELD (A) AND PROFIT (B) GAPS OF RICE. GAPS ARE DEFINED AS THE DIFFERENCE BETWEEN THE TOP 10 PERCENTILE FARMERS AND THE POPULATION MEAN

The same survey and crop-cut data was analyzed using machine learning approaches in order to identify contributing factors for variable yield and efficiency outcomes. This analysis revealed that

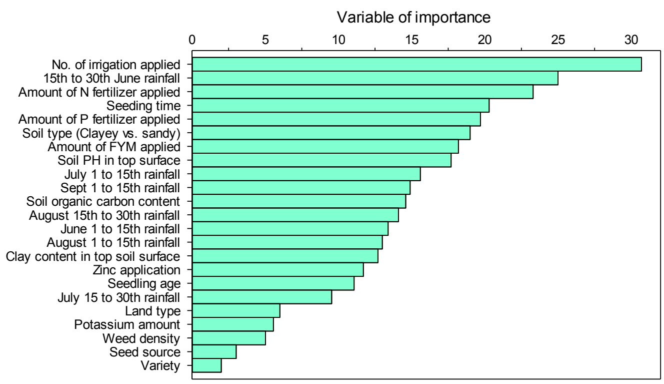


FIGURE 11A. IMPORTANCE OF MANAGEMENT AND CLIMATE FACTORS TO RICE YIELD OUTCOMES IN THE WESTERN TERAI

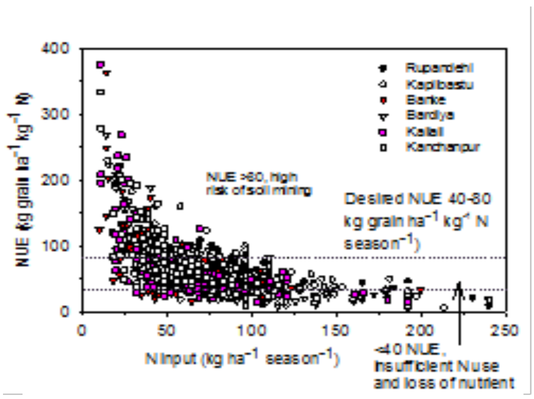


FIGURE 11B. NITROGEN USE EFFICIENCY IN RICE IN WESTERN TERAI DISTRICTS the number of irrigations followed by the amount of rainfall from 15–30 June, N fertilizer applied, seeding date, and phosphorus fertilizer applied are the major yield-determining factors for rice in the Terai (Figure 11A). More than two-thirds of rice in Nepal is produced under rainfed conditions, so early rainfall and the application of irrigation are paramount to its success. Analysis also revealed that NPK application rates are less than half of the recommended rate (N <50, P <20, and K <15 kg/ha), suggesting that the majority of farmers are unsustainably mining indigenous soil fertility and that imbalanced and inadequate fertility is compromising crop productivity (Figure 11B). The power of single interventions for improving crop productivity were also confirmed, with the simple step of planting rice hybrids increasing yields by 730 kg/ha and net profit by US$ 75/ha.

Wheat yield and profit gaps

A similar exercise was conducted for wheat in 2017 that included surveys of 1,745 production fields from seven western Terai districts, i.e., Rupandehi, Kapilvastu, Dang, Banke, Bardiya, Kailali and Kanchanpur. Among these districts, three major homogeneous areas were identified using k-means cluster analysis. Cluster-1 was located in the western Terai region (Rupandehi and some parts of Kapilvastu and Dang), cluster-3 was located in the far-western Terai (Kailali and Kanchanpur) and Cluster-2 was mixed western and mid-western Terai (Kapilvastu, Dang and Banke). The average grain yield was higher in Cluster-3 (2.9 t ha^{-1}), followed by Cluster-1, (2.8 t ha^{-1}), with significantly lower productivity in Cluster-2 (2.1 t ha^{-1}).

The highest attainable yield gap existed in Cluster-1 (1.98 t ha^{-1}) followed by Cluster-3 (1.5 t ha^{-1}) and Cluster-2 (1.1 t ha^{-1}). Cluster-3 had a higher profit gap (407 USD ha^{-1}), followed by Cluster-1 (333 USD ha^{-1}) and Cluster-2 (275 USD ha^{-1}). Fertilizer use and irrigation intensity were notably lower in Cluster-2, are were the primary contributors to poor yield and profitability.

Table 5. Characterization of wheat production across the Terai districts from the household survey (*mean and standard deviation*).

	Cluster-1 (N=618)	Cluster-2 (N=442)	Cluster-3 (N=685)	Mean (N=1745)
Yield (kg ha^{-1})	2810 ± 741	2139 ± 548	2905 ± 702	2677 ± 751
Farm size (ha)	0.70 ± 0.88	0.52 ± 0.45	1.02 ± 1.02	0.78 ± 0.88
Seeding date	22- Nov ± 6.8	22- Nov ± 7.6	21- Nov ± 7.4	22- Nov ± 7.2
Seed rate (kg ha^{-1})	172 ± 32	141 ± 36	158 ± 35	159 ± 36
Nitrogen (kg ha^{-1})	104 ± 21	60 ± 20	84 ± 24	85 ± 28
Phosphorus (kg ha^{-1})	72 ± 15	42 ± 15	55 ± 19	58 ± 21
Potash (kg ha^{-1})	1.2 ± 5.6	0.6 ± 3.1	0.8 ± 4.3	0.9 ± 4.6
FYM (kg ha^{-1})	202 ± 1451	576 ± 2281	656 ± 2325	475 ± 2055
No. of irrigation	1.48 ± 0.66	1.27 ± 0.77	1.49 ± 0.62	1.43 ± 0.68
Rainfall (mm)	33.9 ± 7.6	39.2 ± 8.4	64.6 ± 12.7	47.3 ± 17.3

Random forest analysis demonstrated that high wheat yields were associated with increased irrigation, high winter rainfall, increased N level, timely seeding, increase seed rate and application of potassium fertilizer. Specifically:

- Wheat yields declined when sowing was delayed beyond November 25, confirming the results of on-station trials conducted with NARC.

- Application of 100 kg N ha^{-1} increased grain yield compared to the low rates, but positive yield responses were observed up to 150 kg N ha^{-1} application, providing further evidence that existing state recommendations are insufficient for capitalizing on yield potential.
- Application of three irrigations significantly increased the grain yield of wheat.

It is important to re-emphazise the differences between clusters, suggesting different 'entry point' priorities for sustainable intensification that are being communicated to partners accordingly.

Table 6: Main agronomic and climatic attributes explaining wheat yield variability across three major production clusters

Rank based on %IncMSE¶	Cluster-1	Cluster-2	Cluster-3
1	Number of irrigation	Rainfall	Seed rate
2	Seed source	Variety	Rainfall
3	Rainfall	Nitrogen level	Number of irrigation
4	Seeding date	Seed source	Nitrogen level
5	Variety	Weed management	Weed management
6	Potassium fertilizer	Number of irrigation	

¶ Rank 1 indicates higher % of increase in mean square error (%IncMSE) = high variable of importance

Extending agronomy basics

In Nepal, government and development partners often focus on new technology introductions without retaining a focus on the basics of sound management that provide the foundation for sustainable intensification. Consequently, many farmers report a low level of knowledge of research-based management recommendations and achieve low yield levels and profitability accordingly. To close this gap, CSISA collaborated with the commodity programs of the National Agricultural Research Council (NARC), including the National Rice Research Program, the National Maize Research Program and the National Wheat Research Program, to develop better-bet agronomy 'tips' covering production practices for rice (including healthy seedlings), maize and wheat. In very simple terms and with an emphasis on actionable advice, the factsheets explain low-risk options for improving management practices from seeding to harvest and storage. CSISA is deploying better-bet agronomic messaging through a range of public and private sector partners, with a companion focus on the development of master trainers so that better-bet agronomy is effectively mainstreamed and fully owned by these partners. Progress in the reporting year by crop was as follows:

	TIPS DISTRIBUTED	REPRINTED BY PARTNERS?	TOT TO PARTNERS (#)	HH APPLYING NEW TECHNOLOGY*	AREA UNDER NEW TECHNOLOGY (HA)*
RICE	10,000	Yes	400	8,177	1,501
WHEAT	2,500	Yes	247	2,138	948
MAIZE	5,000	Yes	212	1,436	400

** Note: Household and area estimates for technology adoption do not capture farmers reached through the efforts of partners to reprint CSISA's outreach materials or otherwise incorporate CSISA's materials in their programs. Those figures are pending.*

B.1.2 Income-generating maize production in neglected hill and plateau ecologies

Promotion of low cost technology for maize intensification in the Terai

Despite the considerable cultivated area (2nd only to rice in extent), Nepal imports about 400,000 tons of maize grain per year, primarily to supply feed mills that support the rapidly growing poultry industry. With the increasing demand, the area under winter and spring maize is increasing in the Terai districts of the FtF zone where irrigation facilities are available. Manual line seeding of maize, is the most common planting method, particularly in winter and spring maize. However, this practice is tedious and requires considerable labor which increases the total production cost and reduces the net benefit from maize production.

AWARNESS PROGRAM FOR PRECISION MAIZE PLANTING IN DANG DISTRICT

CSISA's participatory evaluation of different machines for maize planting and weed management found that they reduce the costs of those practices by 50% compared to manual seeding and weeding. By facilitating a novel public-private collaboration between machinery traders and the Prime Minister's Agriculture Modernization Project, CSISA is catalyzing a transition to scale-appropriate mechanization for maize **with more than 200 ha of maize was planted using precision planters operated by service providers in the Maize Super Zone.** For mechanized weeding and 'earthing up' in the Terai, CSISA has supported the commercialization of service markets for mini-tillers, that are commonly found commonly only in hilly areas since their introduction by the CIMMYT team in 2011. Through the opportunity created by regular row geometry from machine planting, mechanical weeding with efficient machines promises to transform the economics of mark-oriented maize production through dramatic cost reduction and yield gains from more timely weed control. The CSISA team is also working on incorporating precision fertilizer top-dressing into a single pass systems that will accomplish all three operations in a single pass of the mini-tiller.

DEMONSTRATION AND TRAINING OF MINI–TILLER FOR WEED MANAGEMENT

Prior to this year's maize season and in collaboration with the Maize Super Zone program and local traders, CSISA organized a service provider training and awareness-raising campaign regarding mechanized maize seeding and weeding. In Satabariya, Dang, the Maize Super Zone command area, there are now four seed drill service providers and five new mini-tiller-power weeder service providers who, after seeing the demonstrations, purchased mini-tillers and started to provide services during this winter season. CSISA plans to help scale the use of mini-tillers in other areas through mini-tiller importers who can now market this additional 'new use' of their mini-tiller in maize and other row crops in Nepal.

Characterizing maize quality with respect to aflatoxin contamination in farmers' storage under different ecological conditions

Aflatoxins are carcinogenic mycotoxins produced mainly by two types of mold – *Aspergillus flavus* and *A. parasiticus.* When ingested for sustained periods they can be acutely toxic to livestock and humans based on causal associations with diseases such as liver cancer. Moreover, even shorter-term exposure can be hazardous with childhood growth stunting also associated with aflatoxin consumption.

Aflatoxin has been found in grain and feed samples in Nepal. The Department of Food Technology and Quality Center (DFTQC), a governmental body, documents that about 20% of the maize samples assessed contained aflatoxin at levels greater than the safety limit of 20 ppb. To assess levels in two district where commercial maize production is increasing, we collaborated with DFTQC to collect and analyze 100 maize samples from 10 local flourmills in Nuwakot and Dang. The samples were analyzed for aflatoxin contamination immediately after collection. Results indicate that 52% of the maize in Nuwakot and 16% in Dang have aflatoxin levels that exceeded the safety standard (i.e. > 20 ppb).

The USAID-funded Nutrition Innovation Lab (Tufts University) has started to document aflatoxin levels in pregnant women and children. Preliminary results document that 95% of the sampled individuals in the Nepali Terai had a detectable aflatoxin levels.[3] Global research shows that the risk of aflatoxin contamination is highest during the rainy season under hot and humid conditions.

In Nepal's mid hills, maize is mainly grown for food or livestock feed. Consumption of aflatoxin-contaminated maize grains as food or feed can affect both animals and humans. However, there is little documentation regarding how aflatoxin contamination varies according to pre-harvest and post-harvest management practices. Therefore, CSISA again collaborated with DFTQC and the Department of Agriculture's Post-Harvest Directorate to:

- assess the level of aflatoxin contamination in maize under farmers' storage conditions in different production ecologies
- understand how pre-and post-harvest management practices affect aflatoxin contamination

Better fertilizer management reduces risk of pre-harvest aflatoxin contamination in maize: Pre-harvest infection and contamination of maize by *A. flavus* is correlated with insect damage and low soil fertility. To determine the influence of soil fertility management on aflatoxin in the mid-hills, CSISA conducted on-farm evaluations of maize under three different fertilizer management regimens: farmers' practice (application of only urea fertilizer), medium fertility (60:30:30 kg NPK/ha) and high fertility level (120:60:40 kg NPK/ha) in six different farmers' fields in Nuwakot, an FtF district. Harvested maize grains were analyzed for aflatoxin levels by the DFTQC laboratory using the ELISA (Enzyme-Linked Immunosorbent Assay) method. The results showed that maize grown under farmers' fertilizer management has high levels of aflatoxin contamination with 40% of the samples exceeding the toxicity threshold of 20 ppb (Figure 12). Under moderate fertilizer application (60:60:60) all of the samples have very low aflatoxin levels of less than 1 ppb. Similarly, with a high level of fertilizer application, around 40% of samples had aflatoxin levels of 1–10 ppb and 60% of the samples had aflatoxin levels below 1 ppb (Figure 12). The higher level of aflatoxin under farmers' fertility management was also associated with the appearance of stalk rot disease in the field.

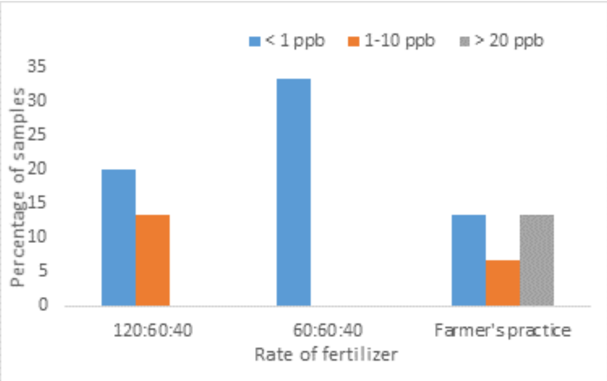


FIGURE 12. AFLATOXIN LEVEL IN MAIZE GROWN UNDER DIFFERENT FERTILIZER MANAGEMENT CONDITIONS

These results highlight the crucial importance of improving soil fertility management to limit the entry of aflatoxin into the food chain. CSISA is working with the NSAF project to both verify results and to ensure that a broad range of partners understand mitigation options for aflatoxin.

Better post-harvest management reduces aflatoxin contamination in maize in wet summers: Research conducted in different parts of the world has consistently shown that post-harvest

[3] CSISA supported the development of the agriculture module for the Nutrition Innovation Lab survey on aflatoxin: http://www.fasebj.org/content/31/1_Supplement/639.42.

contamination by aflatoxin is more severe than pre-harvest. Improper harvesting, delays in processing, and poor storage practices can increase the risk of aflatoxin contamination.

In the hills of Nepal, most farmers store maize on the cob with the husk intact. To assess cost-effective and practice methods for mitigating post-harvest aflatoxin issues in maize, CSISA again collaborated with DFTQC to evaluate different post-harvest management practices. In the improved storage method, maize grains were taken off the cob immediately after harvest and sun dried. When the grain moisture reached 12%, grains were stored under four different types of hermetic bags available in the Nepalese market, with a common non-hermetic plastic storage bag as a check. Maize samples were analyzed for aflatoxin contamination at the beginning of storage and three months after storage. Maize samples were also taken from 18 households where maize cobs were stored without de-husking and mostly kept in stacks on the side of the house. Aflatoxin levels under all improved practices were < 1 ppb. However, under farmers' storage practices – storing without de-husking – more than 50% of the samples had aflatoxin levels exceeded the safety standard of 20 ppb (Figure 13). After six months of storage, the aflatoxin levels with improved practices remained < 1 ppb. These results demonstrate that removing grain from the cob and drying it immediately after harvest dramatically reduces aflatoxin contamination during storage. CSISA is working with mechanization partners to increase the commercial availability of low-cost maize shellers and de-huskers that will facilitate transitions to improved maize storage practices.

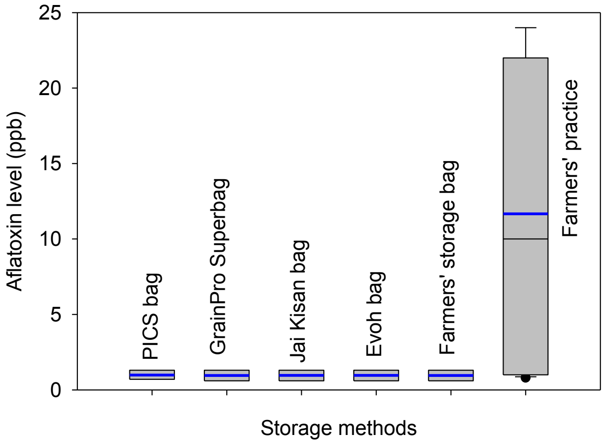


FIGURE 13. AFLATOXIN LEVEL IN MAIZE UNDER DIFFERENT STORAGE PRACTICES

A collapsible dryer for faster drying at the community level: Drying maize and rice during the summer season is challenging, mainly due to frequent rainfall and high humidity. Grain quality can deteriorate if not dried properly. Grain Pro has developed a special tarpaulin that farmers can use to dry maize and other grains (Figure 14a). In collaboration with the District Agriculture Development Office, Mero Agro Pvt. Ltd (private suppliers) and farmers groups, CSISA has demonstrated the collapsible dryer for maize in Nuwakot district. Researchers measured the grain moisture content

FIGURE 14a. DRYING MAIZE GRAIN ON COLLAPSIBLE DRYER

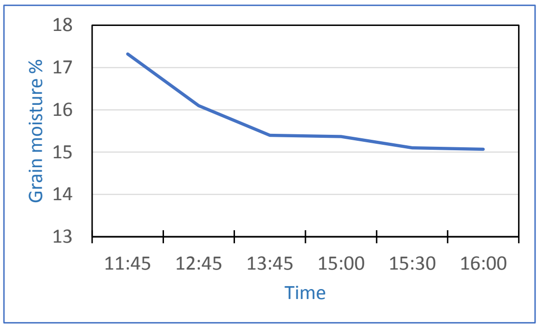


FIGURE 14b. MEASUREMENT OF GRAIN MOISTURE OVER TIME ON MAIZE DRIED UNDER COLLAPSIBLE

over time during the demonstration, which showed that in four hours the grain moisture dropped by 2.3% (from 17.3% to 15%) (Figure 14b). Farmers were happy with the dryer as it helped reduce grain loss through spillage and could be conveniently and quickly closed if it rained. However, the initial price for the dryer is very high and is not affordable for individual farmers. The availability of the dryer on a rental basis could facilitate uptake. CSISA has shared the outcomes of the demonstration with the post-harvest directorate and PMAMP during the joint planning meeting. Further study is needed to evaluate different drying options that are safe, affordable and economical. Larger capacity 'batch' drying options are also being evaluated that could be deployed through cooperatives or at mills.

Partnership with the Prime Minister's Agricultural Modernization Project (PMAMP) for the sustainable intensification of staple crop production

With a planned commitment of more than US$ 100 m and a 10-year performance period, the Prime Minister's Agriculture Modernization Project is the centerpiece of the Nepal Government's efforts to implement the *Agriculture Development Strategy* (ADS) that was passed by parliament in 2016. The ADS provides a roadmap for investment and aims to make the country self-reliant in agriculture production through targeted science-led innovation, progressive policies, and support to the emerging private sector. The PMAMP is organized around 'super zones' (commercial areas of more than 1,000 ha), zones (> 500 ha), blocks (> 50 ha) and pockets (> 10 ha). After consultation with the PMAMP leadership and by invitation, CSISA has initiated deep collaborations with the commodity programs for wheat, maize and rice that extend into the FtF zone. For example, the Maize and Wheat Super Zone programs have included CSISA in their technical and advisory committees and joint work plans were developed for the 2017–18 wheat, maize and mung bean seasons. Key activities include:

- Demonstrating mechanized crop establishment in new areas by mobilizing CSISA-supported service providers;
- Contributing to the development of new commercial pocket areas (> 10 ha each) for maize, wheat and mung bean by linking input and output value chain actors with producer groups;
- Organizing technical trainings on sustainable intensification production technologies for key intermediaries from the PMAMP, Department of Agriculture, and private sector;
- Sharing extension publications in the forms tips, posters, booklets and videos that draw from CSISA's applied research programming.

Under this partnership, the first national Maize Forum (October 9–10, 2017) and Rice Forum (December 14–15, 2017) were organized, which included more than 35 key public and private stakeholders for each crop. To frame the discussion, CSISA scientists presented a synthesis of findings from production practice surveys as well as on-farm experiments conducted in different seasons and geographies. Discussion at the forum then emphasized the identification of proven best practices for sustainable intensification, consideration of scaling pathways for knowledge and technological innovations, areas for future research, and joint work plan development for both rice and maize for the coming season. Similar events were also held for wheat (Q3 2017) and farm mechanization (Q4 2017).

Going forward, CSISA sees the PMAMP as the core mechanism for scaling sustainable intensification technologies for cereals in Nepal. As such, CSISA will continue to make contributions to the PMAMP at the strategic and operational levels. For example, technical traning for DSR was conducted in the rice super zone with CSISA's technical facilitation in 2018. Within the same season, farmers covered about 30 hectares with DSR and expected that additional hectares would be brought under DSR during the next spring and monsoon rice seasons. Farmers who took up the technology

HANDS-ON DSR TRAINING IN THE RICE SUPER ZONE observed that the cost of rice cultivation was reduced by around 30–40%, in part because farmers could save about 60–70% of the total crop establishment costs.

C. Achieving Impact at Scale

C.1 Growing the input and service economy for sustainable intensification technologies

C.1.1 Integrated weed management to facilitate sustainable intensification transitions in rice

In Nepal, manual hand weeding is the most common method of weed control in rice. Because of the scarcity of labor and consequent increase in labor wages, manual weed control is becoming expensive and laborers are often not available at critical weeding times, leading to late weeding and high yield losses - up to 40%.

Recently, some farmers have started using herbicides for achieving timely and economical weed control, but there is almost no data available on the types of weeds that are most common, or on the contemporary control strategies implemented by farmers and supported by the private sector. To address these gaps and best target integrated weed management interventions, CSISA conducted a field survey of current weed management practices and began gathering spatial information on problematic weeds across the landscape.

Surveys covered 403 households across six Terai districts in the FtF zone over a two-year period. Forty weed species including annual grassy weeds, broad-leafs, and sedges were documented in rice and wheat. In 2016, *Cynodon dactylon*, *Cyperus iria*, *Fimbristylis miliacea*, *Alternanthera* spp, and *Cyperus difformis* were the top five weed species, covering >65% of the total weed population in rice (Figure 15). In 2017, the dominant weed species changed with *Cynodon dactylon*, *Echinochloa colona*, *Cyperus iria*, *Echinochloa crusgalli*, and *Fimbristylis* spp topping our lists. In wheat, *Anagalis sps*., *Chenopodium sps*., *Medicago sps*., *Vicia sativa*, *Sensecio sps.* were the top five major weeds found in rice–wheat systems (Figure 15). This information is now being shared with private dealer and government extension partners to better match weed control products and management guidance to the dominant weed flora in the Terai of Nepal.

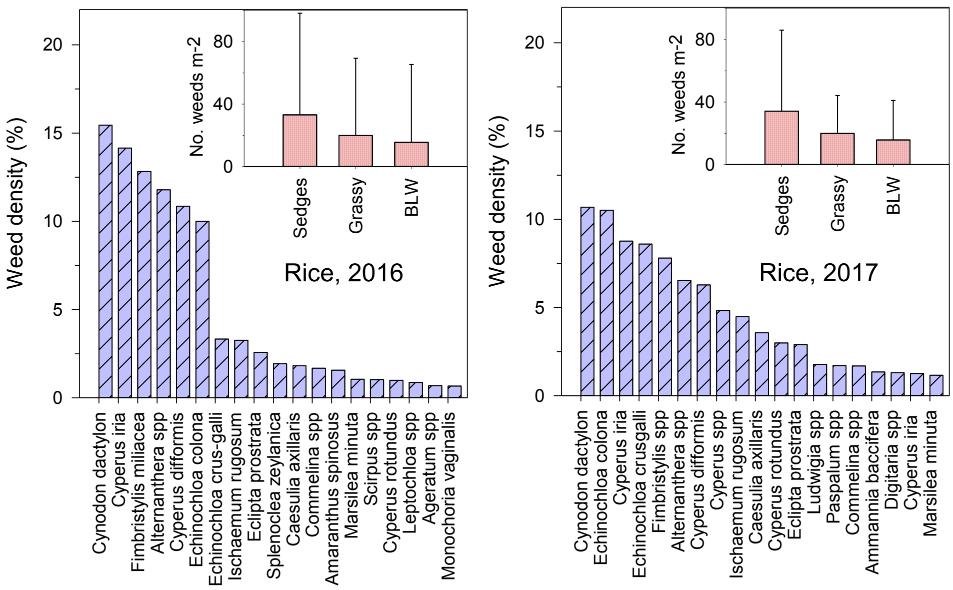


FIGURE 15. RELATIVE DENSITY OF DIFFERENT WEED SPECIES AND TYPES FOR RICE IN THE WESTERN TERAI REGION OF NEPAL

C.1.3 Commercial expansion of scale-appropriate machinery and associated service provision models for reapers and seeders

Scaling mechanized wheat seeding through service providers

In Nepal, the national average wheat productivity is far below other Asian countries with similar production ecologies. A CSISA survey conducted across the Terai's wheat growing districts in 2016 showed that >25% of the wheat farmers suffer net financial losses, mainly due to high production costs and low productivity. Zero tillage significantly reduces the cost of sowing wheat and helps facilitate early seeding, especially in lowland areas, thereby reducing production costs and increasing productivity while significantly reducing risk and boosting resilience by helping farmers avoid terminal heat stress. CSISA is facilitating mechanized wheat sowing by facilitating the emergence of well-trained service providers. CSISA's collaborative effort with partners in 2017–18 facilitated 1,545 farmers to adopt mechanized wheat on 887 hectares. Most encouragingly, mechanized seeding adoption has been achieved through the increased private sector provision of seed drills with more than 70 drills sold for the 2 and 4-wheel tractor platforms during the reporting period (Figure 16). There were no seed drills commercially sold in the FtF zone prior to CSISA's market facilitation efforts in 2014.

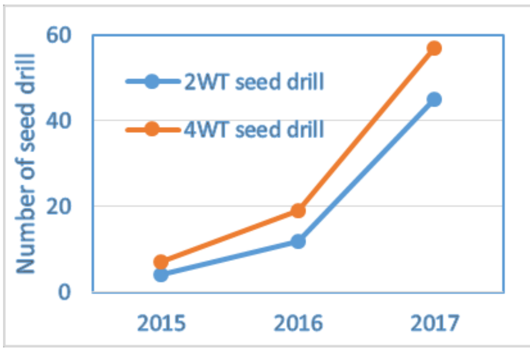


FIGURE 16. SEED DRILL SALES IN FOUR MID AND FAR-WESTERN TERAI DISTRICTS

Service providers are key to increasing access to capital-intensive mechanization technologies by making them available for a fee to small- and medium-scale farmers who do not have the financial resource to purchase their own machinery. With technical and market development support from CSISA, more than 200 service providers have now purchased seed drills in the Terai region. CSISA conducted a survey of 85 service providers in six Terai districts to help develop a 'service provider profile'. On average, each provider operates within a 20 km area and charges on average US$ 12–15 per hour. Figure 17 shows the distribution of service providers located in FtF districts in the Terai and the circle indicates the maximum distance that each service provider reached to provide services to farmers.

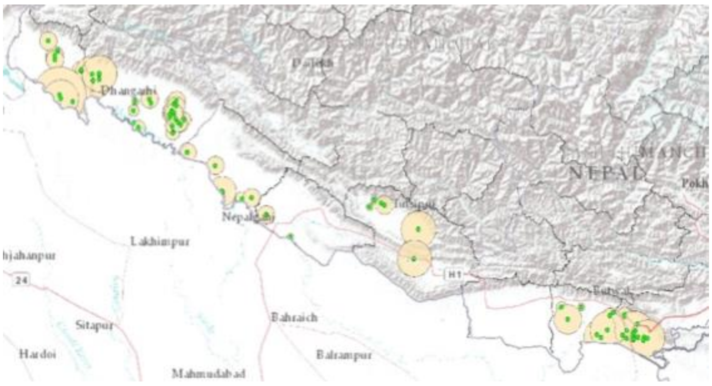


FIGURE 17. DISTRIBUTION OF SEED DRILL SERVICE PROVIDERS LOCATED IN CSISA WORKING DISTRICTS. THE CIRCLE INDICATES THE MAXIMUM DISTANCE TRAVELLED TO REACH FARMERS.

Building relationships across the machinery value chain

In the first five years of CSISA (2009–14), the project focused almost exclusively on new technology introductions with concomitant activities for demonstrations and training. To capitalize on the demand created, we began broaden our approaches in 2015 to emphasize marketing campaigns, building backward linkages with machinery manufacturers (Indian and Chinese), and best leveraging government cost-share programs that served to stimulate private sector investments. Table 7 highlights private sector business partnerships for the supply of various modern machinery planters, harvesters, laser land levelers and other equipment for both 2-wheel and 4-wheel tractors that have been built by CSISA.

Table 7. CSISA's facilitation efforts across the machinery value chain in the FtF zone of Nepal

Exporter / Location	Importer	Partnership Established	Product(s)
Khedut India	SKT (initially) BTL and Global Trading (currently)	March 2016 January 2017	Lower-cost seed drills for minitiller Lower-cost seed drills for two-wheel tractor (2WT) Lower-cost seed drill four-wheel tractor (4WT) Lower-cost manual planters, jab planters and pull planter
National Agro India	The Habi Kubir and Sons	December 2015 Apr – Dec 2016	Premium four-wheel tractor seeders and planters
KGBK, Jharkhand	Kubir and Sons	March 2016	Hand tools (weeders, etc.)
Durga Engineering Odisha, India	SKT	May 2016	Open drum thresher
Dharti India	Kubir and Sons	December 2016	Lower-cost minitiller, 2WT, & 4WT seeders
Various Chinese suppliers	BTL SKT Kubir and Sons Tikapur	Before project 2014 2014 2016	2WT reapers
Various Chinese suppliers	BTL	July 2016	Premium vertical plate maize planter
Various Chinese suppliers	SKT and AMC	2016	Hand-cranked seed and fertilizer spreader
Various Chinese suppliers	Shrestha Agro, SKT, BTL, AMC	2015	Irrigation-water pumps for mini-tillers
National Agro India	RCT Engineering	Nov 2017	4WT ZT seeders Laser land levelers

Sales of reaper-harvesters boost mechanized harvesting in Nepal's Terai

Reapers save cost, time and drudgery over manual harvesting, and increase the likelihood of on-time planting – benefits that increase profitability by more than $100 per hectare every season. CSISA's efforts to scale the reaper-harvester has resulted in the private sector sales of 2,877 reapers for the 2-wheel

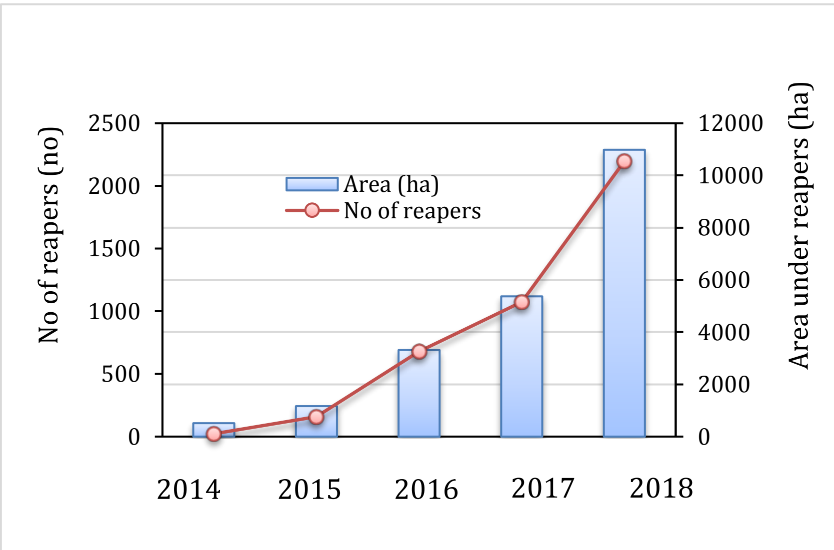


FIGURE 18. ESTIMATED REAPER NUMBER AND TOTAL AREA HARVESTED FOR RICE AND WHEAT

tractor. In reporting year, we estimate that farmers have used these reapers to harvest 14,385 ha of rice and wheat (Figure 18). More than 95% of service providers purchased reapers at their own cost without any subsidy. With increased demand, the number of importers/suppliers has also increased. Whereas in 2016 four traders were involved in importing reapers, the number has increased to seven in 2018.

Demand for precision land leveling increases in Nepal Terai

A small number of farmers in the Terai plain region in Nepal are saving irrigation water and increasing yields with the use of the laser land leveler (LLL). The laser land leveler allows water to be distributed evenly within fields, increasing crop growth, resource recovery, and water-use efficiency. However, the high cost of equipment poses a barrier to scaling – even through service providers.

CSISA introduced laser land leveling technology in the central Terai in 2010. Scientists worked with farmers on technology demonstrations, participatory evaluations and awareness-raising campaigns. CSISA also provided operational and business development training to potential service providers. Workshops were organized among manufactures from India, local traders, government personnel and key farmers to discuss its scope for market development and for scaling-out the technology in the region.

Presently, the number of laser land leveler service providers has increased to 27, and there are now five sales outlets for LLL across the Terai from a base of zero in 2013. The Government of Nepal is supporting land leveling by providing a subsidy for LLL purchases and raising awareness on the importance of leveling land.

To understand farmers' willingness to pay for laser land leveling services towards the goal of market development, CSISA conducted a scoping study on the adoption of laser land leveling technology in the western Terai. The study characterized interest in using laser land leveling services if services were available as a chargeable rental service. We used the semi-bound dichotomous choice model by taking the average per-hour charge for laser land leveling services (US$ 15.00 per hour) practiced by innovative service providers in the central Terai. The individual willingness to pay for LLL services for each of the farms was further derived by predicting it from interval regression. Results showed that farmers' willingness to pay for LLL services ranges from US$ 5 to 33 per hour. Furthermore, we observed a heterogeneous demand for LLL services across different farming strata. With an average willingness to pay of US$ 15.50 for per hour of LLL services, the predicted willingness to pay for LLL services for the largest 25% of farmers (landholding ≥ 1.82 ha) was significantly higher (US$ 22 per hour of service) than the lowest 25% of farmers (landholding < 0.24 ha) whose average willingness to pay for LLL services was US$ 11.40 per hour of LLL service (Figure 19). This study showed that farm size is the most important factor that derives the farmers' willingness to pay for laser land leveling services and gives guidance on the market potential in different parts of the Terai for the private sector and well as insights into how government support programs can be efficiently targeted to ensure inclusive access to this technology.

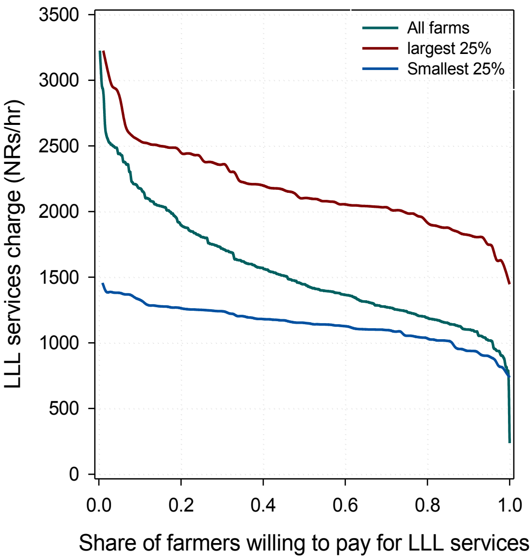


FIGURE 19. SHARE OF FARMERS WILLING TO PAY FOR LLL SERVICES

Survey of mini-tiller sales and impacts in the mid-hills of Nepal

Since 2012, CSISA has played significant role in scaling the mini-tiller, a small (*5 to 9 horse power*) tractor particularly useful for the mid-hills, through field demonstrations, awareness-raising programs for public and private partners, and through market development. Currently, more than 10,000 units have already been sold across the country. To understand the impact of the adoption of a mini-tiller on farm income and the service economy, CSISA recently conducted a survey in collaboration with the Agri-engineering Directorate and the Nepal Agriculture Machinery Entrepreneurs Association (NAMEA) in six mid-hill districts.

Traditionally, bullocks and manual laborers were the only sources of tillage in the mid-hills of Nepal. A shortage of agricultural labor, mainly due to youth migration, has significantly affected agriculture production in the hills. Survey results (n = 1,004 households) indicate that 69% of farms perceive that that timely availability of agricultural labor is the major production constraint in the hills.

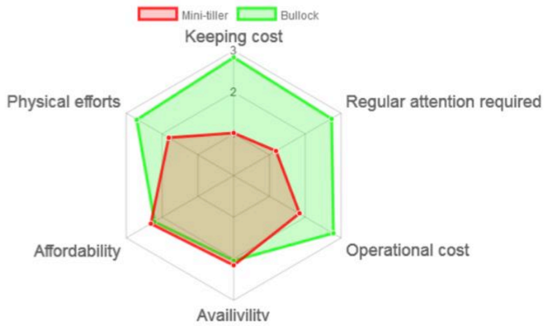


FIGURE 20. KEY CONSIDERATIONS FOR BULLOCKS VERSUS THE MINI-TILLER IN MID-HILLS. LOWER VALUES INDICATE MORE FAVORABLE PERCEPTIONS OF FARMERS.

Labor shortages affect the timeliness of crop management activities and the adoption of the mini-tiller can help overcome labor shortage problems, particularly for tillage. Compared to the mini-tiller, the cost of raising and keeping bullocks is much higher because they require feed, concentrates, fodder and labor. Although bullocks provide farmyard manure that is useful for increasing crop productivity, the daily care of raising bullocks involves significant drudgery for farmers, particularly due to the amount of time involved in collecting fodder. Our survey shows that the mini-tiller substantially reduced or eliminated the costs of keeping bullocks, and reduced or eliminated the drudgery of maintaining them, thereby reducing the operational cost of farming and reducing the attention required to keep bullocks (Figure 20). The mini-tiller is primarily used for tillage, while <1% of farmers also are using it for pumping irrigation water and transportation (using a small trailer attachment). Tillage and crop establishment costs were significantly lower for MT adopters compared with bullocks: savings of US$ 108/ha for rice, US$ 45/ha for maize, US$ 40/ha for wheat, and US$ 37/ha for vegetables.

Initial analysis showed that farm households that adopted mini-tiller tillage (through purchase or rental) produced higher yields for both cereals and fresh vegetables compared to non-adopters. On average, adopter households increased their productivity by 0.4 to 0.5 t/ha for major cereals and by 4 t/ha for fresh vegetables (Table 8). Increased crop productivity with mini-tiller adoption is likely driven by more timely crop establishment.

Table 8: Impact of mini-tiller on tillage cost and crop productivity of major cereals (rice, wheat and maize) and fresh vegetables in study areas

Crops	Adopters	Non-adopters	Difference	*t*-value
Rice (N= 302 Adopter, 322 Non-adopter)				
Tillage cost (US$/ha)	132	240	108	12.97***
Grain yield (kg/ha)	5518	4989	529	-3.36***
Maize (N= 276 Adopter, 466 Non-adopter)				
Tillage cost (US$/ha)	118	163	45	5.80***
Grain yield (kg/ha)	3436	2989	446	-2.85***

Wheat (N= 106 Adopter, 199 Non-adopter)				
Tillage cost (US$/ha)	130	170	40	2.24**
Grain yield (kg/ha)	2201	1942	258	-2.07**
Fresh vegetables (N= 203 Adopter, 201 Non-adopter)				
Tillage cost (US$/ha)	146	183	37	3.02***
Production (tons/ha)	13.58	9.47	4.10	-5.16***

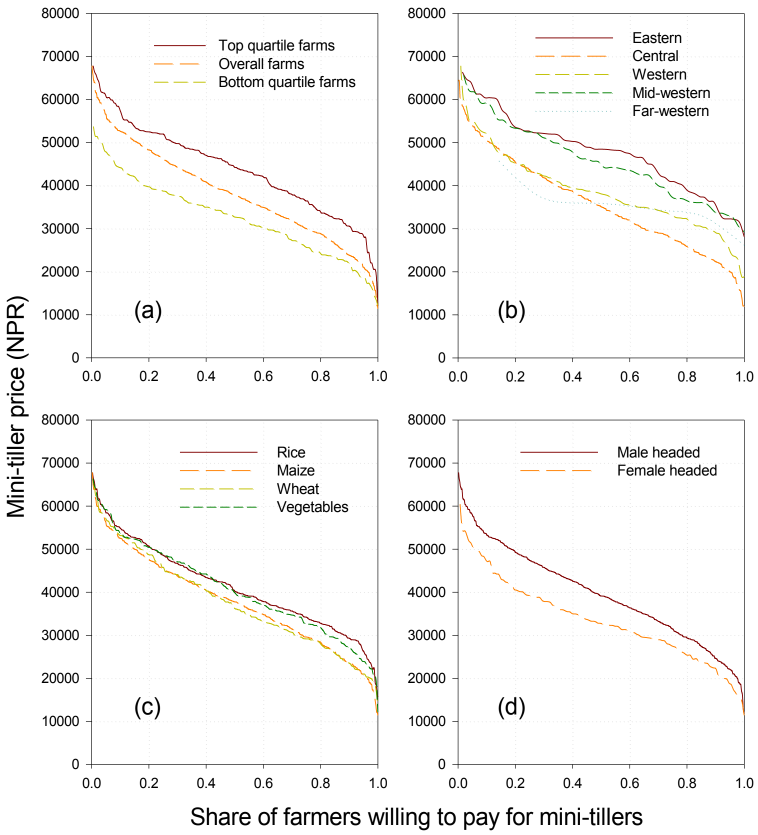
*** Statistically significant at 1% level, exchange rate US$ 1 = 100 NRs

A huge number of Nepalese workers are migrating abroad in search of better employment opportunities, resulting in acute labor shortages in agriculture. CSISA is strengthening service provision opportunities and, through surveys, attempting to document the income-generating potential of different mechanization platforms and services to help further enthuse the emergence of more entrepreneurs. Out of the 254 mini-tiller owners surveyed, 26% are providing services for tillage to the neighboring farms. On average, each owner serviced nine neighboring farms with an average area of 1.8 ha during the surveyed year, excluding their own land. The average rental service charge for tillage was US$ 5.5/hr and service providers were earning more than US$ 200/ha/year in additional income. The unit cost of the mini-tiller is around US$ 550, making the payback period less than three years. Low investment cost, short payback period and the chance to generate extra income from rental services makes the mini-tiller potentially important for rural entrepreneurship development in hilly areas of Nepal. Also, CSISA research also shows that most of the mini-tillers procured by farmers were subsidized (70%) either by government programs or development organizations. Interestingly, farmers who purchased a mini-tiller at full cost were more likely to be involved in providing services to other farms than the farmers who purchased or obtained a mini-tiller through a partial or complete subsidy.

Service providers reported that mini-tillers often vibrate too much vibration during tillage. Our survey results show that 53% of mini-tiller adopters reported vibration coming from the mini-tiller during tillage as the major constraint of mini-tiller adoption. Other problems adopters faced included wear and tear of spare parts and unavailability of spare parts locally. On average each mini-tiller owner spent US$ 67.50 (NRs 6,748) for repair and maintenance annually. Only 8% of mini-tillers owners reported that they obtained mini-tiller repair and maintenance training and 84% responded that the training was useful. CIMMYT and its partners have provided repair and maintenance training to farmers as part of the earthquake recovery support program, yet most farmers responded that they have problems accessing repair and maintenance services locally.

Characterizing the scale-appropriate mechanization demand in the mid-hills of Nepal

In order to understand farmers' demand for mini-tillers, CSISA conducted a willingness to pay study. The willingness to pay and demand characterization is helpful for the private sector and Government to target the expected volume of sale in different geographies. Results show that the overall farmers' average willingness to pay was 31% lower than actual mini-tillers' prevailing price in the market. However, there was a heterogeneous demand across large and small quartile farms and the smallest quartile farms were willing to pay 26% less for the technology compared with the top quartile farms. Figure 21 shows the study area and mini-tiller demand characterization across different farm size categories, cropping systems, household genders and regions.



FFIGURE 21: DEMAND CURVES FOR MINI–TILLERS ACROSS DIFFERENT FARM SIZE, REGIONS, CROPPING SYSTEMS, AND HOUSEHOLD GENDER

Agricultural Machinery Testing and Research Center, Nawalpur

The CSISA-supported Agricultural Machinery Testing and Research Center (AMTRC), co-located at the National Oil Research Center in Nawalpur, Sarlahi District, and run by NARC, was inaugurated in February 2018. With approximately US$ 145K provided by CSISA for machinery procurement, the center has built a new Dynamometer Testing Center and rehabilitated an older office and quarters that were given to AMTRC by the Oil Research Farm. In April, NARC also provided a co-investment of US$ 85,000 to compete the first round of building construction. CSISA provided an additional US$ 20,000 sub-grant to the center to jumpstart the testing of select agricultural machinery. The AMTRC had been chosen by the United Nations Center for Sustainable Agricultural Mechanization (UN-CSAM, www.un-csam.org) to be one of five member countries' machinery testing centers to participate in a needs assessment from an outside team of senior agricultural engineers. AMTRC staff will also receive advanced training on machinery testing protocols. Depending on the outcomes of the needs assessment, AMTRC could qualify for further investment by UN-CSAM for increasing AMTRCs testing capacity.

Agricultural Mechanization Forum with PMAMP and DOA

Another in a recent series of CSISA-sponsored thematic meetings through our partnership with the PMAMP was held on 'Mechanization for Sustainable Intensification of Nepalese Agriculture' in Kathmandu on February 14-15, 2018. Participants hailed from various governmental and non-governmental, research and educational, finance and banking, and private organizations. The objective was to review the current knowledge of, and practices in, machinery value chains in Nepal and begin to develop a strategic roadmap for scaling innovations. Some initial activities were identified for fast tracking such as (1) planning for trainings of trainers and local service providers by

DAE, NARC, and CSISA and private sector suppliers for the reaper-harvester, laser land leveler and direct seeded rice with Rice and Wheat Super Zones and (2) similar activities on the promotion of maize planters and power-weeders for Maize Super Zone farmers for spring and summer maize.

Design Sprint update

Dharti Agro and Khedut Agro have now have established dealers in Nepal and also have begun marketing the improved seeders that emerged from the CSISA-supported collaborative design sprint that was devised to overcome long-standing design issues that were limiting sales of seeders for the 2-wheel tractor platform. Dharti has now 10 pieces of 4-wheel tractor and two pieces of 2-wheel tractor seeders in stock with their dealer (Kubier and Sons in Itihari) and Khedut not only has stock but also has recently sold 15 4-wheel tractor zero till drills to the FAO's climate change project in Nepal.

CSISA mechanization video series and farmer field days

CSISA Nepal released four short videos highlighting the value of mechanization and service provision in Nepal. Featuring farmers who have adopted technologies such as seed drills, power tillers, mini tillers and reapers, the videos highlight that mechanization can save time and cost and reduce drudgery. They also point out that extra income can be made from becoming a service provider, and that these opportunities to earn extra income can help reduce incentives for Nepal's youth to go abroad for work.

Sutra Media Works (the filmmaker) and CSISA hosted four video showings in the field so that farmers, potential service providers, self-help groups and Nepal government representatives could see the films, ask follow-up questions and discuss locally relevant issues raised by the videos. Held in Bardiya, Dang, Kailali and Kanchanpur for 296 attendees (including 72 women), the films were well received and the discussion participants identified the following preconditions for mechanization to spread broadly: (1) increased awareness of agricultural technologies at the local level (i.e. demand generation), (2) technical training on how to use the equipment, (3) spares and repairs for fixing machines, and (4) mechanisms to bring the cost of technology and services into reach.

Banking Sector Policy Changes and Financing for Agri-Mechanization

Over the past three years, CSISA has held multiple rounds of meetings with banks and micro-financing institutes (including USAID Development Credit Authority partner Laxmi Bank) about the unmet need for financing agricultural machinery in Nepal. Until recently, there had been little or no movement by the banks to connect with the agri-machinery industry, outside of financing 4-wheel tractor sales. Approximately 1.5 years ago, the Government of Nepal announced that the 10% of the funds that commercial banks must lend to the rural sector could no longer be channeled through rural development banks but had to be directly loaned from the commercial banks themselves. There was also a warning from the government that there will be an increase in the penalty for not meeting the target, which some banks had elected to pay rather than go through the extra cost of managing loans to rural clients.

These changes in the policy environment have reignited interest within the banking sector in agri-machinery loans. One recent outcome was the bank tie-up between Nepal–Bangladesh Bank and BTL Limited for the financing of tractors and attachments. A second has been that Laxmi Bank has a new loan product arrangement with SKT Nepal Pvt. Ltd. to finance agro equipment end users via selected dealers of SKT Nepal that is backed by dealer's buy back guarantee and a corporate guarantee of SKT Nepal. Financing is restricted to 70% of the invoice value, with the loan size ranging from NRs 40,000 per invoice and a maximum of NRs 500,000 per borrower. Laxmi Bank anticipates building a total loan portfolio of approximately NRs 20 million under this scheme at the piloting phase. Given the importance of finance for overall growth of the mechanization sub-sector, CSISA will continue to facilitate relationships between banks and our private sector partners like SKT and BTL.

C.2 Managing risk by coping with climate extremes

Understanding and coping with monsoon variability

Rice is grown in all districts of Nepal but more than 70% of total rice production comes from the Terai region. Since most rice systems are rainfed or only partially irrigated, production is highly dependent upon the onset, distribution, and cessation of monsoon rainfall.

To understand rainfall variability and its effects on rice production in the Terai and to understand farmers' coping mechanisms under both drought and flood conditions, long-term (1976–2014) rainfall and productivity trend data from 21 Terai districts were assessed.

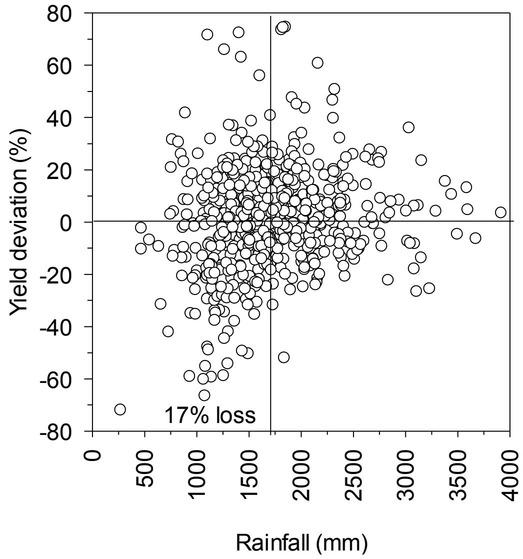


FIG 22. RELATIONSHIP BETWEEN SEASONAL RAINFALL AND RICE YIELD OUTCOMES FOR 21 TERAI DISTRICTS

Results underscore the complex relationships between seasonal rainfall and yield outcomes, but also clearly show that the most extreme reductions in yield (> 25% deviation from de-trended mean) occur when precipitation falls below 1,700 mm (Figure 22).

A companion simulation study was conducted to explore the yield of transplanted rice under irrigated and rainfed conditions in three FtF districts (Kanchanpur, Banke and Rupandehi) using the ORYZA3 model. The simulation study showed a declining trend of rice yield potential under rainfed conditions (Figure 23). However, in the same period when supplementary irrigation was applied, rice yield potential actually increased. This simulation study underscores the importance of irrigation for coping with monsoon variability.

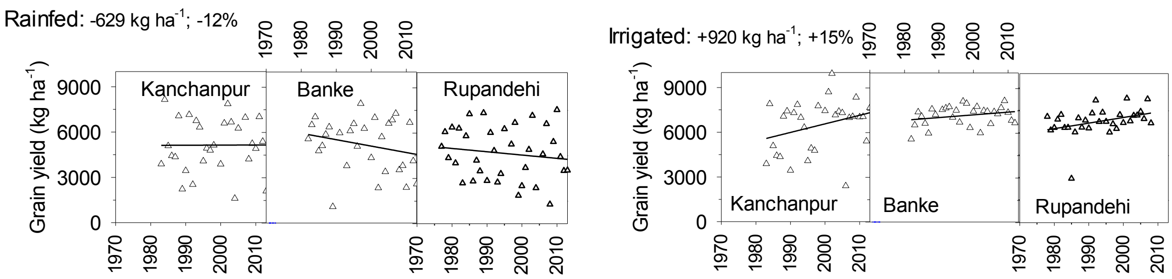


FIGURE 23. THE LONG-TERM SIMULATED YIELD OF TRANSPLANTED RICE UNDER RAINFED AND IRRIGATED CONDITIONS

Through CSISA's surveys and stakeholder engagements, it has become clear that many farmers who insufficiently irrigate rice do, in fact, have access to irrigation water but choose not to use it. To change this scenario and increase systems resilience, food security, and profitability, CSISA has partnered with the Water Resources Management Group at Wageningen University to characterize farmer decision process around irrigation use in rice. Case studies were developed for Banke, Rupandehi and Kailali Districts using semi-structured interviews, household surveys, and ethnographic decision-tree models.

Our results indicate that irrigation is constrained by many of the same factors across the entire area, but with varying degrees of importance. The most influential factors associated with lower irrigation application rates in rice include: 1) 'loss aversion'-induced delays (e.g. concern that rains will eventually come, eroding the value of applied irrigation – a core issue in all districts), 2) lack of reliable electricity (Banke), 3) shortages of pumpsets (all), 4) turn-taking for shared tubewells (Rupandehi), 5) financial constraints (Kailali), and 6) pump maintenance-induced delays (Rupandehi, Kailali).

Efforts to encourage more optimal use of irrigation infrastructure will fundamentally require improvements in decision support tools for irrigation scheduling to address loss aversion. In Rupandehi, increasing tube well density is likely to stimulate informal water markets to provide more benefits by driving down rental delays. In Banke, the large number of existing agricultural electricity connections and shallow tubewells renders a reliable electricity supply a worthy focus point for improving irrigation utilization in the driest of the three districts. In Kailali, cash constraints are of larger importance. Bringing down water prices through improved pump system design and provision of credit are promising entry-points.

CSISA's yield and production practice survey for the 2016 rice crop confirms the importance of supplemental irrigation for reducing risks and achieving high and stable crop yields. Across the Terai districts where the survey was implemented (total of more than > 1,050 households), farmers who irrigated three or four times had rice yields that averaged approximately 4.5 t/ha, whereas farmers who did not irrigate achieved yields of 3.0 t/ha, indicating that water stress in even a 'good' monsoon year reduces rice yield potential by 33%.

Challenges faced during the reporting period

1. Evolving process of political devolution:
    - Nepal recently entered into the complicated effort of building a federated structure with more regional autonomy. One result is that the agricultural budget that used to be with the District Agriculture Development Offices has been diverted to new, local administrative units. As there is no clear-cut breakdown of local budget by sector, many agricultural development support programs have been deferred or otherwise delayed.
    - Also, as the Department of Agriculture and the many of its district-level Agricultural Development Offices are mostly concentrating on transitioning to the new provincial republican structure, CSISA's collaborative work with District Agriculture Development Offices and Agriculture Service Centres has been negatively affected. For example, the dissemination of better-bet agronomic messages, supporting the development of the service economy and stronger agro-machinery markets has slowed down.
    - Quick and repeated changes in political leadership have affected CSISA's work. For example, workplans have been devised with one set of staff, only to have those staff transferred to another office. This is common in PMAMP units, zones and superzones. The recent decision by the federal government to establish Agriculture Knowledge Centers under the provincial governments, which are deemed to be equivalent to the previous district agriculture development offices, is also creating confusion.
2. Funding uncertainty
    - In September 2017, it became clear that FY18 funds for this project were expected to be delayed and/or greatly reduced.
    - In response to funding uncertainty and delays, CSISA had to reduce its staff strength by around 75% as we conserve funds.
    - CSISA received around 70% of our FY18 obligation in August 2018.

D. Policy Reform

D.1 Seed Systems

Bangladesh

Activities around seed system policy reforms have been phased down in this reporting period due to transitions in IFPRI CSISA leadership and larger project-related factors. However, CSISA continues to maintain close relationships with partners on the seed systems front in Bangladesh, including IFPRI's Bangladesh Policy Research and Strategy Support Program and Agricultural Policy Support Unit, the main CGIAR centers with offices in Dhaka, the national research system, and the donor community, and is positioned to leverage these relationships to pursue additional activities around seed systems policy research if there is sufficient interest and funding to support these activities.

Nepal

CSISA entered into a collaboration with the USAID-supported Nepal Seed and Fertilizer project (NSAF), led by CIMMYT, to determine the demand and supply gaps required to bring about a systemic policy change in varietal turnover. To assess farmers' demand for quality and timely availability of seed, CSISA had initiated discussions to field a discrete choice experiment among farmers in Nepal to better assess the specific varietal traits that farmers desire in cereals seeds. The objective was to allow CSISA to have a better understanding of ground-level issues and provide a basis of evidence on which to advise the Government of Nepal on policy and regulatory options under the Nepal Seed Vision 2020 as the Nepal government's intention is to reduce the subsidy burden on the exchequer by replacing universal subsidies with a targeted voucher system. However, activities in this area have been suspended in light of priorities of the Nepal government and partners and transitions within the IFPRI CSISA leadership.

D.2 Scale-appropriate mechanization

Bangladesh

CSISA had engaged in determining the potential impact and tradeoffs associated with the Government of Bangladesh's various policies to support and protect domestic agricultural equipment manufacturers, such as customs duties and tariffs, credit facilities, and other support mechanisms. CSISA had also characterized the status of the agricultural machine industry and the dispersion of agricultural machines throughout Bangladesh, including the structure of the aforementioned trade barriers on agricultural equipment. This task also attempted to understand the sensitivity of supply and demand to price changes, and changes in government revenue as a result of changes to trade policies. During the exercise, several important data gaps were identified that restricted our ability to infer the complete picture – such as administrative data on specific machines and data on supply and demand elasticities for relevant agricultural machines. It became apparent that a significant investment of staff time and resources would be required to complete the analysis. Continued work on this activity beyond December 2017 proved difficult for CSISA considering the uncertainty around project funding and CSISA's inability to continue to support in-country staff during the reporting period. However, with latest update on renewed funding, efforts are being made to re-instate the original problem at hand and address it using secondary as well as primary data that can be summarized to arrive at policy narratives to inform the Government of Bangladesh.

The need for understanding gender dynamics in emerging markets for agricultural machinery resulted in a collaborative partnership between CSISA, GCAN (a Feed the Future Initiative) and CSISA-MI. This partnership aimed to jointly generate evidence that sheds light on gendered differences in women's and men's involvement in emerging markets of reaper-harvester machinery services in the Feed the Future Zone in Bangladesh. Results from this study point towards the fact that many technical, economic, and cultural barriers constrain women's full participation in reaping the benefits from these machinery, but there is potential in reducing these gaps by prioritizing joint learning, collective hiring and lowering the costs of service provision. With frequent migration of men out of rural areas to secure more remunerative employment, women farmers represent a relatively untapped market of latent demand if access to these services is enhanced. At the same time, encouraging women to turn into service providers has immense potential in providing them with potential business opportunities and raising their income-generating capacities.

Nepal

Due to funding uncertainty, efforts in this direction had been halted under CSISA, but our continued interest in the area has resulted in IFPRI's participation in other USAID potential grants that allow us to engage in experiments around scale-appropriate mechanization in Nepal. Considering renewed funding since October, we have initiated conversations around the service economy of key machines such as power tillers in Nepal and wish to use the expertise of partners and stakeholders to inform the relevant policy narrative in the country.

D.3 Soil fertility management and fertilizer markets

Bangladesh

In both Bangladesh and Nepal, there are legitimate concerns about fertilizers being smuggled across the border from India and subsequently sold on the black or grey markets. The government of India has introduced a fertilizer monitoring system that is meant to track fertilizer supplies from the manufacturer to the retailer and ultimately to the end user, which has the expressed intent of eliminating diversions of fertilizer stocks to Bangladesh and Nepal. CSISA is closely following the policy landscape on both sides of the border to determine the impact of such a policy on the availability of fertilizer in Bangladesh, particularly in the border areas. The delayed implementation of India's Aadhar-enabled fertilizer management system has impeded CSISA's efforts to qualitatively assess the impacts on fertilizer supplies in Bangladesh, as has the funding scenario. However, insights from the challenges faced in the implementation of such policy were summarized into a CSISA Research Note published in April 2018.

Nepal

CSISA's collaboration with NSAF continued into the current reporting period, allowing us to leverage project activities to jointly expand our knowledge base and insights on the key policy concerns of the Nepalese government around the establishment of strong internal manufacturing systems to support the demand for key agricultural inputs, a portion of which is currently being met by grey markets around the India-Nepal border. Data from the NSAF project's baseline survey provides some insights into this phenomenon as well as the demand-supply gaps in effective nutrient application behavior amongst the farmers in Nepal. CSISA has undertaken a comprehensive analysis of these data to identify the price variants and other bottlenecks in the availability of key inputs such as Urea and DAP and employed the evidence to design a structured willingness to pay experiment with farmers in Nepal that was rolled out into the field during May- June 2018. Data were collected from 600 respondents spread across the Hill and *Terai* districts from east, central and western part of the country.

The experiment was designed to unearth latent demand of quality and timely availability of fertilizers using modern experimental valuation techniques. While detailed analysis of the results from this exercise are underway, we have been able to generate preliminary insights around Nepalese farmer's differential valuation for the product (key agricultural inputs – Urea and DAP) and the constraints to access the product for the end users. Data collected as part of this activity point to a high positive valuation for both reduced transaction costs and certainty associated with obtaining fertilizers. We also find that the willingness to pay for Urea was statistically significantly higher in the hilly regions of Nepal than the plains, while for DAP was higher in the plains than the hills. Given the topographical diversity in Nepal, the certainty premium that farmers placed on fertilizers was higher for those living in the hills. This result confirms the hypothesis that the Nepal government should focus in ensuring regular supplies in the hard-to-reach areas to ensure timely application of fertilizers. The quality of fertilizers received was found to be one of the barriers to adoption – we found that farmers who faced issues with quality in the past had higher implicit valuation for fertilizers as a whole and would like to pay more for obtaining quality fertilizers. Contrary to what was expected, we found no differences in farmer's valuation for fertilizers for those living close to the India border versus the farther residents. This implies that most farmers still depend on the Nepal government's channels of cooperatives and agrovets for procurement of key inputs and the need to strengthen the supply chain there is more imperative. Results from this study are currently being summarized in the form of a policy brief that will be shared with relevant stakeholders with a hope to inform the Nepal government's voucher system design and efforts towards the development of stronger supply chains across the country.

D.4 Agricultural risk management

Bangladesh

CSISA has been evaluating alternatives for providing risk management solutions to smallholder farmers in Bangladesh, specifically stress-tolerant rice cultivars developed under the Stress-Tolerant Rice for Africa and South Asia project, and index insurance. In this reporting period, CSISA has been able to generate evidence to support efforts for increasing the scope and reach of agricultural risk management throughout the region.

First, CSISA generated the first field-level evidence on the efficacy of an innovative risk management tool that bundles a novel index insurance product with a yield-enhancing (specifically, reducing yield variability) stress-tolerant rice variety. The bundled risk management product aims to address risks related to deficient rainfall during the summer monsoon season in Bangladesh. Index insurance is generally less expensive to administer, is less prone to informational asymmetries such as adverse selection and moral hazard, and typically entails lower reinsurance costs. Consequently, it is typically considerably less expensive than conventional crop insurance. When specially calibrated to complement the performance profile of the drought-tolerant rice variety, the bundled product can provide monotonically increasing (or at least non-decreasing) benefits, since the insurance component would still provide benefits beyond the drought stress level at which the relative benefits of the drought-tolerant variety begin to decline. Overall, we find that when bundled with index insurance, farmer's valuation of the variety increases. For insurance, farmer's value insurance on its own, but when bundled with drought-tolerant rice variety, their valuation for the insurance component (as well as for the overall bundled product) increases as well. Overall, our results suggest that bundling drought-tolerant rice with index insurance may provide a mechanism for managing drought risk and may result in increased demand for both the rice variety as well as the index insurance, while simultaneously reducing the cost of the complementary index insurance component. Results from this study form the basis for a manuscript that was published in *Economic Development and Cultural Change* in early 2018.

Second, through a multi-year randomized controlled trial, CSISA was able to assess the demand for and effectiveness of a hybrid index insurance product designed to help smallholder farmers in Bangladesh manage crop production risk during the monsoon season. While index insurance confers some obvious advantages over the conventional indemnity-based crop insurance, experiences in many countries thus far suggests that insurance programs will likely entail government interventions such as subsidies, at least in the short-run to encourage uptake. This study compared the relative effectiveness of two such government interventions: an upfront discount or a rebate returned to the farmer at a later date. While most farmers would prefer the discount, there is evidence that some farmers prefer the assurances of a subsequent payment (the rebate) even if the insurance does not pay out. The price elasticity of demand implied by the results suggests that there would be a need for a 15 percent discount or 33 percent rebate relative to the actuarially fair cost of insurance to ensure sufficient insurance uptake. When assessing the impacts of the index insurance product on farmers' productive behavior and agricultural outcomes, the study found that the hybrid index insurance product generated both ex ante risk management effects as well as ex post income effects. Purchasing encouraged farmers to take on greater risk exposure during the monsoon season, particularly through expanding area under higher-value crops and through investments in high-risk, high-return agricultural inputs such as fertilizers and irrigation (by 30 percent and 24 percent, respectively). The results also suggest that insurance has positive effects on agricultural production during the subsequent dry season, even though the insurance was not meant to provide any risk mitigation during this season. This effect may be principally due to increased liquidity following the receipt of an insurance payout. Insured farmers increased expenditures on fertilizers and seeds by 10 and 28 percent, respectively, resulting in an 8 percent increase in rice production. Results from this study also were published in the *Journal of Development Economics* in September 2018 and will continue to be re-designed in the form of clear cut messages in policy briefs for circulation amongst stakeholders.

In December 2017, CSISA co-organized a regional dialogue on agricultural risk management in Dhaka. The event was conducted in partnership with the CGIAR research programs on Policies, Institutions and Markets and Climate Change, Agriculture, and Food Security. The goal of the dialogue was to provide a platform whereby experiences and ideas can be shared among various stakeholders and across disciplinary and geographic boundaries, all for the enhancement of rural livelihoods in South Asia, with a particular focus on risk management. There is considerable interest within the international development community in mitigating these risks through insurance as became evident from the policy dialogue. Policy makers, practitioners, and researchers from Bangladesh, India, and Nepal convened to share their experiences with implementing agricultural insurance across the region and to learn about the latest agricultural research on this subject. While insurance has been around for a very long time, many of its more traditional forms have suffered from low demand and asymmetric information between insured and insurer, giving rise to adverse selection and moral hazard. The agricultural research community has responded to these challenges by identifying and developing research-based innovations for agricultural insurance, such as index-based insurance programs that can minimize the severity of adverse selection and moral hazard; the use of cutting edge remote sensing and information technologies; and the bundling of insurance with novel "climate-smart" agricultural technologies and practices that are more resilient to adverse weather conditions than traditional technologies and practices, thus serving an important risk management function in their own right. The discussions also focused on determining region-specific approaches to managing crop insurance, in light of varying socio-political factors within the participating countries (India, Nepal and Bangladesh). A platform was thus created, as a result of this convening that allows CSISA to continue to generate more evidence and inform policy on the tried and tested potential methods of risk reduction.

Due to internal staffing changes within IFPRI, future activities on this component have been suspended to ensure the efforts of the current team are utilized in the areas of their expertise.

Nepal

The aforementioned regional dialogue hosted in Dhaka in December 2017 provided CSISA researchers an opportunity to learn from policymakers and practitioners in Nepal about the specific challenges that have been encountered in their efforts to introduce agricultural insurance in Nepal, while also sharing examples from the experiences of other countries in the region and providing evidence-based policy solutions based on small-scale pilot programs. Owing to funding uncertainty, no further activities were undertaken with respect to agricultural risk management in Nepal. Additionally, due to internal staffing changes within IFPRI, future activities on this component have been suspended to ensure the efforts of the current team are utilized in the areas of their expertise.

Engagement with Missions, FTF partners and project sub-contractors

USAID Missions

In Bangladesh, the CSISA Phase III Bangladesh country coordinator regularly updates the USAID/Bangladesh Mission staff under the Office of Economic Growth with regards to ongoing activities. CSISA is also regularly consulted by the Mission for information on cereal-based cropping systems, agricultural mechanization, and appropriate agricultural development investments. Notable consultations include requests for information and ideas on improving gender mainstreaming in agricultural development, in addition to solicitation of ideas for future investments. Most recently and at the Mission's request CSISA Phase III participated in a field visit to Bangladesh and project sharing program for Dr. Gary Lindon, the Acting Deputy Assistant to the USAID Administrator.

CSISA engaged with the Nepal mission in the following core areas in FY18:

- Provided technical advice and support to the KISAN II project (USAID-Nepal's flagship FtF program) on staple crop management.
- Shared technical insights into challenges and opportunities confronting the sustainable intensification of lentil production in Nepal to the USAID-funded projects, i.e., 'Nepal Seed and Fertilizer' (NSAF) and KISAN II.

FTF partners

CSISA Phase III also directly collaborates with the following FtF projects:

- **Agricultural Inputs Project (AIP):** This CNFA-led project works to improve the knowledge of and access to quality agricultural inputs for farmers in the Feed the Future zone of Bangladesh. Phase III collaborates with AIP and the Agricultural Input Retailer Network to scale-up farmers' access to information on better-bet agronomy and integrated weed management. Details on AIP can be found here: https://www.cnfa.org/program/agro-inputs-project/. AIP closed in September of 201.
- **Rice Value Chain (RVC) Project:** The IRRI-led RVC project was a 15-month activity starting on October 1, 2015 and ending on the December 31, 2016. It builds on the lessons learned from the, Cereal Systems Initiative for Southeast Asia in Bangladesh, and supports the private sector improve the efficiency of the rice value chain. The project will work out of hubs based in Ashore, Khulna, Barisal and Faridpur. Because of RVC's closure at the end of 2016, CSISA Phase III will build on the project's activities and inherit staff and partnerships to continue to scale-out farmers' use of premium quality rice varieties in the FtF zone.
- **Cereal Systems Initiative for South Asia – Mechanization and Irrigation (CSISA-MI) project**: CSISA-MI emerged out of CSISA's ongoing efforts in the USAID/Bangladesh Mission-funded CSISA expansion project (2010–15), and during CSISA Phase II. It continues to be strategically aligned with the broader CSISA Phase III program in Bangladesh, and is led by CIMMYT in partnership with International Development Enterprises (iDE). CSISA-MI is a five- year project (July 2013 – September 2018) that focuses on unlocking agricultural productivity through increased adoption of agricultural mechanization technologies and services. The CSISA-MI Project Leader has a position on the CSISA Phase III technical coordination committee. The Phase III Bangladesh Country Coordinator also maintains a position on the leadership committee of CSISA-MI.
- Although it does not fall under the FtF program, CSISA wheat blast research activities on disease forecasting and modeling are also strategically aligned with the USAID-Washington funded **Climate Services for Resilient Development (CSRD) project**,

which falls under the Global Climate Change Office Bureau for Economic Growth - Education and Environment. Strategic alignment with CSISA is assured as the CSRD Project Leader is also the CSISA Phase III Bangladesh Country Coordinator.

- The **Nepal Seed and Fertilizer (NSAF)** project, a $15 m USAID-Nepal initiative, was a direct outshoot of progress made by CSISA on seed systems and integration soil fertility management. CSISA staff deeply collaborate with NSAF on scientific and operational matters. The lead of CSISA, Andrew McDonald, acts as the senior advisor for NSAF.
- **The KISAN project**, part of USAID's global Feed the Future initiative, is a US$ 20 million five-year program working to advance food security objectives by increasing agricultural productivity. KISAN works collaboratively with CSISA by utilizing technical and extension materials and advice to improve the uptake of better-bet sustainable agriculture production and post-harvest practices and technologies for targeted cereals. KISAN has a reach of hundreds of thousands of farmers, who have been exposed to CSISA information, materials, and technologies through this partnership.

During the reporting period, CSISA and KISAN have:

- ✓ Produced accessible guides for **better bet agronomy for rice and maize** – information that is generally not available to smallholders**.** KISAN has reproduced these guides with their own resources and they provide the backbone of their technical training programs for maize and rice, the two core staple crop value chains for the project.
- ✓ Developed a factsheet on *Stemphylium* management for lentil and provided training to technicians from District Agriculture Development Offices, KISAN, seed companies and some key farmers in different districts with the objective to disseminate the information to additional farmers.

Project Sub-Contractors

CSISA Phase III maintains three sub-contractual partners in Bangladesh that are essential in scaling-out CSISA supported technologies and for reaching farmers at large. This is particularly important as CSISA is coordinated through a partnership of three research institutions. It is only by working with development partners that the knowledge products produced through the CGIAR's research can be effectively deployed in farmers' fields. CSISA therefore strategically vets and selects partners based on their philosophical alignment with the CSISA approach and ability to generate impact at scale. Current partnerships include the following:

- International Development Enterprises (iDE): This sub-contract extended through 2018 but was cut when USAID FY18 funding became uncertain. The purpose of iDE's involvement in CSISA-III was to leverage iDE's existing work in CSISA-MI to contribute to the agricultural machinery commercialization objectives of CSISA-III. Specifically, iDE built upon its relationships with private sector and financial sector partners to support the commercialization of target technologies – power tiller operated seeder and reaper– first in Dinajpur District and then in other districts of Rangpur Division. More about iDE can be found here: https://www.ideglobal.org/country/bangladesh. Due to funding shortfalls in 2017-18, all mechanization value chain work with iDE were however rendered impossible, with the sub-grant suspended.
- Agricultural Advisory Society (AAS): The purpose of the sub-agreement is to increase knowledge, skills, and practice of farmers on the quality rice seedlings production through video shows and training on healthy rice seedlings production in seven FTF districts within two CSISA hubs (Ashore and Faridpur) in the southwestern region. The

sub-grant's target output is the development of awareness and motivation on healthy rice seedlings production of 24,000 interested farmers through video shows and training on the healthy rice seedlings production at 240 communities in seven FTF districts within Ashore and Faridpur hubs. More about AAS can be found here: http://aas-bd.org/. Due to funding shortfalls in 2017-18, additional activities with AAS were however rendered impossible and no further sub-granting was conducted.

- Agricultural Input Retailers' Network (AIRN): AIRN formed as a result of CNFA led efforts in the above-described Agricultural Inputs Project. Partnering with CSISA, AIRN is training 800 inputs dealers on the principles and practices of integrated weed management in Faridpur and Ashore Hubs. More about AIRN can be found here: http://www.aipbd.org/airn/airn/. Due to funding shortfalls in 2017-18, additional activities with AIRN were however rendered impossible and no further sub-granting was conducted.
- The Bangladesh Research Institute (BRRI): Under this agreement, BRRI assists with (1) implementation of on-farm trials of new Premium Quality Rice (PQR) varieties in 6 Upazilas within 3 hubs of CSISA to identify best-bet premium quality varieties in terms of yield and farers', millers', and traders' preferences, (2) on-farm performance evaluations of integrated weed management options to increase yield and profit in farmers' fields, (3) on-station trials to develop/ fine tune mat nursery method of raising rice seedlings for manual transplanting, and (4) Organize additional on-farm trials and collect necessary crop cut data as required. More information is available online about BRRI can be found here: http://www.brri.gov.bd/index.php?lang=en

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Appendix 2 – Project subcontractors and key partners

BANGLADESH				
PARTNER	**PARTNERSHIP OBJECTIVE**	**ALIGNMENT WITH THEMES**	**LEVERAGING OPPORTUNITY**	**STATUS OF PARTNERSHIP**
Government of Bangladesh				
Bangladesh Agricultural Research Institute (BARI)	Development, validation, and refinement of technologies and new research methods, boosting scaling capacity	Innovation towards impact	With a network of regional research stations and strong input into the development of extension materials, approaches, and policy, and with integration in the Ministry of Agriculture, BARI provides leveraging opportunities to mainstream sustainable intensification innovations into the Government of Bangladesh NARES system.	CIMMYT working to prepare an amendment for this sub-grant to refocus activities on wheat blast and early wheat sowing research in light of funding cuts and delays to CSISA from USAID.
Bangladesh Rice Research Institute (BRRI)	Development, validation, and refinement of technologies and new research methods, boosting scaling capacity	Innovation towards impact	With a network of regional research stations and strong input into the development of extension materials, approaches, and policy, and with integration in the Ministry of Agriculture, BRRI also provides leveraging opportunities to mainstream sustainable intensification innovations in the Government of Bangladesh NARES system.	IRRI maintains a formal partnership MoU with BRRI. BRRI has collaborated with CSISA in Phase II and CSISA has continued the partnership until the recent fund crisis. Further funding for BRRI's research partnership is on hold until there is clarification on funding levels and time-frames from USAID.

Department of Agricultural Extension (DAE)	Extension and scaling	Achieving impact at scale	DAE boasts over 5,000 field extension agents throughout Bangladesh. In CSISA Phase II and CSISA-BD, DAE collaborated with activities within Bangladesh's Feed the Future zone, and in Dinajpur hub. By sensitizing DAE agents to sustainable intensification technologies and approaches, large opportunities for improved reach and awareness raising among farmers are possible, with sustainability aims for messaging after Phase III is completed.	CSISA continues to collaborate with DAE on an informal and synergistic basis, despite funding cuts. The volume of activities however have been reduced due to the project's inability to support large field campaigns and collaborative metings with DAE.
Agricultural Information Services (AIS)	Production of extension materials for DAE use	Achieving impact at scale	AIS produces extension materials and media that are used by DAE. Strategic partnerships with AIS facilitate the integration of sustainable intensification principles into extension materials and messaging.	Collaboration continues on an informal basis.
Bangladesh Television (BTV)	Large-scale public showings of training videos and materials on national television	Achieving impact at scale	In CSISA Phase II, and CSISA-BD, work with BTV resulted in millions of television viewers being exposed to messaging on improved crop management and scale-appropriate machinery on the weekly farm oriented program Mati-o-Manush (MoM)	CSISA continues to collaborate with BTV to produce select educational video programming.
Bangladesh Private Sector				
Janata Engineering	Development and sales of scale-appropriate machinery	Achieving impact at scale	Domestic production and import of sustainable intensification scale-appropriate machinery and sales through the private sector	Established relationship with commercial Joint Venture Agreement (JVA). The JVA however was terminated in 2017 due to funding uncertainties and fund transfer delays to CSISA from USAID.
Metal Pvt. Ltd	Development and sales of scale-appropriate machinery	Achieving impact at scale	Domestic production and import of sustainable intensification scale-appropriate machineries and sales through the private sector	Established relationship with commercial Joint Venture Agreement (JVA). The JVA however was

				terminated in 2017 due to funding uncertainties and fund transfer delays to CSISA from USAID.
Rangpur Foundry Limited (RFL)	Development and sales of scale-appropriate machinery	Achieving impact at scale	Import of sustainable intensification scale-appropriate machineries and sales through the private sector	Established relationship with commercial Joint Venture Agreement (JVA). The JVA however was terminated in 2017 due to funding uncertainties and fund transfer delays to CSISA from USAID.
Advanced Chemical Industries	Sales of scale-appropriate machinery, fungicides, weed control products and seed. IRRI is working with ACI to produce a range of hybrid and open-pollinated rice seeds	Achieving impact at scale	Import of sustainable intensification scale-appropriate machineries and sales through the private sector. Along with a range of chemical and cereal seed products.	Established relationship with commercial Joint Venture Agreement (JVA). The JVA however was terminated in 2017 due to funding uncertainties and fund transfer delays to CSISA from USAID.
Bangladesh projects				
Agricultural Extension Project (AEP)	Coordination assistance for interactions with DAE/AIS, capacity development of DAE Extension Agents in scaling and new extension methods	Achieving impact at scale	AEP works closely with DAE and AIS and assists in coordination of both bodies to align to CSISA's objectives. In addition AEP is working with 6,000 farmer groups in the areas where CSISA III is operating.	Established and ongoing working arrangement, though without formal agreement of fund transfers.
Women's Empowerment Project (WEP)	WEP identifies and facilitates linkages to women entrepreneurs	Systemic change towards impact	WEP works with both the Women's Ministry and DAE and will identify women who interested in adopting CSISA technologies. WEP will serve an important role in healthy rice seedling enterprises.	CSISA was in the process of developing a working relationship with WEP, although these activities have been placed on hold

				due to funding uncertainties from USAID.
NGOs				
iDE Co-implementer and project subcontractor	Development of business models, facilitation of private sector partners in scale-appropriate machinery scaling	Achieving impact at scale; Innovation towards impact	Value chain and market development NGO responsible for business modeling and joint venture agreements with the private sector partners listed above	Formal CSISA-MI and CSISA Phase III partner. Subcontracts under CSISA-MI and CSISA III were formalized in 2018-18. The CSISA III subcontract for $400,000 over four years was however suspended due funding uncertainties and fund transfer delays to CSISA from USAID.
Agricultural Advisory Society (AAS) Project subcontractor	Facilitates village screenings of training films and conducts follow-up studies	Achieving impact at scale	Working with AAS in Phase II and CSISA-BD, we were successful in reaching 110,000 farmers in village training video screenings accompanied by question and answer sessions to raise awareness among farmers on scale-appropriate machinery and associated crop management practices.	Plans for further sub-contracts to AAS in 2017-18 have been suspended due funding uncertainties and fund transfer delays to CSISA from USAID.
Agro-Input Retailers Network (AIRN) Project subcontractor	Trains input dealers & retailers	Achieving impact at scale	Will train 800 advanced retailers in integrated weed management in Southern Bangladesh by Feb 2017.	Plans for further sub-contracts to AIRN in 2017-18 have been suspended due funding uncertainties and fund transfer delays to CSISA from USAID.
Universities				

Wageningen University	Strategic research on farmer decision making processes and fallows intensification	Innovation towards impact	Strategic high-end research capacity to assist in the analysis of farmer decision-making processes with respect to intensification decisions	Formal established working relationship with CIMMYT; this relationship entails research deliverables in support of CSISA Phase III
Georgia Tech University	Technical support for the development of scale appropriate machinery	Innovation towards impact	Laboratory facilities for rapid prototyping of machinery innovations and technical support on testing in collaboration with BARI	Established yet informal relationship in co-support of CSISA III, with ongoing collaboration
Bangladesh Agricultural University	Bangladesh's largest and first agricultural university	Innovation towards impact	Bangladesh's largest agricultural university, with influence over the next generation of young scientists, many of whom go on to work in BARI, BRRI, and the DAE	Relationship with Phase III in process of establishment. Relationship is envisioned to be informal
Bangabandu Sheik Mujibur Rahman Agriculture University (BSMRAU)	Strategic partnership in wheat blast research, and in advancing methods of crop cut surveys	Innovation towards impact	BSMRAU scientists have formally collaborated with CSISA-BD and CSISA Phase II on the basis of individual sub-contracts to co-support research efforts in crop cuts and accompanying diagnostic surveys. Additional informal collaboration in geospatial analysis and remote sensing in support of wheat blast development and spread is ongoing.	Sub-contracts to BSMRAU have been suspended due funding uncertainties and fund transfer delays to CSISA from USAID.

NEPAL				
PARTNER	**PARTNERSHIP OBJECTIVE**	**ALIGNMENT WITH THEMES**	**LEVERAGING OPPORTUNITY**	**STATUS OF PARTNERSHIP**
Government of Nepal				
Ministry of Agricultural Development	Technical guidance for GoN investments in agricultural development	All	New Agriculture Development Strategy approved by GoN in Fall of 2015. CSISA acts as a technical partner to shape the loan and investment programs associated with ADS, which may exceed $100 m USD.	Active and sanctioned by CIMMYT's host country agreement
Department of Food Technology and	Strategic and applied research on maize quality	Innovations Towards Impact	DFTQC is responsible for providing the laboratory-based facility to verify the quality of the grain grown and stored under different environment.	Active and long-standing

Quality Control (DFTQC)				
Nepal Agricultural Research Council (NARC)	Strategic and applied research on SI technologies	Innovation towards impact	NARC is responsible for providing the science basis of all state recommendations; their endorsement and ownership of emerging sustainable intensification technologies is essential.	Active and long-standing
Department of Agriculture (DoA)	Front line extension and support to farmers, service providers, and private sector	Achieving impact at scale	DoA has staff at the district level across Nepal and considerable budgets to support programming; CSISA assist in improving the quality of extension messaging and works to deepen linkages to private sector.	Active and long-standing
Nepali private sector				
Machinery importers (BTL, SK Traders, Dahal, etc.)	Introduction and market development for scale-appropriate machinery	Achieving impact at scale	Rapid expansion of investment in scale-appropriate machinery and support for emerging service provision markets.	Active and long-standing
NIMBUS	Introduction and market development for new crop varieties and hybrids	Achieving impact at scale	Registration and market development for hybrids in the Feed the Future zone from a base of zero in 2015.	Active since 2015
NGO				
NAMEA	Trade association formed with the help of CIMMYT to create an enabling environment and policy dialogue for scale-appropriate mechanization in Nepal	Systemic change towards impact	Important voice for private sector with GoN as the Agriculture Development Strategy support programs take shape.	Active since 2014
SEAN	Trade association strengthened with the help of CSISA to create an enabling environment and policy dialogue for seed	Systemic change towards impact	Important voice for private sector with GoN as the ADS support programs take shape.	Active and long-standing

	system strengthening / SMEs in Nepal			
Universities				
University of Illinois	Strategic research and landscape diagnostics to uncover patterns of spatial variability in crop performance and the contributing factors for yields gaps in Nepal cereal crops	Innovation towards impact	Collaboration with advanced research institution increases the quality of science conducted in Nepal; national partners learn new research methods and contribute to the formulation of new research questions.	Active
University of Nebraska	Opportunities for agronomic practices to conserve water, reduce risk, and enhance yields in maize-based systems in the hills of Nepal	Innovation towards impact	Collaboration with advanced research institution increases the quality of science conducted in Nepal; national partners learn new research methods and contribute to the formulation of new research questions.	Active
Wageningen University	Role of livestock and value chains in farmer willingness to invest in maize intensification	Innovation towards impact	Collaboration with advanced research institution increases the quality of science conducted in Nepal; national partners learn new research methods and contribute to the formulation of new research questions.	Active
Projects				
Building Resilience and Adaptation to Climate Extremes and Disaster (BRACED)-DFID	Opportunistic partnership to take advantage of value chains, entrepreneurial skills and collections centers created by BRACED partners	Achieving impact at scale	DFID-UK funded BRACED project has priority on 'Developing Climate Resilient Livelihoods for local communities through public-private partnership for 500,000 poor people in western Nepal that suffer from climate extremes and disasters'. CSISA is taking advantage to disseminate the better-bet technology, farm mechanization at scale through the BRACED networking	Active for 2+ year

Knowledge-based Integrated Sustainable Agriculture and Nutrition (KISAN)	Strategic partnership to co-support on the large scale deployment of extension information and technologies	Achieving impact at scale	The KISAN project, part of USAID's global Feed the Future (FTF) initiative, is a US$ 20 million five-year program working to advance food security objectives by increasing agricultural productivity. KISAN works collaboratively with CSISA by utilizing technical and extension materials, and advice, to Improve the uptake of better-bet sustainable agriculture production and post-harvest practices and technologies for targeted cereals. KISAN has a reach of hundreds of thousands of farmers, who have been exposed to CSISA information, materials, and technologies through this partnership.	Active for 3+
High-value Agriculture Project (HVAP) - IFAD	Opportunistic partnership to take advantage of value chains and entrepreneurial skills created by HVAP, including among women farmers	Achieving impact at scale	HVAP has worked on literacy, numeracy, and value chain strengthening for high value commodities like vegetables. CSISA is taking advantage of the social and market capital created by HVAP to introduce and expand commercial maize production in the mid-hills.	New
Nepal Seed and Fertilizer Project (NSAF) -USAID	Strategic partnership to co-support on the large scale deployment of extension information and technologies	Achieving impact at scale	USAID-Nepal funded NSAF (Nepal Seed and Fertilizer, $15 m from 2016–2021) project, an initiative with a focus that spans the applied science-to-development continuum, inclusive of market facilitation efforts to expand private sector-led fertilizer sales. CSISA is taking advantage to disseminate the better-bet technology at scale through the NSAF networking	Active

Appendix 3 – Indicators

Indicator / Disaggregation	2018		2019	2020
	Target	Actual	Target	Target
EG.3-2: Number of individuals participating in USG food security programs [IM-level]			41,130	53,415
Sex of individuals participating (no double counting)			41,130	53,415
Male			36,477	46,600
Female			4,653	6,815
Not Applicable (for household members counted from HH-level interventions)				
Disaggregates Not Available				
Age Category of individuals participating (no double counting)			41,130	53,415
School-aged children (only for total reached by USG school feeding programs, regardless of actual age)				
15-29			5,589	7,141
30+			35,541	46,274
Not Applicable (for household members counted from HH-level interventions)				
Disaggregates Not Available				
Type of individuals participating (double-counting allowed)				
Parents/caregivers				
Household members (household-level interventions only)				
School-aged children (only for USG school feeding programs)				
People in government				
Proprietors of USG-assisted private sector firms				
People in civil society				
Laborers (Non-producer diversified livelihoods participants)				
Producer: Smallholder farmer			41,130	53,415
Producer: Non-smallholder farmer				
Producer: Aquaculture				
Producer: size Disaggregate Not Available				
Type of individual Not Applicable				
Type of Individual Disaggregates Not Available				

Indicator / Disaggregation	2018		2019	2020
	Target	Actual	Target	Target
EG.3.2-1: Number of individuals who have received USG-supported short-term agricultural sector productivity or food security training [IM-level]	256	268	665	991
Type of Individual	256	268	665	991
Producers	87	240	322	480
Male	61	125	231	344
Female	26	113	91	136
Disaggregates Not Available		2		
People in government	38	13	93	139
Male	33	10	69	104
Female	5	3	24	35
Disaggregates Not Available				
People in private sector firms	87	9	177	263
Male	81	7	135	200
Female	6	0	42	63
Disaggregates Not Available		2		
People in civil society	38	6	73	109
Male	34	6	56	84
Female	4	0	17	25
Disaggregates Not Available				
Disaggregates Not Available	6			
Male	2			
Female	4			
Disaggregates Not Available				

Indicator / Disaggregation	2018		2019	2020
	Target	Actual	Target	Target
EG.3.2-7: Number of technologies, practices, and approaches under various phases of research, development, and uptake as a result of USG assistance [IM-level]			26	26
Total number of unique technologies / practices / approaches from all categories (no double-counting)			26	26
Plant and Animal Improvement Research - Unique number of technologies / practices				
Production Systems Research - Unique number of technologies / practices			26	26
Social Science Research - Unique number of technologies / practices				
Disaggregates Not Available (research category not listed or unknown) - Unique number of technologies / practices				
Production Systems Research				
Phase of Research (double-counting allowed)				
Phase I: Under research as a result of USG assistance				
Phase II: Under field testing as a result of USG assistance			11	11
Phase III: Made available for uptake as a result of USG assistance			4	4
Phase IV: Demonstrated uptake by the public and/or private sector with USG assistance			11	11

Indicator / Disaggregation	2018		2019	2020
	Target	Actual	Target	Target
EG.3.2-17: Number of farmers and others who have applied improved technologies or management practices with USG assistance [IM-level]	11,548	34,662	68,550	89,025
Producers	11,548	34,662	68,550	89,025
Sex	11,548	34,662	68,550	89,025
Male	10,393	29,415	61,286	78,267
Female	1,155	5,247	7,264	10,758
Disaggregates Not Available				
Technology type				
crop genetics	1,227	5,995		
cultural practices	5,063	25,294	61,310	78,165
livestock management				
wild fishing technique/gear				
aquaculture management				
pest management	1,227	1,359		
disease management				
soil-related fertility and conservation	152	811	2,945	4,418
irrigation				
water management (non-irrigation)				
climate mitigation				
climate adaptation	3,879	1,203	4,295	6,443
marketing and distribution				
post-harvest - handling and storage				
value-added processing				
other				
Disaggregates Not Available				
Commodity				
Maize		1,970	3,220	4,830
Rice		28,167	38,245	61,568
Wheat		4,390	27,085	22,628
Disaggregates Not Available or Other		135		

Indicator / Disaggregation	2018		2019	2020
	Target	Actual	Target	Target
EG.3.2-18: Number of hectares of land under improved technologies or management practices with USG assistance [IM-level]	3,811.00	16,348.00	25,900.00	34,251.00
Technology type				
crop genetics	400.00	1,469.00		
cultural practices	2,361.00	12,645.00	23,370.00	30,244.00
pest management	300.00	788.00		
disease management				
soil-related fertility and conservation	50.00	580.00	1,522.00	2,283.00
irrigation				
water management (non-irrigation)				
climate mitigation				
climate adaptation	700.00	866.00	1,008.00	1,512.00
other				
Disaggregates Not Available				
Sex	3,811.00	16,348.00	25,900.00	34,251.00
Male	3,430.00	13,400.00	22,411.00	29,063.00
Female	381.00	2,948.00	3,489.00	5,188.00
Joint				
Association-applied				
Disaggregates Not Available				
Commodity				
Maize grain		1,495.00	2,090.00	3,135.00
Rice		12,286.00	12,200.00	19,700.00
Wheat		2,421.00	11,420.00	11,130.00
Disaggregates Not Available or Other		146.00	190.00	285.00

Indicator / Disaggregation	2018		2019	2020
	Target	Actual	Target	Target
EG.3.2-24: Number of individuals in the agriculture system who have applied improved management practices or technologies with USG assistance [IM-level]			68,550	89,025
Value Chain Actor Type: Smallholder producers			68,550	89,025
Sex (no double-counting)			68,550	89,025
Male			61,286	78,267
Female			7,264	10,758
Disaggregates Not Available				
Age category (no double-counting)			68,550	89,025
15-29			6,855	8,902
30+			61,695	80,123
Disaggregates Not Available				
Management Practice or Tech Type (double-counting allowed)				
Crop genetics				
Cultural practices			61,310	78,165
Livestock management				
Wild-caught fisheries management				
Aquaculture management				
Natural resource or ecosystem management				
Pest and disease management				
Soil-related fertility and conservation			2,945	4,418
Irrigation				
Agriculture water management-non-irrigation based				
Climate mitigation				
Climate adaptation/climate risk management			4,295	6,442
Marketing and distribution				
Post-harvest handling and storage				
Value-added processing				
Other				
Commodity				
Maize			3,220	4,830
Mung Bean (NRVCC)				
Rice			38,245	61,568
Wheat			27,085	22,627
Disaggregates Not Available or Other		135		

Indicator / Disaggregation	2018		2019	2020
	Target	Actual	Target	Target
EG.3.2-25: Number of hectares under improved management practices or technologies with USG assistance [IM-level]			25,900.00	34,250.00
Type of Hectare: Crop land			25,900.00	34,250.00
Sex of Owner / Manager (no double-counting)			25,900.00	34,250.00
Male			22,411.00	29,062.00
Female			3,489.00	5,188.00
Association-applied				
Disaggregates Not Available				
Age of Owner / Manager (no double-counting)			25,900.00	34,250.00
15-29			2,590.00	3,425.00
30+			23,310.00	30,825.00
Association-applied				
Disaggregates Not Available				
Management Practice or Tech Type (double-counting allowed)				
Crop genetics				
Cultural practices			23,370.00	30,455.00
Livestock management				
Wild-caught fisheries management				
Aquaculture management				
Natural resource or ecosystem management				
Pest and disease management				
Soil-related fertility and conservation			1,522.00	2,283.00
Irrigation				
Agriculture water management-non-irrigation based				
Climate mitigation				
Climate adaptation/climate risk management			1,008.00	1,512.00
Other				
Commodity				
Maize			2,090.00	3,135.00
Mung Bean (NRVCC)			190.00	285.00
Rice			12,200.00	19,700.00
Wheat			11,420.00	11,130.00
Disaggregates Not Available or Other		146.00		

Indicator / Disaggregation	2018		2019	2020
	Target	Actual	Target	Target
EG.5.2-1: Number of firms receiving USG-funded technical assistance for improving business performance [IM-level]	66	80	97	146
Type of Firm	66	80	97	146
Formal		26	87	131
Informal	66	54	10	15
Disaggregates Not Available				
Duration	66	80	97	146
New	42	66	44	66
Continuing	24	14	53	80
Disaggregates Not Available				