Cereal Systems Initiative for South Asia
Phase III

— Building Resilience in South Asia's Cereal Systems —

Annual Report
1 October 2018 to 30 September 2019

CSISA

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Grant Summary Information

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Has this project been granted a no-cost extension (NCE)? Delays in funding disbursements and budget shortfalls relative to the proposed USAID grant in 2017, 2018, and 2019 suggest that the project is likely to require and request a no-cost extension in the near future. This issue is under discussion with the project's agreement officer representative (AoR).

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Contents

Abbreviations

AAS	Agricultural Advisory Society
ACDI/VOCA	Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance
AEZ	agro-ecological zones
AIRN	Agriculture Inputs Retailers' Network
AIS	Agricultural Information Services
AMTRC	Agricultural Machinery Testing and Research Centre
BARI	Bangladesh Agriculture Research Institute
BRRI	Bangladesh Rice Research Institute
BWMRI	Bangladesh Wheat and Maize Research Institute
CCAFS	Climate Change, Agriculture and Food Security
CGIAR	*formerly the* Consultative Group for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
CSISA-MI	CSISA-Mechanization and Irrigation
DAE	Department of Agricultural Extension
DAT	days after treatment
DSR	direct-seeded rice
FAW	fall armyworm
FY	fiscal year
GoN	Government of Nepal
HSD	honestly significant difference (test)
IFPRI	International Food Policy Research Institute
IRRI	International Rice Research Institute
IWM	integrated weed management
MoALD	Ministry of Agriculture and Livestock Development
MoP	muriate of potash
Mt	metric tons
NAMEA	Nepal Agricultural Machinery Entrepreneurs' Association
NARC	Nepal Agricultural Research Council
NDVI	normalized difference vegetative index
NOPTs	nutrient omission plot trials
NPR	Nepali rupees
NSAF	Nepal Seed and Fertilizer project
PMAMP	Prime Minister Agriculture Modernization Project
PQR	premium quality rice
RARS	regional agricultural research station
RDC	Rice and Diversified Crops Activity
RY	relative yield

SRFSI	Sustainable and Resilient Farming Systems Intensification in the Eastern Gangetic Plains
USAID	United States Agency for International Development
USG	urea super granules

In Memoria

This report is dedicated to the memory of Dr. Dakshinamurthy "Dakshin" Vedachalam, who sadly passed away on October first of this year. Dakshin worked as CSISA's lead Communications Specialist based in Delhi, India, and contributed to CSISA activities in India, Nepal, and Bangladesh. He was extremely talented and was a wonderful photographer who had a passion for teaching and coaching his colleagues and peers. Dakshin had a huge heart and was a very, very warm person. He also cared deeply about CSISA and the CSISA family, and was instrumental in assuring that CSISA's work was effectively communicated to our donors, partners, and farmers. He will be greatly missed.

Executive Summary

With the support of USAID and the Bill and Melinda Gates Foundation, the Cereal Systems Initiative for South Asia (CSISA) was established in 2009 with the goal of increasing the productivity and resilience of millions of farmers by the end of 2020. CSISA is led by the International Maize and Wheat Improvement Center (CIMMYT) and is implemented jointly with the International Food Policy Research Institute (IFPRI) and the International Rice Research Institute (IRRI) in addition to numerous public and private sector partners.

- Operating in rural Bangladesh, India and Nepal, CSISA works to increase the adoption of resource-conserving and climate-resilient agricultural technologies, and improve farmers' access to market information and enterprise development.
- CSISA supports women farmers by improving their access and exposure to modern and improved technological innovations, knowledge and entrepreneurial skills.
- In synergy with regional and national efforts, CSISA collaborates with numerous strategic public, civil society and private-sector partners.

The project has over time developed into a more comprehensive research for development program with many additional and synergistic investments by USAID/Washington and USAID's Missions in Nepal and Bangladesh to deepen the scope and impact of CSISA's work.

This report focuses on the current third phase (2015–2020, CSISA III) of the 'base' or 'original' set of CSISA investments.[2] The third phase is focusing on USAID's support to activities in Nepal and Bangladesh where CSISA is supporting partners in the public and private sectors to better contribute to sustained change by addressing systemic weaknesses. By addressing these areas and fostering new connections and collaborative efforts across the innovation system, CSISA is seeking to mainstream elements of its approach and to ensure a successful exit at the termination of Phase III.

BANGLADESH HIGHLIGHTS

- ***Large-scale impact among farmers:*** As a research into development project, CSISA continued to demonstrate that large-scale impact is possible in Bangladesh's cereal-based farming systems. A total of **59,166 farmers implemented crop management practices recommended by the project and its partners on 17,113 hectares** in Bangladesh during the reporting period, meeting many of the project's related targets. The details of specific activities and achievements – which include the scope of farmers reached by additional information, crop advice, and technical or market support – are given below.

- ***Mass Media Campaigns:*** CSISA continued to support efforts to extend information on improved agronomic practices to farmers by **distributing 34,000 informational leaflets on healthy rice seedling practices, 37,500 leaflets on how to achieve benefits from early wheat sowing, and 15,000 wheat blast mitigation fact sheets to farmers** through partner organizations. Videos on growing healthy rice seedlings and on early wheat sowing were also shown in 638 villages to 64,018 farmers (24% women).

- ***Scaling-out integrated weed management:*** In support of the Bangladesh Rice Research Institute (BRRI), CSISA continued to raise awareness among Bangladeshi farmers on integrated weed management (IWM) technologies and practices. Major achievements from the period include the

[2] CSISA III is primarily referred to as 'the project' throughout this report

following:

- Trained **255 agricultural input retailers** in Dinajpur on identifying weed species, selecting appropriate herbicides, dosages and the use of knapsack sprayers and their calibration. The monitoring and evaluation of this work indicated that 80% of the dealers passed on IWM messages to farmers, resulting in **8,300 farmers who have applied IWM** techniques on approximately **4,600 ha of crop land**.
- Trained 208 Department of Agricultural Extension (DAE) and NGO staff (including 27 women) as trainers on integrated weed management.
- Conducted research resulting in the preliminary development and improvement of mechanical weeders for upland line sown crops, including machine sown direct-seeded rice.
- Completed 20 'family' IWM training events for 250 husband and wife farmers (500 persons).
- In addition, CSISA launched a collaboration with BRRI, which for the first time ever in Bangladesh screening the weed competitiveness of the major rice cultivars that are grown throughout the country. Weed competitive varieties are crucial in integrated weed management; when farmers use high-yielding and weed competitive varieties in order to reduce herbicide spraying and laborious hand weeding.

- ***Beating the heat with early seeding:*** A farmer awareness-raising **video on the benefits of and methods for timely wheat seeding was shown to 64,018 farmers** (76% male 24% female) **across 794 showings** in collaboration with the Agriculture Advisory Service (AAS) and the Agriculture Information and Communication Center (AICC). The project also prepared a leaflet on the benefits of early wheat seeding and distributed 34,059 copies to farmers. As a result of these and associated activities, wheat seeding occurred earlier by at least five days in 2018/19 on 22,613 ha across Bangladesh.

- ***Fighting back against Fall armyworm****:* The fall armyworm (FAW, *Spodoptera fruigiperda*) first appeared in Bangladesh in November 2018. It is a major pest of maize. Because of the prominence of maize and this crop's importance for income generation in Bangladesh's cereal farming systems, CSISA took emergency action and rapidly responded. Key achievements in this period include: (a) **rapid training on FAW for 755 agricultural retailers**, and (b) **video campaign on FAW management that reached 13,057 registered maize farmers** (33% women) in 238 video show trainings.

- ***De-risking direct seeded rice:*** CSISA continued collaboration with the Bangladesh Rice Research Institute (BRRI) and the Department of Agricultural Extension (DAE) to evaluate and identify ways to overcome technical constraints to dry direct seeded rice (DSR). DSR is a method of growing rice that avoids manual transplanting and economizes on costly or scarce water resources. Trials conducted by CSISA and BRRI showed that the pattern of DSR performance changes depending on the type of landscape that farmers grow rice in. In addition, CSISA implemented a number of **DSR awareness raising activities**, including training seed drill owners, linking farmers to governmental subsidy programs to access DSR-appropriate seeds, and by holding farmer field days.

- ***Catalyzing market growth in premium quality rice****:* Since 2016, CSISA has worked as a **catalyst to expand premium quality rice production in Bangladesh's Feed the Future (FtF) zone** and also in the Dinajpur hub since the beginning of 2019. Importantly, CSISA has already met its primary targets with respect to the acreage covered and the production of new premium quality rice (PQR) varieties in Bangladesh. As such, the project has moved toward more strategic research efforts to address some of the constraints encountered in the PQR market, in order to find ways to assure a more consistent flow of benefits to smallholder farmers growing PQR varieties.

Preliminary findings suggest that aroma, fine grain quality (i.e., slender, size, shape), and good taste are the three commonly perceived attributes used to define 'premium quality rice.' These, when combined with traits like 'good' and clean appearance, consistency, purity, and packaging, fetch the highest market prices. CSISA will convene workshops in the next reporting period with major private sector PRQ millers, buyers, and sellers to develop new activities that can improve PQR markets while benefiting farmers through more profitable sales.

- ***Beating back wheat blast:*** Wheat blast is a fast-acting devastating fungal disease that threatens wheat productivity in the Americas and South Asia. CSISA evaluated the effects of late wheat sowing on wheat blast severity and incidence across different what varieties. **Trial results confirmed that timely sown wheat can help farmers escape wheat blast risks.** In addition, to explore options for cultivar mixtures to reduce wheat blast infestations, the project and Bangladesh Maize and Wheat Research Institute (BWMRI) selected the three varieties BARI Gom 26 (blast susceptible), BARI Gom 33 (which carries a wild wheat chromosome segment that confers blast resistance) and BARI Gom 30 to test in differing seeding mixtures. Preliminary results strongly indicate that farmers who lack sufficient BARI Gom 33 seed can still achieve reduced blast infections and maintain yield by mixing this variety with other commonly available but disease susceptible varieties, except BARI Gom 26. This provides **important initial evidence that ecological management strategies that deploy functional diversity in variety types can be used to overcome disease risks**.
- ***Science innovations:*** CSISA **pushed research and methodological boundaries** in the reporting period by conducting Bangladesh's first ever **artificial intelligence ('machine learning') study to improve maize nutrient management recommendations** across the country. To develop more precise and efficient nutrient management for maize in the eastern Indo-Gangetic Plains, the spatial variability of relative yields predicted by data-driven machine learning approaches will need to be combined with information on farmers' crop management practices and robust attainable yield estimates. This work represents an important first attempt to apply artificial intelligence, data science, and advanced geo-spatial analytics to improve nutrient recommendations in Bangladesh.

NEPAL HIGHLIGHTS

- ***Expanding impact in the Feed the Future Zone***: During the reporting period, a total of **15,735 farmers** – 29% of whom were women, and 12% of whom were youth – applied sustainable intensification technologies (mainly cultural management practices, soil fertility conservation techniques, and resilience-building climate adaptation practices) in Nepal's Feed the Future Zone of Influence as a result of project activities. The project recorded that these farmers covered **10,031** hectares. 9,258 of these hectares were cereal crops, distributed at 62%, 18% and 18% in rice, wheat and maize, respectively. The reminder of the acreage was devoted largely to legumes. Most of the that farmers applied CSISA also facilitated direct and indirect trainings through partners that reached a total of 224 farmers, 27% of whom were women.
- ***Low-cost solutions delivered at scale by service providers***: In Nepal, **104 new service providers** are now providing mechanized wheat sowing services to farmers using 135 four-wheel tractor-operated seed drills and 15 power tiller operated seed drills. In 2018, **565 farmers had used these service providers to sow 553 ha of their fields**. Most of this was to sow zero tillage wheat and direct-seeded rice. The average service charge for the providers to sow zero

tillage wheat was USD[3] 14 hour^{-1}, a dramatically reduced cost compared to conventional tillage.

- ***Reducing constraints imposed by weeds in cereal cropping systems:*** In Bardiya and Banke districts, **74 agrovets and 37 government agriculture technicians were trained** on calculating the correct doses, the method and timing of application, the advantages of herbicidal weed management and government's rules on use and safety precautions. Clear outcomes resulted as **farmers improved weed control on 500 ha**. With the **technical advice and urging of CSISA, in its 2018/19 budget the Government of Nepal provided a 50% subsidy to farmers to buy labor saving and woman-friendly weeding machines.** The new machine introduced by CSISA takes about 15 hours to weed one hectare at a cost of $45 as compared to $132 ha^{-1} for manual weeding.
- ***One-of-a-kind international seminar on scale-appropriate farm machinery:*** The project held a **traveling seminar** on 'Scale-appropriate Machinery for Cereal Crop Harvesting in South Asia' on 25–29 March 2019. **More than 40 delegates**, including international experts, private sector scaling partners and dignitaries such as the Director General of Nepal's Department of Agriculture and the Chief of Prime Minister Agriculture Modernization Project (PMAMP) attended. On the last day of the seminar, delegates from China, Bangladesh, India, Sri Lanka and Vietnam explained how the use of farm machines have spread across their countries' farms. These discussions and presentations included private and public sector representatives interested in finding sustainable, equitable, and productive solutions to grain harvesting challenges for all farm sizes and farmers across the region.
- ***Lowering production costs with direct seeded rice:*** The cultivation of rice is increasingly costly in Nepal due to the growing cost of rural wage labor – particularly for rice transplanting – resulting from the widespread out-migration of working age men. Growing rice through direct seeding can help respond to these problems. Key activities on directly sown rice included (a) prior to the monsoon rice season, a program run by the project with the Prime Minister Agriculture Modernization Project (PMAMP), Bardiya Rice Super Zone raised the awareness of **52 farmers** (40 male, 12 female) about recommended practices for growing direct-seeded rice. An experienced service provider and the Chief of Bardiya Rice Super Zone also visited and orientated participants. (b) CSISA raised awareness about seed drill services with **more than 100 seed drills purchased by service providers** in the project's working areas. (c) As a result of these activities, DSR was grown by **164 new farmers on 157 ha of their fields**.
- ***Mass media awareness raising:*** CSISA carried out a number of **mass media campaigns**. The project produced and supported the broadcasting of radio jingles in Banke, Bardiya, Dang Kailali, Kanchanpur and Kapilvastu districts on (a) the importance of using quality maize hybrid seed, (b) mechanized maize seeding, (c) improved rice cultivation techniques, (d) integrated weed management, and (e) the negative effects of straw burning.
- ***Rapid and low cost solutions to rice and wheat harvesting:*** The project has taken a lead role in introducing two-wheeled tractor (2WT) attached reapers to the Nepali market as scale-appropriate machines to replace the time consuming laborious manual harvesting of crops. As of September 2019, there were **3,495 of these machines in Nepal's Terai southern plains and almost 16,000 ha of rice and wheat was being harvested** by them. Recently, these attachments have begun to be sold outside the project's area, including in the eastern Terai, with 30% of 2WT reapers sales occurring there in the reporting period. The number of importers of 2WT reapers has increased.

[3] All dollars mentioned in this report are United States dollars (hereafter $)

- ***Strategic and applied maize research in Nepal's mid-hills***: Research by CSISA that assisted in achieving these outcomes determined that in the hills of Nepal, the use of **hybrid maize had increased productivity by 1,937 kg ha^{-1} on average** among farmers. Conversely, non-adopters of hybrid maize could have increased their maize productivity by almost 1 Mt ha^{-1} and per capita food expenditure by $22 if they had replaced the local or improved varieties they were using with hybrid varieties.

POLICY REFORM AND RESEARCH HIGHLIGHTS

- ***Knowledge sharing and partnerships to solve problems in South Asia's seed systems:*** Although policy reform activities were phased down in this reporting period due to funding uncertainty and delays, several important contributions to project outputs were achieved. In Nepal, the project entered into a **collaboration with the USAID/Nepal Mission supported and CIMMYT-led Nepal Seed and Fertilizer project (NSAF)** to determine the demand and supply gaps that need filling to bring about systemic policy change on varietal turnover. As part of this collaboration, CSISA participated in the International Seed Conference and Expert Consultation held by NSAF and the CSISA Scaling Project in September 2019 in Kathmandu, Nepal. **This enabled CSISA to advise the Government of Nepal on policy options for its Nepal Seed Vision 2020**.
- ***Balanced nutrient use to improve crop productivity:*** In this reporting period in Bangladesh, the project carried out a **diagnostic analysis of fertilizer application behavior in Bangladesh** and the role of the country's subsidy policies on application rates. Expenditure on fertilizer by farmers exceeds 10% of the total value of rice output. However, the often-imbalanced application of fertilizer affects crop yields, farmers' profits, soil health and the environment. These findings help identify the trends in fertilizer application and the effects of changing the subsidy and fertilizer pricing policy on farmers' use of fertilizers.
- ***Experimental approaches to assessing machinery service provision potential***: In June 2019 the project carried out a study of 300 farmers in the southern part of Bardiya district in Nepal's western Terai to see if relaxing credit and information constraints could improve the **uptake of manual hand-crank fertilizer spreaders** as a service provision and business-generating opportunity for rural entrepreneurs. Overall, farmers were interested in using these spreaders, but most were unwilling to pay or would only pay if the service was guaranteed. This study confirms CSISA's ongoing work on spreaders as a tool to be used by farmers themselves in their own fields; but not for service provision and income generation from serving other farmers.
- ***Facilitating evidence exchanges to improve soil nutrient management***: As part of project engagement with NSAF and policymakers in Nepal, the project held a regional policy dialogue on **Innovations for Advancing Farmer's Use of Balanced Nutrient Application in South Asia** on 5 September 2019 in Kathmandu.

Note: As with the 2019 semi-annual report (October 2018–March 2019), the current document reflects a period during which project funding was uncertain and reduced, which led to delays and cut-backs in implementing planned activities. Although funding was supplied by USAID in late 2018 for the third fiscal year (FY) of activities; funds came more than nine months after their anticipated date of receipt. Funds were also 30% less than anticipated based on the budget in the CSISA Phase III proposal. This follows a 41% shortfall in the project's second year (FY 2017). As a result, most of the activities implemented by CSISA in Nepal and Bangladesh in FYs 2016/17 and 2017/18 were suspended or shrunk as the project was unable to retain all its staff. Although an additional tranche of funds was received in the second half of 2019 from USAID, these funds were actually for FY 2018/19, meaning that they came late and the project has faced challenges in rapidly using them as they arrived after the main cropping seasons that CSISA focusses on. To date, CSISA has received only 70% of the overall five-year planned budget, despite being at the end of the fourth of the project's five years. This report reflects this status, and discusses the need for an extension into at least 2021 to cope with the funding delays and uncertainties.

Context, Approach and Theory of Change

Since the food price crisis of 2007–2008, agricultural research and development in the developing world has received considerable public, private sector, and donor investment. In South Asia, attention has shifted to focus on the impoverished areas of the Eastern Indo-Gangetic Plains – particularly Nepal and Bangladesh – where cereals feed over half a billion people (Photo 1). Nevertheless, investments in agriculture have been less adept at supporting transformative change than originally anticipated. While progress has been made on addressing some of the systemic weaknesses that contribute to low rates of rural development. Many key problems persist:

- **Research organizations** narrowly construe their mandates and are only partially oriented towards farmers and the private sector as clients of research outputs.
- **Resilient** agronomic practices and livelihood strategies are insufficiently considered in comparison to technical interventions for yield improvements.
- **Agricultural extension** primarily focuses on single technologies or generalized 'packages of practices', which are not underpinned by rigorous or participatory field evaluations that lead towards the better targeting of development interventions.
- **Livelihood** initiatives do a commendable job of reaching underserved communities, including women farmers, but rarely have the technical competence to extend their reach.
- The **private sector** – although learning quickly – lacks strategic experience in the emerging markets in the region along with the types of locational intelligence that can steer engagement and support smallholder farmers' access to new technologies.
- **Small entrepreneurs** generally lack access to support services, both for business development and technical improvements in their attempts to serve clients and generate revenue.
- Progressive **policies** ostensibly support farmers, but often impede private investment.
- There is mostly only limited **cooperation across organizations** in the agricultural research-for-development space. This limits opportunities to leverage skills and harness synergies for development impact.

Photo 1: CSISA focuses on raising the productivity and resilience of smallholder farmers in South Asia's most important cereal farming areas, as shown in this photo of wheat harvest in Barisal, Bangladesh.

Agricultural research and development efforts are complicated by the risks inherent in cropping in areas where weather patterns are erratic, water resources are poorly developed or irrigation is costly, heat stress is a binding constraint, and timely field operations are frequently compromised by rapidly declining diminishing supply and costs for rural labor. Despite these challenges, there is considerable promise that the many individual strengths within the innovation system[4] in South Asia can be marshaled and coordinated to spur and sustain transformative change. With support from the Bill & Melinda Gates Foundation and the 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. The project has developed into a program of investments in Bangladesh, India, and Nepal with a number of synergistic side-investments provided mainly by USAID's Missions in Bangladesh and Nepal (Figure 1).

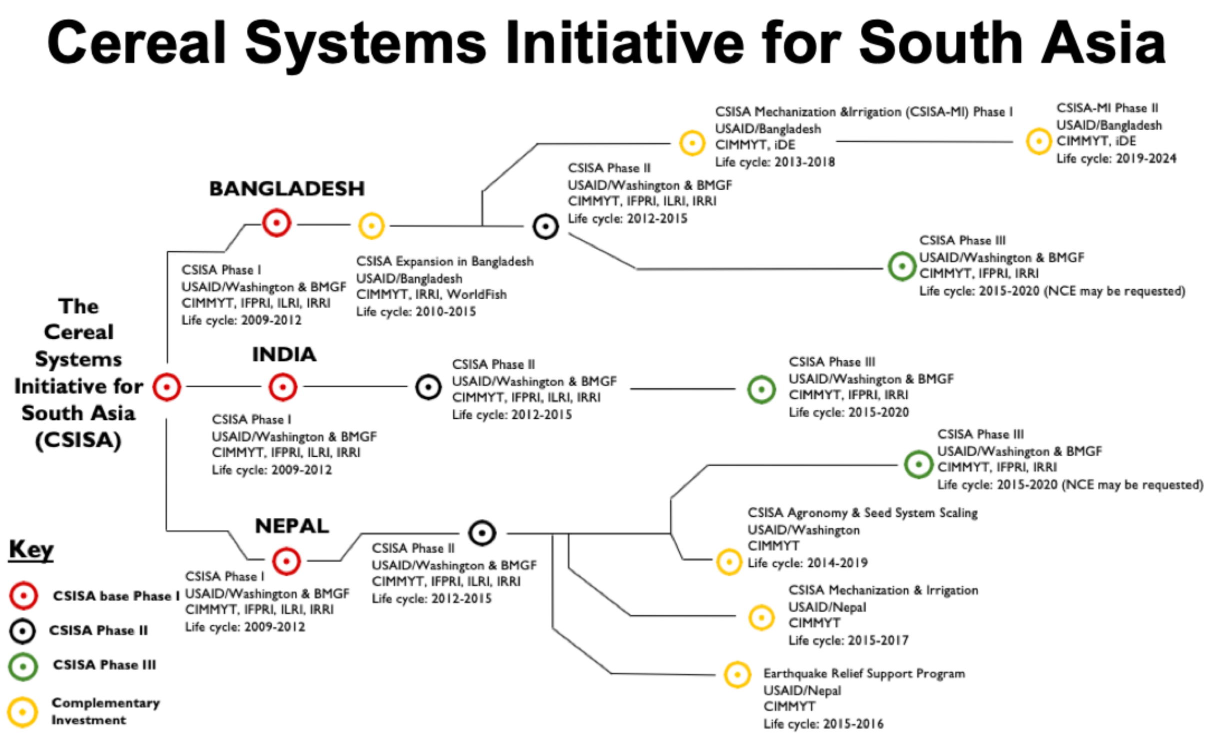

Figure 1: Evolution of USAID and Bill and Melinda Gates Foundation (BMGF) investments in the overall CSISA program in Nepal, Bangladesh and India since 2009 indicating core CGIAR and INGO partners, including new investments in the CSISA Mechanization and Irrigation project in Bangladesh.

CSISA aims 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.[5] As a science-driven and impact-oriented initiative, the project is positioned at

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[4] Innovation systems can be understood as networks of business, organizations and people – including farmers, researchers, extension agents, policy makers and entrepreneurs – that, through the sum of their actions bring new technologies, innovations, products processes or policies into use. Efforts to coordinate these groups and actors can accelerate the rate of uptake of technological innovation that can improve the impact of development interventions. CSISA plays a coordinating and facilitating role in South Asia as an agricultural innovation system broker.

[5] 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.

the intersection of a diverse set of partners in the public and private sectors, occupying the crucial middle-ground where research meets development. The project generates data and evidence on improving crop production and identifying more sustainable means of growing crops, and then scales them out to partners in the public and private sector to raise the awareness of farmers and other stakeholders on these options. By engaging with a network of partners as an agricultural innovation systems broker, CSISA is built on the premise that transformative development typically requires not one single change, but the orchestration of several changes.

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

1. The **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 research for development (R4D).
3. **Generating critical knowledge and research-based products** that will support technology scaling-out (among farmers and service providers) and also scaling-up (institutional systems change that sustains technology generation and availability) for durable development impacts.
4. **Improving the policy environment to support sustainable intensification** in CSISA's target geographies by (a) prioritizing scaling efforts and (b) working through national partners to address policy constraints to increase the productivity and resilience of smallholder farming systems.

The project thus carries out research and shares results on the constraints and benefits of technologies and works with partners to extend evidence-based options to farmers and stakeholders on a targeted and strategic basis.

Rather, it emphasizes ends rather than means…. The combination of the terms 'sustainable' and 'intensification' is an attempt to indicate that desirable outcomes around both more food and improved environmental goods and services could be achieved by a variety of means.' (Pretty, J. and Bharucha, Z.P. (2014). Sustainable intensification in agricultural systems. *Annals of Botany* 114: 1571–1596.)

1. Bangladesh – Achievements

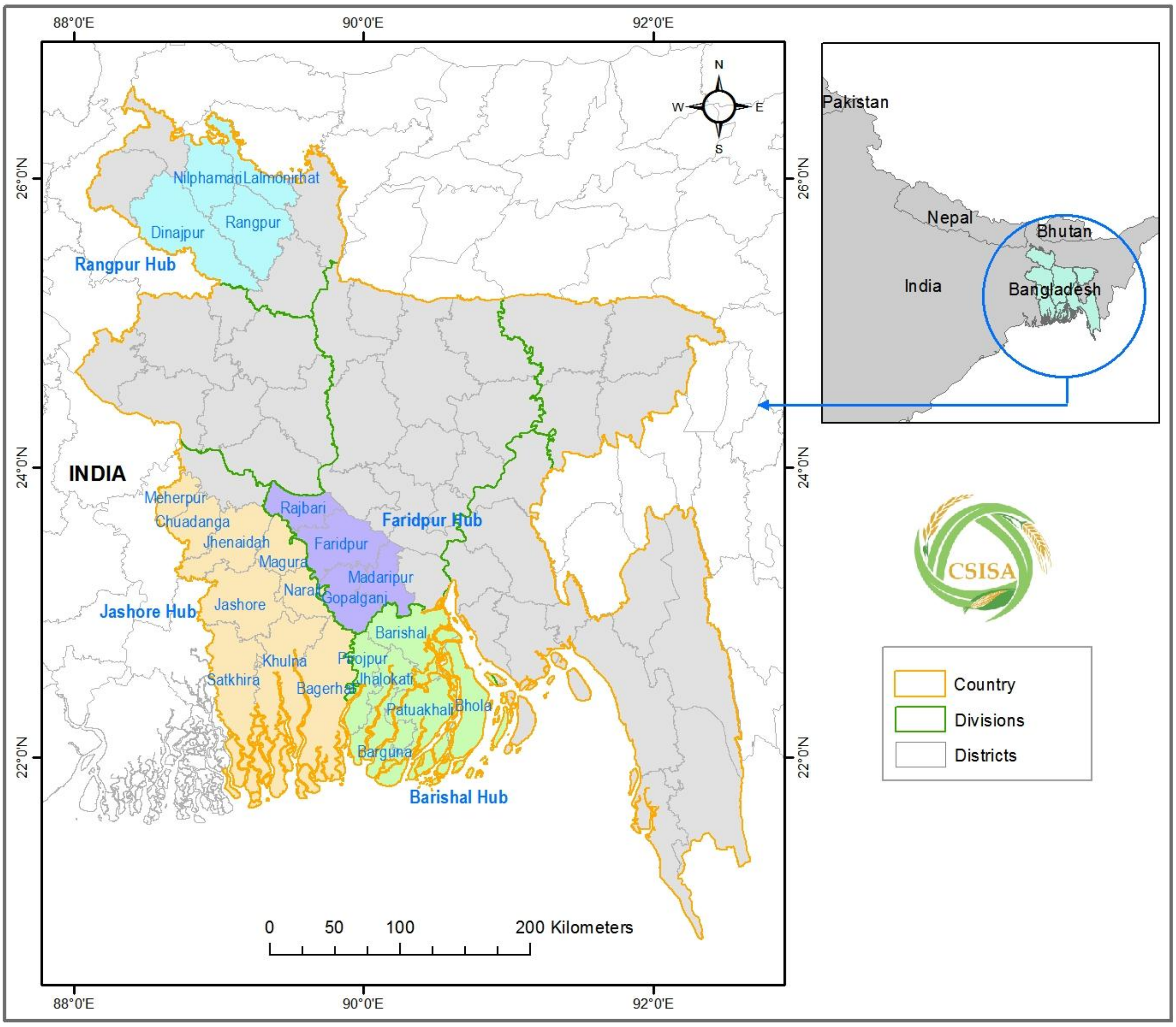


Figure 1.1: The CSISA project works in Bangladesh's USAID Feed the Future Zone of Influence (south western Bangladesh) and in Rangpur Division in northern Bangladesh

A. INNOVATION TOWARD IMPACT

A1. Reducing risk to facilitate uptake of sustainable intensification practices

A1.1 Directly-sown rice to address labor and energy constraints to precision rice establishment

The direct-seeding of rice in dry conditions (i.e. with no repetitive wet soil tillage after initial ploughing) is a relatively well-known method to reduce farmers' production costs by saving labor on crop establishment and tillage (Photo 1.1). In some cases, these approaches also mean that farmers have to use less irrigation water. These approaches can be termed 'direct-seeded rice (DSR)', which is more common in South East Asia, though less widely practiced in South Asia. In Bangladesh, the scope for direct-seeded rice (DSR) is mainly in the pre-monsoon *aus* season (usually sown in April-May and harvested in July-August – also known as *kharif-1*). However, despite efforts by a number of research and development organizations to encourage DSR, these techniques have only been adopted by a few Bangladeshi farmers.

In response, the CSISA project has been working since 2016 with the Bangladesh Rice Research Institute (BRRI), the Department of Agricultural Extension (DAE), non-government organizations (NGOs) and private sector entrepreneurs (especially seed drill owners) in the *aus* season to address the constraints to the direct seeding of rice through on-farm research and by raising farmers' awareness about its benefits.

Between April and August 2019, CSISA and BRRI planned and conducted the following on-farm research activities to identify ways of overcoming the constraints to the direct seeding of rice.

Photo 1.1: Left: dry direct sowing of rice by machine seed drill. Right: direct-seeded rice crop at vegetative stage (Alanuzz*aman* Kurishi)

Direct seeded rice performance evaluation study 1

An on-farm evaluation of i) direct-seeded rice sown by seed drill, ii) rice direct-seeded by hand, and iii) transplanted rice was conducted in the following landscape positions[6] during the monsoon in CSISA's Jashore and Faridpur working domains, which include these and adjacent districts:

- 'high-land' – no stagnant water during the *aus* season
- 'medium land' – stagnant water continuously for less than one month during the *aus* season
- 'low-land' – stagnant water continuously for one or more months) during the *aus* season,

and on high and medium-land in CSISA's working areas in Rangpur division.

There were six farmers' fields in each position in Jashore and four farmers' fields in each position in the Faridpur and Rangpur working areas. Each farmer's field represented one statistical replication.

In Jashore, the three newly released rice varieties BRRI dhan 83, BRRI dhan 85 and BINA dhan 19 were direct-seeded by seed drill and by hand and transplanted in each field giving nine treatment plots in each farmer's field. In Faridpur and Dinajpur, the varieties BRRI dhan 85 and BINA dhan 19 were established in the three different ways giving six treatment plots in each farmer's field.

The performance of the different varieties in the three landscape positions and the two direct seeding establishment methods were evaluated compared with transplanted rice in terms of grain yield, labor use, cost-saving and added net returns (added return from yield benefit + cost-saving).

[6] Note that the term landscape position is used here to imply stagnant water conditions in the monsoon.

The results in the Jashore and Faridpur study sites found grain yields to be significantly different for the varieties by landscape position and crop establishment method.

- In Jashore, BRRI dhan 83 produced the highest yield (4.9 Mt ha^{-1}) followed by BRRI dhan 85 (4.6 Mt ha^{-1}) and BINA dhan 19 (4.3 Mt ha^{-1}) (Table 1.1).
- In Faridpur, BRRI dhan 85 gave the highest yield (2.8 Mt ha^{-1}) followed by BINA dhan 19 (2.1 Mt ha^{-1}). But these crops were severely affected by a flash flood at grain filling stage resulting in no harvest on the low-land plots and lower yields compared with Jashore (Table 1.1).
- In Faridpur and Dinajpur, grain yields were significantly different between crop establishment methods across landscape positions (Table 1.2) and rice varieties. The highest yields were obtained in transplanted rice at both Faridpur (2.7 Mt ha^{-1}) and Dinajpur (4.7 Mt ha^{-1}) followed by machine sown direct-seeded rice and hand sown direct-seeded rice.

Table 1.1: Grain yields of newly released *aus* rice varieties across three landscape positions and three establishment methods – Jashore and Faridpur hubs, *aus* season, 2019

Varieties	Mean grain yields ($Mt\ ha^{-1}$)	
	Faridpur area trial locations	Jashore area trial locations
BRRI dhan 83	–	4.9 a
BRRI dhan 85	2.8 a	4.6 b
BINA dhan 19	2.1 b	4.3 c

Note: The letters denote statistical differences at the 95% level using Tukey's HSD (honestly significant difference) test

Table 1.2: Rice grain yields as influenced by crop establishment methods across landscape positions and varieties – Faridpur and Dinajpur hubs, *aus* season 2019

Crop establishment methods	Mean grain yields ($Mt\ ha^{-1}$)	
	Dinajpur area trial locations	Faridpur area trial locations
Transplanted	4.7 a	2.7 a
Dry direct-seeded, machine-sown in lines	3.9 b	2.4 b
Dry direct-seeded, hand broadcast	3.6 b	2.2 c

Note: The letters denote statistical differences at the 95% level using Tukey's HSD (honestly significant difference) test.

Grain yields were significantly affected by the interaction effect of landscape positions and crop establishment methods in Jashore hub. The highest yield (5.0 Mt ha^{-1}) was obtained with machine sown rice on medium land, which was similar to the yields from machine sown rice on high-land (4.8 Mt ha^{-1}), hand broadcast sown rice on medium-land (4.7 Mt ha^{-1}) and transplanted rice on low-land (4.9 Mt ha^{-1}) and medium-land (4.6 Mt ha^{-1}) (Table 1.3).

Table 1.3: Rice grain yield as influenced by landscape positions and crop establishment methods, Jashore area trial locations, *aus* season 2019.

Landscape positions	Crop establishment methods	Grain yields (Mt ha^{-1})
High-land	Machine sown in line	4.8 ab
	Hand broadcast	4.5 bcd
	Manual transplanted	4.3 cd
Medium-land	Machine sown in line	5.0 a
	Hand broadcast	4.7 abc
	Manual transplanted	4.6 abcd
Low-land	Manual transplanted	4.9 ab
	Hand broadcast	4.3 cd
	Machine sown in line	4.1 d

Note: The letters denote statistical differences at the 95% level using Tukey's HSD test

In Dinajpur, rice grain yields were significantly affected by the interaction effect of landscape position, rice variety, and crop establishment method. BRRI dhan 85 and BINA dhan 19 produced similar yields (3.5–4.0 Mt ha^{-1}) when direct-seeded by machine and hand broadcast on both high and medium land, which were lower than those of transplanted rice in the respective landscape positions except for BINA dhan 19 on medium-land (Table 1.4).

The interaction effects of landscape positions and rice varieties significantly affected rice grain yields across crop establishment methods in locations where DSR was evaluated in Faridpur. The yields of BRRI dhan 85 were higher than BINA dhan 19 on both high and medium-land (Table 1.5).

Table 1.4: Rice grain yield as influenced by landscape positions, variety and crop establishment methods – Dinajpur area trial locations, *aus* season 2019

Landscape positions	Varieties	Crop establishment methods	Grain yields (Mt ha^{-1})
High-land	BRRI dhan 85	DSR line sown	4.0 c
		DSR broadcast	3.7 c
		Transplanted	5.0 a
	BINA dhan 19	DSR line sown	4.3 bc
		DSR broadcast	3.8 c
		Transplanted	5.1 a
Medium-land	BRRI dhan 85	DSR line sown	3.5 c
		DSR broadcast	3.5 c
		Transplanted	5.0 a
	BINA dhan 19	DSR line sown	3.7 c
		DSR broadcast	3.6 c
		Transplanted	3.6 c

Note: The letters denote statistical differences at the 95% level using Tukey's HSD (honestly significant difference) test.

The following net effects of direct-seeded rice on yield were compared with transplanted rice:

- yield benefit (yield benefit = yield of direct-seeded rice – yield of transplanted rice)
- cost save (cost save = cost of transplanted rice – cost of direct-seeded rice)
- added net return (added net return = yield benefit x price of paddy + cost savings).

Yield – The median yield benefit for direct-seeded rice was 0.4 Mt ha^{-1} on high-land, 0.3 Mt ha^{-1} on medium-land, but with a reduction of 0.7 Mt ha^{-1} on low-land (Figure 1.2.1). The yields of direct-seeded rice were less than transplanted rice on 25% of the farmers' fields on high and medium lands and on 90% of the farmers' fields on the low-land.

Table 1.5: Rice grain yields as influenced by landscape positions and variety across establishment methods – Faridpur area trial locations, *aus* season 2019

Landscape position	Variety	Grain Yield (Mt ha^{-1})
High-land	BRRI dhan 85	3.3 a
	BINA dhan 19	2.4 b
Medium land	BRRI dhan 85	2.3 b
	BINA dhan 19	1.8 c

Note: The letters denote statistical differences at the 95% level using Tukey's HSD test.

Cost saving – The median costs saved for growing DSR were $254 ha^{-1} on high-land, $271 ha^{-1} on medium-land and $275 ha^{-1} on the low-land (Figure 1.2.2). The cost savings were more than $220 ha^{-1} on the high-land, $240 ha^{-1} on the medium-land and $153 ha^{-1} on the low-land on 75% of farmers' fields.

Net returns – The added net returns were minus $19 ha^{-1} on 10% of farmers' fields on high-land and minus $0.4 ha^{-1} on 25% of the farmers' fields in low-land (Figure 1.2.3). Median added net returns were highest on the medium-land ($355 ha^{-1}) followed by the high-land ($327 ha^{-1}) and were only $92 ha^{-1} on low-land. Positive added net returns were obtained by 75% of farmers who established trials on high-land (>$ 190 ha^{-1}) and medium-land (>$ 238 ha^{-1}).

Preliminary results – The preliminary results for one season indicate that on 'high' and 'medium' lands most of the direct-seeded rice fields yielded more and had lower growing costs than the transplanted rice and subsequently gave higher net returns. However, the performances of direct-seeded rice was not so attractive on the low-land fields. This study will continue across the next *aus* season (2020) in order to validate these conclusions.

Figure 1.2 (Below): Results of comparing dry direct-seeded rice to transplanted rice at high, medium and low-landscape positions – Jashore working areas, *aus* season, 2019

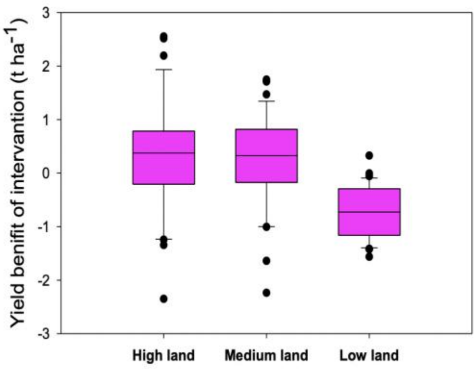


Figure 1.2.1: Yield differences of dry direct-seeded rice

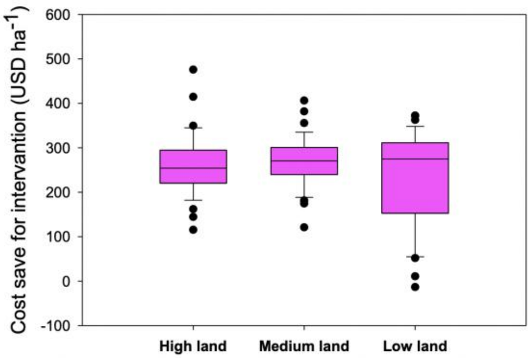
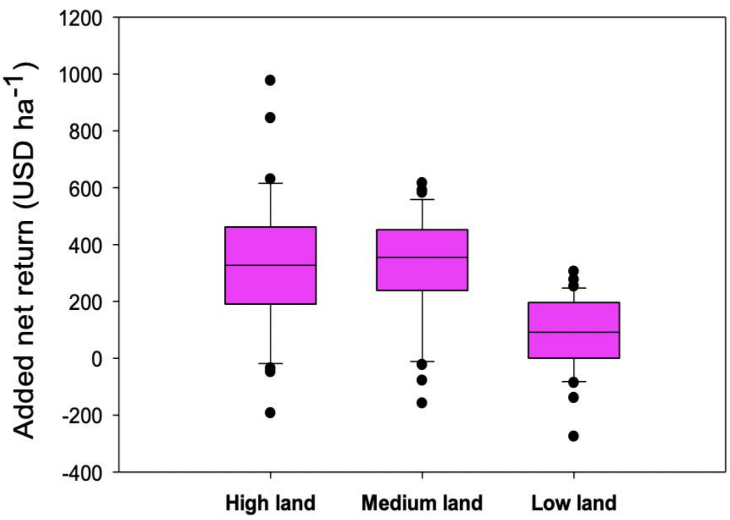


Figure 1.2.2: Costs saved growing dry direct-seeded rice



Note: The horizontal lines in the boxes represent the median; the boundaries of the boxes closest to zero indicate the 25th percentile and the boundaries of the box farthest from zero indicate the 75th percentile. 'Whiskers' below and above the boxes indicate the 10th and 90th percentiles, while bullets are outlying points.

Figure 1.2.3: Added net returns of growing dry direct-seeded rice

Performance evaluation study 2

The second study evaluated nine popular rice varieties that are recommended for growing in the *aus* season in farmers' fields in Jashore, Dinajpur and Faridpur trial locations. Each farmer's field represented a replication and the number of replications for each variety varied from 6–10. Only yield data are reported here; the other data will be reported in the next report.

BRRI dhan 83 gave the highest yield (4.9 Mt ha^{-1}) (Photo 1.2) followed by BRRI dhan 28 (4.2 Mt ha^{-1}) and BINA dhan 19 (4.0 Mt ha^{-1}). The yields of the other six varieties ranged from 3.5–3.6 Mt ha^{-1} (Table 1.6). This trial will be continued in the next *aus* season in 2020.

Photo 1.2: Machine sown BRRI dhan 83 in line in farmer's field in Jashore hub, *aus* 2019 Sharif Ahmed)

Table 1.6: Yield performance of nine popular *aus* rice varieties across Jashore, Faridpur and Dinajpur hubs – *aus* season, 2019

Variety	Mean grain yield ± standard error ($Mt\ ha^{-1}$)
BRRI dhan 83	4.9 ± 0.3
BRRI dhan 28	4.2 ± 0.3
BINA dhan 19	4.0 ± 0.2
BRRI dhan 85	3.6 ± 0.3
Rahim Swarna	3.6 ± 0.2
BRRI dhan 26	3.5 ± 0.2
BR 14	3.5 ± 0.2
Nerica	3.5 ± 0.3
BRRI dhan 48	3.6 ± 0.2

Awareness raising activities

In addition to the above on-farm research activities, the project successfully implemented the following direct-seeded rice awareness raising activities during the 2019 *aus* season:

- **Linking to governmental subsidy programs to reduce risks to adoption** – The project linked farmers with the DAE's *aus* rice seed subsidy program in the 2019 *aus* season. CSISA team members facilitated direct-seeded rice establishment by machine seed drill in 190 farmers' fields (150 in Jashore and 40 in Faridpur) using seeds provided by DAE. The project also provided best management practice guidelines for direct-seeded rice to these farmers.
- **Trained service providers** – In March and April 2019, the project ran five one-day training events for machinery service providers who own seed drills that can be used for DSR in Jashore, Faridpur and Dinajpur working locations. These trainings, which were held before the start of the 2019 *aus* season, briefed the 103 participants on how to directly sow rice and on basic agronomy issues.
- **Field visits and field days** – The project ran field visits for policy makers and other stakeholders and field days for farmers to direct-seeded rice fields. During the 2019 *aus* season 11 visits were run across the 3 hubs to direct-seeded rice fields for 206 persons from DAE, NGOs and research organizations where they exchanged ideas with and listened to the experiences of farmers. The project also held 11 field days at crop maturity in direct-seeded rice fields, which were attended by 822 farmers who saw the performance of direct-seeded rice.
- **Sharing meetings** – Project staff provided 735 DAE and NGO staff with information about local seed drill service providers, direct-seeded rice establishment techniques and best management practices for direct-seeded rice during *aus* season 2019 at 20 of their weekly meetings.
- **Learning centers** – The project established 16 direct-seeded rice learning centers (demonstration areas in which farmers were regularly convened to discuss and learn from growth and progress on crop performance) in 19 farmers' fields during *aus* season 2019. Local farmers, service providers and DAE staff learned how to establish and manage direct-seeded rice by viewing different crop management operations and the performance of direct-seeded rice. This should encourage them to directly seed rice in the next season.

A1.2 Agronomic and variety recommendations to reduce the threat of wheat blast

Wheat blast is a fast-acting devastating fungal disease that threatens wheat productivity in the Americas and South Asia. In 2016, Bangladesh suffered its first severe outbreak. In 2017, with project support, the Bangladesh Maize and Wheat Research Institute (BWMRI) released a blast-resistant wheat variety (BARI Gom 33) developed from CIMMYT breeding lines in Mexico. However, there are only limited supplies of seed of this variety and wheat crops in Bangladesh and South Asia remain very vulnerable to the disease. It is estimated that it will take years to multiply sufficient seed to cover all Bangladesh's wheat areas with the resistant variety. For this reason, alternative management techniques, i.e. integrated disease management, remains crucial. The continued spread of blast in South Asia – where more than 100 million tons of wheat are consumed per year, could devastate grain markets and undermine the ability of smallholder farmers to sustain their families. Blast is strongly driven by climate anomalies, and more humid or hot years are likely to see additional outbreaks.

The comparatively cooler and drier weather in the 2019 wheat flowering stage in February 2019 limited wheat blast sporulation and disease intensity in the FtF zone. The disease appears to have been contained to less than 100 hectares in the 2018/19 growing season. In mid-January 2019, minor blast infections were reported from Meherpur District in wheat that had been seeded overly early and suffered early season heat. Continuous rain from 24–27 February 2019 created a favorable environment for inoculum build up and sporadic minor infections were found in late seeded crops in 19 districts. This continued the trend whereby, each year since 2016, sporadic minor infections have been found in new districts of Bangladesh, indicating the spread of the fungus and its adaptability to new environments. Outbreaks are likely to continue in future years now the disease is established.

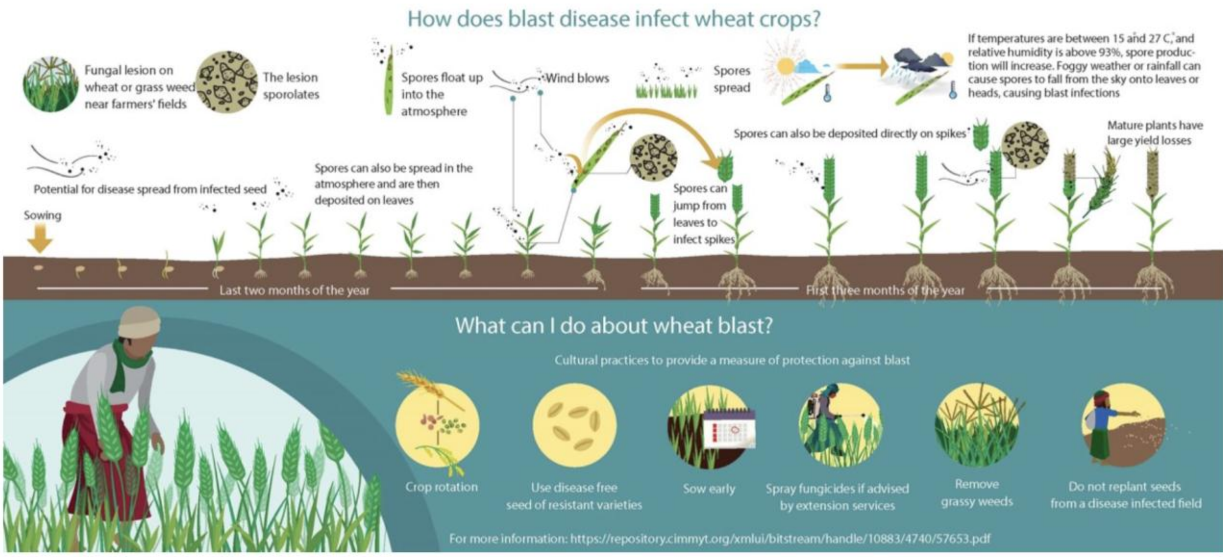


Figure 1.3: In 2019, the CSISA project developed infographics, including the one shown, which were printed in Bangla and English and distributed to farmers and extension agents throughout Bangladesh to increase awareness and understanding of the biology and ecology of wheat blast disease, and to provide insights on how to manage the disease. These infographics are available on [CSISA's website](#).

In this reporting period the project continued to raise awareness on the biology and ecology of the disease among farmers, extension agents, and agricultural policy makers in South Asia. The project and its government and NGO partners addressed wheat blast by issuing 30,000 factsheets to farmers and other stakeholders and running other awareness raising activities (Figure 1.3) that help farmers adopt crop management and variety recommendations to reduce the threat of wheat blast. These activities strengthen the resilience of smallholder farmers by helping them mitigate the negative consequences of the disease.

Farmers are accordingly adopting recommended practices such as the earlier sowing of wheat to avoid maturity at times when blast is most likely, the use of blast resistant and tolerant varieties, treating seeds with fungicides, and, where economically and environmentally rational, spraying fungicides. As a result, wheat blast infection is reducing year by year and has reduced from affecting 15,000 ha in 2016 to less than 100 ha in 2019.

In this reporting period, the project continued its collaborative research with:

- BWMRI to verify agronomic control methods for wheat blast; and
- the USAID funded Climate Services for Resilient Development (CSRD) in South Asia project to develop an early warning system for wheat blast.

In 2018/19, demonstrations were conducted with newly released blast resistant and zinc-enriched BARI Gom 33 wheat in collaboration with BWMRI and the DAE during which seed of this variety were distributed to farmers for multiplication (Photo 1.3). Additional project activities conducted with BWMRI are described below.

Photo 1.3: Showing the performance of several wheat varieties, including blast disease resistant BARI Gom 33, to farmers in a blast-affected area of Faridpur district in early 2019 (MA Arafat)

Responses of new wheat varieties to different seeding dates

Previous researcher designed and managed trials conducted by the project with BWMRI scientists at Jashore Regional Agricultural Research Station (RARS) indicated that wheat blast attacks existing cultivated varieties more vigorously when wheat is seeded late. This is largely because the climatic conditions (specifically higher minimum temperatures, humidity, fog and light precipitation) that favor wheat blast infection are more common late in the growing season. However, the blast sensitivity of newly released varieties under a range of environmental and cropping conditions had yet to be precisely quantified. Six varieties, including the susceptible BARI Gom 26 (grown as a control variety), were tested in experimental trials with five seeding dates (25 November; 5, 15 and 25 December 2018 and 5 January 2019) at research stations in the three different agroecological zones of Dinajpur, Jashore and Rajshahi (Photo 1.4). This was the second round of trials leading on from the same trials in 2017/18.

The two years of trials show the following results:

- There were no blast infections in any seeding date at Dinajpur and none in the 25 November and 5 December seedings at Jashore and Rajshahi including the susceptible check BARI Gom 26. Blast infections started in the 15 December seeding and increased with later seeding dates. The highest disease severity was found in the 5 January seeding of BARI Gom 26 with 85.9% infection compared to only 10.3% of BARI Gom 30, 8.2% of BARI Gom 32 and 0.96% of the BARI Gom 33 trials.
- Irrespective of variety the highest yield in Dinajpur was recorded from the 25 November seeding in both years with the yield decreasing significantly ($p \leq 0.05$) with increasing lateness of seeding. The yield of BARI Gom 30 was the highest in all sowing conditions at Dinajpur, which was statistically similar to that of BARI Gom 32 and BARI Gom 33. Whereas, at the different conditions of Rajshahi and Jashore, BARI Gom 33 produced the highest yield followed by BARI Gom 31 and BARI Gom 28.

The two years' results suggest that location-specific sowing times may influence yield and susceptibility to wheat blast. The results will be used to validate the wheat blast prediction model and early warning system (that is under development by the complementary Climate Services for Resilient Development project) and to refine and formalize recommendations for how farmers can reduce the incidence of blast on wheat.

Photo 1.4: (Left) CSISA staff explaining the wheat blast trials conducted with BWMRI to trainees and (right) mist irrigation in the cultivar mixture trial at Jashore where misting is used to stimulate infections and measure crop performance under high disease pressure (TJ Krupnik)

Effect of cultivar mixtures on wheat blast

Many studies report that mixing different varieties of grain crops can reduce disease incidence and severity. In many cases, mixing cultivars also increases yield. Such options open doors for the potential ecological management of diseases without using fungicides. In this reporting period, to explore options for cultivar mixtures to reduce wheat blast infestations, the project and BWMRI selected the three varieties of BARI Gom 26 (blast susceptible), BARI Gom 33 (which carries a wild wheat chromosome segment referred to as 2NS that confers blast resistance) and BARI Gom 30 to test in different seeding mixtures. Ten sub-plot treatments were prepared and sown on 23 December 2018 with three sole variety and six two variety mixtures with i) 33% + 66%, ii) 33% + 33% + 33%, and iii) 66% +33% cultivar seed densities.

The experiment was conducted in a split-plot design with five replications at Jashore Regional Agricultural Research Station. The main plots were divided into fungicide and non-fungicide treatments to further assess if cultivar mixtures can reduce relative yield losses when fungicide protected plots are compared to unprotected plots under high disease pressure (Photo 1.5). The experiment and replications were surrounded by three border rows of BARI Gom 26, and were sprayed with blast fungal inoculum at seven-day intervals starting from the late vegetative/early reproductive stage of the crop. The Nativo 75WG fungicide was sprayed by a trained applicator five days after each inoculation in the fungicide main plot. The whole experiment was subsequently put under mist irrigation (Photo 1.4 right), with misting stopped from 24 hours before to 24 hours after fungicide spraying.

Photo 1.5: Left: Well controlled leaf diseases in fungicide-applied cultivar mixture plots. Right: no disease control in plots without fungicide (DB Pandit)

While blast is a concern, *Bipolaris* leaf blight is the most common disease of wheat in Bangladesh, although it typically causes only limited damage. The experiment therefore also measured whether or not the fungicide controlled this disease. *Bipolaris* leaf blight data was recorded three times at Zadok growth stages 75, 80 and 85 from the flag leaves of 30 randomly tagged plants and converted to percent diseased leaf area. Wheat blast incidence and severity percent was recorded from those randomly tagged 30 plants three times at the above three growth stages. The percent disease index was calculated using percentage blast incidence and severity.

The results indicate that using cultivar mixtures can produce significant for yield, percent disease index of wheat blast and percent diseased leaf area for *Bipolaris* leaf blight. Fungicide spraying reduced the diseased leaf area in flag leaves by 63.9% and the disease index for wheat blast by 29.1%, which in turn led to a 32% increase in grain yield. These results also indicate that *Bipolaris* leaf blight is more controlled with fungicides than blast, which may be due to the inoculation of blast spores in the favorable environment of misting irrigation.

Figure 1.4: Change in percentage diseased leaf area (DLA) of bipolaris leaf blight (BpLB), disease index (DI) of wheat blast & yield in response to fungicide spraying

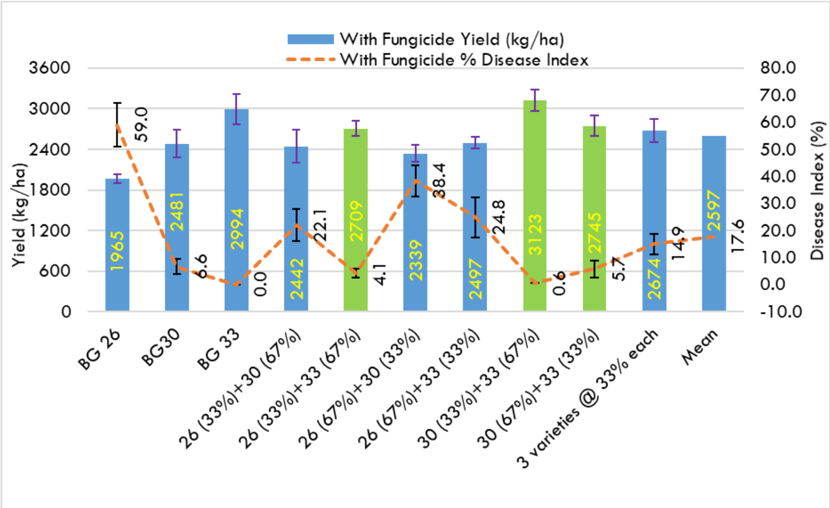


Figure 1.5: Initial performance of wheat variety mixtures and sole variety crops for yield and wheat blast disease index with fungicide spraying (Green colored mixtures were potential good yielding mixtures to control wheat blast)

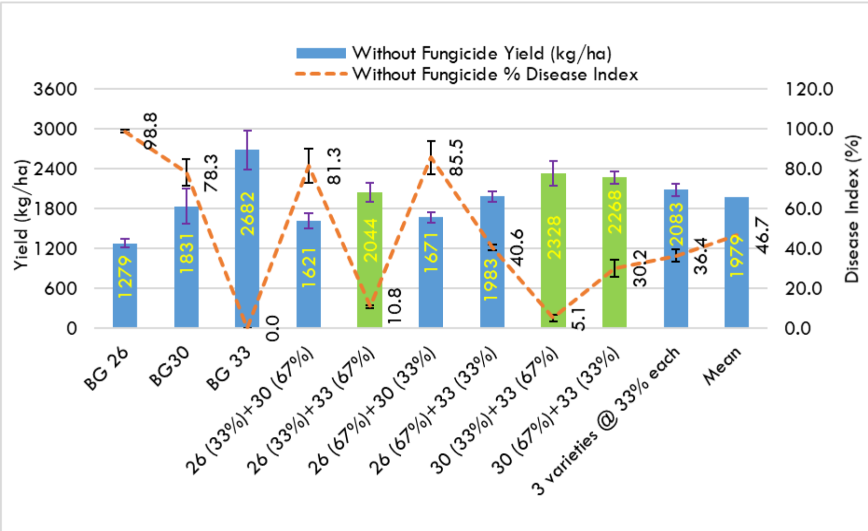


Figure 1.6: Initial performance of wheat variety mixtures and sole variety crops for yield and wheat blast disease index without fungicide spraying (Green colored mixtures were potential good yielding mixtures to control wheat blast)

Other detailed results are as follows:

- In both the with and without fungicide plots, the lowest yield and highest level of disease was recorded in BARI Gom 26 and the highest yield in the without fungicide condition was in BARI Gom 33 (Figure 1.5 and Figure 1.6)
- In the fungicide treated plots the highest yield occurred in the BARI Gom 30 (30%)–BARI Gom 33 (67%) mixture, with BARI Gom 33 only yielding a little less.
- The percentage disease index in the BARI Gom 30 (33%)–BARI Gom 33 (67%) mixture was lower that the single variety BARI Gom 30 and similar to the resistant variety BARI Gom 33 with fungicide spraying. The latter mixture also had high yield and low levels of blast in the without fungicide condition showing its potential to mitigate wheat blast without losing yield.
- Yield was also high and disease less in the BARI Gom 30 (67%)–BARI Gom 33 (33%) and the BARI Gom 26 (33%)–BARI Gom 33 (67%) mixtures.

These trials need carrying out for a further 1-2 years to provide more definitive conclusions.

The CSISA–BWMRI variety mixture trials and preliminary results were also featured on national television. They were broadcast to farmers across the country in the 4 April 2019 edition of Bangladesh TV's Mati-O-Manush farming program (Photo 1.6).[7]

Photo 1.6: The project collaborates with the Bangladesh Wheat and Maize Research Institute to conduct wheat cultivar mixture trial in Jashore to examine the potential of sowing mixed seed of different varieties for suppressing blast disease. Click the image to see the CSISA wheat pathologist Harun-Or-Rashid discussing this collaboration on *Mati-O-Manush*, the country's most watched agricultural TV program (Bangladesh Television)

Efficacy of foliar and seed fungicides

Disease control – Since the 2016/17 wheat cropping season, the project has provided support to the Bangladesh Agriculture Research Institute (BARI) and BWMRI to conduct three years of tests to identify high-performing, low-cost and low environmental toxicity fungicides for wheat blast. In all three years, the fungicides were sprayed twice at the heading stage of the crop and at 12-15 days after the first spraying.

In 2018/19, all of the six tested fungicides were effectively controlled wheat blast (as compared to the control plots), with the highest yield increase obtained by spraying Nativo 75 WG (38%), followed by Amistar Top 325 SC and Folicur 250 EW – the same results as in 2017/18. The highest net profit was obtained from spraying with Nativo 75 WG. Thus, Nativo 75 WG (Tebuconazole 50% + Trifloxystrobin 25%) and Amistar Top 325 SC (Azoxystrobin 20%+ Difenoconazole 12.5%) were the most effective products for controlling wheat blast, although they are costly. These findings have been used by BARI

[7] See 2 minute 14 seconds into the clip.

and BWMRI to produce information leaflets, which have been distributed to Bangladeshi wheat farmers (Figure 1.7).

Seed treatment – In 2018/19, the third annual test was carried out on the efficacy of four seed treatment fungicides with an untreated control. Provax 200 WP (Carboxin 37.5% + Thiram 37.5%), Vita Flo 200 FF (Carboxin 37.5% + Thiram 37.5%), Rovral 50 WP (Iprodione 50%) and Goldman 80 WP (Mancozeb 80%) were tested in collaboration with BWMRI to observe the control of the seed borne prevalence of wheat blast and disease incidence on spikes. All the fungicides achieved 100% control of blast in laboratory condition and significantly increased plant populations over the control treatment in field conditions. Seed treated with fungicides not only reduced and controlled initial inoculums of blast but also controlled other seed borne fungi including *Bipolaris sorokinia* and *Alternaria*, *Curvularia* and *Fusarium* species. All the fungicides are approved by USAID's Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP). Because of its comparatively better efficiency Provax 200 is recommended to treat seed following recommended phytosanitary regulations.

Figure 1.7: Wheat blast control leaflet developed by the Government of Bangladesh with support from CSISA

Wheat blast surveillance – In the 2018/19 cropping season, CSISA and BWMRI scientists carried out surveillance in farmers' fields and trial sites in Bangladesh's major wheat-growing areas to assess the incidence of wheat blast disease. Surveys were carried out in 36 districts across 152 farmers' fields and trial sites. Sixty-one sites amounting to 40% of all sites were infected with wheat blast. Blast was found in six new districts but with low incidence and severity. Bhola District in south-central Bangladesh in particular showed a higher level of disease severity under late planting. However, early planted fields in the infected districts tended to escape severe infection. The lowest level of disease infection was in Naogaon district. Overall, disease incidence was comparatively low with insignificant yield losses.

A2. Adding value to extension and agricultural advisory systems

A.2.1 Building precision nutrient management approaches around scaling pathways

Leveraging artificial intelligence to refine nutrient management recommendations for maize

Although precision nutrient management has been an important component of project activities in Bangladesh, research under this activity was suspended in consultation with USAID during this period due to funding delays and the lack of full fund transfer. However, project field staff continued to advise farmers, the DAE and agricultural input dealers on appropriate crop and nutrient management strategies through one-to-one interactions, at meetings and at farmer field days. In addition, project researchers continue to analyze data on precision nutrient management for maize collected in previous project years. Major learnings from this work are presented below.

The project used data from nutrient omission plot trials (NOPTs) the 2011/12 and 2012/13 rabi seasons from 324 farmers' fields across ten agro-ecological zones (AEZ). First, an additive main effect and multiplicative interaction (AMMI) model was used to explain maize yield variability to nutrient addition in different agro-ecological zones. Then, a random forest model regression model was used to predict regional variability of N-, P-, and K- and Zn-limiting yield relative to balance fertilization (NPKZn). Mean yields in the non-limiting nutrient 'sufficiency' plots were highest in the Active Ganges Floodplain (AEZ 10) in the first year and Young Brahmaputra and Jamuna Floodplain (AEZ 8) in the second year, and were consistently lower in the Old Meghna Estuarine Floodplain (AEZ 19) (Figure 1.8).

The nutrient omission treatments explained about 60% of yield variation in both years, the AEZ explained 30 and 32%, while the AEZ × NOPT interaction explained 8.4% and 7.3% of variation in the first and second years respectively. The yiled ranges across AEZs were:

- 0.15–1.00 Mt ha^{-1} for relative N (RY_N)
- 0.41–1.21 Mt ha^{-1} for relative P (RY_P)
- 0.17–1.37 Mt ha^{-1} for relative K (RY_K)
- 0.6–1.56 Mt ha^{-1} for relative Zn (RY_{Zn}).

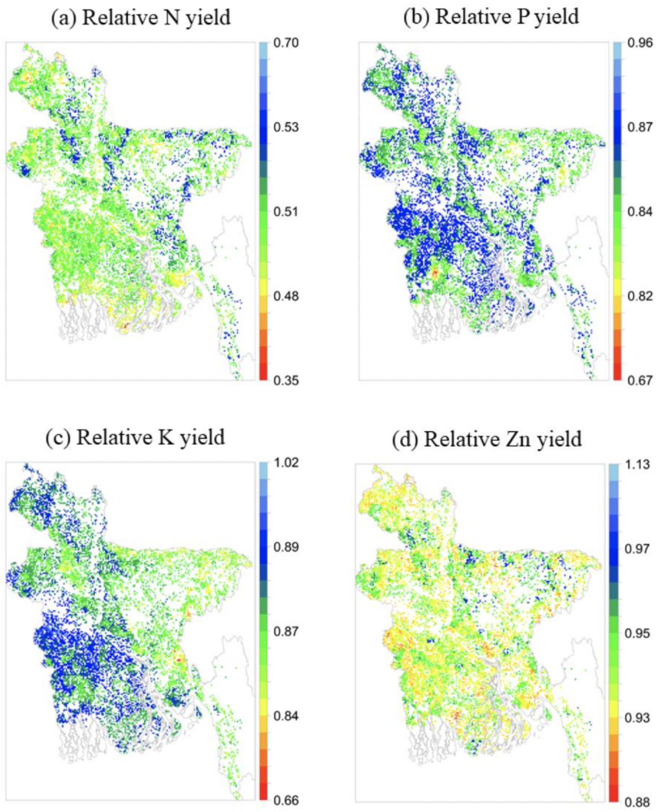


Figure 1.8: Distribution of predicted relative yields (%) of N, P, K and Zn across Bangladesh's upland *rabi* areas. Note: different scales used as maps show the spatial variability of yield responses

The relative yield (RY) explained by the random forest machine learning (artificial intelligence) algorithm on hold-out test data set in the following order: RY_N (43%) > RY_P (41%) > RY_K (28%) > RY_{Zn} (1%). The predicted median RY of N, P, K and Zn which represent average soil fertility, was 0.51, 0.84, 0.87 and 0.97 accounted for 44, 54, 54 and 48% upland *rabi* (dry season crop) area, respectively. To develop more precise and efficient nutrient management for maize in the eastern Indo-Gangetic Plains, spatial variability of RY predicted by data-driven machine learning approaches will need to be combined with information on farmers' crop management practices and robust attainable yield estimates. This work represents a first methodological attempt to apply machine learning and advanced geo-spatial analytics to improve nutrient recommendations in Bangladesh.

The project draws the following conclusions and implications from the results for future research aimed at the development of informed and appropriate precision nutrient management recommendations:

- In multi-year, multi season on-farm experiments conducted across a broad geographical area, as in this study, and where farmers are partially involved in managing their plots (e.g., by choosing irrigation rates and source, weeding frequency and timing, etc.), considerable noise resulting from environmental and management heterogeneity may be expected, calling for multivariate analytical methods to begin to parse out and distill actionable information from the data.
- Our data indicate a lack of relationships between soil test results and omission plots yields, indicating that conventional programs that develop fertilizer recommendations based on the

common suite of laboratory procedures to determine soil nutrient levels is unlikely to be appropriate for rabi maize grown after rice in the Eastern Indian Gangetic Plain.

- As either an analytical unit or recommendation domain, our data indicate that agroecological zoning might also be inappropriate for fertilizer recommendations because of the wide variability and inconsistent results encountered when yield response is considered at this broad level.

The outputs of this work will be used next year by CSISA to describe potential changes in crop management recommendations for maize farmers.

CSISA supported PhD student publishes study on urea deep placement in rice

During the reporting period, the project engaged with researcher and PhD student, Shah-Al Emran, of the Department of Crop Sciences at the University of Illinois at Urbana-Champaign, to independently analyze data from southern Bangladesh examining the effect of the deep placement of urea super granules (USG) on rice productivity. USG is a fertilizer technology that has been supported by the USAID/Bangladesh Mission in recent projects including those led by the International Fertilizer Development Center. Details of this research have been published in the peer-reviewed journal *Field Crops Research*, and are available here.

B. SYSTEMIC CHANGE TOWARD IMPACT

B1. Partnerships for inclusive growth around commercial pockets and neglected niches

B1.1 Deployment of better-bet agronomic messaging through input dealer networks and development partners

The adoption of science-based agronomic management practices by farmers can reduce yield gaps and increase the productivity and profit of crops in farmers' fields. Communicating such better-bet agronomic practices to farmers through easily understandable communication materials is an important way of scaling out the use of such practices by farmers. In 2016/17, the project produced a video on raising healthy rice seedlings and early wheat sowing, leaflets and booklets on healthy rice seedlings, mung bean cultivation and early wheat sowing and a fact sheet on wheat blast mitigation. Since then, the project continued to use these materials to deploy recommendations on appropriate agronomic practices to smallholder farmers in partnership with the Department of Agricultural Extension (DAE), the Agriculture Information and Communication Centre (AICC), the Agriculture Information Service (AIS), the Agricultural Advisory Society (AAS) and the Agri-input Retailer Network (AIRN).

Between October 2018 and September 2019, for example the project distributed 34,000 healthy rice seedling leaflets, 37,500 early wheat sowing leaflets and 15,000 wheat blast mitigation fact sheets to farmers through its government partner organizations in Jashore, Faridpur, Barishal and Dinajpur working locations. At the same time, videos on healthy rice seedlings and early wheat sowing were shown to farmers in 638 villages across the project hubs to 64,018 farmers (24% women). The deployment of these information and communication materials has resulted in the application of improved management practices by farmers – particularly for healthy rice seedling techniques that are both easy to implement and effective at improving yield and productivity (Photo 1.7)

Photo 1.7: Farmers' tending to healthy rice seedlings raised using appropriate management practices recommended by CSISA and BRRI in Barishal (Washiq Faisal)

B1.2 Winter rabi season development of fallow-lands in coastal Bangladesh

Since the inception of the third phase, the project has focused work in Southern Bangladesh to assess ways in which dry season fallow land – which represents an enormous resource for increasing the productivity of farming systems in the FtF zone (Photo 1.8) – can be reliably brought into production using sustainable intensification technologies and management practices.

Photo 1.8: Large tracts of fallowed land that could be brought into production with surface water used for irrigation as seen from over northern Patuakhali district in Bangladesh (TJ Krupnik)

To accomplish this, the project conducts strategic research on pathways and approaches to encourage fallow land intensification, starting with the development of a thorough understanding of trajectories of farming systems change within the region. Understanding how systems have changed and where their current trajectories are headed given biophysical and social constraints that farmers face is crucial to inform development planners and policy makers and advise on appropriate development interventions within the region.

In 2018/19, CSISA i) developed a data set on the factors driving agricultural change in Bangladesh, ii) identified factors for increasing cropping intensity, iii) identified farmers' preferred crops for rabi fallows intensification, and iv) estimated farmers' willingness to invest in fallows intensification. Much of this work has recently been published in the journal Agricultural Systems, available here.

A long-term longitudinal data set on factors that drive agricultural change

Bangladesh's coastal farming systems are undergoing rapid change. Understanding past and present agricultural diversity, dynamics, and trajectories of change is crucial to inform policies towards meeting the Sustainable Development Goals. To understand long-term agricultural change and the drivers affecting the intensification of agriculture in the south-central coastal zones, the project developed a long-term longitudinal data set of 502 households on farming system trajectories and drivers of change, spanning the twenty years from 1995 to 2015. This data is farm household level recall panel survey data for 1995, 2000, 2005, 2010 and 2015. Two districts within polders (Patuakhali and Barguna) and a single district outside of polders (Barisal district) were selected from among the 27 districts in southern Bangladesh due to their potential for crop intensification and surface water irrigation. The long-term data is available on the CSISA dataverse website. The variables in the data set include farm structural and functional characteristics, household resource endowment, agricultural management information, and data on off- and on-farm income, in addition to biophysical and socio-economic and demographic attributes. This data set is useful for understanding future development interventions and needs of south Bangladesh's agrarian population.

Results from this study indicate that rather than focusing on *boro* rice cultivation to overcome land fallowing in the winter season, which has been a long-term policy priority of the Government of Bangladesh, the development of stress tolerant mung bean varieties and extension support to improve nutrient management may be beneficial for fallows intensification, alongside efforts to improve in-field drainage to facilitate early winter season land preparation. Setting these issues aside, pathways to catalyze intensification of these systems are also likely to require efforts to ameliorate environmental risks posed by extreme weather, policies to improve sharecropping arrangements and land tenure security, alongside farming systems re-design that incorporates households' development aspirations and the attributes affecting their crop choices. Further details can be found in this study.

Factors that can improve cropping intensity

Building on the above analysis, during the reporting period the project also employed quantitative models to identify factors that can improve cropping intensities in south-central Bangladesh. Key findings were as follows:

- Mechanization, quality extension support and markets were the most significant factors that enhanced cropping intensities in the region.
- The inundation class (flooding land type) of farmland influenced cropping intensities, reinforcing the requirement for post-monsoon field drainage and clearing drainage canals to facilitate winter season cropping.
- Cyclones have a negative influence on cropping intensities and off-farm income activities.

Secure land tenancy rights were positively associated with cropping intensity. In focus groups, sharecroppers reported being averse to invest in land management or irrigation in the absence of secure land rights. Tenure insecurity could also reduce farmers' interest in improving soil quality over time as farmers discount future investments. At current rates, the cost of securing tenure rights through land registration is roughly 10% of the value of land, which is prohibitive to small and marginal farmers in the coastal region. This provides evidence of the need for revised land tenure policies and improvements on informal land sharing arrangements alongside technical efforts to intensify fallow land.

The results also showed that, while cropping intensities both within and outside polders, reduces with increased farm fragmentation; farmers respond to this and other environmental stresses through off-farm income generation. Bangladeshi inheritance laws stipulate the sub-division of land to multiple heirs their parents' deaths. Amending these laws to prevent sub-division would probably assist in supporting crop intensification.

There have been considerable crop losses associated with previous extreme weather events in coastal Bangladesh. Severe cyclones have significantly affected cropping intensities as a single unit increase in cyclonic severity has been associated with a two or three-time reduction in cropping intensity within and outside polders, respectively. In focus groups, farmers who had experienced cyclones and extreme weather indicated that they had responded by reducing the cropped area and by fallowing to hedge risks. Opportunities for climate services that increase farmers' ability to anticipate and cope with extreme climatic events may be beneficial in reducing environmental risk in southern Bangladesh.

Farmers' preferred crops for rabi fallows intensification

The above analyses are useful from a policy perspective, but development planners also need to better understand farmers' incentives and constraints on their choice of crops for intensification in fallow periods to promote the intensified cropping of fallow-lands. During the reporting period, the project conducted additional field studies to evaluate farmers' preferences for potential crops suitable for sustainable intensification in south-central Bangladesh, and the nature of attributes and the most important socio-economic forces driving their preferences. A socio-behavioral experiment based on random utility framework was developed and tested, with results analyzed during the reporting period, among farmers in Southern Bangladesh to understand their crop preferences. The respondent farmers showed a strong preference for cultivating mung beans and maize on fallow-land. The majority of them from outside the polder areas (62%) selected mung beans as their primary choice followed by maize (22%), *boro* rice (8%), leaving fallow (4%) and wheat (4%). The preferences of the within polder farmers were similar with 66% of them preferring to grow mung beans, 22% maize, 5% wheat and 4% *boro* rice. The government's development master plan for the Southern region proposed by the Ministry of Agriculture and FAO in 2013 suggested increasing *boro* rice production on fallow-land. This, however, conflicts with the growing popularity of mung beans in the winter season. Focus groups indicated that low rice grain prices, relatively higher labor costs and high irrigation costs are disincentives for growing *boro* rice. Although mung beans are favored as a low-input opportunity crop that fetches better prices, the storms and waterlogging that are common in the coastal region significantly suppress yields. Further studies are needed to investigate these issues.

B1.3 High-value, premium quality rice (PQR) expansion in Bangladesh

The project has been working as a catalyst to expand premium quality rice production in Bangladesh's FtF zone since 2016 and in the Dinajpur hub since the beginning of 2019. Importantly, CSISA has already met its primary targets with respect to acreage and the production of new PQR varieties in Bangladesh. As such, the project has moved toward more strategic research efforts to address some of the constraints encountered in the PQR market, in order to find ways to assure a more consistent flow of benefits to smallholder farmers who grow PQR varieties. In response, during the reporting period, a rapid assessment of value chain actors of premium quality rice was carried out to identify constraints and opportunities in the premium quality rice value chain towards improving the production and marketability of premium quality rice in the domestic and other potential export markets. The study:

- traced the flow of premium quality rice from producers to the end-market;
- identified the quality attributes of premium quality rice and the varieties that qualify; and
- provided insights on constraints and opportunities in the value chain.

Rapid assessments were conducted in the north and south. The first round was conducted in April–May 2019 at Sherpur, Dinajpur and Dhaka city and the second round in mid-June 2019 in Jheneidah district. A discussion guide was used to facilitate focus group discussions with farmers. A process-based questionnaire was used for the midstream actors (i.e., paddy traders, processors, wholesalers and exporters) to capture integrated activities. A separate questionnaire was used for the retailers.

The preliminary findings of the flow of PQR from farmers to consumers are shown in Figure 1.9. Preliminary findings suggest that aroma, fine grain quality (i.e., slender, size, shape), and good taste are the three commonly perceived attributes used to define 'premium quality rice.' These, when combined with traits like 'good' and clean appearance, consistency, purity, and packaging, fetch the highest market prices. The survey results also reveal two distinct premium quality rice market segments and value chain paths.

PQR market segment type I – The first type of premium quality rice segment is short-grain tasty aromatic rice. These are consumed on special occasions like weddings, family functions, and religious celebrations. Since aroma is one of the most important attributes, this rice is usually cooked in its non-parboiled raw form. The other characteristics of this type are as follows:

- Although most varieties are traditional varieties (e.g. Kataribhog, Chinigura, Kalizira, Badshabhog, Tulsimala, Chinisagor, Jiramini, Mozzim Zira, Shampa Katari, Jira Katari), the modern variety BRRI dhan 34 has become popular because of its higher crop yield alongside its aroma, fine grain and good taste. The area coverage of BRRI dhan 34 is more than the other traditional varieties. This variety is typically labeled *Chinigura* rice.
- Farmers face several challenges in cultivating premium quality rice varieties such as increased risk from pests and diseases and overall lower yields than other varieties. Farmers are interested in being trained to intensify their production of these varieties.
- The survey results suggest little evidence of specialization in the context of maintaining quality and purity of this type of rice.
- Actors further up the value chain face other challenges and opportunities. The domestic and global demand for premium quality rice is increasing annually. However, the cultivation of popular premium quality rice varieties takes place only in the monsoon season. Consequently, the premium quality rice varieties available on the market are in fact combinations of premium quality rice varieties of varied grades blended by value chain actors to fulfill demands in certain market segments.

PQR market segment type 2 – The second segment is long, slender, fine grained rice that has good taste. Additional attribute like aroma makes the rice more premium in this segment. This type of rice is typically consumed parboiled. Different value chain actors identified BRRI dhan 50, commonly known as *Banglamoti*, as the most premium variety in this segment. It is grown during the *boro* season and is a relatively newly released variety. It is becoming very popular with different value chain actors and is replacing *Nazirshail* particularly in the Khulna division due to its Basmati-like appearance. The other characteristics of this segment were found to be as follows:

- The stability of the aroma of BRRI dhan 50 was the major problem faced by value chain actors. When this variety was released five years back it had a good aroma but its aroma has reduced over the years.
- The main challenge that hampers most midstream actors trading and selling BRRI dhan 50 is the fluctuation of the market price. Imports of variety from other countries makes the situation more problematic.

- The high production, marketability and profitability of BRRI dhan 50 has led to the area grown increasing year after year. Millers and processors are expanding their operations and business around the production and processing zone of BRRI dhan 50. This creates an opportunity for BRRI dhan 50 to expand in other regions of Bangladesh both for production and processing with proper intensification and improved market access.

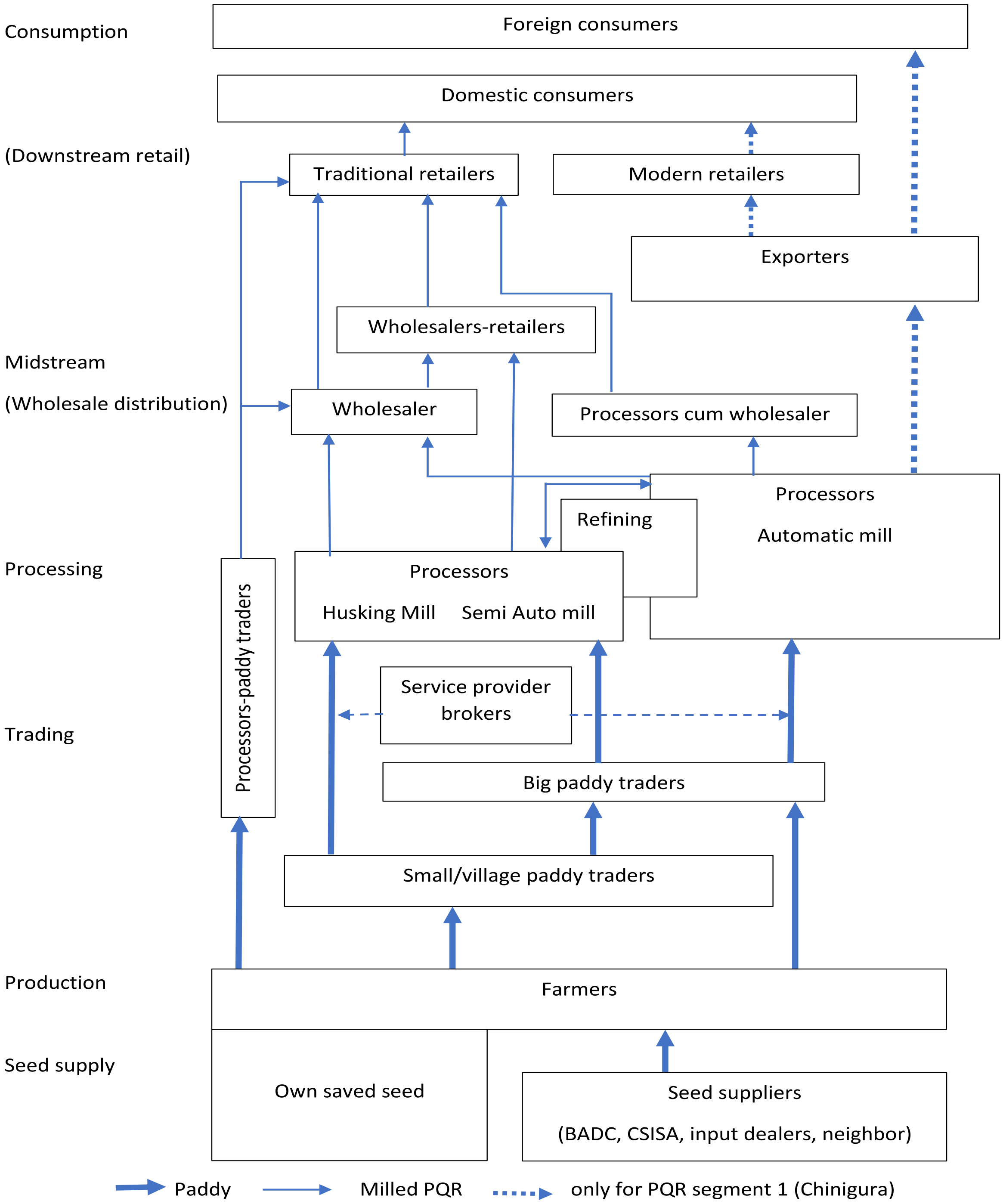


Figure 1.9: The flow of premium quality rice up the value chain from farmers to retailers in Bangladesh (2019 CSISA study)

Way forwards – Estimating value chain actors' preferences and their willingness to invest to improve premium quality rice and comparing it with consumers' willingness to pay is the next step in understanding these value chains. To elicit preferences and calculate the desire to invest the project plans to carry out an incentivized choice experiment across the value chain. As a first step, the project will conduct an experiment with producers and millers to identify attributes that are consistent across value chain (quality, purity, type) and attributes that are specific to value chain actors such as yield, fertilizer, and acreage allocation. The experiment, which is now underway, will control for choice variations in the *aman* and *boro* seasons in Bangladesh.

B2. Bringing participatory science and technology evaluations to the landscape and back again

B2.1 Increasing the capacity of the National Agriculture Research and Extension System to conduct participatory science and technology evaluations

This CSISA workstream suffered set-backs and delays that resulted from the uncertainty in project funding as described in the Executive Summary and Challenges sections of this report. Despite these issues, CSISA however was able to attract additional synergistic and complementary funding from the CGIAR Research Program on Climate Change, Agriculture, and Food Security to work with national partners – most notably the Department of Agricultural Extension – to collect crop cut data and management practice information from farmers at a large scale that will be used to characterize the challenges farmers face and to identify, using novel machine learning and data mining analytics, new methods and ways that famers can increase productivity and resilience while reducing their environmental impact.

This complementary investment that will support CSISA activities is based on the following premise and logic. Heterogeneity in soils, hydrology, climate, and rapid changes in rural economies including volatile prices, aging and shrinking farm workforce, agricultural feminization, and uneven market access are among the many factors that constrain the transition of South Asia's cereal-based farming systems to climate-smart agriculture. Most previous research on these issues have employed manipulative experiments analyzing agronomic variables, or survey data from project-driven initiatives. This can obscure the identification of relevant factors limiting of contributing productivity and resilience in farmers' own fields, leading to inappropriate extension, policy, and inadequate institutional alignments to overcome limitations to CSA. Alternative approaches utilizing large heterogeneous datasets, however, remain insufficiently explored, though they can represent a powerful source of technology and management performance information.

This additional Climate Change, Agriculture and Food Security (CCAFS) co-investment in CSISA – the 'Big data analytics for climate-smart agriculture in South Asia' project is responding to this challenge by developing digital data collection systems to source, data-mine and interpret a wide variety of primary agronomic management and socioeconomic data from tens of thousands of smallholder rice and wheat farmers in India, Nepal and Bangladesh. Activities include:

- Deploying and scaling-up the use of digital tools to collect detailed information on farmers' crop management practices, yield and profitability, resilience enhancing practices, and to simulate greenhouse gas emissions.
- Generating actionable crop management advisories by the use of data mining and machine learning analytical techniques.
- Development of telephone and IVR platforms for rapid collection of data on farmers' management practices at a large-scale. These platforms intend to act as two-way channels to push crop management advice to farmers while collecting data. Advisories on actionable climate-smart

practices will be packaged in easy-to-understand formats and pushed to an anticipated 0.5 million farmers through telephone networks.

- Building interactive and customizable web-based dashboards presenting post-season research results and providing crop productivity and resilience enhancing management recommendations.

In Bangladesh, CSISA staff are in the process of training 125 DAE agents on how to collect survey information from farmers using tablet-based surveys that push data on a near real-time basis to a cloud repository for analysis. The project will then work with DAE to analyze these data using machine learning and artificial intelligence data mining algorithms to identify patterns in the data and to crystallize insights on how to improve productivity and resilience while limiting the environmental impact of farming practices. DAE will then use this information to deploy improved and appropriate crop management advice to farmers at a large-scale. In the next reporting period, this CCAFS assistance to CSISA is anticipated to result in surveys being collected from up to 13,000 rice and wheat farmers in Bangladesh. Updates on this activity will be provided in the next reporting period.

C. ACHIEVING IMPACT AT SCALE

C1. Growing the input and service economy for sustainable intensification technologies

C1.1 Integrated weed management to facilitate sustainable intensification transitions in rice

Since 2016, the project has been playing a catalytic role to develop and raise awareness among Bangladeshi farmers about the benefits of adopting integrated weed management. The project in collaboration with the Bangladesh Rice Research Institute (BRRI) identified the most effective and profitable options for transplanted rice through on-farm research in 2016/17 and 2017 as the careful and safe application of relatively less toxic Mefenacet + Bensulfuron methyl as pre-emergence herbicide followed by either Bispyribac-sodium or Penoxsulam as post-emergence herbicide followed by one hand weeding.

On-farm activities on integrated weed management were suspended in *boro* season 2017/18 and *Aman* season 2018 due to funding shortfalls. During 2018/19, the project focused on identifying the rice varieties best able to compete with weeds and assessing the diversity and composition of weeds in farmers' rice fields.

Raising awareness of integrated weed management options by farmers

The following activities were carried out in project year 2018/19 in partnership with the Department of Agricultural Extension (DAE) and the Agro-Inputs Retailer Network (AIRN) to raise farmers' awareness on the benefits of integrated weed management by farmers:

- In December 2018, the project trained 255 agro-input retailers in seven batches in Dinajpur on identifying weed species, selecting appropriate herbicides, dosages and the use of knapsack sprayers nd their calibration. These retailers are now better able to advice farmers about the safe and appropriate use of herbicides to control weeds in their rice fields. Monitoring of this work indicated that 80% of the dealers passed on IWM messages to farmers, resulting in 8,300 farmers who have applied IWM techniques on approximately 4,600 ha of crop land.
- In July to September 2019, the project provided a training of trainers on integrated weed management to 208 DAE and NGO staff (including 27 women) across the Faridpur (3 batches in July 2019), Dinajpur (3 batches in September 2019) and Barisal working locations (5 batches in July

2019).

- On 10 July 2019, the project ran a workshop in Jashore working areas, where 34 agro-input retailers, spray machine dealers, sprayer mechanics, agricultural machinery dealers and agricultural machinery manufacturers explored how to make sprayer multiple nozzle booms available.
- In June 2019, in Jashore hub, the project developed mechanical weeders for upland line sown crops, including machine sown direct-seeded rice, and demonstrated them in farmers' fields at six locations of Jashore, Jhikargacha and Jheneidah (Photo 1.9).

Photo 1.9: Mechanical weeding demonstration in a dry direct-seeded rice field in Jhikargacha during the 2019 *aus* season (Enamul Haque)

- In July 2019, across Jashore, Faridpur and Dinajpur working areas the project conducted 20 training events and trained 250 husband and wife farmers (500 persons) on identifying the weed species found in rice fields, critical times for weed control, sprayer calibration, the use of multi nozzle booms and the safe use of herbicides. This occurred at the start of the 2019 *aman* rice transplanting season and helped farmers adopt effective and less expensive weed control in their rice fields.

A workshop involving national partners from the National Agriculture Research and Extension System, NGOs, herbicide companies, input dealers and private entrepreneurs is planned for 10 October 2019 to communicate the key results and actionable recommendations on integrated weed management.

Activities to find the rice varieties best able to compete with weeds

Partnering with BRRI, the project has also been conducting on-farm and on-station trials since November 2018 to identify high yielding and weed-competitive rice varieties for the *aman* and *boro* seasons. Weed competitive varieties are crucial in integrated weed management. When farmers use high-yielding and weed competitive varieties, they increase their options to reduce herbicide spraying and laborious hand weeding. This addresses CSISA's goals to reduce labor demand in cereal-based farming systems while also evaluating and scaling-out more ecologically sound pest management practices. Trials were successfully completed in two locations in Gazipur district for *boro* season 2018/19 and established in *Aman* season 2019.

The *boro* season trials tested the 14 most popular high yielding rice varieties including four hybrids. The results show the hybrid rice varieties performing better than the inbred rice varieties in terms of competitiveness with weeds, and among the hybrids Mollika and SL-8 yielded the most under weedy conditions (Figure 1.10). The lowest yield losses (10–15 %) and the lowest weed biomass under weedy conditions occurred in BR17 indicating that it performs better under weedy condition (Figure 1.10 and Table 1.7). The results of the *Aman* season trial will be reported in the next report.

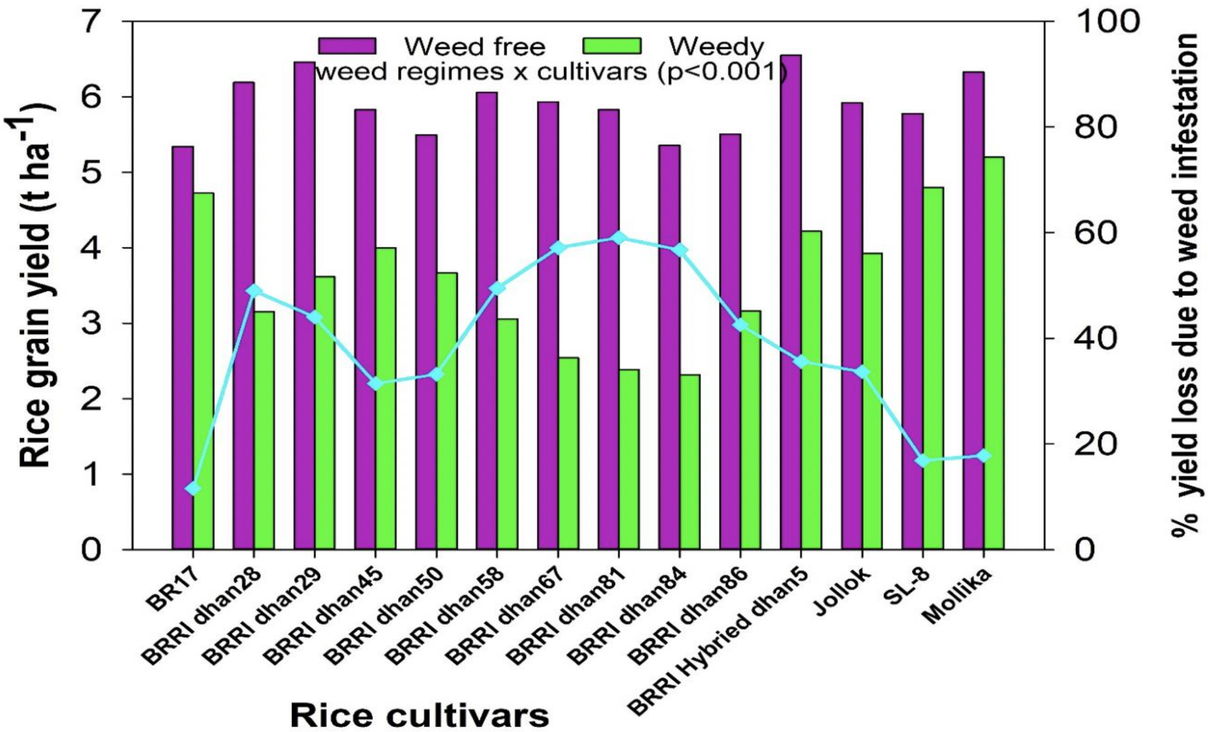


Figure 1.10: Rice grain yields under weed free and weedy conditions and percentage yield losses due to weed infestations – *boro* (winter) season 2018/19 CSISA trials

Table 1.7: Weed biomass (grams m^{-2}) with different rice cultivars under weedy conditions at 30–70 days after transplanting (DAT)

Cultivars	Weed biomass (g m^{-2})		
	at 30 DAT	at 50 DAT	at 70 DAT
BR17	9 e	20 g	11 h
BRRI dhan 28	29 a	68 de	31 def
BRRI dhan 29	18 cd	81 bc	42 abc
BRRI dhan 45	14 de	44 f	27 efg
BRRI dhan 50	17 cd	64 e	33 cdef
BRRI dhan 58	20 bc	76 cde	40 abcd
BRRI dhan 67	24 ab	81 bc	44 ab
BRRI dhan 81	26 a	79 cd	46 a
BRRI dhan 84	17 cd	92 ab	41 abcd
BRRI dhan 86	17 cd	67 de	43 ab
BRRI hybrid dhan 5	24 ab	74 cde	42 abc
Jollok	20 bc	98 a	35 bcde
SL-8	17 cd	40 f	24 fg
Mollika	14 de	41 f	17 gh

Note: The letters denote statistical differences at the 95% level using Tukey's HSD test

Identifying weed diversity and composition in farmers' rice fields

Since the 2017 *aman* season (June/July to November/December 2017), the project has studied weed diversity and composition in farmers' rice fields under rice-rice and wheat-jute-rice cropping systems with the two controls of a herbicide to control weeds and no herbicide to control weeds. This study was again carried out in the 2019 *aman* season in 120 farmers' fields across Jashore and Faridpur, where rice is intensively cultivated (Photo 1.10). The goals of this work are to:

Photo 1.10: Weed and rice plant sample collection from a farmer's field in Faridpur (no herbicide applied) as part of the weed diversity, composition, and competition study. The results will be communicated to DAE to use to advise smallholder farmers on improved weed management (Sharif Ahmed)

- determine the effects of environmental variables, cropping systems and weed management options on the composition and diversity of weed species;
- formulate appropriate weed management strategies for increased yields and profits; and
- identify the most troublesome weeds and provide this information to herbicide companies for developing better safe herbicides.

The results will be reported in the 2019/20 report.

C1.2 Commercial expansion of two-wheel tractor-based machinery and associated service provision models for reapers and seeders

In its first two years (2015 and 2016), the project worked intensively to established enabling market conditions to scale-out the use of multi-crop reapers and two-wheel tractor-based seeding equipment in northwestern Bangladesh. Activities were undertaken to complement the successful market initiatives undertaken in south Bangladesh's FtF zone through the USAID/Bangladesh Mission-funded CSISA-Mechanization and Irrigation initiative. However, activities in the Dinajpur working area had to be cancelled in 2017/18 due to budget delays and shortfalls. This resulted in the decision to cancel joint venture agreement (JVA) contracts with several private sector partners and a leading micro-finance institution.

At the time of reporting, the project has not been able to re-establish these partnerships, as private sector collaborators are reluctant to join hands with the project given the uncertainty with respect to CSISA's ability to consistently support terms agreed in these agreements. The project is now reconsidering the strategy for this work stream now that partial funding has been restored, with potential activities under planning that may be implemented in 2019/20. Additional details on work on this topic in the reporting period are available in the project's semi-annual 2018/19 report. Importantly, the project collaborated closely with IFPRI's Gender, Climate Change and Nutrition Integration Initiative (GCAN), funded by USAID/Washington to complete a comprehensive study on 'Gender and agricultural mechanization: A mixed-methods exploration of the impacts of multi-crop reaper-harvester service provision in Bangladesh is now available online.

C2. Managing risk and increasing resilience by coping with climate extremes

C2.1 Early wheat for combating heat stress in Bangladesh

Wheat consumption in Bangladesh is increasing by around 10% per year. However, the country produces only about a fifth of the amount it consumes, and there is little scope to increase the area under wheat due to the decreasing area of arable land and competition other high-value crops. Except for costly imports, Bangladesh's main option to increase national wheat availability is to increase yield; but Bangladeshi winters are warm and brief. As a temperature sensitive crop, such warmth – which scientists refer to as terminal heat stress – causes reduced grain filling in wheat and lower yields. BWMRI recommends wheat to be sown between 15 and 30 November with yield reducing by 1.3% per day for seeding beyond 30 November. Recent data shows that:

- in Jashore the highest yields occur for 15–22 November seeded wheat with yield reducing by 32 kg/ha/day afterwards; and
- in Dinajpur, the yields from 15 November to 6 December seeding were almost the same with a 22 kg/ha/day reduction afterwards.

These reduced yields are due to high temperatures at grain filling that reduces grain weight and the number of grains per spike due to pollen sterility above 32°C. Also, farmers who also sow late may experience problems with storms and rains in late February to early March before their crop is harvested, This results in 'lodging' – where the crop is physically knocked to the ground, and reduced grain weight and is more susceptible to leaf blight, leaf rust and wheat blast. Wheat seeding at recommended times is therefore very important for increasing wheat yields.

Focus group discussions held by the project in 2016 with 300 farmers identified excessive soil moisture at seeding time as the main cause of late wheat seeding followed by farmers' knowledge gaps on the benefits of early seeding and late *aman* harvests. In 2018/19, the project raised the awareness of many farmers about the benefits of early wheat seeding through the following activities:

- Ten meetings were held between mid-October and mid-November 2019 to advise farmers, machinery service providers, dealers and extension personnel to seed wheat using power tiller operated seeders, to harvest *aman* rice at 80% maturity by reaper, in order to reduce the turn-around time between *aman* harvest and wheat seeding to facilitate early wheat seeding.
- Thousands of farmers were advised on proper land selection, the timely transplanting of early *aman* varieties, machinery reaping and seeding to facilitate early wheat seeding at different trainings, field days, workshops, meetings events organized by CSISA III project, the CSISA-Mechanization and Irrigation project and other CIMMYT-supported projects.
- A CSISA video on early wheat seeding was shown 860 times in November 2018 to 116,000 farmers (76% male 24% female) of whom 64,018 were registered for attendance at shows in collaboration with the Agriculture Advisory Service (AAS) and the Agriculture Information and Communication Center (AICC) (Photo 1.11). Many of these shows were broadcast in the evening at marketplaces.
- In November 2018, the project prepared a leaflet on the benefits of early wheat seeding and distributed 34,059 copies to farmers at video shows and other project events.

Photo 1.11: The project video on early wheat seeding was shown across the project area to farmers and their families in the reporting period

To assess the impact of project interventions, in this period the project collected data from DAE records and a phone survey with farmers who had seen the early wheat seeding video on the timing of their wheat planting in the 2018/19 season and 2017/18 seasons. This found that wheat seeding happened earlier by at least five days in 2018/19 on 22,613 ha belonging to 26,127 farmers. The project assumed that that about 20% of this area (4,523 ha) was planted earlier due to project interventions. The project thus reached its target of 24,000 farmers following the recommendation to plant early. But it could not reach its targeted 8,000 ha planted early in the project's 20 working districts due to i) the 15% reduction in the area of wheat sown in 2018/19 compared to 2017/18, which happened due to the threat of wheat blast, ii) the government subsidizing alternate crops, iii) low grain prices in the previous year and iv) less economic returns than maize. There was also halving in the area of wheat planted per farmer from 0.336 ha in 2017/18 to 0.17 ha in 2018/19. These factors are being taken into account in revising work plans for the 2019-20 season.

C2.2 CSISA leads the way in fighting back against the fall armyworm

The fall armyworm *Spodoptera fruigiperda*, is a global threat to farmers, especially to maize farmers. It first appeared in South Asia in India in mid-2018 and by November 2018 had arrived in Bangladesh. Damaged maize was found in several districts, including CSISA working areas in the FtF zone. Further details on the biology and ecology of FAW are given in CSISA's 2018/19 semi-annual report.

Although FAW attack could not be foreseen and was not part of the project's original work plans, maize is integral to South Asian cereal systems and is a very profitable crop that is expanding rapidly across Bangladesh. The government aims to double national maize production over the next five years. The project responded to this emergency situation and is leading the way with BWMRI and DAE in the FAW response. Notable project achievements in 2018/19 were as follows:

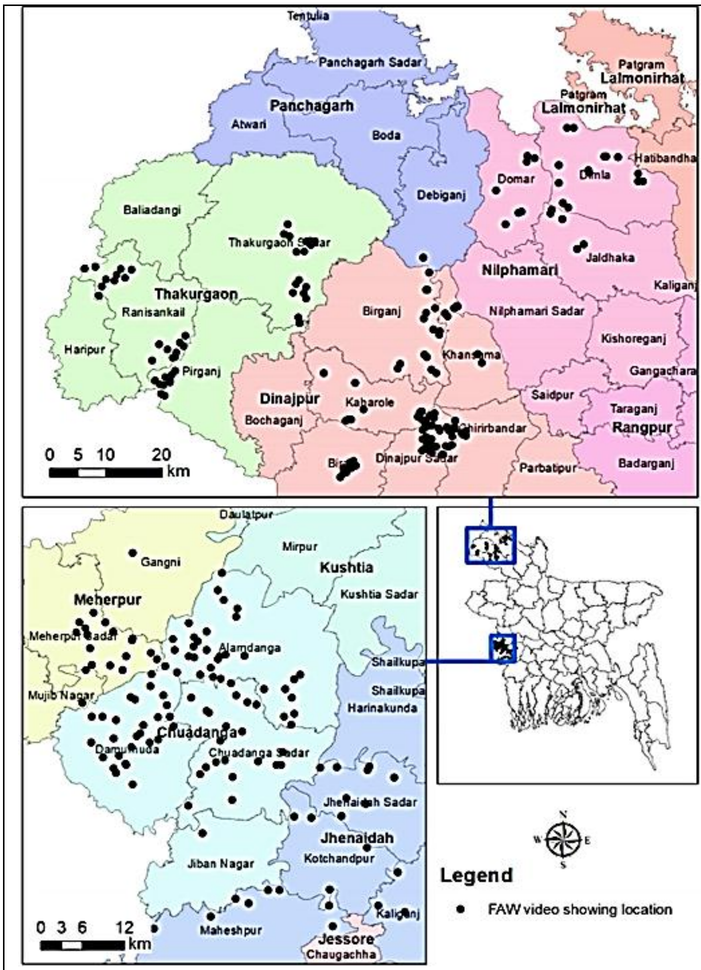


Figure 1.11: Locations where FAW awareness raising videos were shown to farmers in 2018/19 (M. Khan)

- Convened the first meeting to discuss fall armyworm with USAID, agricultural researchers and policy makers in late 2018.
- In late 2018, translated and dubbed two informative videos into Bengali:
  - *How to identify and Scout for Fall Armyworm* by Scientific Animations Without Borders
  - *Fall Armyworm Life Cycle and Damage to Maize*, by the Centre for Agriculture and Bioscience International.
- In December 2019, supplied videos on pendrives to 200 DAE officials to raise the awareness of field level officials and maize farmers on how to combat the new insect.
- Prepared a leaflet in Bengali in collaboration with CABI and BARI, which at the end of the reporting period was being printed ready to distribute to farmers.
- Developed four informational graphics on fall armyworm that are being distributed to farmers and agricultural input dealers en masse at the end of the reporting period. These are presented in Appendix 3 in English and Bangla and advice farmers on FAW biology, ecology, and integrated pest management.
- During the reporting period the project took emergency action and worked with AIRN to train 755 agricultural retailers on integrated pest management principles for controlling fall armyworm. As retailers are often farmers' first point of contact for pest management advice; trainees learned how to identify the insect, the symptoms of their presence and means of control, prioritizing preventive measures by crop management and bio-pesticides.
- Starting in February 2019, the project and AAS also started an awareness raising and training program for farmers in maize growing districts, during which the above videos were shown and leaflets and infographics distributed. By early April, 13,057 maize farmers had participated in 238 video show trainings (33% female) at the locations shown in Figure 1.11.
- CSISA began collaborating with USAID's fall armyworm task force and is working towards the

implementation of a training of trainers program for DAE staff in October 2019 prior to Bangladesh's primary maize growing season.

These activities resulted in additional attention on FAW by the USAID/Bangladesh Mission, which has subsequently worked with CSISA and Michigan State University's Borlaug Higher Education for Agricultural Research and Development program to implement a new project strategically aligned with CSISA, which is starting at the time of writing. The 'Fighting Back Against Fall Armyworm' project is a 15-month investment led by CIMMYT that will enable additional emergency activities against FAW in Bangladesh. The project has the six inter-related objectives shown in Box 1.1. Updates on project progress and synergies with CSISA will be described in future CSISA reports.

Box 1.1: The objectives of the Fighting Back Against Fall Armyworm project

Objective 1. Develop educational materials to aid in reaching audiences with information to improve understanding and management of FAW

- 1.1: Educational material development workshop with partners under the Ministry of Agriculture
- 1.2: Production of Bangla Language Educational Videos

Objective 2. Assist the Department of Agricultural Extension (DAE) in deploying awareness raising and training campaigns

- 2.1. Deploy FAW Master Trainer of Trainers program with DAE and national partners
- 2.2. Technical and organizational assistance to DAE in organizing training roll-out on large scale basis

Objective 3. Institutional change to improve crop protection and integrated pest management

- 3.1. Expand FAW population monitoring efforts and provide technical assistance to DAE
- 3.2. Raise awareness among partners on registration processes for new pest management technologies

Objective 4. Prepare the private sector for appropriate FAW response

- 4.1. Build private sector capacity and awareness of FAW
- 4.2. Train the private sector to deploy FAW management advice
- 4.3. Assist the private sector to design crop consultant program(s)

Objective 5. Standing FAW taskforce supported

- 5.1: Support FAW task force model to tackle emerging and emergency threats
- 5.2: Support institutional recognition of the FAW Task Force's technical advice
- 5.3 Assist the task force in influencing pest control product registration processes
- 5.4 Assist in developing an information portal on FAW

Objective 6. Generate data and evidence to guide integrated FAW management

- 6.1. Screening studies to evaluate the effectiveness of new pest control materials
- 6.2. FAW severity, incidence and management surveys to inform mitigation efforts
- 6.3. Studies to characterize natural enemies of FAW in Bangladesh

2. Nepal – Achievements

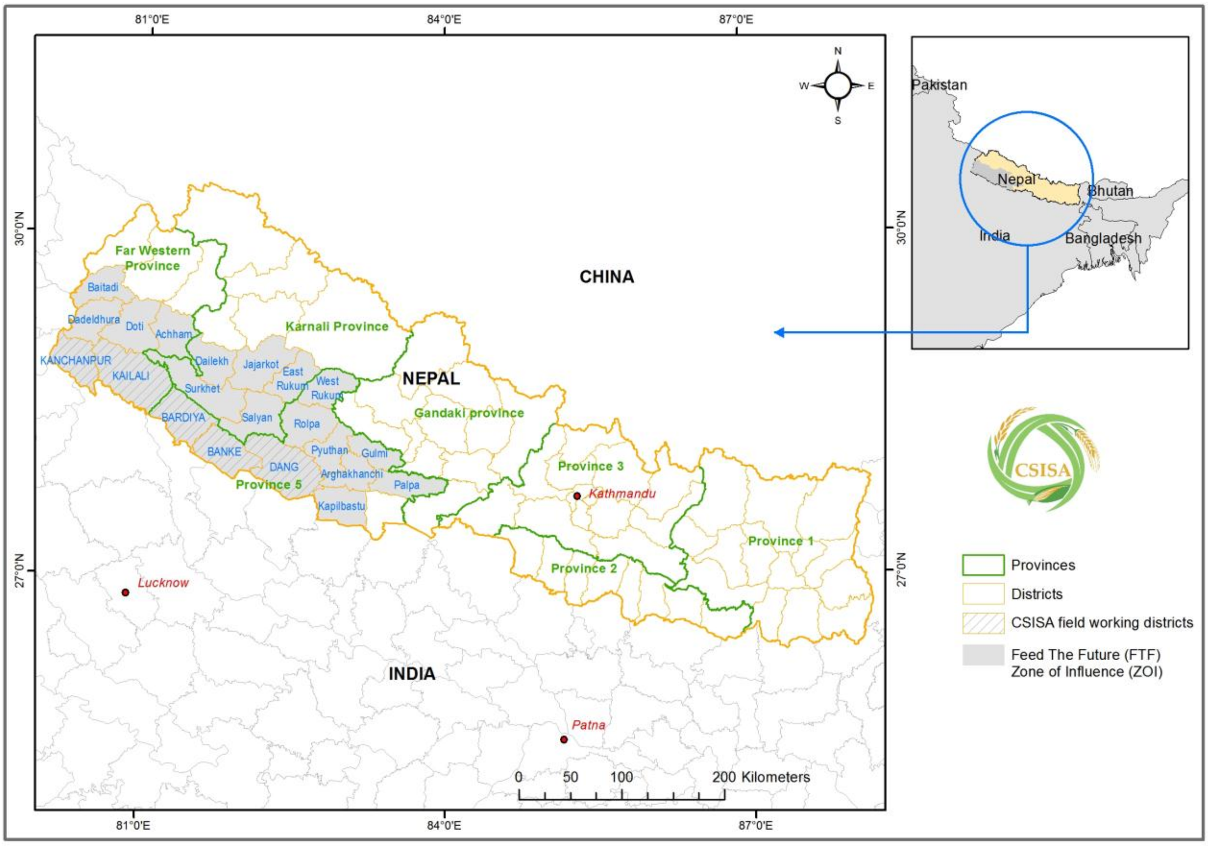


Figure 2.1: The CSISA project mainly works in five western Terai districts in Province 5 and the Far Western province. [8] **Its secondary working area is the other Feed the Future zone districts.**

A. INNOVATION TOWARD IMPACT

A1. Reducing risk to facilitate uptake of sustainable intensification practices

A1.1 Directly-sown rice to address labor and energy constraints to precision rice establishment

The cultivation of rice is increasingly costly in Nepal due to the growing cost of rural wage labor – particularly for rice transplanting – resulting from the widespread out-migration of working age men. This has resulted in lower profit margins for farmers and yield penalties because of challenges farmers face finding labor on time to carry out crop management operations. Growing rice through direct seeding (Photo 2.1) can help to respond to these problems. DSR does not involve raising, uprooting and planting seedlings and thus requires less labor. In addition, 'dry' direct-seeded rice does not involve repetitive wet tillage after ploughing, which reduces the cost of production and assists in the maintenance of soil structure and hence quality. Direct seeding also reduces the amount of water needed and allows for timely planting when early rains are insufficient for transplanting. Research has

[8] Note: Nepal's Far Western province (where the project works) was previously called Province 7.

shown that this method saves up to 75% of labor costs and can reduce irrigation water requirements by up to 30%.

CSISA therefore works to raise farmers' awareness of DSR and to popularize its use. Since 2014 the project has raised awareness on direct-seeded rice by informing and training farmers. Importantly, CSISA recommends growing directly seeded rice under irrigated conditions as growing it in rainfed conditions often leads to major weed infestations as this modality does not benefit from the underwater suppression of weeds. The project also recommends careful weed management and the direct seeding of rice only where irrigation is assured. Strategies for reaching farmers include training programs, radio-jingling, distribution of publications and the strengthening of mechanical service provision enterprises that can support DSR. CSISA has also worked with agrovets to make appropriate, low-toxicity but effective herbicides more available in local markets to address the fact that direct-seeded rice can suffer more weed problems than puddled and transplanted rice.

Photo 2.1: Main season line-sown direct-seeded rice at tillering stage in a farmer's field in Kailali (Lokendra Khadka)

Almost all the project's 2018/19 activities on direct-seeded rice were run in partnership and collaboration with the Prime Minister Agriculture Modernization Project (PMAMP), and the project provided technical backstopping to most of PMAMP's training programs in this reporting period (see B1 for additional description of the project's extensive collaboration with PMAMP). Key activities included:

Raising awareness about directly sown rice

In June 2019, prior to the monsoon rice season, a program run by the project with PMAMP's Bardiya Rice Super Zone raised the awareness of 52 farmers (40 male, 12 female) about recommended practices for growing direct-seeded rice. An experienced service provider and the Chief of Bardiya Rice

Super Zone orientated participants on good practices and sources of support while participants shared and discussed their experiences.

Increasing access to seed drills to facilitate directly sown rice

The cultivation of direct-seeded rice requires the use of mechanical seed drills (planters) for sowing. These machines are attached to two or four-wheeled tractors. However, it is almost impossible for smallholder farmers to buy these attachments and the tractors needed to pull them. The project has therefore raised awareness about seed drill services and more than 100 seed drills have been purchased by service providers in the project's working areas.

Establishment of demos and trails to support directly sown rice

In May and June 2019, the project guided the staff of Kanchanpur Rice Super Zone on how to establish large demonstrations-cum-trials of dry direct-seeded rice in the fields of ten farmer groups (Photo 2.2). Leading on from the above and soon after, the project provided further technical guidance to PMAMP to establish trials at four locations in Kanchanpur Rice Super Zone, each with the four treatments of rainfed direct-seeded rice, wet direct seeded rice, mechanical transplanted rice and farmers' practices. The project also showed Kanchanpur PMAMP personnel how to evaluate trial results.

Photo 2.2: A direct-seeded rice field demonstrated by Kanchanpur Rice Super Zone (Lokendra Khadka)

Training of technicians to increase capacity in directly sown rice

The project supported PMAMP Kanchanpur to build the capacity of its technicians on using seed drills. In June 2019, 15 technicians from Kanchanpur Rice Super Zone and local custom hiring service centers were trained on scale-appropriate machines and the direct-seeding of rice including how to calibrate seed drills. In addition, in May 2019, refresher training was provided on direct-seeded rice technology to 25 service providers, lead farmers and government technician in Jhalari, Kanchanpur.

Training of PMAMP trainers on directly sown rice

In June 2019, the project ran a training of trainers course in Rajapur in Bardiya Rice Super Zone on mechanical direct-seeded rice for 17 agriculture technicians and 15 service providers in coordination with Banke and Bardiya agriculture knowledge centers, the local government and USAID's KISAN II project (Photo 2.3). The participants are now equipped to train farmers on the subject.

Directly sown rice field days and exposure visits

The project held a farmer field day in September 2019, which demonstrated direct-seeded rice to 30 farmers from Kailali and Kanchanpur and gave them the opportunity to share their experiences with other farmers and service providers (Photo 2.4).

Photo 2.3: Training agricultural technicians on direct-seeded rice, June 2019, Bardiya (Salin Acharya)

Exposure visits help disseminate best practices to farmers. On 15, 17 and 18 September 2019, the project ran exposure visits to direct-seeded rice fields for 39 lead farmers and 33 government personnel in Banke and Bardiya in collaboration with PMAMP and these district's agriculture knowledge centers (Photo 2.5). These visits enabled the first-hand observation of practices and new technologies by taking farmers and government staff from new project areas to established areas to witness the technology and to discuss and raise awareness on DSR.

In addition, the project ran a training with Kanchanpur Rice Super Zone from 15–19 September 2019 on the maintenance and operation of seed drills and other machines including weeders, laser land levelers, power tillers, irrigation pumps, spreaders and reapers. The project shared its experience and ideas for the efficient operation of these machines with 20 participants from RCT agro-engineering workshop (Jhalari), RK hardware (Belauri), Manjari agro dealer (Dhangadhi) and Himsikhar Cooperative (Dhangadhi), which should strengthen the supply chain of these machines.

These activities have led to an increasing number of farmers growing directly seeded rice and the establishment of seed drill service providers. Direct seeded rice has been adopted and tried out across the project's districts and in the 2019 monsoon season 164 farmers grew directly-seeded rice on 157 ha in PMAMP's Bardiya Rice Super Zone alone (Photo 2.6) However, a number of farmers who have tried it out abandoned this technique after achieving less than expected yields meaning that the spread of direct-seeded rice has been less than expected.

Photo 2.4: Farmers field day on direct-seeded rice, Badaipur, Kanchanpur, 17 September 2019 (Pradip Chaudhary)

Photo 2.5: The direct seeding of rice in PMAMP's Rice Super Zone, Bardiya (Hari Acharya)

To confront barriers to the adoption of DSR, in August–September 2019, the project carried out a study in eight FtF districts to investigate the limited adoption of direct-seeded rice. The preliminary results suggest that, rather than the availability of seed drill services, weed control is the major bottleneck. This is due to the lack of availability of herbicides due to the under-developed local market structure and farmers' inadequate knowledge of the timely application of herbicides. Moreover, in irrigated conditions, farmers have to directly seed rice before the monsoon rain starts in early June, and late or intermittent monsoon rains lead to a lack of or only limited underwater suppression of weeds. Overall the surveyed farmers were not practicing the recommended management practices of timely irrigation, weed control and other intercultural operations leading to low yields and thus low levels of adoption.

These findings are being used to re-prioritize activities on DSR in 2020, and will be shared with project partners to refocus on activities that can increase impact.

Photo 2.6: Exposure visit of Banke and Bardiya district government technicians to observe direct-seeded rice, 15 September 2019 (CIMMYT)

B. SYSTEMIC CHANGE TOWARDS IMPACT

B1. Partnerships for inclusive growth around commercial pockets and neglected niches

Collaboration with the Prime Minister Agricultural Modernization Project (PMAMP)

CSISA works in close partnership with the Prime Minister Agricultural Modernization Project (PMAMP) to raise awareness about sustainable intensification technologies and management practices. PMAMP is run by the Ministry of Agriculture and Livestock Development (MoALD) and started in 2017. PMAMP works on the following topics, many of which closely align with CSISA's interests:

- The development of small business agricultural production centers (pockets)
- The development of commercial agricultural production centers (blocks)
- The development of commercial agricultural production and processing center (zones)
- The development of large commercial agricultural production and industrial centers (superzones).

Since collaboration began, PMAMP has leveraged CSISA as a core technical partner for advice and technical support – especially at the field level. CSISA has shared its experiences and provided technical backstopping for PMAMP to support the scaling up of new technologies like DSR. CSISA's collaboration has also included strengthening the knowledge and skills of PMAMP personnel on appropriate and resource-conserving machines and encouraging PMAMP to work on complete cropping systems rather than just single crops (as per its remit). CSISA also works to help PMAMP target their activities. In late 2018, for example, PMAMP added new rice super zones in Bardiya and Kanchanpur to its working areas, a decision taken in part based on CSISA's presence and support.

The details of key project collaboration work streams with PMAMP in Nepal include:

- A1.1 on direct-seeded rice
- B1.1 on mechanized maize seeding, increasing spring rice production and the crop cut and production surveys
- B1.2 on mechanized maize cropping and addressing the threat of aflatoxin in maize production[9]
- C1.1 on integrated weed management in rice
- C1.3 on wheat straw reaper-bailers.

B1.1 Deployment of better-bet agronomic messaging through input dealer networks and development partners

Media campaign to raise awareness on registered maize hybrids

In Nepal, the use of unauthorized and unregistered maize hybrids marketed through illegal pathways results in the planting of low-quality seed. In most cases, farmers do not pay attention to which seeds they grow and the information on seed packets. This ultimately adversely affects farmers who suffer from reduced productivity. In May–June 2019, the project supported the broadcasting of messages on two local FM radio stations in the FtF zone about the desirability and the benefits of using registered high-yielding maize hybrid seeds. The messages explained what farmers should look for on packets to ensure they buy registered hybrid maize seeds.

Media campaign to increase use of mechanized maize seeding

In this reporting period, the project supported PMAMP's Dang Maize Super Zone and Dang Agriculture Knowledge Centre to raise awareness on mechanized rice seeding and to guide farmers on which machines to buy and employ. In early 2019, radio jingles were aired on six radio stations covering Dang district on the benefits of seeding maize mechanically.

[9] Seeing the increased interest by farmers in Dang in mechanizing maize and the good scope for collaboration with Dang Maize Super Zone, in February 2019 the project reestablished a field office in Dang. The Dang office continues to operate and support PMAMP at the time of writing.

Media campaign to create awareness improved rice cultivation

The project also raised awareness on improved rice growing in the western Terai and Kapilvastu through radio messaging spots on local FM radio stations (Table 2.1) .

Table 2.1: Raising awareness on improved rice growing technologies through radio messaging in 2018/19

	Technologies and media campaign locations	No. FM stations	Duration
1.	Registered hybrid rice varieties (Banke, Kailali)	2	2 months
2.	Benefits of mechanical direct seeded rice (Banke, Bardiya, Kailali, Kanchanpur, Dang)	3	2 months
3.	Safe herbicide application (Banke, Bardiya)	4	1 month
4.	Herbicide weed management in rice (Banke, Bardiya)	3	1 month
5.	Negative environmental effects of straw burning (Kapilvastu)	3	1 month

The results of the 2018 wheat crop-cuts and production practices survey also confirm that farmers in Nepal's Terai can take advantage of growing longer duration varieties of wheat. The adoption of such varieties coupled with early sowing may enable wheat plants to escape the terminal stress that results in decreased productivity. The 2018 results show a gain of almost 0.5 Mt/ha when long duration wheat is sown early.

Raising awareness on high yield potential spring rice

Nepal imports about $386 million of cereal grains, most of which is rice. The government aims to replace rice imports with domestically-grown rice by increasing rice productivity and the area of rice. However, there is limited potential to expand the area of main season monsoon rice. One of the main foci of the government and PMAMP is therefore to expand the area of spring rice (including direct seeded rice), which is planted in March under irrigation. This work is happening in consultation with the project and will be reported on in the next semi-annual report following compilation of data from the currently ongoing rice harvests.

Some of the challenges to spring rice that have been identified by CSISA and that are being addressed in tactical activities with PMAMP include the following:

- **Mechanical capacity development:** Through interacting with the project, PMAMP staff have recognized that the main challenges to establishing direct-seeded spring rice are the reliability of irrigation, seed drill calibration, seed germination and high seedling mortality caused by the colder temperatures at germination time.

- **High moisture content and challenges to marketing:** Spring rice is planted in March/April and harvested at the beginning of the monsoon in June/July (just prior to main season rice planting) resulting in the grain having a high moisture content which decreases its storability. The grain from the project's spring 2019 rice crop-cuts had a moisture content of 20%, which is much higher than the recommended 12%–14%. To explore how to address this issue, in March 2019 the project brought in consultants knowledgeable on the sun-drying of rice in east Asia to present to the project and PMAMP about different types of sun driers. However, most of these driers are too expensive for smallholder farmers to acquire. The project is now working with PMAMP to raise awareness on a service provision model to provide farmers with access to these driers.
- **Insufficient research evidence**: Only limited research has been carried out to address the challenges of growing spring rice in the project's working areas. The project collaborated with PMAMP to assess the performance of spring rice varieties under farmer management in the 2018/19 spring season. Four prominent spring seasons rice varieties were tested under farmer management conditions in Kailali district. The Hardinath-3 variety performed the best with an average yield of 7.5 Mt/ha (Figure 2.2). In 2019/20, the project and PMAMP will work to and raise awareness on higher yielding rice varieties and good management practices to increase the productivity of spring season rice. Spring season rice has the highest yield potential due to the higher levels of solar radiation and number of growing degree days.

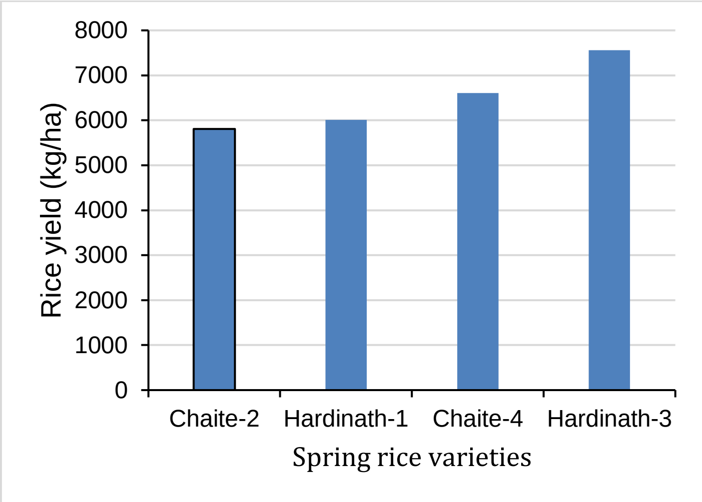


Figure 2.2: Varietal yield performance of spring season rice under farmer management, 2019, Bhajani, Kailali

B1.2 Income generating maize production in neglected hill and plateau ecologies

Harnessing the transformative power of hybrid maize in Nepal's Midhills

There is large potential for increasing the productivity of maize farming in Nepal's major maize production domain, its Midhills (Photo 2.7). Most farmers grow low yielding local or improved varieties and simply switching to hybrid maize varieties would substantially increase yield. However, the adoption of hybrid maize in project districts has been limited due to restricted domain-specific registrations. Concerns are also often raised that hybrid seed locks farmers into repurchasing seed each year, although project data indicates that hybrid maize usually raises productivity and incomes to cover re-investment in seed, provide additional income and improve food security. Some key activities implemented during the reporting period are as follows.

Domain extension for maize

CSISA has project assisted its national partners to expand the domains of varieties of registered hybrid maize to the western part of the country where they were previously unregistered. The project was the key player in expanding the domains of the most prominent maize varieties into the FtF zone. This has resulted in the expansion of the area under which maize cultivation can be supported by PMAMP and associated projects throughout Nepal.

Hill maize productivity study

In this reporting period, the project's further analysis of data from the 2017 mini-tiller adoption study on the impacts of cultivating hybrid maize found that:

- the use of hybrid maize had increased productivity by 1,937 kg/ha;
- the resulting increased maize productivity increased household incomes, which led to an $11 increase in expenditure on food by these households; and
- non-adopters of hybrid maize could have increased their maize productivity by almost 1 Mt/ha and per capita food expenditure by $22 if they had replaced the local or improved varieties they were using with hybrid varieties.

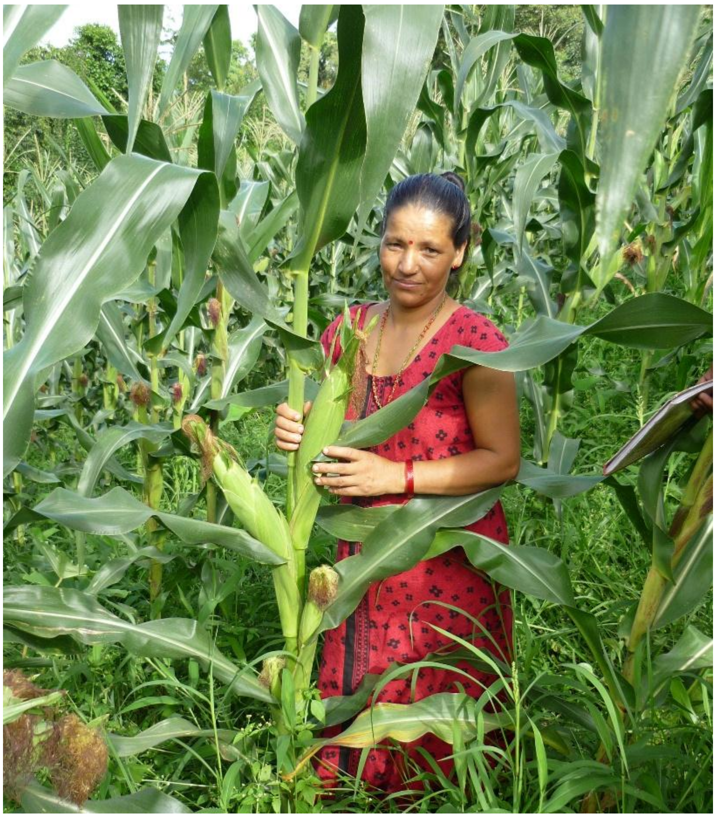


Photo 2.7: The increased productivity of maize, which is the primary staple crop in Nepal's Midhills, can improve the food security of poor households (Gokul Paudel)

The study concluded that in the Midhills:

- food insecure households with less than six months per year food self-sufficiency and farms of less than 0.3 hectares in size (marginal farmers) would benefit the most from planting hybrid maize; and
- female-headed households tend to achieve higher productivity gains from adopting hybrid maize than male-headed households.

The study findings suggest that supporting the diffusion of hybrid maize could have a large positive impact on maize productivity and rural livelihoods in Midhills Nepal. As such, the project is working to disseminate this information to national development partners. The findings were documented and submitted for publication in the *Food Security* journal in April 2019. The article will be shared with stakeholders and should help strengthen hybrid maize promotion policies in the Midhills and similar domains in South Asia.

Continued support for appropriate mechanization of maize cropping

The collaboration between CSISA and PMAMP's Dang Maize Super Zone, which started in 2016/17, has led to the spread of mechanized seeding and weeding and other promoted technologies beyond the super zone. In this reporting period the project addressed the lack of knowledge and skills of owners and operators to operate and maintain farm machinery. Examples of work during the reporting period include:

- **Training-and-farmers field day:** On 28 June 2019, the project held a field training-and-farmers field day at Satbariya Machinery Custom Hiring Center, Dang. This center is run by a farmers' cooperative with support from the project and Dang Maize Super Zone. Twenty-eight members of Dang's other machinery custom hiring centers, which are supported by Province 5's Smart Farming (Krishi) Village Program, 8 lead farmers from Dang Mustard Zone and 2 technicians from Dang Agricultural Knowledge Center observed 2WT and 4WT maize seed drills, a mini-tiller weeder, a maize cob harvester and maize threshers in action (Photo 2.8). Participants discussed and informally evaluated the most appropriate technology for specific crops and domains.

Photo 2.8: Farmers field day participants observing and operating a maize cob harvester, Dang, June 2019 (Sagar Kafle)

- **Extending support to new PMAMP areas:** PMAMP has worked with the project to extend its impact beyond its original working areas. Until recently, PMAMP worked only in the south of Dang district (Deukhuri Valley) in its Maize Super Zone. Since 2018/19 it has been working on scaling out mechanized maize seeding to the northwestern (Dang Valley) part of the district. This year the project worked to scale out mechanized maize seeding from the Dang Maize Super Zone to other parts of Dang. A focus was to extend the use of seed drills, most of which are attachments to four wheel tractors and a few are attachments to two-wheel tractors.

Photo 2.9: Khadka machinery's seed drill sowing maize in June 2019 (Sagar Kafle)

- **Seed drill training and support**: The following support to seed drill owners and operators outside Dang Maize Super Zone happened just before the 2019 monsoon rainfed maize seeding and enabled the wider availability of seed drills. For example, in June 2019, the project raised awareness on mechanized maize seeding in Shantinagar Rural Municipality, Dang where rainfed maize is widely grown in the monsoon. Project personnel spent four days assisting Khadka Machinery Custom Hiring Center (Photo 2.9) and Saunepani Agriculture Machinery Custom Hiring Center with calibrating and solving problems with their seed drills, which often caused them to lie idle. This resulted in a rapid upsurge in the area under mechanized maize seeding from a few hectares to about 30 ha in the municipality using custom hiring center seed drills. However, a similar attempt to support Bishnupur Farmer Cooperative of Shantinagar to get its maize seed drill working failed due to the unavailability of a 4WT tractor to operate the drill and lack of engagement by cooperative members.

Similarly, in 2018/19 the seven custom hiring centers in northwest Dang had purchased seed drills with support from PMAMP; but most had been unused as cooperative members and suppliers lacked knowledge on operating and maintaining them. In June 2019, the project trained an operator from each center to operate and maintain their machines including on proper seed rates and spacing. These activities are expected to pay dividends in 2020 – with refresher trainings, CSISA expects PMAMP work in Dang will be more timely, effective, and efficient, ultimately benefiting farmers.

- **Other machinery trainings**: In May-June 2019, the project ran 16 training events for farmers and custom hiring centers on the use of seed drills and other machinery. (a) In Dang, the members of 7 farmer cooperatives and 6 farmer groups were trained to operate small jab planters, mini-tiller weeders, multi-crop seed drills and threshers (Photo 2.10). (b) In Banke, the project worked with Dang machinery supplier Surya Traders to expand mechanized maize seeding (drills) and weeding (weeders) as used in Dang Maize Super Zone. A raised bed seed drill imported by the trader was also tested to evaluate its efficacy and suggest improvements. These machines prepare raised beds and plant to avoid the problem of prolonged flooding, which can negatively affect growth.

Photo 2.10: CSISA technicians showing members of Shakti Farmers' Cooperative how to use jab planters, Dang (Sagar Kafle)

Photo 2.11: A farmer showing her maize sown, which was sown with a multicrop seed drill, Punarbash, Kanchanpur (Lokendra Khadka)

In February 2019, the project also demonstrated scale appropriate machines including jab planters and multi-crop seed drills with Kanchanpur Agricultural Knowledge Center and Kanchanpur Super Rice Zone. The project guided the drill owner on the proper use of these machines to sow the seeds of different crops. And the farmers in PMAMP's Joshipur Maize Pocket (Kailali) and Punarbash Maize Pocket (Kanchanpur) subsequently started using a multi-crop seed drill to plant their maize, which has reduced the cost of establishing the crop and made for more uniform planting (Photo 2.11).

Addressing the threat of aflatoxin to maize

Aflatoxins are harmful compounds that are produced by a fungus that can infect crop plants and grain of a variety of legumes and cereals including maize in Nepal. During the reporting period, project personnel participated in the 'Feed the Future Innovation Lab for Nutrition Scientific Symposium: 25 Years of Progress for Nepal' on 27–29 November 2018 in Kathmandu. The project delivered presentations on the availability and scaling-out of the use of grain drying options and ii) pre- and post-harvest management techniques to reduce aflatoxin contamination in maize. The presentations highlighted the activities of CIMMYT and its project partners and raised awareness on potential dry chain technologies and agronomic management practices to reduce aflatoxin fungus on maize.

Meetings and discussions at the symposium led to the formation of an informal network by the project with PMAMP super zone members and the Department of Agriculture's Post Harvest Section for follow-on in-depth discussions on the topics discussed at the symposium. As a result of the network's formation, PMAMP and the former DoA's Center for Agricultural Infrastructure Development and Mechanization Promotion decided to procure and test mechanical dryers for spring rice and summer maize, although initial evaluations indicate that the relatively high costs of machinery may limit their availability. PMAMP and the center aim to improve the quality of rice and maize grain and reducing aflatoxin fungus on them.

B2. Bringing participatory science and technology evaluations to the landscape and back again

B2.1 Increasing the capacity of the National Agriculture Research and Extension System to conduct participatory science and technology evaluations

In line with the activities and additional Climate Change, Agriculture and Food Security (CCAFS) supported investment that is synergistic with CSISA and described in the Bangladesh B.2.1 section of this report, CSISA in Nepal is also working to use survey data and data science approaches to analyze survey data and develop improved crop management recommendations for farmers. This work is conducted in close coordination with PMAMP and the Nepal Agricultural Research Council, and represents a major change in the ways in which CSISA's partners conduct research, develop extension recommendations, and advise farmers. The approach is based on the use of digital survey tools and artificial intelligence approaches to the analysis of data.

Open Data Kit is an open-source, free-to-use digital data collection tool that can be run on smartphones and tablets. The project uses it to conduct farmer surveys; gather information on cereal crop management practices; and track machinery adoption, agronomic management trainings and farmers' adoption of technologies (Photo 2.12). The project in Nepal and Bangladesh has created ten Open Data Kit forms to capture data along with GPS latitude and longitude in near real time. These are used to survey farmers at a large-scale and to identify patterns in yield and productivity, and to make inferences on how these patterns are driven by key management practices observed in the data. These geotagged datasets allow CSISA scientists to examine factors that contribute to agronomic performance by combining surveys with secondary datasets including soil characteristics and weather data from satellites. This permits more nuanced learning and diagnostics that can be used to make crop management recommendations given to farmers by partners like PMAMP more data-driven and appropriate. Most of the resulting project-related datasets from Bangladesh and Nepal on rice and wheat crop management practices are now under analysis.

During the reporting period, the project expanded the use of the data kit in collaboration with government agencies including PMAMP. ODK is now being used for the sampling of the diagnostic crop-cuts and production practices surveys and to track the adoption of farm machines. Enumerators and PMAMP and provincial government personnel have been provisionally trained and orientated on its use; more advanced trainings will take place in November of 2019.

Recent and anticipated crop-cut surveys to identify ways to improve farmers' crop productivity

The project carries out annual and periodic diagnostic crop-cut and production practices surveys of rice and wheat to improve understanding of farmer management practices in project working areas. In Nepal, surveys are carried out in between six and eight districts including Kanchanpur, Kailali, Bardiya, Banke, Kapilbastu, and Rupandehi. The project conducted its latest wheat crop cut survey in March/April 2019 and the production practices survey in August/September 2019 from the sample of 1,200 farmers. More than 6,000 observations were made of farmers' crop management practices. The results are stored on the projects' server. The 2019 rice crop-cut survey will take place in November of 2019 in collaboration with PMAMP and the Nepal Agricultural Research Council (NARC). In July and August 2019, the project held two meetings with PMAMP and NARC to discuss survey methodology and how the findings can help transform traditional Nepalese agriculture to more evidence-based agronomic practices. These meetings formalized the project's support for the crop cut and diagnostic surveys – it was agreed that future such surveys will be done by PMAMP, with NARC providing technical backstopping for the production practice surveys.

Photo 2.12: A CSISA enumerator using the Open Data Kit on a tablet to collect data from a farmer (Gokul Paudel)

Further analysis of previous surveys

The following write ups (i to iv) present the results of the further analysis of crop cut data during the reporting period showing how data-driven insights can provide recommendations to improve the productivity and resilience of cropping in Nepal's FtF zone:

i) Rice yields: Analysis of the data from the 2016 summer rice crop-cuts in Banke, Bardiya, Kailali, Kanchanpur, Rupandehi and Kapilbastu (with machine learning tools) suggests that rainfall variability and fertilizer and irrigation management were the major factors affecting yield. The results are as follows with responses illustrated in the dependence plots of the rice response in Figure 2.3:

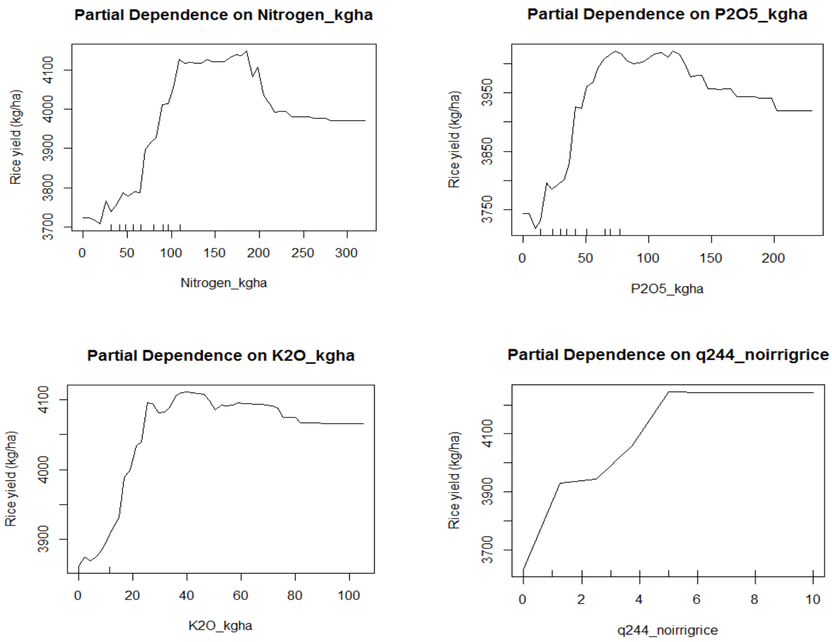


Figure 2.3: Response of nitrogen (N), phosphorus (P_2O_5), potash (K_2O), and number of irrigations on rice yields in CSISA districts determined through digital analysis of 2016 crop-cut data

- **Nitrogen** – An average of 72 kg ha^{-1} of nitrogen was applied to the rice, which is 28 kg ha^{-1} less than the recommended 100 kg ha^{-1}. There were higher yields when up to 110 kg ha^{-1} of nitrogen was applied, after which a plateau and then decline was observed. These results should be used to guide the revision of the recommended rate for nitrogen in the FtF zone.
- **Phosphorous** – The average phosphorus application rate was 47 kg ha^{-1}, close to the recommended 50 kg/ha. However, rice yields were highest with 70 kg ha^{-1} of phosphorous indicating that the recommended rate may need changing.
- **Potash** – Almost 87% of the farmers had not applied any potash fertilizer, with an average of only 3.5 kg ha–1 applied. Rice yields were highest when 40 kg ha^{-1} of potash was applied (Figure 2.3) indicating that an additional 36.5 kg per hectare would enhance rice productivity by 300 kg ha^{-1} even if farmers did not change other management practices. This indicates that the proper application of potassium is important to enhance rice productivity in the FtF zone. A major problem of very low potash application is the heavy nutrient mining by crops of potash from the soil. In response, the project is now providing targeted advice to farmers through PMAMP and provincial governments through its information and communication materials for the balanced application of potash to soils.

These results show that increased applications of fertilizer are very likely to enhance rice productivity in the FtF zone and provide useful evidence to convince PMAMP and other stakeholders to raise awareness on and further experiment with increased application of nitrogen, phosphorus and potash and for changes in the recommended application rates. The project has shared these results with the Nepal Seed and Fertilizer Project, which is working on site-specific fertilizer recommendations in the FtF zone.

ii) Addressing variation in crop management practices: Rice crop management practices vary across the project's area. The further analysis of the 2016 rice crop-cut and production practices data identified three 'clusters' or types of farmers differentiated in terms of rice crop production and management practices (Figure 2.4), with the cluster-wise means of rice production practice parameters shown in Table 2.2.

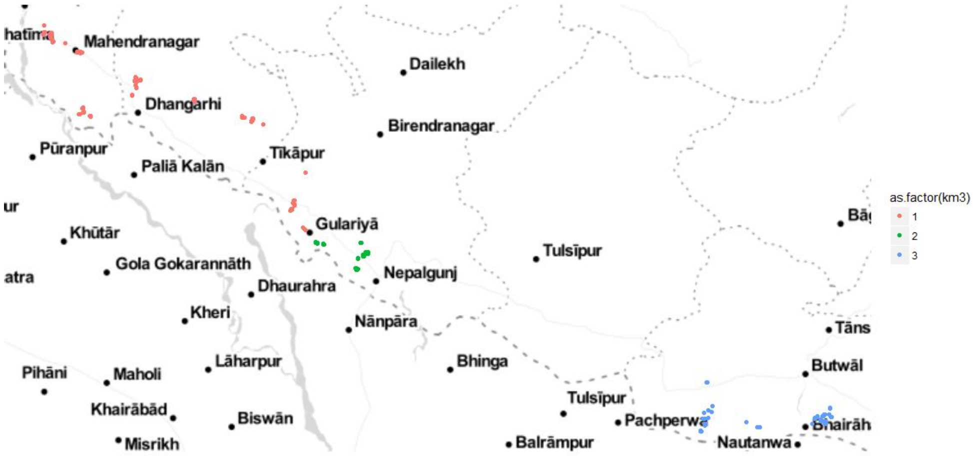


Figure 2.4: The three clusters (from k-mean clustering) indicating three rice cultivation management practices areas in CSISA districts

Cluster 3 to the south and southwest of Butwal tended to have the highest yields (average 4.8 tons ha^{-1}) and better crop management practices. Cluster 1 in Kanchanpur, Kailali and western Bardiya, and Cluster 2 to the west of Nepalgunj had lower yields of about 3.3 Mt ha^{-1} and poorer crop management practices. Farmers here tended to apply low levels of nutrients and irrigated their rice less frequently. Inadequate irrigation undermines the resilience of rice crops when less than average monsoon rainfall occurs. These farmers also transplanted older seedlings, which can cause lower productivity. This type of analysis identifies areas with less desirable agricultural practices to indicate where the project and other initiatives should raise awareness on improved and more resilient practices. The data is being further scrutinized and will be presented to PMAMP officials in Kathmandu, Kanchanpur, Kailali and western Bardiya prior to the 2020 summer rice season.

Table 2.2: Spatial variation in crop management practices for rice cultivation in CSISA districts (mean values; *N* = number of farmers surveyed)

	Cluster 1 (*N*=469)	Cluster 2 (*N*=254)	Cluster 3 (*N*=329)	All farmers (*N*=1,052)
Rice yields (kg/ha)	3,462	3,282	4,938	3,894
Farmyard manure applied (kg/ha)	3,850	2,070	1,796	2,572
Nitrogen applied by farmers (kg/ha)	60	63	96	73
Phosphorous applied by farmers (kg/ha)	40	34	68	47
Potash applied by farmers (kg/ha)	1.9	1.2	7.3	3.5
Zinc applied by farmers (kg/ha)	0.9	0.2	1.2	0.8
Number of times crop irrigated	1.5	1.1	2.2	1.6
Seedling establishment time (Julian days of year)	160	164	174	166
Transplanting time (Julian days of year)	189	190	201	193
Harvesting time (Julian days of year)	298	303	318	306

iii) Closing rice yield gaps: Rice productivity in Nepal averages 3.5 Mt ha^{-1} and less in the FtF zone, which shows the potential to close the yield gap in the FtF zone. Further analysis of the 2016 summer rice crop-cut and production survey data identified the major drivers of standing crop biomass measured as the normalized difference vegetative index (NDVI) through remote sensing, which is correlated with yielding ability. In 2016, the rice crop-cut survey used the NDVI stratified sampling methods to identify households for the survey. The survey was carried out in six districts (Figure 2.5).

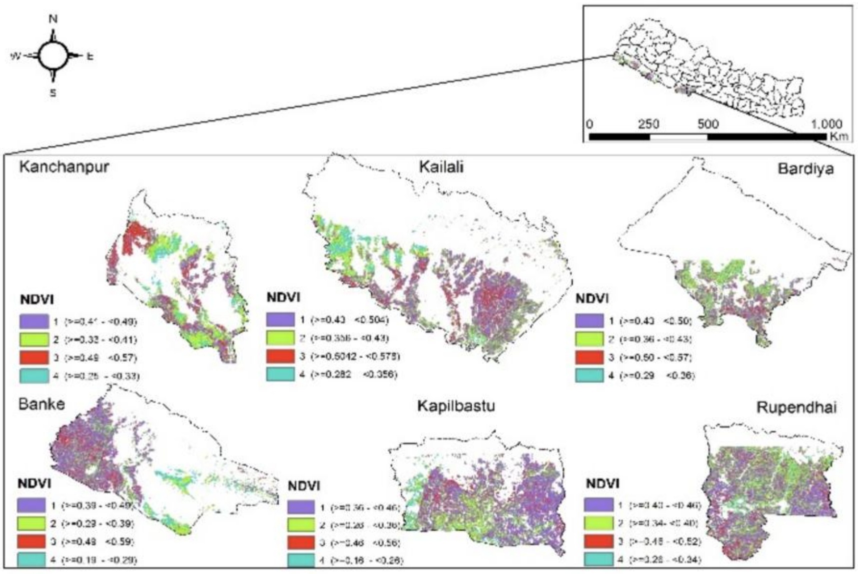


Figure 2.5: The satellite-derived stratification of NDVI values in study locations in Nepal

Fertilizer application rates were found to be the most important driver of yield followed by number of irrigations. The farms with the 10% highest yields had applied more nitrogen, phosphorus and potassium and were the same as those with the higher NDVI values. While environmental and profitability outcomes of these observations need further scrutiny, the analysis shows that identifying NDVI values can identify farmers who could benefit from mid-season advisories on improved agronomy to reduce the risk of yield losses due to sub-optimal management (Figure 2.6).

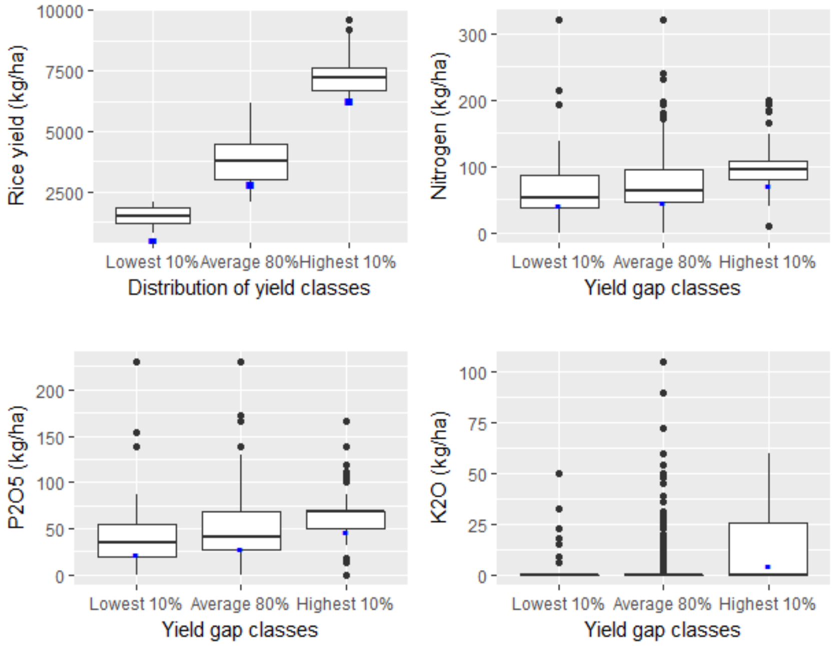


Figure 2.6: Fertilizer application rates on mid-summer 2018 rice by elite farmers (10% highest yields), average farmers (middle 80%), and the 10% lowest yielding farmers

iv) Wheat yield and management findings: The further analysis of the 2018 wheat crop-cut data found average wheat productivity of 2.5 Mt/ha with the highest yielding 10% of farms harvesting 4.5 Mt/ha of wheat, the median 80% 2.5 Mt/ha and the bottom 10% a third of this amount (1.5 Mt/ha) (Figure 2.7). The agronomic management practices of the top 10% of farms should be demonstrated and communicated to other farmers to improve their yields.

The project also used machine learning to further analyze the wheat data. Figure 2.8 shows outputs that identify the major productivity drivers of wheat in the region. These outputs:

- highlight sowing time as the most important predictor for wheat productivity in Nepal's Terai, confirming and justifying the project's encouragement of early wheat sowing;
- identify the pathways for attaining sustainable wheat production in Nepal's Terai under farmer-managed conditions; and
- identify proper nitrogen application and weed management as the main drivers of wheat yields.

In early 2019, these results were disseminated to PMAMP and other stakeholders at meetings and cross-learning sessions in Province 5 and the Far Western Province. This is the first time in Nepal that data science approaches have been employed to inform agricultural development organizations as to the complexity of farmers' own management practices in their fields, a process that informed a rich discussion on re-prioritizing extension activities and investments in the coming year for PMAMP's work in particular. The project's research team is now assessing the economic and environmental consequences of these methods and investigating if the same results hold true for male and female-headed households and younger farmers.

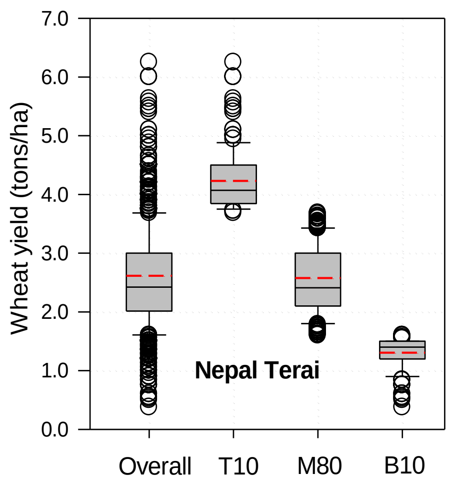


Figure 2.7: Wheat productivity of all 1,684 farms, top 10%, middle 80% and bottom 10% farms. 2018 diagnostic survey

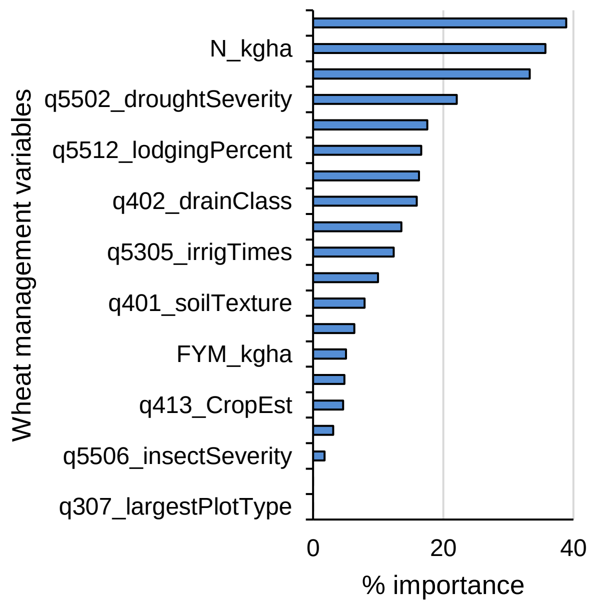


Figure 2.8: Results from the application of the recursive partitioning Random Forest decision tree machine learning algorithm to identify the main productivity drivers of wheat in Nepal's Terai

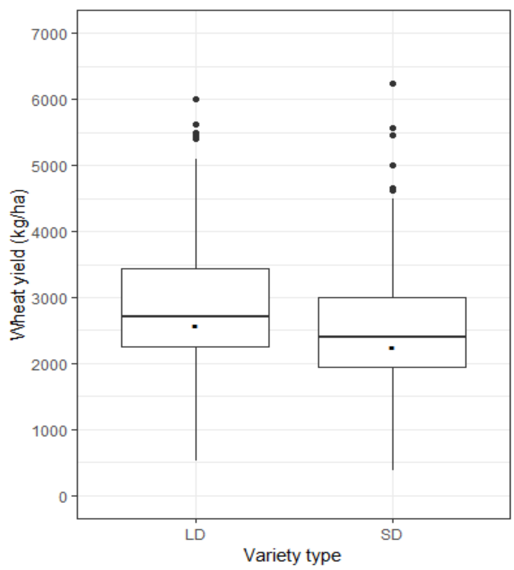


Figure 2.9: Planting long duration (LD) varieties of wheat can increase yield by almost 0.5 Mt/ha more than short duration (SD) varieties

C. ACHIEVING IMPACT AT SCALE

C1. Growing the input and service economy for sustainable intensification technologies

C1.1 Integrated weed management (IWM) to facilitate sustainable intensification transitions in rice

Weed species composition studies to guide IWM strategies

Many farmers in Nepal's Terai are adopting rice-wheat and rice-lentils planting patterns based on land suitability and their daily food needs. Weed management is a crucial aspect of cultivation. In the 2019 monsoon season, the project assessed weed species composition in 120 rice fields in its Nepalgunj and Dang working areas. This work was undertaken to identify the key weeds that are bottlenecks to productivity, and to assess ways to prioritize major weed management issues. The main weed species were logged and weed and rice biomass samples taken from five 50 × 60 cm^2 sampling areas of 120 fields (Photo 2.13). rice and weeds were oven dried to gauge the dry weight to assess the competition effect. At the end of the 2019 summer rice season, a farmer household survey will gather crop management information and the socioeconomic situation of the communities. The results will be reported next semi-annual report.

Photo 2.13: Enumerators taking rice weed samples from a field in Banke (Sagar Kafle)

Safe herbicide use and equipment training

In August 2019, the project ran separate one day training events for Bardiya and Banke agrovets and local government technicians on the use of herbicides in coordination with the district agrovet associations and the Regional Plant Protection Office, Banke. In all, 74 agrovets and 37 government agriculture technicians were trained on calculating the correct doses, the method and timing of application, the advantages of herbicidal weed management and government's rules on use and safety precautions (Photo 2.14).

In addition to the above efforts, CSISA worked to increase capacity in the use of appropriate weed control equipment. Flat fan nozzles are superior to standard round nozzles as they more uniformly apply herbicides.

Photo 2.14: Capacity building training for agrovets on the use of herbicides and pesticides on rice in coordination with the Regional Plant Protection Office in Banke and Bardiya (Hari Acharya)

Activities on this topic included the following:

- In May 2019, three agrovets were trained on how to use flat nozzles on spray pumps to apply herbicides and to motivate them to sell these nozzles. The project then linked them with an importer of the nozzles. These agrovets are stocking these nozzles, which are proving popular as many local farmers are buying them.
- In July 2019, a mobile van awareness raising campaigning program was conducted in coordination with agrovets in PMAMP's working area in Bardiya district to raise awareness on flat fan nozzles for applying herbicides. The campaign was run across six villages via announcements broadcast on megaphones.

Rice weeder demonstrations

In July 2019, in coordination with PMAMP's Banke Rice Super Zone, CSISA demonstrated a power-operated rice weeder in fields in Rajapur, Bardiya to 65 farmers (Photo 2.15). With the technical advice and urging of CSISA, in 2018/19 the super zone had provided a farmers group with a 50% subsidy to buy this labor saving and woman-friendly appropriate machine. Male and female farmers operated it and saw the benefits over manual weeding as it reduces weeding costs and solves the labor shortage problem at peak weeding times. The machine takes about 15 hours to weed one hectare at a cost of \$45 as compared to \$132 ha^{-1} for employing 30 laborers[10].


Photo 2.15: Demonstration of power operated and manual rice weeder in coordination with PMAMP, Rice Super Zone, Bardiya district (Hari Acharya)

Agrovet capacity building in integrated weed management

Since 2016, the project has raised awareness on machines and herbicides for controlling weeds in rice and wheat across the FtF zone, mainly through agrovets (the term used for agricultural input dealers in Nepal):

- In September 2018, the project and PMAMP's Kailali Wheat Super Zone, trained agrovets to identify the main weeds of wheat to enable them to recommend the most suitable herbicide to farmer. The subsequent improved application of herbicides controlled weeds more effectively across about 500 ha of farmers' fields in Kailali Wheat Super Zone.
- The project also distributed 800 copies of a poster through Banke Agrovet Association to raise the awareness of farmers and agrovets on the safe use of herbicides and pesticides. It also distributed posters to agrovets in Banke district showing the weeds of rice and wheat to facilitate the selection of the proper herbicide (Photo 2.16).

[10] Note that the machine can be only used on line transplanted rice up to 20-25 days after planting.

Production tips on integrated weed management distributed through agricultural input dealers

During the 2019 wheat season, 500 copies of improved wheat production tips printed on flex displays were distributed to farmers and agrovets in western Terai districts (Photo 2.17). These displays give information on the importance of weed management, the major weeds species and weed control measures including about the use of new herbicides. In this period, the project also advised agrovets how to make low cost safety clothing to sell to farmers (Photo 2.18).

Photo 2.16: An agrovet displaying a poster of weed species of rice to enable the identification of weed species and, subsequently, the appropriate herbicide (Lokendra Khadka)

Photo 2.17: Flex banners in an agrovet showing CSISA rice & wheat production tips (Hari Acharya

Photo 2.18: RH agrocentre, Joshipur, Kailali agrovet demonstrating a locally made safety apron for applying herbicide (Lokendra Khadka)

C1.2 Commercial expansion of scale-appropriate machinery and associated service provision models for reapers and seeders in Nepal

Two-wheeled tractor power tillers are increasingly used by Nepalese smallholder farmers to cultivate their fields. Since 2016, the project has provided technical assistance to machinery value chain actors to increase demand for 2-wheeled tractor mounted seed drills in Dang and the surrounding districts they serve. The project is studying their adoption and spread and raising awareness about other labor-saving machines for carrying out the range of farm operations. The following passages review progress on scale-appropriate machinery during the reporting period:

Supporting the spread scale appropriate seeders to reduce drudgery in crop establishment

In this reporting period, and as noted in section BI for Nepal, the project supported the spread of maize seeders in Dang. It supported Kishan Trades and Suppliers of Lamahi, Dang to show farmers, farmer group and cooperative users how to operate and maintain seeders. The company tested the seeders in the field to assess their effectiveness and adjusted the machines to suit farmers' needs. The project and Kishan Trades also demonstrated the seeders to about 200 farmers at five locations in Dang in June 2019 to generate awareness about their usefulness (Photo 2.19). Similarly, technical assistance was provided to Kusumia Traders of Tulsipur, Dang to operate 2-wheeled tractor mounted seeders in farmers' fields in June 2019.

Machinery prioritization with PMAMP

With the project's technical assistance and continuous efforts, Dang Maize Super Zone and Dang Agricultural Knowledge Center now have 2-wheeled tractor mounted seeders as priorities for government subsidies. Ten of these seeders were purchased by farmers in Dang between October 2018 and September 2019, largely due to project and partner promotion of them.

Photo 2.19: Two-wheeled tractor mounted seeder demonstration with Kisan Traders, Dang (Shovaram Devkota)

Introducing and testing small maize cob harvesters

The harvesting of maize cobs is a labor-intensive manual job. The project is exploring options for the cost-effective mechanized harvesting of maize. In May 2019 the project and Dang Maize Super Zone held four field evaluations-cum-demonstrations of a single row self-propelled maize cob harvester (Photo 2.20). This Indian machine is simple with a short turning radius and is easily adjusted for crop height and plant density. The machine importantly also chops up the residue. It was roughly calculated that using these harvesters was 10% less costly than manual harvesting with greater savings likely with more skilled operators. harvesters also chop-up stalks and leaves as they harvest thus helping with the decomposition of residues and saving farmers from having to disc harrow to chop-up stalks and leaves, thus reducing tillage costs. They also assist in evenly distributing residues across fields, making it easier to apply conservation agriculture such as mulching the subsequent crop. This can have important implications for the maintenance or restoration of soil health. The project plans to further evaluate this type of machine and to assist potential suppliers to create demand in the next reporting year.

Photo 2.20: Small maize cob harvester tested and demonstrated in farmer field in Dang (Sagar Kafle)

Scaling mechanized wheat seeding through service providers

In this reporting period the project updated the profiles of seed drill service providers in the project's working areas including in Rupandehi, Nawalparasi and Kapilbastu, where the project worked in its first phase (Figure 2.10). Overall, 104 service providers were providing mechanized wheat sowing services to farmers (Photo 2.21) using 135 four-wheel tractor-operated seed drills and 15 power tiller operated seed drills. In 2018, 565 farmers had used these service providers to sow 553 ha of their farms. Most of this was to sow zero tillage wheat and direct-seeded rice. The average service charge for the providers to sow zero tillage wheat was \$4 $hour^{-1}$, a dramatic reduction compared to conventional tillage.

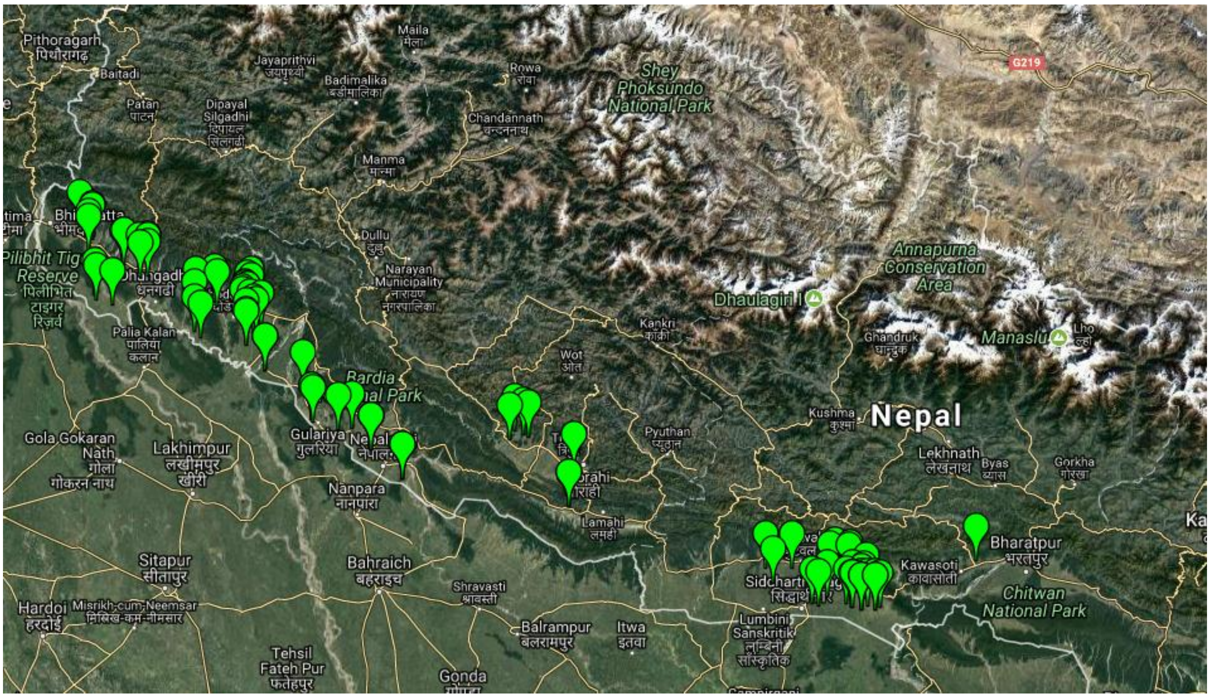


Figure 2.10: Locations of seed drill service providers in western Nepal that have emerged from CSISA's activities.

Understanding adoption dynamics to fine-tune zero-tillage wheat business models

The availability of zero tillage services is a core part of the project's theory of change for more sustainable crop establishment. The project's support and awareness building has led to about 200 seed drills being available in Nepal's Terai, many of which can be used for zero tillage. However, most drills are used for crop establishment following prior plowing, and only a few seed drill service providers focus on zero tillage seeding. This raises important research questions on why zero tillage has not accelerated in Nepal as it has in other CSISA working areas such as in India's Punjab. In response, during this reporting period, the project interviewed all service providers who own zero tillage seed drills to identify constraints and catalysts. By 30 September 2019, 900 households have been surveyed including zero tillage adopters, dis-adopters and non-adopters. The data cleaning process, analysis and outputs will be shared soon and the adoption dynamics results will be shared in the next period.

The spread of inferior rotavator tillers negatively impacts soil health and wheat productivity

In April 2019 the project published a paper on the impact of rotavator tillage on wheat productivity in Nepal's Terai in the *Journal of Agricultural Economics to* fill a gap in the evidence of the impact of rotavator tillage on farmer fields across soil gradients and time. The farm household survey of wheat farmers in Nepal found that rotavator tillage led to inferior outcomes despite significant cost savings for preparing land. With rotavator adoption, farmers lost about 284–309 kg of wheat grain and about $93–101 of profits on average per hectare per season. The adoption of rotavators appears to be driven by the cost and time savings for land preparation. Against this backdrop, new policy and extension efforts are required that discourage rotavator use and favor more sustainable tillage technologies.

Photo 2.21: A young farmer in Kanchanpur with his crop of zero-till drill-sown wheat (Lokendra Khadka)

Traveling Seminar on Scale-Appropriate Machinery

The project held a traveling seminar on 'Scale-appropriate Machinery for Cereal Crop Harvesting in South Asia' between 25 and 29 March 2019. More than 40 delegates, including international experts, private sector scaling partners and dignitaries such as the Director General of Nepal's Department of Agriculture and Chief of PMAMP attended. Participants visited a variety of project sites and project partners across Nepal's Terai. Field visits, demonstrations and discussions with farmers and service providers began in Rupandehi district and proceeded to Kailali district, with several stops in-between.

Delegates observed technologies used in farmers' fields and discussed progress on mechanized cereal production in Nepal and broadly across Asia. Participants saw Nepal's scale-appropriate, private sector-led mechanization in farmers' fields, including the use of large combine harvesters and self-propelled reapers in Rupandehi and the recent spread of thousands of two-wheel tractor reapers in Banke, Bardiya and Kailali. Delegates discussed issues with farmers who use the services of machinery service providers, the service providers, machinery importers and sales agents.

On the last day of the seminar, delegates from China, Bangladesh, India, Sri Lanka and Vietnam explained how the use of farm machines are spreading across their countries' farms. These discussions and presentations included private and public sector representatives interested in finding sustainable, equitable, and productive solutions to grain harvesting challenges for all farm sizes and farmers across the region. Professor Ding Qishuo, College of Engineering, Nanjing Agricultural University, recalled his 20 years' experience in southern China and found similarities with the situation in Nepal's Terai, where "a huge gap in rural manual labor may need to be filled by machinery". He pointed out the large opportunity for promoting mechanized harvesting in Nepal's Terai although said that much needs doing to document and quantify local farming systems with the possibility of leaning lessons from other Asian countries to apply to Nepal's farming systems. Further details can be found in CSISA's 2018-19 semi-annual report.

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

The project has taken a lead role in introducing two-wheeled tractor (2WT) attached reapers to the Nepali market as scale-appropriate machines to replace the time consuming laborious manual harvesting of crops. The manual harvesting of one hectare of cereal crops typically takes 20 person days at a cost of about $88 ha^{-1}. Farmers can save $70–$88 ha^{-1} ha^{-1} by switching from manual to reaper harvesting. The project and its government (former DoA's Directorate of Engineering) and private sector partners began raising awareness on and promoting the reaper attachments in 2014 through field demonstrations and awareness campaigns and training users and suppliers on their operation.

According to the main machinery importers who work with CSISA, as of September 2019, there were 3,495 of these machines in Nepal's Terai (Figure 2.11) and almost 16,000 ha of rice and wheat was being harvested by them. Recently these attachments are also being sold outside the project's area, including in the eastern Terai with 30% of 2WT reapers sales occurring there in the reporting period. The number of importers of 2WT reapers has increased from four in 2014 to eight in 2019. Self-propelled reapers with their own engines account for about a tenth of sales.

Another sign of the growing use of reapers occurred in late 2018 where two more two-wheel tractor reaper importers opened in the FtF zone – DKAM Traders and Naya Tulsi Traders, both in Tikapur, Kailali. The presence of five importers in the Far West means that reapers are affordable there. However, various subsidy programs from central and provincial governments and projects such as the Rani Jamara Kulariya Irrigation Scheme (which in 2018 offered 50% subsidies to 150 farmers to buy reapers), are likely to depress sales as farmers delay purchase with the hope of accessing a subsidy. The project is therefore discussing with government partners how fair prices can be offered to accelerate farmers' access to crucial equipment without distorting the overall machinery market.

In the absence of solid quantitative data, the project conservatively estimates that each reaper harvests 5 hectares of rice or wheat per season to arrive at its estimates of coverage. A new study in Nepal's Terai by Access Advisory and supported by the CSISA Scaling project estimates the area covered and number of farmers accessing reaper services in Nepal's Terai to be 2-3 times higher. The paper is expected to be published in the next reporting period

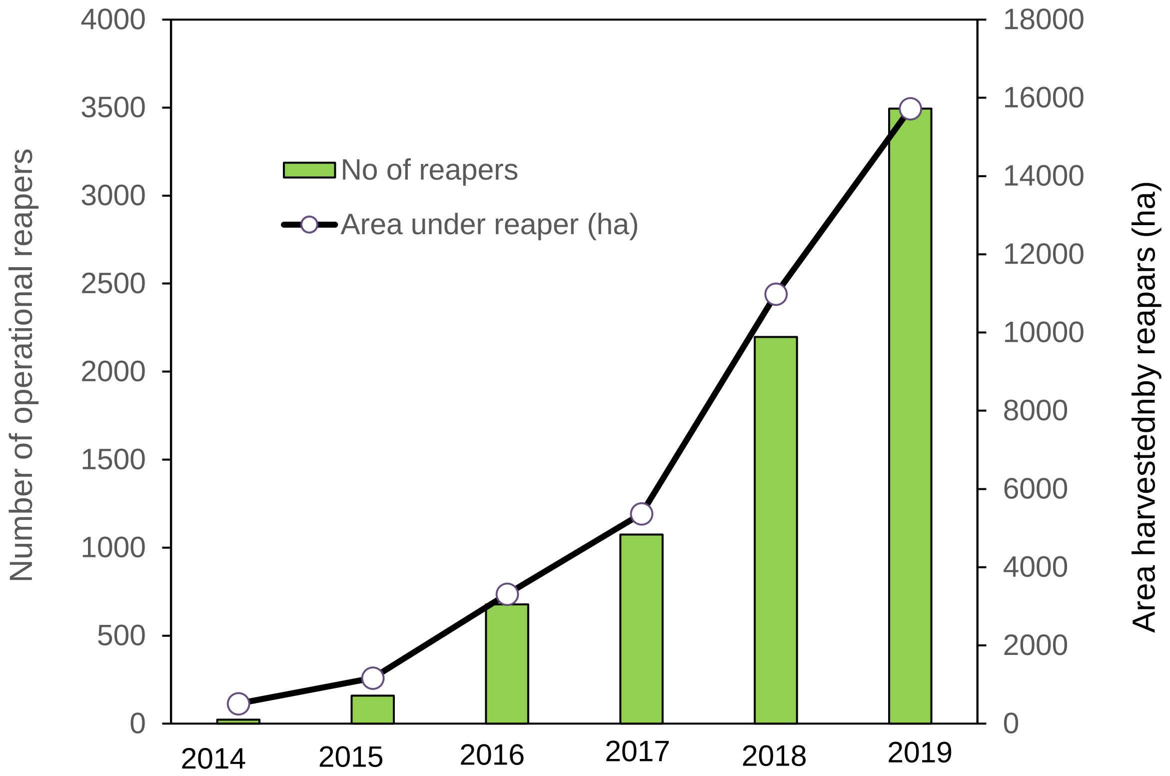


Figure 2.11: Number of 2-wheel tractor-attachable reaper-harvesters in Nepal's Terai, 2014–2019 (source: project surveys of importers, NAMEA)

Reaper trainings

In March 2019, the project supported four suppliers to run programs that trained about 300 reaper service providers on operating and maintaining their machines. Also in this reporting period the project produced a user-friendly reaper operating and maintenance manual and printed 3,000 copies that are being distributed to service providers and other stakeholders (Figure 2.12).

Figure 2.12: The reaper manual

Wheat straw reaper-bailers can improve livestock feeding practices

The management of wheat straw is a serious problem in Nepal's Terai. The burning off of straw leads to declining soil fertility and polluted air. Four-wheel tractor attached wheat bailers enable the efficient gathering of straw for use as livestock feed.

On 15 April 2019, the project ran demonstrations of a reaper-binder, straw reaper (also known as a straw combine) and a straw baler at Jhalari, Kanchanpur in collaboration with RCT Agro-machinery and Engineering Workshop (Photo 2.22). Journalists from Jhalari FM radio, technicians from PMAMP's office in Belauri municipality, farmers, and students from Krishnapur Technical College attended. This event exposed farmers to new options to process their crops and raised awareness on the use of wheat residue for livestock feed instead of burning off. Since then the project has been further encouraging farmers to experiment with reaper-binders, bailers and straw combines through demonstrations in partnership with machinery dealers. It is also partnering with local FM radio stations to broadcast the contact details of service providers and the benefits of bailing straw.

Photo 2.22: Students from Krishnapur Technical College, a journalist and farmers observing a straw combine demonstration at Jhalari, Kanchanpur, Nepal in March 2019 (Scott Justice)

While such work has focused on rice wheat systems, an August 2019 field tour by project staff near Gulariya in Bardiya identified an innovative service provider who is using his straw combine for harvesting maize stalks, The machine was not only capable of lifting and harvesting but also cutting the stalks into valuable maize *busa* (livestock feed). According to the owner there is a higher demand for his machine on maize than on wheat. The project will take this into consideration with Dang Maize Super Zone partners in the 2019 winter maize season.

Expanding evidence of farmer demand for mini-tillers in the Midhills

In November 2019, a paper on the demand for mini-tillers was accepted for publication in the *Technology in Society*. The paper analyzes smallholder farmers' willingness to pay to buy scale-appropriate farm machines in Midhills Nepal using the case of small two-wheeled tractor mini-tillers, which are mainly used for preparing agricultural land. The study of 628 farming households (Figure 2.13) found that farm size, local wage rates, out-migration, access to credit, and associations with agricultural cooperatives positively influenced the uptake of mini-tillers while number of draft animals owned negatively influenced uptake. On average, farmers were willing to pay 31% less than the actual price of a mini-tiller. It was also found that the 25% of households with the smallest farms, typically the poorest farm households, were willing to pay 26% less for the mini-tiller than the 25% best off farmers. In the context of the widespread scarcity of labor and rising rural wages, support should focus on supporting small farms to access the technology through service provision models.

Also in this reporting period, a paper on productivity impacts of scale-appropriate mechanization on rice productivity in Nepal's Midhills was published in *Land Use Policy* (Figure 2.13).

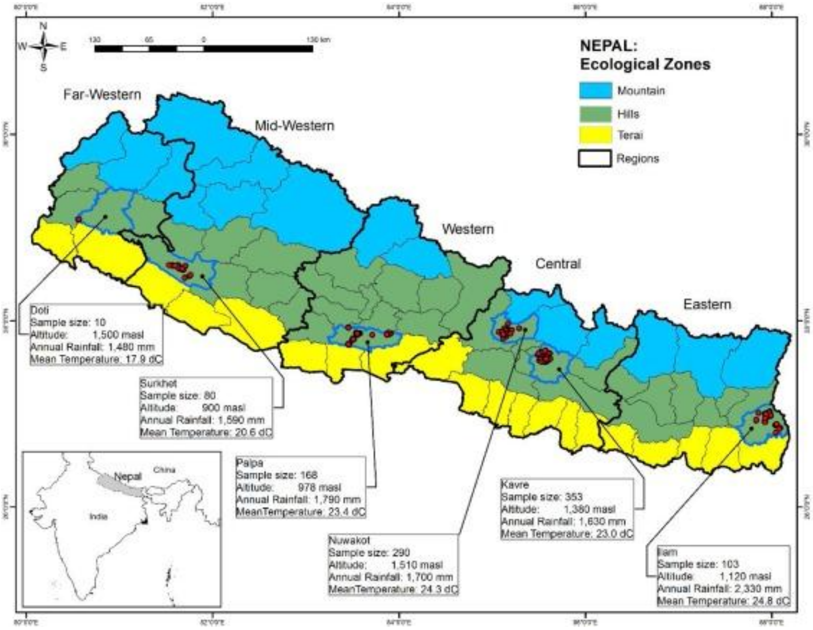


Figure 2.13 Map of areas in Nepal's Midhills where the willingness to pay for mini-tillers was assessed

Mini-tiller weeder expansion

There has been widespread adoption of mini-tillers across Nepal's Midhills since the 2015 earthquakes, mainly for tillage in rice-maize and rice-wheat systems. Inspired by this, and learning of the use of mini-tillers in India's plains for inter-cultivation and earthing up row crops, the previous phase of the project (Phase II) and the early months of CSISA Phase III raised awareness on mini-tillers for both tillage and weeding between maize rows in Nepal's Terai. Evidence of project impact can be found in the strategic partnerships that CSISA fosters, as described below:

In early 2018, the project's partner PMAMP's Dang Maize Super Zone began providing 50% subsidies for farmers to buy mini-tillers. Hundreds of hectares of the zone's maize area are now being mechanically weeded, resulting in average savings of nearly $100 per hectare on weeding costs. This also prompted a backwards linkage in creating additional demand for 2 and 4-wheel tractor maize planters for line sowing as only line sown maize can be mechanically weeded.

Also, in late 2018, project staff in the Far Western Province and Province 5 began noticing unexpected increased sales of mini-tillers to Terai farmers, not for weeding but for primary tillage and the puddling of rice fields. Project office in Kailali and Dang began running minor demonstrations and training and supporting the provision of spares and repairs for mini-tiller buyers. At the end of this reporting period, the project found that suppliers of mini-tillers in the Midhills, although cautious about increased demand in the Terai, were actively marketing these machines across the Terai. The project expects this market for mini tillers to grow from small and middle-sized farms across the Terai that seek to be independent of tillage service providers. Such sales in the Terai could reach up to 2,000 mini-tillers per year in the near future.

Mini-tiller adoption and gender dynamics

In 2017, the project carried out a study on the adoption of mini-tillers by Midhills farmers. The widespread out migration of men due to the lack of income opportunities and food insecurity has increased the roles and responsibilities of women farmers. In this reporting period, the adoption rates of male and female-headed households were analyzed from the datasets (Photo 2.23). The study showed that the substantially lower adoption of mini-tillers in women-headed farming households was linked to less land ownership by women, women's lower levels of education and their less access to information and to inputs and output markets. The results suggested substantially lower mini-tiller adoption female-headed households even if they have similar characteristics to male-headed households. This could be due to women farmers having less strength than men, being more risk averse and less experienced and skilled in using machinery. The study concluded that female-targeted farm mechanization programs are needed to encourage the adoption of mini-tillers by female-headed households. CSISA staff are now in discussion with PMAMP and partner organizations to more strongly target activities and assure gender-equitable access to machinery.

Photo 2.23: Women farmers operating a mini-tiller in the Midhills (Peter Lowe)

Gender studies spark new training activities in scale-appropriate machinery for women

In February 2019, the project organized a two-day training on mini-tiller weeding for 32 women members of the 16 custom hiring centers managed by PMAMP in Dang Maize Super Zone (Photo 2.24). The training led to a third of participants being able to start the gasoline engines and operate them independently while the others were able to operate the machines (especially the diesel engine mini-tillers) after getting help to start them.

Photo 2.24: Left: A woman trainee trying to start a mini-tiller during the training in Dang. Right: Trainees learning to operate mini-tiller weeders at the training (Sagar Kafle, CIMMYT)

Following the training, which included members of the Salleri Mahila Samuha cooperative, Dhankhola, several trained women began to help their cooperative's designated male operator Mitralal with tilling winter and spring crops. He would start the cooperative's harder-to-start diesel tiller after which the women both tilled their own fields and trained other women how to use the machine. The increased number of operators enabled the cooperative to plow nearly 20 hectares of 60 member and non-member' farms in the winter and spring cropping seasons. Mitralal commented that,

> *"I would not have been able to service so many farmers if our women had not supported tilling operations. They [the women] find it difficult to start diesel mini-tillers so I start it for them and leave them to till the ground."*

The Dhan Khola women farmers' mini-tillers are also being extensively used and thus begun to need repairs. Project staff have been providing advice and informal training on their repair. The project plans to follow up with trainees and help increase the number of mini-tillers, particularly with women service providers.

Collaboration with the Nepal Agricultural Research Council's agricultural machinery centers

The following progress was made in the reporting period on project collaboration with NARC's agricultural machinery testing and promotion centers, which are based in Province 2 in the Terai:

- The government's Agricultural Machinery Testing and Research Centre (AMTRC) was established in 2018 at Nawalpur in Sarlahi district with project support. NARC's continued, strong buy in for supporting the center continued as construction began in October 2018 of a main office building and officer quarters, which was completed in July 2019. The project also arranged a visit and facilitated collaboration between the center and a University of Manchester group on the testing of pumpsets.
- To help jumpstart machinery testing at the center, the project placed an agricultural engineer intern there in March-August 2019. The intern also supported collaboration between the project, AMTRC and NARC's Agricultural Implement Research Center (AIRC), Birganj on the center's new research project, which is following up on CSISA's earlier work on a two-wheel tractor shallow tube well drilling attachment. CSISA plans to continue support in 2019/20 with visits by the intern for the development of seeder-planter testing protocols for testing new models of seeders and planters that are newly available in the market.
- In this period, the center's staff were trained by CSISA technicians on using seed drills to sow wheat (in November 2018), to sow mustard and maize (March 2019) and to sow groundnuts and rice (May 2019). The planned testing of seed drills could not be carried out due to ongoing construction at the center and this activity is planned for the next seeding season in October–November 2019
- The Agricultural Machinery Promotion Center (AMPC) is located at Naktajhih in Dhanusha district. Project-supported service provider and mechanics trainings could not be conducted as planned in the center's first fiscal year (2018/19) due to delays in the receipt of the main budget from the central government and delays in renovating the facilities. In the meantime, in December 2018 the project assisted the center to run a training of trainers program on how to operate laser land levelers, during which half a hectare of fields was leveled.
- The project responded by assisting the center to repair and equip its training hall and renovate its training garage-workshop facility. This work was completed in September 2019 to enable the center to now proceed with its delayed training program for agriculture technicians, mechanics and lead farmers in the next reporting period.

C2. Managing risk by coping with climate extremes

Climate change is increasingly challenging South Asian agriculture due to the more extreme temperatures and the increasingly erratic and difficult to predict monsoon rainfall. This heightens the importance of farmers having access to irrigation to buffer against drought stress and provide flexibility for early planting that otherwise depend on monsoon rains and residual moisture. CSISA III work in 2017 and 2018 found that the high cost of irrigation, in combination with smallholder farmers being reluctant to pay for irrigation when rain is likely in the near future, inhibits the use of irrigation across Nepal's Terai. This situation presents opportunities for low cost ways of increasing supplementary irrigation on rice and wheat to strengthen the resilience of cropping systems (Photo 2.25).

Partnerships to reduce irrigation prices through technology development

Since 2017, the project has been i) exploring options to develop inexpensive solar powered irrigation systems (the *sasto solar sichai* technology) made from components that are available in local markets and

Photo 2.25: CIMMYT staff setting up a pump test in a rice field (Subash Adhikari)

ii) supporting the former DoA's development of low-cost mechanical well-drilling technology (Photo 2.26). The latter was initially developed by the project. During the reporting period, project staff continued to backstop efforts to improve and market these technologies. These technologies have garnered the interest of private sector actors, and the project is trying to maintain their affordability to encourage wider uptake.

These activities, together with the project's support to the Agricultural Machinery Testing and Research Centre (AMTRC) and the Agricultural Machinery Promotion Testing and Research Center (AMPC) (see last sub-section of C1.3), are strengthening local capacities to develop agricultural services and are crucial to bring innovations to scale and support farmers to cope with the increasing variability of monsoon rainfall.

Understanding scaling bottlenecks for scaling up timely rice planting

The timely planting of rice is critical, not only for the improved synchronization of rice cultivation with monsoon rain patterns, but also by allowing early wheat planting to avoid terminal heat stress. While the importance of timely planting is well understood, inhibitors to scaling and farmers' reasons for making planting decisions are largely unknown. Initial research in the Terai in 2017 and 2018 and complementary larger scale validations across the border in Bihar and Eastern Uttar Pradesh, are currently being analyzed and evaluated by project staff. Results show monsoon onset and the availability of irrigation water as the main drivers of rice establishment, making work on reducing the cost of irrigation critical for dealing with intermittent periods of no rainfall during the monsoon season

and other system dynamics such as terminal heat stress due to late planting. The lack of the timely availability of seed, fertilizer, labor and land preparation equipment and grazing by wild animals are additional inhibitors. These findings are being analyzed by project staff and a Wageningen University Ph.D. student to identify recommendations for government policies and development programming to scale up technologies to assist farmers to plant their crops earlier.

Photo 2.26: CIMMYT staff testing the new well-drilling technology in Banke (Anton Urfels)

Sharing CSISA III work with international stakeholders at World Irrigation Forum 3

From 1–7 September 2019, the Wageningen University PhD student shared CSISA's irrigation-related work with an international audience at the third World Irrigation Forum organized by the International Commission on Irrigation and Drainage. The event was attended by policy makers, practitioners and researchers from leading universities, the World Bank, FAO, ADB and government officials. CSISA's work was presented at the International Workshop of the ICID Working Group on Global Climate Change and Agricultural Water Management. The presentation highlighted the ground level work of CSISA III on what drives farmers' decision-making and the project's efforts to remove the bottlenecks for framers to use irrigation more effectively to buffer against climate extremes and strengthen system resilience and food security. The project's work garnered much interest at the forum and led to follow up meetings with FAO, IWMI and other international research and development organizations.

3. Policy Reform – Achievements

D1. SEED SYSTEMS

Bangladesh

As described in the semi-annual report, activities in Bangladesh around seed system policy reform were phased down in during this reporting period due to transitions in the project's leadership within the International Food Policy Research Institute (IFPRI) and project funding uncertainties as described in the Executive Summary and 'Challenges Faced During the Reporting Period' section of this report. CSISA, however, maintains a rich network of contacts and partners in seed systems work in Bangladesh, and the project is positioned to leverage these relationships to pursue additional seed systems policy research activities if there is sufficient interest and funding to support such activities in the future. One potential avenue for strengthening this work is to align it with ongoing work in the CGIAR Research Program on Policy, Institutions and Markets. Further details of work in this area will be provided in the next report.

Nepal

Assessing varietal turnover gaps

In Nepal, the project entered into a collaboration with the USAID/Nepal Mission supported and CIMMYT-led Nepal Seed and Fertilizer project (NSAF) to determine the demand and supply gaps that need filling to bring about systemic policy change on varietal turnover. As part of this collaboration, CSISA participated in the International Seed Conference and Expert Consultation held by NSAF and the CSISA Scaling Project in September 2019 in Kathmandu, Nepal. This participation enabled CSISA to bring in evidence and expertise on technological and market innovations on seed markets in other parts of the world for a better understanding of the ground-level issues and towards advising the Government of Nepal on policy and regulatory options under its Nepal Seed Vision 2020. The Nepal government intends to reduce the subsidy burden on its exchequer by replacing universal seed subsidies with a targeted voucher system; and the project has expressed interest in technical collaboration on recommending the best ways to take this issue forwards.

To build on this collaboration, CSISA will undertake additional activities in 2019/20 to inform the Nepalese policy and regulatory environment on building an efficient seed system in Nepal. CSISA's policy inputs will be targeted towards varietal registration and release, seed certification and quality assurance, domestic and foreign investment in the seed industry as well as subsidies and prices. Support will be in the form of analytical guidance for implementing the National Seed Vision. Outputs will include communications and outreach through government and stakeholder dialogues as well as the preparation of a country diagnostics report with actionable recommendations. This exercise is expected to result in sound seed policies, regulations and guidelines that create an enabling environment for increased investment in Nepal's seed industry.

D2. SCALE-APPROPRIATE MECHANIZATION

Bangladesh

Impact of protective policies

In the context of renewed funding, discussions to re-invigorate CSISA activities on the scale-appropriate mechanization component for Bangladesh have begun. In coordination with CIMMYT and other national partners in Bangladesh, a priority setting exercise is planned for early 2020 to determine policy questions on enhance the country's capacity for manufacturing agricultural machinery. The project aims to support the Bangladesh government's policy to build internal manufacturing capacities of agricultural implements and spare parts and to reduce dependency on imports from China by providing data-backed recommendations on the feasibility of such an approach and a broader understanding of the implications on in-country prices and the adoption of machinery. The project is anticipated to provide a diagnostic review of potential policy options to undertake such an approach in collaboration with the USAID/Bangladesh CSISA-Mechanization and Irrigation (CSISA-MI) Phase II project in Bangladesh.

Nepal

Due to funding uncertainties, the project halted its direct policy work on scale-appropriate mechanization in Nepal in 2017. Staff transitions within the IFPRI team within CSISA due to funding uncertainties also hindered the project's ability to contribute to this workstream. Efforts were therefore redirected towards soil fertility management and fertilizer market work, which emerged as more relevant workstreams in light of the project's new priorities.

D3. SOIL FERTILITY MANAGEMENT AND FERTILIZER MARKETS

In this reporting period the project focused on strengthening soil fertility management and fertilizer policies in Bangladesh and Nepal to leverage existing research and activities on the Bill and Melinda Gates Foundation (BMGF) component of the project, which now focuses on India but also coordinates with Nepal and Bangladesh.

Bangladesh

Bangladesh, like other South Asian countries, is a net importer of urea, phosphate and potash-based fertilizers. As much as 70% of its total urea is imported. The demand for fertilizer is rising; but declining soil quality and the poor management of application are concerns alongside the increasing dependency on imports of urea.

In this reporting period, the project carried out a diagnostic analysis of fertilizer application behavior in Bangladesh and the role of the country's subsidy policies on application rates. Using data from the Bangladesh Economic Review (2018), the project observed that the cost of fertilizer for farmers is highly subsidized and accounted for approximately 45% (69,360 million taka or $823 million) of the agricultural budget in 2014/15 (as per allocations to the Ministry of Agriculture, Ministry of Livestock and Ministry of Food). In 2017/18, subsidies for fertilizer and other agriculture inputs amounted to 60,000 million taka ($712 million), accounting for 43% of the agriculture budget's allocations and 0.26% of national gross domestic product (GDP). Despite these huge subsidies, farmers spend a significant proportion of their input costs on fertilizers.

Expenditure on fertilizer by farmers exceeds 10% of the total value of rice output. However, the often-imbalanced application of fertilizer affects crop yields, farmers' profits, soil health and the environment.

To explore this further, the project undertook secondary analysis of Bangladesh Integrated Household Survey (BIHS) data. This dataset includes information on household characteristics, including agriculture in 2011 and 2015. The project analyzed this data to better understand fertilizer application trends among farmers. Initial results are given in Box 3.1.

These findings help identify the trends in fertilizer application and the effects of changing the subsidy and fertilizer pricing policy on farmers' use of fertilizers. The project plans to continue this analysis using other data sources and prepare a policy brief to summarize findings and recommendations on fertilizer pricing policy for the Government of Bangladesh.

Box 3.1: results of diagnostic analysis of fertilizer application behavior in Bangladesh, 2011–2015

- Most farmers applied urea and phosphate to their rice while only 78.6% applied muriate of potash (MoP).
- Of the 1,642 farmers who applied urea in 2011, in 2015 over 50% had increased their application rates while 47.3% had lowered their rates.
- The number of first-time MoP users increased by 15.6% in 2015 while 53% of existing users increased their application rates.
- The application of phosphate was increased by 49.4 percent of the farmers.
- Fertilizer application rates were higher on *boro* than *aman* rice.
- There was an increase in the average amount of MoP applied to *boro* and *aman* crops, with an increase of almost 20 percent on *boro* rice.
- Urea application intensified on *boro* rice.
- More phosphate was applied to *boro* than *aman* rice.
- There was a 35% increase in the application of phosphate on *aman* rice and 15.5% on *boro* rice.

Nepal

In the previous reporting period (2017/18), the project's focus narrowed towards soil fertility management and fertilizer markets. The project's collaboration with NSAF continued to expand the knowledge base and insights on government policy concerns on ways to meet the demand for fertilizers, a portion of which is currently met by grey markets around the India-Nepal border. In 2019, Nepal's Ministry of Agriculture and Livestock Development (MoALD) discussed the establishment of a urea manufacturing facility in Nepal to reduce dependence on imports. However, government officials indicated that establishing such a facility would cost as much as $1 billion, which would be very difficult for the Government of Nepal to fund. The government has therefore decided to focus on improved procurement, distribution and balanced nutrient application. In this reporting the period the project therefore focused on supporting strategies to encourage farmers to change their fertilizer application behavior.

Fertilizer spreaders

Most Nepalese farmers apply fertilizer by hand, which is time-consuming and leads to non-uniform application that can result in variable within-field yields. It was therefore decided to raise awareness about a low-cost spreader machine. Hand-held fertilizer spreaders spread fertilizers uniformly more rapidly while avoiding farmers directly contacting fertilizer (Photo 3.1). The project has found this machine to efficiently and uniformly apply fertilizer and to save farmers' time. However, there has been little uptake mainly because of poor understanding of its use and credit constraints among farmers.

In response, in June 2019 the project carried out a study of 300 farmers in the southern part of Bardiya district in Nepal's western Terai to see if relaxing credit and information constraints could improve the uptake of spreaders. The study also looked at the impact of different extension approaches as, in India, approaches that provide farmers with information on fertilizer application rates through in-person visits and interactive voice responses (IVR) over the phone have improved fertilizer application rates.

This area of Bardiya borders India meaning that its farmers can easily buy fertilizers in India. The project divided the 300 farmers into one control (no intervention) group and three treatment groups of 75 farmers, with the project paying a service provider to apply fertilizer[11].

- The first treatment group received free spreader services without any extension messaging.
- The second group received free spreader services and face-to-face extension messaging.
- The third group was identical to the second while also receiving extension messaging through a video prepared by the project (Figure 3.1).

Farmers who received free spreader services were offered a second round of fertilizer application a few days later for the payment of a small fee. Farmers provided their own fertilizers.

Photo 3.1: Screenshot from the [video](#) shown to farmers on the use of handheld spreaders

Data collection was completed in August 2019 with the following main findings:

- More than 50 of the 225 farmers in the treatment groups called for the spreader service on their fields. However, the service could only be delivered to 41 due to logistical issues. Among the 41 farmers, (counter intuitively) the highest demand was from farmers who were *not* provided with

[11] Note that most of CSISA's previous work on spreaders has not focused on spreader service provision. Rather, the project has encouraged farmers to use spreaders in their own fields. The work detailed in this section of the report is a departure from this and represents an investigation to assess if and how spreaders could be used on an entrepreneurial, fee-for-services basis.

information or extension by the project.

- Among the farmers who called for the spreader services, the desire to experiment with new technology, the prospect of saving time and the free service were the main reason.
- Those farmers who did not avail of the spreader service listed preference for the traditional method of broadcasting, non-familiarity with spreaders and fertilizer unavailability as their major reasons given for not using the spreader service (Figure 3.1)
- Over 75% of the users stated a willingness to pay less than NPR 10 per katha for spreader services in the next rice season (1 katha = 338.63 m^2). To contextualize, the going labor rate for manual fertilizer spreading in Bardiya is approximately 35 NPR per katha.
- There was no demand for the paid second application. This could have been because of the timing of data collection, as until then, most farmers had yet to carry out their second round of urea application.

Overall, farmers were interested in using fertilizer spreaders, but most were unwilling to pay or would only pay if the service was guaranteed to be available on the required day. Additional insights are needed to determine the value they put on these machines and implications on their cost of production. This study confirms CSISA's ongoing work on spreaders as a tool to be used by farmers in their own fields and not for service provision and income generation by serving other farmers.

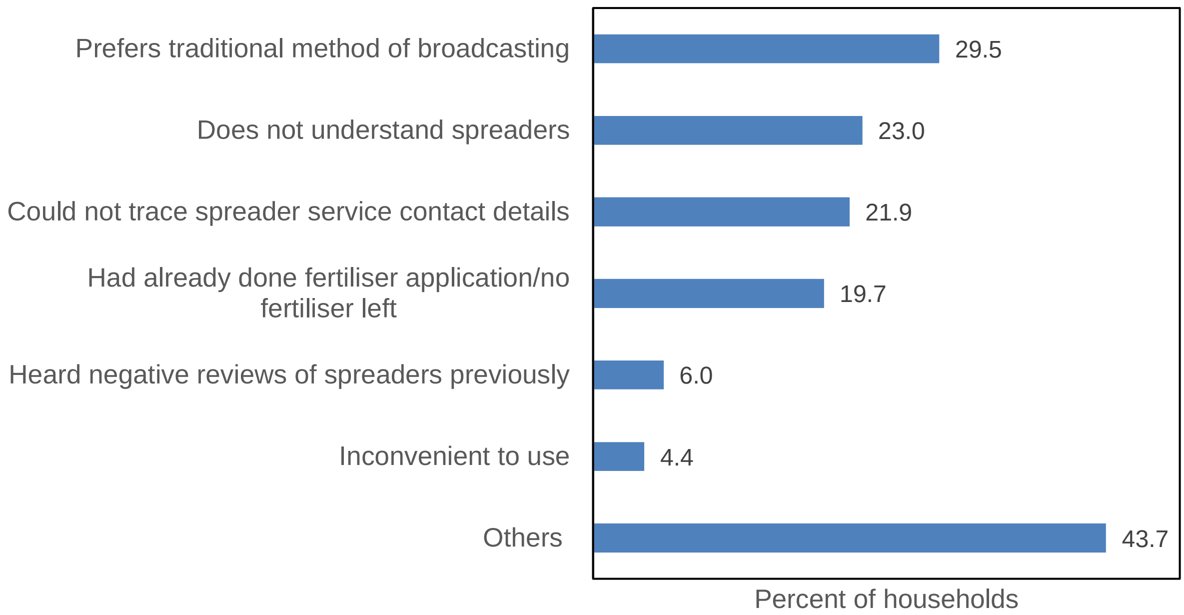


Figure 3.1: Reasons for not availing spreader service among 183 farmer households (IFPRI-CSISA 3 experiment, 2019)

Alongside the experiment, the project also collected data on the farmers' application rates of key fertilizers and sources of purchase to get additional insights into the structural barriers that affect application behavior.

- **Source**: At the country level only cooperatives are allowed to sell urea and diammonium phosphate (DAP), the two most used fertilizers. Nepal often faces fertilizer shortage and farmers try to obtain fertilizer from any source. The surveyed farmers reported that for the 2018 rice season, cooperatives and agro-dealers[12] were the major source of urea and DAP. However, for the 2019 rice season, farmers reported buying these fertilizers mainly from agro-dealers and agents

[12] Who buy from cooperatives and from India and sell in markets where cooperatives are not available

who buy from India and sell in Nepal.

- **Application**: Low usage of other fertilizers was found among the studied farmers, with only 10% of them reporting applying MoP or micronutrients to their fields. It is believed that shortage of supply and lack of information about the benefits of balanced nutrient application are the main barriers to the application of phosphate fertilizers.

Follow up: Leading on from the study findings, the project has therefore initiated discussions with the Sana Kisan Bikash Bank (one of the largest credit and agricultural cooperative networks in Nepal) to carry out a study to identify the constraints to the uptake of MoP and micronutrients in the coming rice season. The study will explore the scope to address information and credit constraints to encourage farmers to carry out balanced fertilizer application.

Regional policy dialogue: As part of the project's engagement with NSAF and policymakers in Nepal, the project held a regional policy dialogue on Innovations for Advancing Farmer's Use of Balanced Nutrient Application in South Asia on 5 September 2019 in Kathmandu. Nineteen policymakers and five private fertilizer company representatives and researchers from India, Nepal, Bangladesh and Sri Lanka attended. The presentations informed Nepalese policymakers on innovations in neighboring countries such as custom blends, experiments and findings on direct-benefit transfers of fertilizers and ground level efforts to promote the balanced application of fertilizers by farmers. There were high-level discussions on Indian fertilizer companies' experiences with producing customized blends and using soil intelligence systems to better target product placement and manage their fertilizer distribution network. A policy brief on balanced nutrient application is being shared with participants and other stakeholders, and is available in Appendix 4 of this report. It is expected to guide Nepal's government to implement important parts of the Agriculture Development Strategy (2014) over the next few years. The project has expressed a willingness to provide cross-country learning at each step.

D4. AGRICULTURAL RISK MANAGEMENT

Bangladesh

Due to staffing changes in the CSISA-IFPRI team and the uncertainty of project funding, agricultural risk management activities have been suspended since 2017/18 to ensure that the efforts of the current team focused on their areas of expertise, i.e., soil fertility management. Given the project's efforts to generate evidence for risk management alternatives in the region, the project is well-placed to undertake relevant analysis if there is continued interest and funding from other partners and policymakers.

Nepal

Owing to funding uncertainty, no further activities were undertaken on agricultural risk management. Additionally, internal staffing changes within the CSISA-IFPRI team led to activities being suspended since 2017/18 to ensure the efforts of the current team focused on their areas of expertise.

4. Challenges Faced During the Reporting Period

CHALLENGES ACROSS COUNTRIES

As described in the 2018-19 semi-annual report, the flow of funds and the amount transferred continue to be uncertain for CSISA. It was not until late May of 2019 that the funds for the 2018-19 year arrived, although they had been programmed to arrive in October of 2018. This has led to delays and cut-backs in planned activities including as described in the text for almost all of CSISA's work packages in Bangladesh, Nepal, and especially on policy reform as described in the sections above. Although he full allocation of funds for the 201819 year did arrive in May 2019, CSISA has to date experienced three years with significant delays in fund transfer and two years during which funds were significantly reduced relative to the planned amount agreed with USAID. To date, CSISA has received only 70% of the overall 5-year planned budget, despite now bring in the last year of formal implementation of the five-year project. For these reasons, CSISA is likely to request a project extension in the coming months.

CHALLENGES IN BANGLADESH

As discussed in the Bangladesh section of the report, the appearance of fall armyworm caused some re-organization of CSISA activities to respond to this serious threat. Although fall armyworm was not initially part of CSISA's initial workplan, maize production is crucial to the project's objectives to increase productivity and resilience in South Asia's cereal systems. CSISA has and will continue to stop-gap on this important topic and work on fall armyworm response until the MSU funds are received for the "Fighting back against fall armyworm" project are received; even after receipt, the project will support to some extent with staff time and intellectual contributions to fall armyworm response activities. In addition to fall armyworm, and as described in section 1.C.2.2, a reduction in the national wheat cropping area in Bangladesh due to the threat of wheat blast, reduced government subsidies for wheat, low grain prices and less economic returns than competing crops, meant that the project achieved only 4,523 ha of early sown wheat compared to its 8,000 ha target for 2018/19.

CHALLENGES IN NEPAL

As described in the 2018-19 semi-annual report, activities in Nepal have also been significantly challenged due to funding delays and shortfalls (as described above).

A relatively consistent and ongoing challenge faced by the project in this period was the uncertainty and lack of permanent governmental agricultural staff working in Nepal's newly formed provinces. The government's new federal constitution, which was promulgated in 2015, began to take full effect in 2017 through to the end of 2018 with the election of the three new tiers of government – federal, provincial and local governments. In the reporting period, these levels of government continued to sort out their relative responsibilities in line with the devolution of responsibilities from central to provincial and local governments. The latter two levels are intended to be more responsible for supporting farmers than under the previous Ministry of Agriculture and district agriculture offices. The project continued to engage closely with governmental partners during this transition period, but has in a number of cases suffered as plans have been made that had to be later abandoned due to provincial and local government staff changes and modifications to governmental priorities.

5. Additional Information

ENGAGEMENT WITH MISSIONS, FEED THE FUTURE PARTNERS AND PROJECT SUB-CONTRACTORS[13]

USAID/Bangladesh Mission

In Bangladesh, the project leader regularly updates USAID/Bangladesh Mission staff who come under the Office of Economic Growth about ongoing activities at formal and informal meetings. The project is also regularly consulted by the Mission on cereal-based cropping systems, agricultural mechanization and appropriate agricultural development investments. Notable consultations in this reporting period include requests for information and ideas on improving gender mainstreaming in agricultural development, in addition to the solicitation of ideas for future investments. During the reporting period, the project cooperated with the USAID/Bangladesh Mission in coordinating and supporting USAID's response to fall armyworm in Bangladesh (see Section C.2.3).

USAID/Nepal Mission

The project continued to engage with the Nepal Mission in the following areas during this reporting period:

- The provision of technical advice and extension media to the KISAN II project (USAID Nepal's flagship Feed the Future program) on staple crop management and private sector development in support of the implementation of Nepal's Agricultural Development Strategy (2015–2035).
- Shared technical insights into challenges and opportunities confronting the sustainable intensification of lentil production in Nepal to USAID-funded projects, principally NSAF and KISAN II.

Feed the Future partners

The project also directly collaborated with the following Feed the Future projects:

- **Rice and Diversified Crops Project** – The Rice and Diversified Crops (RDC) Activity is led by the Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance (ACDI-VOCA). It aims to increase incomes and improve food security and nutrition in the Feed the Future zone through systemic market changes that promote a diversified farm management approach oriented to intensified rice production and higher-value, nutrient-rich crops. CSISA Phase III provides regular technical advice to RDC.
- **Cereal Systems Initiative for South Asia** – The CSISA Mechanization and Irrigation (CSISA-MI) project, which began in 2013 emerged out of CSISA's efforts in the USAID/Bangladesh Mission-funded CSISA expansion project (2010–15), and during CSISA Phase II. It is 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 was a five- year project (July 2013–September 2018, which secured a no-cost extension to September 2019. CSISA-MI focuses on improving agricultural productivity through the increased adoption of agricultural mechanization technologies and services. A second phase has now been approved and the CSISA Phase III team was intimately involved in the development of the USAID proposal to USAID that achieved the award. The CSISA-MI Project Leader participates in the overall India-Nepal-Bangladesh CSISA

[13] A full list of partners and details can be found in Appendix II.

Management Committee, and the committee's coordinator (the CSISA Phase III Project Leader for Bangladesh and Nepal) sits on CSISA-MI's executive committee and regularly contributed to strategy making in this reporting period.

- **Wheat blast research** – Although it does not fall under the Feed the Future program, CSISA wheat blast research activities on disease forecasting and modeling are 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. The strategic alignment of these activities with CSISA Phase III is assured as CSRD's project leader is now also the project leader of CSISA Phase III Bangladesh and Nepal.
- **The Nepal Seed and Fertilizer (NSAF) project** (2016–21) is a $15 million USAID-Nepal initiative and a direct outshoot of progress made by CSISA on seed systems and integrated soil fertility management. CSISA staff collaborate frequently and deeply with NSAF on scientific and operational matters.
- **The KISAN project** – The Knowledge-based Integrated Sustainable Agriculture and Nutrition project is part of USAID's global Feed the Future initiative. It is a five-year project (2017–22) which is facilitating systemic changes in the agricultural sector including: (i) greater climate-smart intensification of staple crops and diversification into higher value commodities; (ii) strengthening local market systems to support more competitive and resilient value chains and agricultural related businesses, and (iii) improving the enabling environment for agricultural and market systems development. This project reaches of hundreds of thousands of farmers, many of whom have been exposed to CSISA information, materials, and technologies through the partnership between CSISA and KISAN.

Project sub-contractors

CSISA Phase III maintains three sub-contractual partners in Bangladesh, who are essential for scaling-out project-supported technologies and for reaching farmers. This is particularly important as the project is coordinated through a partnership of three research institutions. These partnerships enable the dissemination of CGIAR research findings to farmers through knowledge products. Details of what each of these partners achieved can be found throughout this report in the sections for Bangladesh and Nepal in particular.

CSISA vets and selects partners based on their alignment with the CSISA approach and their ability to generate impact at scale. In this reporting period the project maintained partnerships with the following three organizations:

- **Agricultural Advisory Society** – The Agricultural Advisory Society (AAS) is a Bangladeshi NGO that works to improve the economic condition of small and poor farmers by improving their agricultural skills and capacities and by demonstrating ways in which they can better manage available resources. The purpose of the project's sub-agreement with AAS is to increase knowledge, skills, and practice of farmers on quality rice seedling production, early wheat sowing and to combat fall armyworm through video shows in the project areas in Bangladesh.
- **Agricultural Input Retailers' Network** – Bangladesh's Agricultural Input Retailers' Network (AIRN) was formed as a result of efforts led by Cultivating New Frontiers in Agriculture (CNFA), a previous USAID funded agricultural inputs project. Partnering with CSISA, AIRN trains input dealers on the principles and practices of integrated weed management and on combatting fall armyworm.
- **The Bangladesh Rice Research Institute (**BRRI) was founded in 1970 and is the country's apex rice research body. BRRI assists the project with the following activities:

1. Implementing on-farm trials of new premium quality rice varieties in 6 upazilas (sub-districts) in three CSISA hubs to identify best-bet premium quality varieties in terms of yield and farmers', millers' and traders' preferences.
2. On-farm performance evaluations of integrated weed management options to increase yield and profits in farmers' fields.
3. On-station trials to develop and fine tune the mat nursery method of raising rice seedlings for manual transplanting.
4. Organizing additional on-farm trials.

- **The Bangladesh Wheat and Maize Research Institute** – The project's agreement with the Bangladesh Wheat and Maize Research Institute (BWMRI), founded in 2019, has established a cooperative and mutually beneficial relationship for carrying out activities with CIMMYT on the following topics:
    1. germplasm exchange, development, delivery, intensification and diversification;
    2. promoting sustainable intensification-based conservation agriculture crop management and improved seed system farm equipment and machinery;
    3. addressing socio-economic and policy constraints that affect the adoption of new technologies;
    4. mainstreaming gender concerns in research for development;
    5. building the capacity of national scientists and partners through training;
    6. engaging the private sector on value chain and market development to benefit maize and wheat farmers.
    7. CSISA leverages this agreement and cooperates with BWMRI on all wheat related work in Bangladesh that the project focuses on.

The details of what the partners achieved in the reporting period are given throughout the report and principally in Chapters 2 and 3.

See Annex 2 for more details on project subcontractors and key partners.

Appendix 1: CSISA III Key Leadership Staff

Name	Role	Institution	Address	Phone	Email
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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 policies, and being integrated in the Ministry of Agriculture, BARI provides leveraging opportunities to mainstream sustainable intensification innovations into the Government of Bangladesh's National Agriculture Research and Extension System.	In 2016, the previous sub-grant was amended and the deliverables shifted towards the newly established Bangladesh Wheat and Maize Research Institute (BWMRI) (see below).
Bangladesh Wheat and Maize Research Institute (BWMRI)	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 inputs into the development of extension materials, approaches and policies, and being integrated in the Ministry of Agriculture, BWMRI provides leveraging opportunities to mainstream sustainable intensification innovations into the Government of Bangladesh's National Agriculture Research and Extension System.	The Wheat Research Centre (WRC), a former component of BARI, was transformed into BWMRI in mid-2018. In 2019 CIMMYT signed a sub-grant agreement with BWMRI to continue research on wheat blast and other subjects.
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 inputs into the development of extension materials, approaches and policies, and being integrated in the Ministry of Agriculture, BRRI also provides leveraging opportunities to mainstream sustainable intensification innovations in the Government of Bangladesh's National Agriculture Research and Extension System.	The International Rice Research Institute (IRRI) maintains a formal partnership with BRRI. BRRI collaborated with CSISA in Phases I and II, continuing in Phase III. Funding for BRRI's research partnership was on hold due to fund unavailability, but restarted in 2019 with USAID funds.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Department of Agricultural Extension (DAE)	Extension and scaling	Achieving impact at scale	The DAE has over 13,000 field extension agents located across Bangladesh. The department collaborated with CSISA Phase II and the USAID/Bangladesh Mission funded CSISA Expansion project in Bangladesh in the Feed the Future zone and Dinajpur hub. The sensitization of DAE agents on sustainable intensification technologies and approaches provides large opportunities for reaching and raising the awareness of farmers, with sustainability through messaging after Phase III ends.	The project continues to collaborate with DAE informally and synergistically, despite funding cuts. The volume of activities reduced in reporting period due to the project's inability to support large field campaigns and collaborative meetings with DAE. CIMMYT also worked with DAE through its Climate Services for Resilient Development (CSRD) and the USAID/Bangladesh mini-grant on wheat blast that closed in September of 2019. And as a part of project activities, the DAE works with CIMMYT to disseminate better bet agronomic practices. In this period, DAE spread messages developed by CIMMYT, BARI and BWMRI on early wheat sowing and fighting wheat blast.
Agricultural Information Services (AIS)	Production of extension materials for DAE use	Achieving impact at scale	AIS is a government agency that produces extension materials and media used by DAE. Strategic partnerships with AIS facilitate the integration of sustainable intensification principles into extension materials and messaging.	Collaboration continued informally. In Dinajpur, AIS supported project activities by conducting village level video showings and trainings on healthy rice seedlings and early wheat sowing.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
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	The commercial joint venture agreement with this firm was terminated in 2017 due to funding uncertainties and fund transfer delays to CSISA from USAID. However, since then, CSISA has maintained active discussions with this partner and could re-establish relations if clear funding timing and commitments can be provided by USAID.
Metal Pvt. Ltd	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	The commercial joint venture agreement with this firm was terminated in 2017 due to funding uncertainties and fund transfer delays to CSISA from USAID. However, since then, CSISA has maintained active discussions with this partner and could re-establish relations if clear funding timing and commitments can be provided by USAID.
Rangpur Foundry Limited (RFL)	Development and sales of scale-appropriate machinery	Achieving impact at scale	Import of sustainable intensification scale-appropriate machinery and sales through the private sector	The commercial joint venture agreement with this firm was terminated in 2017 due to funding uncertainties and fund transfer delays to CSISA from USAID. However, since then, CSISA has

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
				maintained active discussions with this partner and could re-establish relations if clear funding timing and commitments can be provided by USAID.
Advanced Chemical Industries (ACI)	Sale of scale-appropriate machinery, fungicides, weed control products and seed. IRRI works with ACI to produce a range of hybrid and open-pollinated rice seeds	Achieving impact at scale	Import of sustainable intensification scale-appropriate machinery and sales through the private sector, along with a range of chemical and cereal seed products.	The commercial joint venture agreement with this firm was terminated in 2017 due to funding uncertainties and fund transfer delays to CSISA from USAID. However, since then, CSISA has maintained active discussions with this partner and could re-establish relations if clear funding timing and commitments can be provided by USAID.
NGOs				
Agricultural Advisory Society (AAS) (project subcontractor)	Facilitates village screenings of training films and conducts follow-up studies	Achieving impact at scale	The project worked with AAS in Phase II and CSISA-Bangladesh to reach 110,000 farmers with village training video screenings accompanied by question and answer sessions to raise awareness among farmers on scale-appropriate machinery and associated crop management practices. During CSISA III, AAS is working to promote better bet agronomy practices including healthy rice seedlings, early wheat sowing and fighting the fall armyworm.	AAS works under project sub-grants to conduct village-level video shows and on training farmers on core CSISA topics.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Agro-Input Retailers Network (AIRN) (project subcontractor)	Trains input dealers and retailers	Achieving impact at scale	AIRN was awarded sub-grants in project year 2018/19 for i) training AIRN dealers on the principles and practices of integrated weed management and ii) equipping them to fight the threat of fall armyworm.	Partnering with the project, AIRN trained input dealers on the principles and practices of integrated weed management and fall armyworm management.
Universities				
Department of Crop Sciences at the University of Illinois at Urbana-Champaign (UIUC)	Strategic research on precision nutrient and rice crop management	Innovation towards impact	The project leader is an active academic committee member for Shah-Al Emran, a Bangladeshi PhD student at this university. Emran is working towards the production of two manuscripts using CSISA data.	Ongoing successful partnership.
Wageningen University	Strategic research on farmer decision making processes and the intensification of fallow fields	Innovation towards impact	Strategic high-end research capacity to assist in the analysis of farmer decision-making processes on intensification decisions	A formally established working relationship with CIMMYT for 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 the rapid prototyping of machinery innovations and technical support on testing in collaboration with BARI	Established informal relationship in support of CSISA III, with ongoing collaboration on manuscripts related to machinery engineering and development. A manuscript on the prototype laboratory is under development.
Bangladesh Agricultural University	Bangladesh's largest and first agricultural university	Innovation towards impact	Bangladesh's largest agricultural university has large influence over the next generation of agricultural scientists, many of who will go on to work in BARI, BRRI and the DAE.	The relationship with this university continued informally. Increased collaboration on fall armyworm control is under way at the time of reporting.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Projects				
Sustainable and Resilient Farming Systems Intensification in the Eastern Gangetic Plains (SRFSI)	Extending CSISA technologies to areas of Northern Bangladesh	Achieving impact at scale	CSISA's experiences in scaling up resource conserving technologies in Bangladesh are an asset to jump start new technologies in northern Bangladesh. This Australian Centre for International Agriculture Research (ACIAR) funded project is scaling up these activities. CSISA supports NARC and other SRFSI partners to spread its technologies.	Active partnership since 2014
Cereal Systems Initiative for South Asia – Mechanization and Irrigation (CSISA-MI	CSISA-MI aims to transform agriculture in southern Bangladesh by unlocking potential productivity through irrigation, small-scale agricultural machinery and agricultural services provision. CSISA III supports CSISA-MI in that CSISA-MI is aligned with the overall CSISA portfolio and the CSISA-MI Project Leader is a member of the overall CSISA Management Committee.	Achieving impact at scale	CSISA-MI is led by CIMMYT in partnership with International Development Enterprises (iDE) under the Feed the Future Initiative. The project has developed and trained local agricultural service providers, created an agricultural mechanization value chain and scaled-out agricultural machinery services across the FtF zone. Through private sector dealers and manufacturers, axial flow pumps, power tiller operated multi-crop seeders and harvesters were introduced for which farmers receive these mechanized services at a reasonable cost, for improved productivity. CSISA Phase III leverages this project's work by aligning its themes with geographies where local service providers have emerged, particularly with respect to fallows development through irrigation, reapers to facilitate rapid rice harvesting and early wheat sowing, and directly sown rice.	Active since 2013 in CSISA Phase II
Rice and Diversified Crops (RDC) Activity	RDC is led by ACDI-VOCA and is working to i) improve food security through systemic changes that	Achieving impact at scale	The USAID Feed the Future Bangladesh Rice and Diversified Crops (RDC) Activity is increasing incomes and improving food security and nutrition in the Feed the Future zone through systemic market changes that	Active since 2016. CSISA Phase III is in discussions with RDC regarding collaboration on integrated weed management and linkages with the

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	increase rural incomes, ii) increase farm productivity and iii) increase farmers' participation in profitable market systems		promote a diversified farm management approach oriented to intensified rice production and higher-value, nutrient-rich crops. RDC is working towards its goals through targeted technical assistance to create scalable market system impacts, ultimately benefiting rural households and expanding opportunities for women and youth.	private sector. CSISA also advises RDC on a regular yet informal basis.

NEPAL

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Government of Nepal				
Ministry of Agriculture and Livestock Development	Technical guidance for Government of Nepal investments in agricultural development	All themes	The government's Agriculture Development Strategy (2015–2035) was approved in late 2015. CSISA acts as a technical partner to shape the loan and investment programs associated with the strategy, which may exceed $100 million.	Active and sanctioned by CIMMYT's host country agreement
Nepal Agricultural Research Council (NARC)	Strategic and applied research on sustainable intensification technologies, crop diversification, and crop management practices	Innovation towards impact	NARC is responsible for providing the scientific basis for all state recommendations, their endorsement and the ownership of emerging sustainable intensification technologies.	Active and long-standing
Provincial governments	To strengthen provincial level policies and provincial government support for agricultural development activities	Achieving impact at scale	Provincial governments are the middle tier of government under the new federal constitution and have a large degree of independence. They have important policy making and oversight roles on agricultural development. In this reporting period the project engaged with and supported the Province 5 and Far Western Province governments.	Active and new since federal government restructuring
Local governments	To strengthen local government support for agricultural development activities	Achieving impact at scale	Local governments are the local tier of government under the new constitution. They have significant roles for implementing agricultural development in their areas and are thus important stakeholders that the project seeks to engage.	Active and new since federal government restructuring
Nepali private sector				
DKAM (farm machinery importer/dealer)	Introduction and market development of reaper-harvesters in Dang (Province 5)	Achieving impact at scale	The rapid expansion of investments in scale-appropriate machinery and support for emerging service provision markets.	Initiated in first half of project year 2018/19

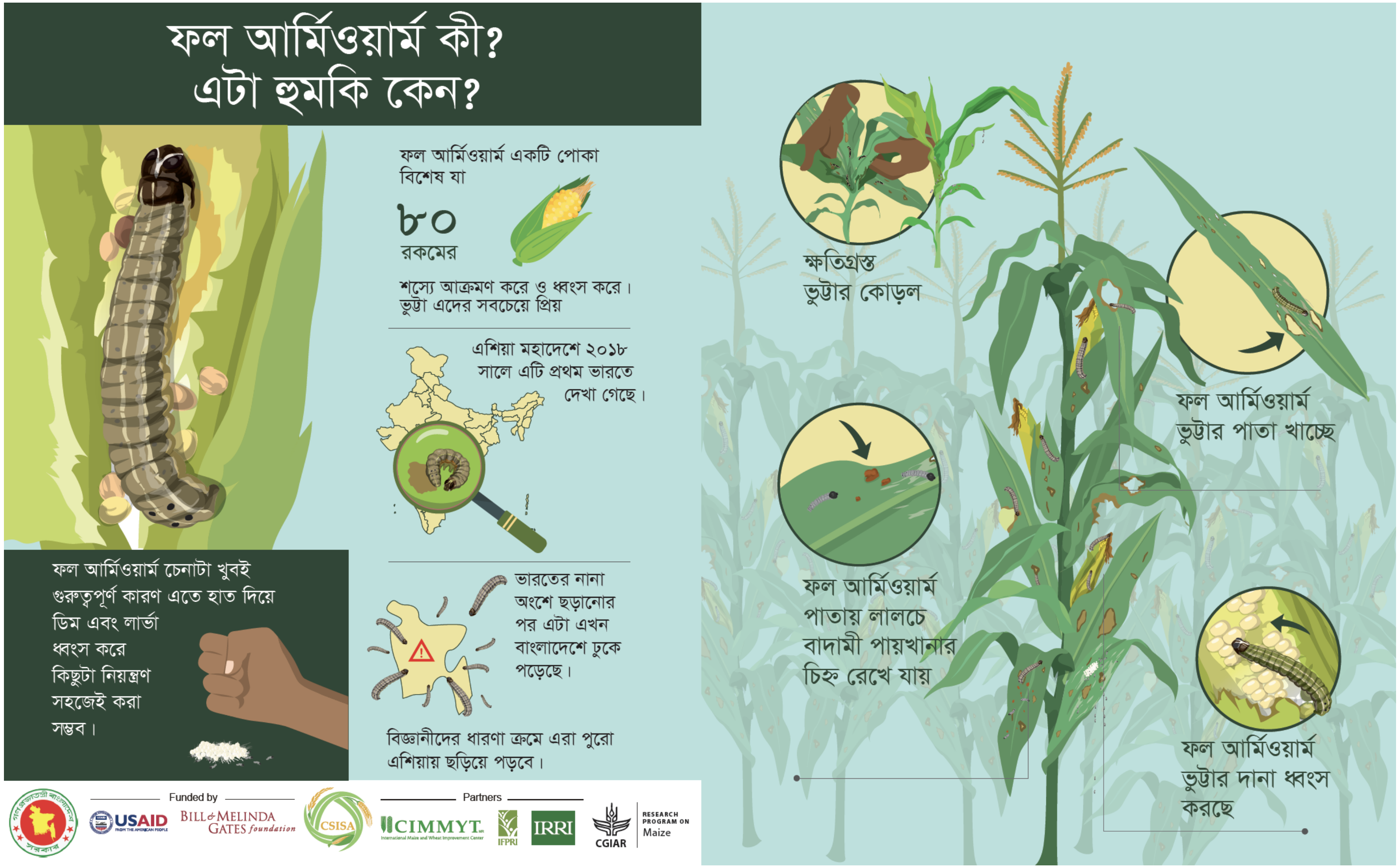
Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Naya Tulsi Traders (farm machinery importer and dealer)	Introduction and market development of reaper-harvesters in Dang (Province 5)	Achieving impact at scale	The rapid expansion of investments in scale-appropriate machinery and support for emerging service provision markets.	Initiated in first half of project year 2018/19
BTL (farm machinery importer and dealer)	Introduction and market development of scale-appropriate machinery	Achieving impact at scale	The rapid expansion of investments in scale-appropriate machinery and support for emerging service provision markets.	Active and long-standing
SK Traders (farm machinery importer and dealer)	Introduction and market development of scale-appropriate machinery	Achieving impact at scale	The rapid expansion of investments in scale-appropriate machinery and support for emerging service provision markets.	Active and long-standing
Dahal (farm machinery importer and dealer)	Introduction and market development of scale-appropriate machinery	Achieving impact at scale	The rapid expansion of investments in scale-appropriate machinery and support for emerging service provision markets.	Active and long-standing
NIMBUS (Nepali feed mill company)	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
Trade associations				
Nepal Agricultural Mechanization Association (NAMeA)	Trade association formed CIMMYT's help to create an enabling environment and policy dialogue for scale-appropriate mechanization	Systemic change towards impact	Important voice for the private sector with GoN as Agriculture Development Strategy support programs take shape.	Active since 2014
Seed Entrepreneurs Association of Nepal (SEAN)	Trade association strengthened with help of CSISA to create an enabling environment and policy dialogue for strengthening seed system and small and medium seed enterprises in Nepal	Systemic change towards impact	Important voice for the private sector with GoN as Agriculture Development Strategy support programs take shape. Provided input to studies on maize hybrids in Nepal	Active and long-standing

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Universities				
Agriculture and Forestry University (Rampur, Chitwan)	Expanded use of digital data collection tools for field diagnostic surveys	Innovation towards impact	Engagement with students and professors to conduct field work and do thesis with CSISA	Previously established and re-invigorated in the reporting period
Wageningen University	Role of livestock and value chains in farmers' 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 formulating new research questions.	Active since 2012
Projects				
Knowledge-based Integrated Sustainable Agriculture and Nutrition (KISAN)	Strategic partnership to co-support 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 $20 million five-year program to advance food security by increasing agricultural productivity. KISAN uses CSISA's technical and extension materials and advice to improve the uptake of better-bet sustainable agriculture production and post-harvest practices and technologies for cereals. KISAN reaches hundreds of thousands of farmers and exposes them to CSISA information, materials, and technologies.	Active since KISAN's first phase
Nepal Seed and Fertilizer Project (NSAF)	Strategic partnership to co-support the large-scale deployment of extension information and technologies	Achieving impact at scale	The USAID Nepal-funded NSAF project ($15m for 2016–2021) focuses on the applied science-to-development continuum, including market facilitation to expand private sector-led fertilizer and seed sales. CSISA is disseminating the better-bet technologies at scale through NSAF's networks.	Active since 2016/17

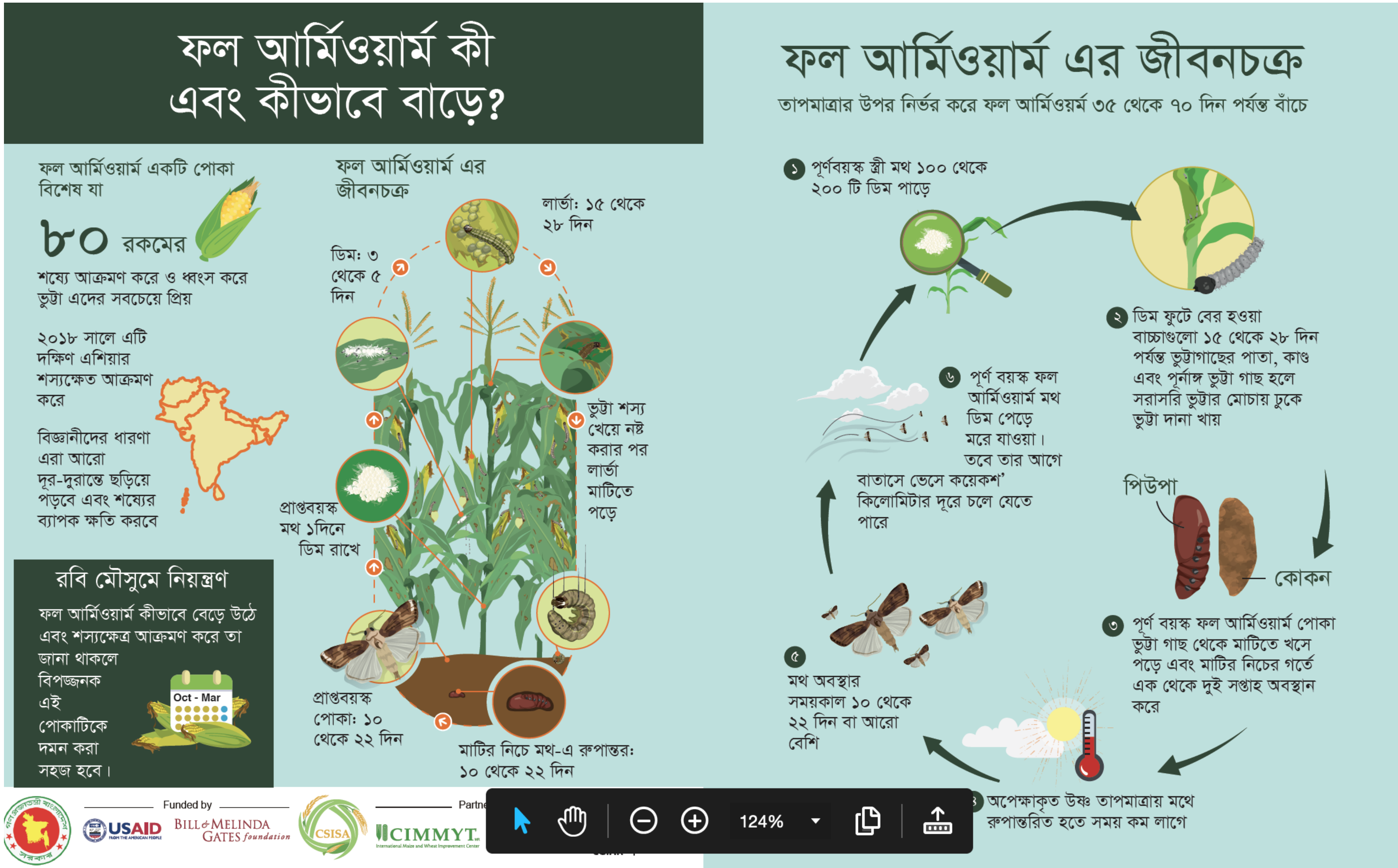
Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Sustainable and Resilient Farming Systems Intensification in the Eastern Gangetic Plains (SRFSI)	Extending CSISA technologies to areas of eastern Nepal	Achieving impact at scale	CSISA's experiences in scaling up resource conserving technologies in western Nepal are an asset to jump start technologies in eastern Nepal. The ACIAR funded SRFSI is scaling up these activities. CSISA is supporting NARC and other SRFSI partners to spread its technologies.	Active since before 2016/17
CSISA Agronomy and Seed Systems Scaling	Strengthening scaling efforts related to best practices for agronomy and improved seed systems for smallholder farmers.	Achieving impact at scale	The CSISA Scaling project (i) strengthens seed systems to give farmers timely access to improved varieties and hybrids of pulses, wheat and maize; (ii) targets niches and identifies practices that enable cropping system intensification by cultivating lentils and mung beans; (iii) recommends best management practices for wheat; (iv) facilitates market development that enables precise nutrient management; and (v) supports the expansion of the private sector for sustainable intensification technologies into western Nepal, including the availability of spares and repairs and service providers to give farmers affordable access to new technologies. CSISA Phase III leverages this project by supplying research information, technologies and recommendations that it scales-out.	Active since 2014. Note that this project ended on 30 September 2019 following a no-cost extension.

Appendix 3: Bangladesh Fall Armyworm Taskforce Approved Versions of CSISA Fall Armyworm Infographics Developed by CSISA During the Reporting Period

Note: The new versions are in the Bangla language. The English language versions of these infographics can be found in the 2018/19 CSISA semi-annual report. These infographics were used by USAID for the Fall Armyworm Global PERSUAP) (Pesticide Evaluation Report and Safer Use Action Plan), which was released in the second half of 2019.



ফল আর্মিওয়ার্ম চেনার উপায়
গুচ্ছ ডিম
গুচ্ছ ডিম খুবই ছোট এবং সাদা,
এগুলো পাতার নিচের দিকে থাকে।
ডিম ফুটে বের হওয়া
ডিম ফুটে বাচ্চা বের হওয়ার
সময় হলে এগুলোকে
অনেকটা সিগারেটের
ছাইয়ের মতো দেখায়।
ফল আর্মিওয়ার্ম এর বাচ্চা
ডিম ফুটে শ'খানেক বাচ্চা হামাগুড়ি
দিয়ে বের হয়ে আসে। এসময়
এদের মাথা কালো থাকে।
বড় হতে থাকা ফল আর্মিওয়ার্ম
বাচ্চা ফল আর্মিওয়ার্ম বা লার্ভা
১ মি.মি.
মাঝবয়স্ক লার্ভা
প্রাপ্তবয়স্ক লার্ভা
৪৫ মি.মি.
পূর্ণবয়স্ক ফল আর্মিওয়ার্ম
ইংরেজি ওয়াইয়ের মতো
স্পষ্ট সাদা দাগ থাকে
mark on
their heads
লেজ
মাথা
শরীরের পিছনের দিকে
একত্রে বর্গক্ষেত্রের চার
কোনার মতো চারটি
কালো বিন্দু থাকে
পিউপার রঙ লালচে-বাদামি
১৫ মি.মি.
লালচে-বাদামি ফল আর্মিওয়ার্ম পিউপাকে পূর্ণবয়স্ক
মথ-এ রূপান্তরিত হওয়ার আগ পর্যন্ত মাটিতে
পাওয়া যেতে পারে।
এইরকম দেখতে
গুটিও খুঁজে পেতে
পারেন মাটির ২ থেকে
৮ সে.মি. গভীরে।
পূর্ণবয়স্ক মথ
পূর্ণবয়স্ক পুরুষ মথের ডানার
কিনারায় স্পষ্ট সাদা দাগ থাকে।
ছড়ানো অবস্থায় পাখাসহ প্রস্থ
৩৮ মি.মি.
পূর্ণবয়স্ক স্ত্রী মথ
বৈচিত্র্যহীন। এদের
ডানার কিনারায়
সাদা দাগ থাকে না।
সিরিয়াল সিস্টেমস ইনিশিয়েটিভ ফর সাউথ এশিয়া (সিসা) প্রকল্প শুরু হয়েছে ২০০৯
হিসেবে আছে আন্তর্জাতিক খাদ্য নীতি গবেষণা ইন্সটিটিউট (ইফপ্রি) ও আন্তর্জাতিক
বিল এ্যাণ্ড মেলিণ্ডা গেট্স ফাউণ্ডেশন, ইউএসএইড, এবং যুক্তরাষ্ট্রের সরকারকে দায়ী
Correct citation: Krupnik, T.J. and Dhungana, H. (2019) What is Fall Armyworm and
আন্তর্জাতিক ভুট্টা ও গম উন্নয়ন কেন্দ্র, ১০/বি, রোড ৫৩, গুলশান ২, ঢাকা থেকে এপ্রিল ২০১৯ এ প্রকাশিত
International Maize and Wheat Improvement Center (CIMMYT).
Office: House 10/B. Road 53. Gulshan-2. Dhaka, 1213, Bangladesh



ফল আর্মিওয়ার্ম কী
এবং কীভাবে বাড়ে?
ফল আর্মিওয়ার্ম একটি পোকা বিশেষ যা
৮০ রকমের
শস্যে আক্রমণ করে ও ধ্বংস করে
ভুট্টা এদের সবচেয়ে প্রিয়
২০১৮ সালে এটি দক্ষিণ এশিয়ার শস্যক্ষেত আক্রমণ করে
বিজ্ঞানীদের ধারণা এরা আরো দূর-দূরান্তে ছড়িয়ে পড়বে এবং শষ্যের ব্যাপক ক্ষতি করবে
রবি মৌসুমে নিয়ন্ত্রণ
ফল আর্মিওয়ার্ম কীভাবে বেড়ে উঠে এবং শস্যক্ষেত্র আক্রমণ করে তা জানা থাকলে বিপজ্জনক এই পোকাটিকে দমন করা সহজ হবে।
Oct - Mar
ফল আর্মিওয়ার্ম এর জীবনচক্র
লার্ভা: ১৫ থেকে ২৮ দিন
ডিম: ৩ থেকে ৫ দিন
ভুট্টা শস্য খেয়ে নষ্ট করার পর লার্ভা মাটিতে পড়ে
প্রাপ্তবয়স্ক মথ ১দিনে ডিম রাখে
প্রাপ্তবয়স্ক পোকা: ১০ থেকে ২২ দিন
মাটির নিচে মথ-এ রুপান্তর: ১০ থেকে ২২ দিন
ফল আর্মিওয়ার্ম এর জীবনচক্র
তাপমাত্রার উপর নির্ভর করে ফল আর্মিওয়ার্ম ৩৫ থেকে ৭০ দিন পর্যন্ত বাঁচে
১ পূর্ণবয়স্ক স্ত্রী মথ ১০০ থেকে ২০০ টি ডিম পাড়ে
২ ডিম ফুটে বের হওয়া বাচ্চাগুলো ১৫ থেকে ২৮ দিন পর্যন্ত ভুট্টাগাছের পাতা, কাণ্ড এবং পূর্ণাঙ্গ ভুট্টা গাছ হলে সরাসরি ভুট্টার মোচায় ঢুকে ভুট্টা দানা খায়
৬ পূর্ণ বয়স্ক ফল আর্মিওয়ার্ম মথ ডিম পেড়ে মরে যাওয়া। তবে তার আগে বাতাসে ভেসে কয়েকশ' কিলোমিটার দূরে চলে যেতে পারে
পিউপা
কোকন
৩ পূর্ণ বয়স্ক ফল আর্মিওয়ার্ম পোকা ভুট্টা গাছ থেকে মাটিতে খসে পড়ে এবং মাটির নিচের গর্তে এক থেকে দুই সপ্তাহ অবস্থান করে
৫ মথ অবস্থার সময়কাল ১০ থেকে ২২ দিন বা আরো বেশি
৪ অপেক্ষাকৃত উষ্ণ তাপমাত্রায় মথে রুপান্তরিত হতে সময় কম লাগে
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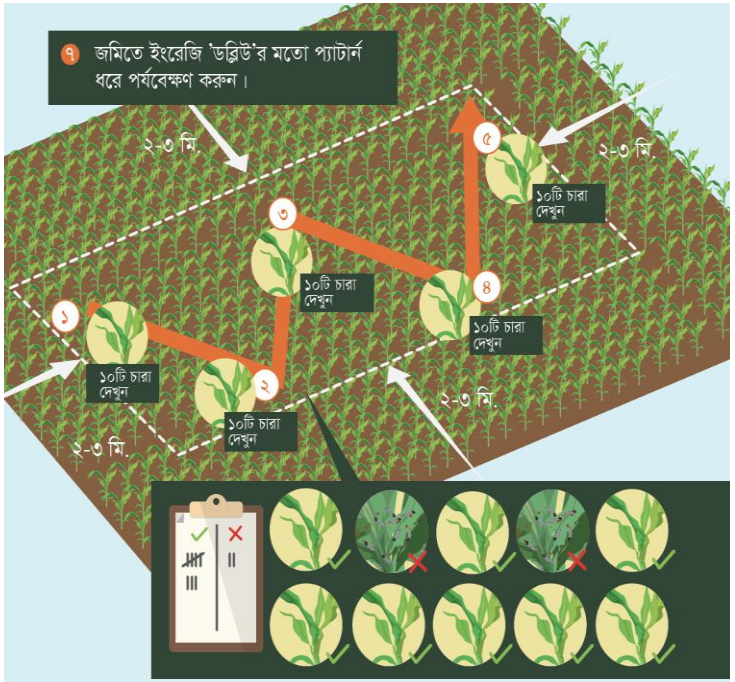
ফল আর্মিওয়ার্ম এর জীবনচক্রের বিভিন্ন ধাপে কীভাবে এদের দমন করা যায়?
ডিমগুলো সাধারণত: পাতার নিচের দিকে থাকে। এগুলো খুঁজে বের করে ধ্বংস করুন।
ফল আর্মিওয়ার্ম নিয়ন্ত্রণ সহজ হয় যখন
এদের বয়স ১০ দিনের কম থাকে
কাজেই শুরুতেই ঘন ঘন ক্ষেতে পর্যবেক্ষণ করুন
জমিতে নিয়মিত নজরদারি করলে বাচ্চা পোকা দেখতে পাবেন এবং খালি হাতে সেগুলোকে পিষে মেরে ফেলুন
সাথি ফসল চাষ পদ্ধতিতে ফল আর্মিওয়ার্ম দিশেহারা হয় ও ছড়ায় না বলে জীবনচক্রের যেকোন সময় এদের নিয়ন্ত্রণ করা যায়।
সাথি ফসল
সেচের সময় ক্ষেতে এমনভাবে পানি দিন যাতে কয়েক সেন্টিমিটার পানি জমে থাকে এতে মথ পর্যায়ে রুপান্তরের জন্য মাটিতে যে পোকাগুলো থাকবে তারা ডুবে মরে যাবে
সেচহীন জমি
সেচের জমি
চাষিবান্ধব যেসব মাকড়শা বা পোকা রয়েছে সেগুলোর যত্ন নিন যাতে তারা লার্ভা বা ডিম ধ্বংস করতে পারে।
কৃষি সম্প্রসারণ কর্মকর্তার সাথে পরামর্শ করে কেবলমাত্র একজন সনদপ্রাপ্ত স্বীকৃত কীটনাশক প্রয়োগকারীর দ্বারা ওষুধ ব্যবহার করুন। অন্য সব পোকা দমন ব্যবস্থা প্রয়োগ ও ব্যর্থ হলে রাসায়নিক ব্যবহার করুন। মনে রাখবেন রাসায়নিক কীটনাশক উপকারি বন্ধু পোকাও ধ্বংস করে।
কীটনাশক ডিম এবং পাতার নিচে এবং পাতার কোড়লে লুকিয়ে থাকা বাচ্চা
সিরিয়াল সিস্টেমস ইনিশিয়েটিভ ফর সাউথ এশিয়া (সিসা) প্রকল্প শুরু হয়েছে ২০০৯ সালে। এতে নেতৃত্ব দিচ্ছে আন্তর্জাতিক ভুট্টা ও গম উন্নয়ন কেন্দ্র (সিমিট) এবং সহযোগি হিসেবে আছে আন্তর্জাতিক খাদ্য নীতি গবেষণা ইন্সটিটিউট (ইফপ্রি) ও আন্তর্জাতিক ধান গবেষণা ইন্সটিটিউট (ইরি)। এখানে বর্ণিত কোন বিষয় বা মন্তব্যের জন্য কোনভাবেই
ইউএসএইড, এবং যুক্তরাষ্ট্রের সরকারকে দায়ী করা যাবেনা এবং কোন রকম বিজ্ঞাপন বা পন্যে
আন্তর্জাতিক ভুট্টা ও গম উন্নয়ন কেন্দ্র ১০/বি, রোড ৫৩, গুলশান ২, ঢাকা থেকে এপ্রিল ২০
Correct citation: Krupnik, T.J. and Dhungana, H. (2019) What is fall armyworm and how does it grow? International Maize and Wheat Improvement Center. Dhaka, Bangladesh.

৭ জমিতে ইংরেজি 'ডব্লিউ'র মতো প্যাটার্ন ধরে পর্যবেক্ষণ করুন।



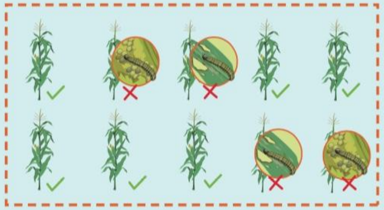
৮ উপরের ছবির মতো জমির ভিতরে (প্রান্তে নয়) ৫টি জায়গায় থেমে দেখুন।

১০ কতগুলো গাছে ফল আর্মিওয়ার্ম আক্রমণ করেছে তা লিখে রাখুন। কতগুলো গাছে আক্রমণ হয়নি তাও লিখে রাখুন।

৯ ৫টি জায়গার প্রতিটিতে ১০টি করে গাছ খেয়াল করুন। উপরের ছবির মতো করে কোন কোন গাছে পোকা দেখেছেন আর কোনগুলোতে দেখেননি তা চিহ্নিত করে রাখুন।

পর্যবেক্ষণে ১০টি চারা গাছের মধ্যে ২টির বেশি ক্ষতিগ্রস্থ পাওয়া গেলে দমন ব্যবস্থাপনা নিয়ে কৃষি সম্প্রসারণ কর্মকর্তা অথবা সিমিটের বিজ্ঞানীর সাথে পরামর্শ করুন

১১ পূর্ণ বয়স্ক ভুট্টা গাছের উপরের তিনটি পাতায় ফল আর্মিওয়ার্মের ক্ষয়ক্ষতির আলামত খুঁজুন।



প্রতি ১০ টি গাছের ৪টিতে ফল আর্মিওয়ার্মের উপস্থিতি বা আক্রমণের চিহ্ন দেখা গেলে, দমন ব্যবস্থাপনা নিয়ে কৃষি সম্প্রসারণ কর্মকর্তা অথবা সিমিটের বিজ্ঞানীর সাথে পরামর্শ করুন

১২ ফল আর্মিওয়ার্মের কারণে শস্যের যথেষ্ট ক্ষতি হয়ে থাকলে, পরামর্শের জন্য কৃষি সম্প্রসারণ কর্মকর্তার সাথে যোগাযোগ করুন।

২টির বেশি
পর্যবেক্ষণে ১০টি গাছের মধ্যে ২টির বেশি চারাগাছ ক্ষতিগ্রস্থ পাওয়া গেলে

৪টির বেশি
পর্যবেক্ষণে ১০টি গাছের মধ্যে ৪টির বেশি বয়স্ক গাছে ক্ষতিগ্রস্থ পাওয়া গেলে

১৩ ক্ষয়ক্ষতির পরিমাণ বেশি হলে কৃষি সম্প্রসারণ কর্মকর্তার সাথে পরামর্শ করে দেখুন বালাইনাশক ব্যবহার করবেন কিনা। বালাইনাশক ছিটানোর জন্য শুধুমাত্র সনদপ্রাপ্ত কর্মীর সহায়তা নিন। এটি সর্বশেষ প্রযুক্তি। পরিবেশের সবচেয়ে কম ক্ষতি করে এমন রাসায়নিক বালাইনাশক বেছে নিন।

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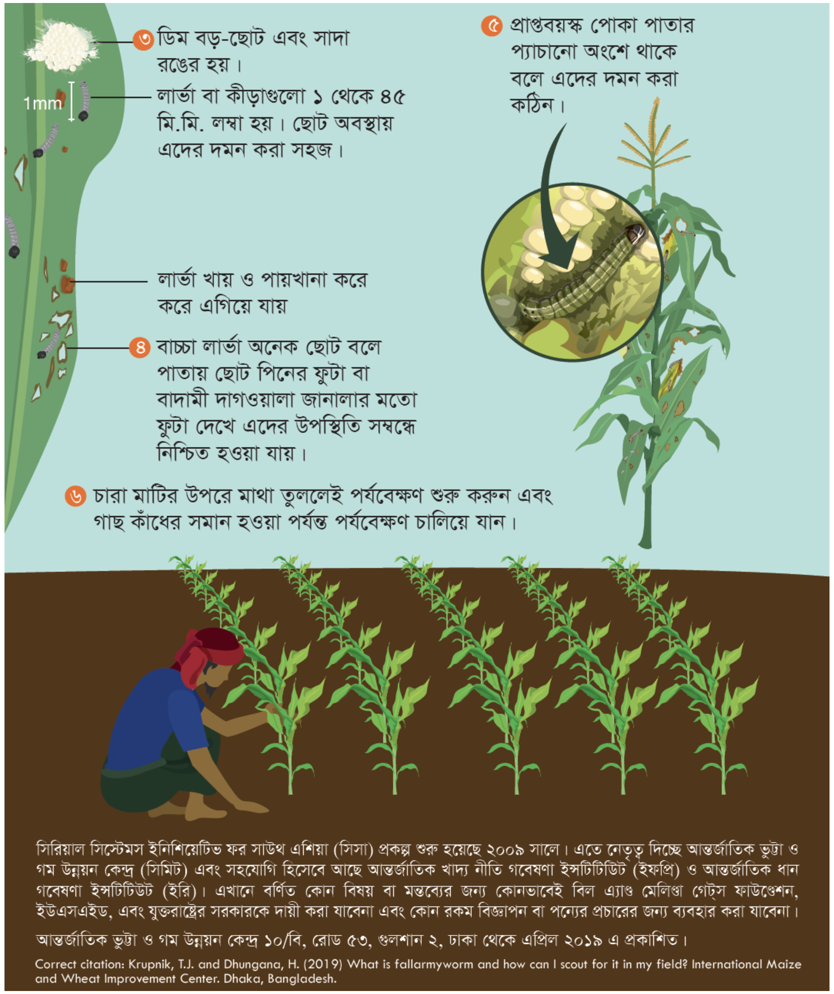

ফল আর্মিওয়ার্মের আক্রমণ হলেকী করতে হবে?
ফল আর্মিওয়ার্ম একটি পোকা বিশেষ যা
৮০
রকমের
শস্যে আক্রমণ করে ও ধ্বংস করে ভুট্টা এদের সবচেয়ে প্রিয়
ফল আর্মিওয়ার্মের বাচ্চা ডিম ফুটে বের হওয়ার পর মাত্র
১ মি.মি.লম্বা হয়
বিজ্ঞনীরা দক্ষিণ এশিয়ায় ফল আর্মিওয়ার্মের উপস্থিতি দেখতে পেয়েছেন এবং আশঙ্কা করছেন এটি কৃষকের ফসলের ক্ষেতে বিপর্যয় ডেকে আনবে।
ফল আর্মিওয়ার্ম দমনের কয়েকটি পদ্ধতি রয়েছে। আসুন সেগুলো শিখি।
আপনার ক্ষেতে পর্যবেক্ষণ করার পর ফল আর্মিওয়ার্মের আক্রমণ ও ক্ষয়ক্ষতি দেখতে পেলে তা দমনে কী করবেন?
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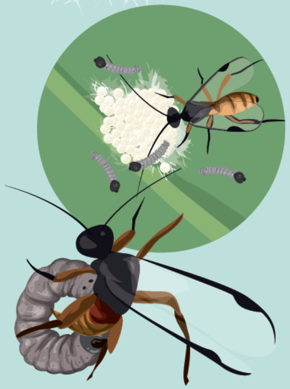
নিয়ন্ত্রণ ব্যবস্থা
পর্যবেক্ষণে ফল আর্মিওয়ার্মের ডিম, বাচ্চা কিংবা পিউপা খুঁজে পেলে হাত দিয়ে পিষে ধ্বংস করুন।
ডিম
বাচ্চা
পিউপা
সেচের সুবিধা থাকলে এমনভাবে সেচ দিন যাতে জমিতে কয়েক সেন্টিমিটার পানি দাড়ায়, এতে পিউপা ডুবে মারা যাবে।
কার্যকর কৃষিতাত্ত্বিক ব্যবস্থায় নিয়ন্ত্রণ
• দেরীতে বীজ বুনবেন না।
দেরীতে বীজ বোনা
• সঠিক সময়ে বীজ বুনুন।
সঠিক সময়ে বীজ বোনা
• সাথি ফসল চাষ করুন। আপনার জমি ও এর আশেপাশের জমিতে ফসলের বৈচিত্র আনুন।
• হাত দিয়ে আগাছা নিধন করুন। এতে জমির পিউপা মরে যাবে।

জৈব কীটনাশক ব্যবহার

- জৈব কীটনাশক যেমন, Bt, এবং Baculovirus- ভিত্তিক জৈব কীটনাশক। Spodoptera frgiperda multiple nucleopolyherovirus ও কার্যকর এবং এতে উপকারী কীটের ক্ষতি কম হয়। এটা ফল আর্মিওয়ার্মকে অসুস্থ করে তোলে ফলে এরা মারা যায়।

- মাকড়শা এবং উপকারী পোকা পালন বা সংরক্ষণ করুন। এরা ফল আর্মিওয়ার্মের ডিম ও লার্ভার ভিতর ডিম পাড়ে। এগুলো কৃষকের বন্ধু, এরা আপনার হয়ে ফল আর্মিওয়ার্মকে মেরে ফেলবে।



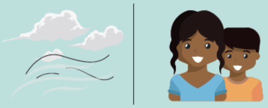
- কিছু মাকড়শা ও পিঁপড়া ফল আর্মিওয়ার্মের ডিম এবং লার্ভা খেয়ে ফেলে।

রাসায়নিকের মাধ্যমে দমন

সতর্কতা

কেবলমাত্র সঠিক পর্যবেক্ষণে অধিকতর ক্ষয়ক্ষতি দেখলে কৃষি সম্প্রসারণ কর্মকর্তা অথবা প্রশিক্ষণপ্রাপ্ত ডিলারের সাথে পরামর্শ করে যদি দেখেন নিরুপায় কেবল তখনই রাসায়নিক কীটনাশক ব্যবহার করবেন। রাসায়নিক কীটনাশক ছিটানোর জন্য শুধুমাত্র সনদপ্রাপ্ত কর্মীর সহায়তা নিন। সঠিক বালাইনাশক বেছে নিন।

পর্যবেক্ষণ ছাড়াই এবং ফল আর্মিওয়ার্মের আক্রমণ বিষয়ে নিশ্চিত না হয়ে রাসায়নিক কীটনাশক ব্যবহার ব্যয়সাপেক্ষ এবং এতে কাজ নাও হতে পারে।



অন্যান্য দমন ব্যবস্থায় ব্যর্থ হলে সর্বশেষ ব্যবস্থা হিসেবে রাসায়নিক কীটনাশক ব্যবহার করুন।

বেশি বাতাসে, এবং যখন শিশু ও অন্য লোকজন কাছাকাছি থাকবে তখন রাসায়নিক কীটনাশক ব্যবহার করবেন না।

ঘরের নিত্যপ্রয়োজনীয় জিনিষের সাথে না রেখে

শিশুদের নাগালের বাইরে একটি তালাবদ্ধ বাক্সে রাসায়নিক কীটনাশক সংরক্ষণ করুন।

সিরিয়াল সিস্টেমস ইনিশিয়েটিভ ফর সাউথ এশিয়া (সিসা) প্রকল্প শুরু হয়েছে ২০০৯ সালে। এতে নেতৃত্ব দিচ্ছে আন্তর্জাতিক ভুট্টা ও গম উন্নয়ন কেন্দ্র (সিমিট) এবং সহযোগি হিসেবে আছে আন্তর্জাতিক খাদ্য নীতি গবেষণা ইন্সটিটিউট (ইফপ্রি) ও আন্তর্জাতিক ধান গবেষণা ইন্সটিটিউট (ইরি)। এখানে বর্ণিত কোন বিষয় বা মন্তব্যের জন্য কোনভাবেই বিল এ্যাণ্ড মেলিণ্ডা গেট্স ফাউণ্ডেশন, ইউএসএইড, এবং যুক্তরাষ্ট্রের সরকারকে দায়ী করা যাবেনা এবং কোন রকম বিজ্ঞাপন বা পন্যের প্রচারের জন্য ব্যবহার করা যাবেনা।

আন্তর্জাতিক ভুট্টা ও গম উন্নয়ন কেন্দ্র ১০/বি, রোড ৫৩, গুলশান ২, ঢাকা থেকে এপ্রিল ২০১৯ এ প্রকাশিত

Correct citation: Krupnik, T.J. and Dhungana, H. (2019) What should I do if I find Fall Armyworm damage? International Maize and Wheat Improvement Center. Dhaka, Bangladesh.

Appendix 4: Regional Policy Dialogue on Soil Fertility Management – Research Note

Development of Balanced Nutrient Management Innovations in South Asia: Lessons from Bangladesh, India, Nepal, and Sri Lanka

Avinash Kishore, Muzna Alvi, Timothy J. Krupnik | October 2019

Introduction

As part of the United States Agency for International Development (USAID)/Washington and Bill and Melinda Gates Foundation supported Cereal Systems Initiative for South Asia (CSISA) and the USAID/Nepal Seeds and Fertilizer (NSAF) project, the International Food Policy Research Institute (IFPRI) and the International Maize and Wheat Improvement Center (CIMMYT) organized a Regional Dialogue on September 5, 2019, in Kathmandu on "Innovations for Advancing Farmers' Use of Balanced Nutrient Application in South Asia." The aim of the event was to facilitate cross-country dialogues on efficient nutrient management in the region. The event saw participation from central and regional government representatives from policy and extension, private fertilizer companies and fertilizer federations, researchers from CGIAR centers, as well as representatives of the donor community. Participants came from India, Nepal, Bangladesh, and Sri Lanka. Interactive discussions were centred around three main themes: (a) cross-country learning and evidence sharing on policies and subsidies to promote balanced nutrient application, (b) market, policy, and product innovations in the fertilizer industry, and (c) learnings and insights on the development of innovative methods in research and extension targeted to farmers. This policy brief summarizes seven key lessons learned from the discussions in the workshop.

Lesson 1: High macronutrient subsidies are common across South Asia

All four countries — Bangladesh, India, Nepal, and Sri Lanka — heavily subsidize urea. Sri Lanka subsidizes urea, phosphate, and potassium-based fertilizers at 78 percent, 83 percent, and 80 percent of the global market price in the 2019 market (Table 1). Subsidies on P and K are smaller in Bangladesh and Nepal. In India, subsidies on nitrogen-based fertilizers are also large and represent a substantial portion of the government's fiscal outlay. The current fertilizer subsidy regime in these countries appears to distort prices and farmers' incentives. A heavy subsidy on urea that ranges from 28 percent to 78 percent across countries, and little to no subsidy on micronutrients, appears to have led to an imbalanced application of fertilizers that can influence soil degradation in intensively cultivated areas of these countries.

Table 1. Prices of urea, phosphate, and potash in Bangladesh, India, Nepal, and Sri Lanka in 2019

Fertilizers	Price (US$/kg)			
	Bangladesh	India	Nepal	Sri Lanka
Urea	0.18	0.08	0.14	0.06
Phosphate	0.30	0.35	0.42	0.06
Potash	0.19	0.23	-	0.06

Source: Sri Lanka — http://ccfl.gov.lk/web/index.php/en/products/fertilizer-price-list; Nepal, India, and Bangladesh gazetted government sources.

Lesson 2: Abolition of fertilizer subsidies does not last

There have been major changes in fertilizer subsidies across the region over the last 25 years. Bangladesh, Nepal, and Sri Lanka all experimented with abolishing or drastically reducing fertilizer subsidies, only to restore them after a few years. The impact of temporary abolition of these subsidies on farmers' welfare, farming practices, or balanced use of nutrients are not well documented. There has been little systematic analysis of the reasons for the abolition and subsequent reinstatement of fertilizer subsidies and their rates across the three countries. Understanding the reasons for these policy reversals could assist in devising more practical and economically sound policy recommendations. While abolishing subsidies may, in theory, be a desirable approach to correct for a long history of market distortions, it is unlikely to be politically feasible nor politically viable in South Asia.

Lesson 3: Farmers' response to sharp changes in fertilizer prices may be limited

Unlike the other three countries, India never completely attempted to abolish fertilizer subsidies. However, the government of India decontrolled prices of phosphate and potash in 2011, resulting in a sharp increase in the retail prices of both nutrients. Following decontrol, the Government of India now fixes the total subsidy allocations for phosphate (P) and potash (K) fertilizers and permits retail prices to float with world prices. On the other hand, the retail price of urea continues to be controlled by the government.

CSISA's analysis of plot-level data on fertilizer use in India shows that the sharp increase in relative prices of P and K (Figure 1) resulted in only small changes in the application rates of the two nutrients to rice and wheat (Figure 2). Contrary to expectations, farmers' response to these changes in the relative prices of N (Urea), P (DAP), and K (MoP) fertilizers in India was surprisingly limited.

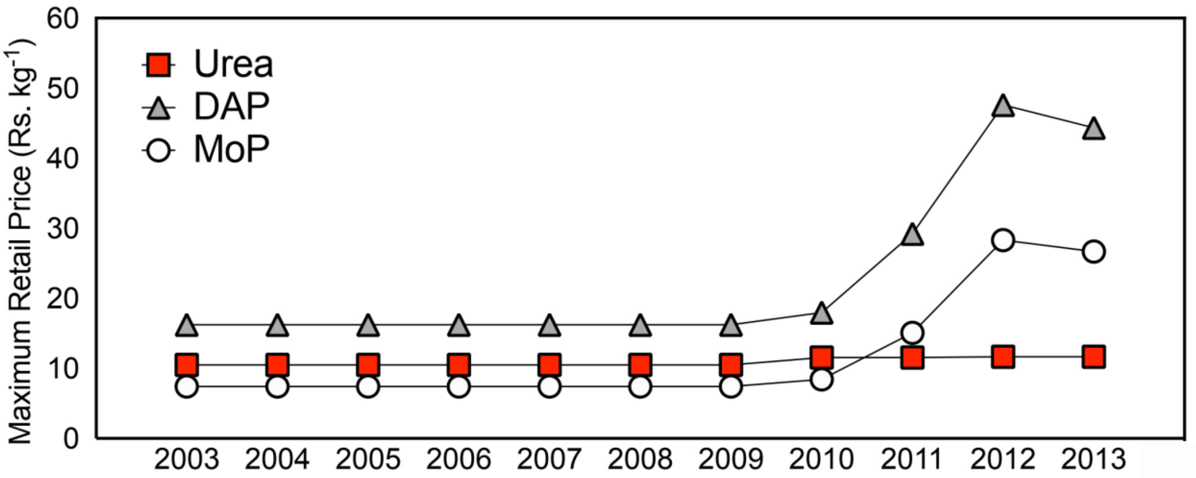


Figure 1. Limited observed responses to sharp changes in fertilizer prices in India: Prices of Urea, DAP, and MoP in India (June 2008-June 2013). Source: Commission for Agricultural Costs and Prices (CACP), several rounds. Note: DAP = Phosphate; MoP = Potash; Rs = Indian Rupees.

This lack of response to major changes in fertilizer subsidies suggests that rationalizing subsidies, though necessary, may not, by itself, lead to balanced application of fertilizers in India. This observation has important implications for other South Asian countries. Lack of information or understanding of crop nutrient requirements among policy planners and farmers is also a major problem. Besides correcting price incentives, there is a need for extension, backed by scientific research and recommendations, to nudge farmers to change behaviour regarding unbalanced and uneconomic fertilizer use.

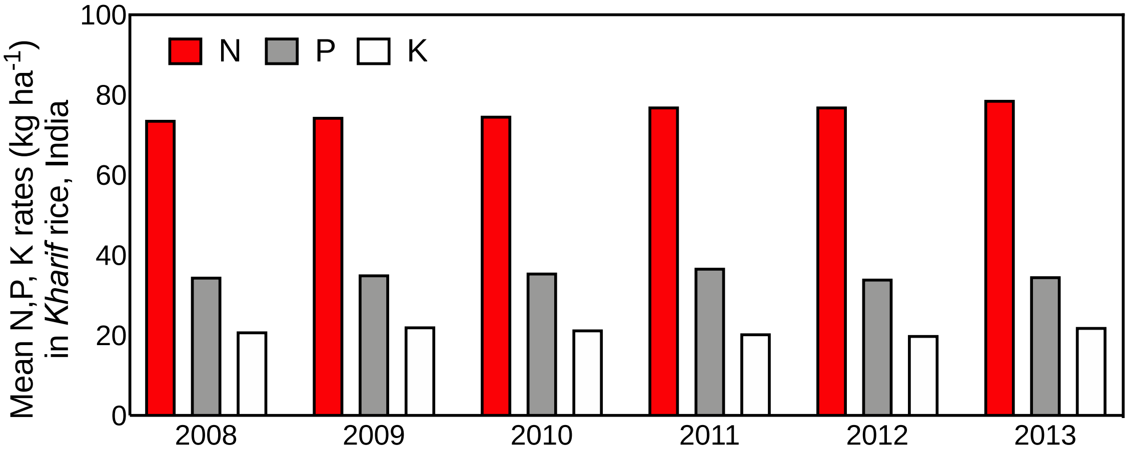


Figure 2. Average application rates (kg/ha) of N, P, and K in Kharif Paddy in India (2008-2013). Source: Commission for Agricultural Costs and Prices (CACP), several rounds.

Lesson 4: Providing soil health cards alone does change farmers' management practices

Extension that is effective in promoting balanced use of fertilizers was one of the key themes of the Kathmandu workshop. Both research institutions and fertilizer companies shared, compared, and contrasted their experiences in soil nutrient testing and extension recommendations. All four countries in the region have public programs to disseminate soil wet chemistry test–based fertilizer use recommendations. In 2015, the Government of India launched a large-scale program where 23.6 million soil samples were tested and 93 million soil health cards (SHCs) providing the results of these tests were distributed among farmers in the first phase. CSISA research in Bihar by IFPRI, however, has demonstrated just giving soil tests–based recommendations to farmers had a negligible effect on their understanding of crop nutrient requirements or actual fertilizer applications. Additional work by CIMMYT and the International Rice Research Institute (IRRI) in Bangladesh and India has found relatively poor relationships between soil nutrient tests and patterns of agricultural productivity for maize and rice, respectively. This appears to result from a mismatch between sampling time, frequency, and the specific tests conducted (for example, total nitrogen rather than available nitrogen, and so on). Extension research by Adventz, Precision Agriculture for Development (PAD) and IFPRI in other states such as Goa, Gujarat, and Odisha also show that few farmers (2-10 percent) who received SHCs understood test results and recommendations.

This does not mean that the SHC concept is a failed one. In independent projects, both IFPRI and PAD experimented with redesigning SHCs in Odisha and Gujarat. In both cases, simplifying the SHC and making it more user friendly led to significant improvement in the comprehension of soil health information. PAD and Adventz also found that repeated engagement with farmers through interactive call centers or personal visits by extension or fertilizer company staff can lead to increases in understanding of SHCs and a small, but significant, increase in the adoption of scientific soil fertility management recommendations. IRRI's experience of deploying app-based fertilizer recommendations to many farmers in different parts of India and Bangladesh also shows the need for a repeated engagement with farmers and field-level extension agents to increase understanding and generate impact. In other words, apps alone – no matter how advanced or comprehensive – are no substitute for educational efforts and dialogue with extension and farmers to advance improved nutrient management. Dr. Peter Crawford of CIMMYT also shared his experience of promoting balanced fertilizer use in Africa. He emphasized the need for farmers' needs assessments and human-cantered design approaches while developing and delivering nutrient application recommendations and extension materials.

Lesson 5: Fertilizer blends work, with caveats

Fertilizer blends, both general and those customized for specific soils in specific locations, have emerged as a viable option to ensure complete plant nutrition and balanced soil nutrient application. There is now a considerable body of work dedicated to studying the best ways of producing and marketing custom blends that are based on agroecological and crop recommendations, in addition to digital soil mapping efforts led by CIMMYT in the region. Nepal also plans to set up its first fertilizer-blending plant, thus putting the issue of custom blends at centre-stage of the fertilizer policy debate in the region. With the proliferation of custom blends, the issue of how subsidies should be structured to promote the use of innovative products at an affordable price for smallholders also becomes important. While one solution is to subsidize end products, much like base fertilizers, there is a need for strong checks to ensure fertilizer blends are held to the same quality standards as other single-nutrient products.

The capital cost of setting up blending plants is very high, thus private fertilizer companies need strong research and development to assure the business case for investments, and to identify which technology to use for blending. Physical, or bulk, blending has been the most common process used until now. However, according to Dr Ramendra Singh of Coromandel International, this technology has also had disadvantages due to non-uniform release of nutrients from blended particles. Workshop participants discussed how this can lead to soil degradation and yield stagnation. Steam granulation and fusion blending are expensive but appear to be more efficient alternatives. A thorough cost-benefit analysis should guide decisions about which technology to adopt.

Lesson 6: Implementing direct cash transfer of fertilizer subsidies requires preparation

The Government of Nepal is exploring the use of vouchers for fertilizer subsidies. The Government of India has also initiated a move to direct cash transfer (DCT) of fertilizer subsidies in a phased manner. Sri Lanka experimented with DCT for two years (four crop seasons) but reverted to the old system of price subsidies in early 2018. Both the ongoing attempts of the Government of India to implement DBT of fertilizer subsidies in phases and the short-lived DCT system in Sri Lanka have useful lessons for Nepal and other countries trying to introduce alternative forms of subsidy for fertilizers.

From 2005 to 2015, farmers in Sri Lanka enjoyed the highest subsidies on N, P, and K fertilizers in the region. All three nutrients were sold at US$3 per 50 kg bag to paddy farmers. In February 2016, Sri Lanka however switched to direct cash transfer of a fertilizer subsidy. Retail prices of fertilizers increased 6.5-fold and farmers received a cash transfer directly to their bank accounts. Economists often prefer cash transfers to in-kind subsidies because the former does not distort prices. However, in Sri Lanka, the government continued to control fertilizer prices even after switching to DCT. During this period, prices of all three macronutrients remained equal, but at a level several times higher than before. Furthermore, while initially only paddy growers were eligible for the cash transfer, later, the government added a few more crops to the eligibility list. Farmers were entitled to a subsidy for up to only two hectares of cultivated land.

These restrictions and targeting requirements created a heavy burden of data collection and monitoring for agricultural extension and monitoring, resulting in irregularities and delays in subsidy delivery. Participants in the workshop learned that many stakeholders were dissatisfied with this system – a realization that has implications for the rest of the region. The government of Sri Lanka also returned to the old system of price subsidies soon after losing local body elections in 2018. Fertilizer prices in Sri Lanka are even lower now than they were before the introduction of cash transfers, with N, P, and K all sold at US$2.75 for a 50 kg bag.

Unlike Sri Lanka, the Government of India plans to shift to cash transfers in a series of planned phases using new technologies to reduce transaction costs and irregularities. The government has installed point of sales (or POS) machines in all 0.22 million fertilizer retail outlets[14]. At present, farm input dealers have to validate all fertilizers sales to farmers using a biometric information unique identification document called Aadhar to control for leakages and fraud.

MicroSave, an Indian organization working closely with the government in monitoring the DBT system, shared results from its process evaluation of the implementation of Aadhar-linked fertilizer sales during the workshop. Poor internet connectivity has been a major challenge in the full implementation of Aadhar-linked sales of fertilizers. Aadhar cards are also not yet linked to land ownership records or soil health cards in most states. As a result, targeting of fertilizer subsidies and using cash transfers to promote recommended fertilizer rates and use remains a challenge.

Although theoretically promising, DBT of targeted subsidies therefore appears to be more challenging than universal subsidies. This is further complicated if operational landholding is used as the criterion for targeting because land records are not digitized and integrated with other farmer identity cards or citizen cards in most of South Asia.

Box: Fertilizer Vouchers: Lessons for Nepal from the Neighboring Countries

The Government of Nepal is considering using vouchers for fertilizers. The recent experience of implementing fertilizer subsidy reforms in India and Sri Lanka offers three lessons for Nepal, which hosted the policy dialogue:

Firstly, governments should not rush to a voucher system for fertilizer subsidies. A rushed reform may even backfire. Policymakers should first build a reliable database of farmers with their land records, to better target new subsidy regimes and assure that smallholders' benefit.

Secondly, if vouchers are to be targeted to a select group of farmers, initial targeting criteria should be as simple as possible. Complex targeting systems lead to higher probabilities of errors of omission and commission. Use of complicated indices for targeting leads to more discretion for lower bureaucrats and more errors and potential for misuse.

Thirdly, the use of fertilizer subsidies as an instrument to promote certain crops and discourage others has not been successful elsewhere in South Asia. Allowing fertilizer subsidies only for paddy in Sri Lanka made subsidy distribution more cumbersome (cropping pattern data had to be collected every season) and led to increased irregularities. Thus, a crop-neutral voucher policy should be explored.

Lesson 7: Interest in organic fertilizers and improved organic matter management is growing

There is rapidly growing interest in organic farming in all the countries in the region. With changing food and preferences and growing incomes, consumer demand is to some extent shifting towards organically grown produce, for fruits and vegetables. Several provincial governments in India have made budgetary provisions for promotion of organic farming in their respective states[15]. Independent organic farm entrepreneurs have also emerged in peri-urban areas bordering big cities, catering to an increasingly health conscious urban clientele. As demand for organic farm produce grows, governments will need to

[14] Open Government Data Platform India. 2019. "Details of Number of Dealers in Each District of India." Accessed October 7, 2019. https://data.gov.in/catalog/details-number-dealers-each-district-india?filters%5Bfield_catalog_reference%5D=87050&format=json&offset=0&limit=6&sort%5Bcreated%5D=desc

[15] See, for example, Maharashtra state: Hindu Business Line. 2018. "Maharashtra Mission for Organic Farming." August 21. https://www.thehindubusinessline.com/news/maharashtra-mission-for-organic-farming/article24746974.ece.

respond with appropriate fiscal and regulatory instruments to support the industry. This is also an opportunity for fostering cross-country learning on farming practices that could enhance productivity and ensure prices for organic produce remain competitive and accessible[16].

With the exception of Sri Lanka, workshop presenters and participants from India, Nepal, and Bangladesh – and especially those from the private sector – discussed their interest in growing organic fertilizer and compost markets. Although these products are likely to be best targeted to high-value horticultural and/or orchard crops as opposed to cereals in South Asia, organic amendments can over time improve soil structure, water holding capacity, and can contribute to nutrient retention and supply. They therefore are an important tool in the maintenance of soil quality and in efforts to mitigate soil degradation. Participants discussed the high transactions costs and barriers to entry for organic fertilizer products. None of the countries participating in the policy dialogue offered subsidies for organic fertilizers, although there appears to be growing demand for these products. Production of organic fertilizers from municipal wastes, particularly from South Asia's population dense cities, may also serve an added advantage as a means of ecological waste management and recycling. Studies into the viability of these programs and policy and market support mechanisms could be beneficial, as interest in this subject appears to be growing.

Conclusions

Seven lessons for policy makers and representatives of the agricultural development sector were identified in this intensive and participatory workshop on balanced nutrient management innovations in South Asia. Key among these are the need to balance micro- with macro-nutrient subsidies, and to organize subsidy programs in ways that assure that secondary macro nutrients – particularly potassium and phosphorous products – are applied alongside fertilizers delivering nitrogen. In addition, additional research and evidence are needed to identify ways to assure that farmers' behavior changes in response to subsidy programs. Efforts to understand how to link high-level price support policies with field-level actions and activities – for example through research on behavioral nudging – could be advantageous in all countries. This lesson has relevance also for the design of extension programs such as India's Soil Health Card program, which could likely be improved through intervention to simplify messages in ways that farmers can both understand and act on.

In addition, participants discussed the need for blended fertilizer products and programs that can support them. Experience with blended products are however uneven in the region – markets for blends are nascent in Bangladesh and Nepal in particular. Cross-country technical support on how to develop blending factories and markets could be leveraged to accelerate blended fertilizer markets and to identify ways to assure equitable access to these potentially beneficial products for smallholder farmers.

Similarly, there is a growing interest in organic fertilizers and compost markets, though awareness and evidence for the viability of these products and markets could benefit from thorough research and appropriate policy support. This is particularly important as these products could assist in reducing or reversing the pace of soil quality decline in the region. Lastly, several countries are experimenting with direct cash transfer to farmers over policy level interventions to control macronutrient fertilizer prices. While desirable from a strict economic perspective, this approach also entails risks as it can result in significant price distortion and use of fertilizers on non-target crops. Though theoretically appealing, direct cash transfer schemes are not universally successful and should be implemented only after sufficient research and evidence has been generated to develop carefully implemented systems.

[16] Nepal and India have already begun taking steps in this direction. See Press Trust of India. 2019. "Farmers from Nepal Get Organic Farming Training in India." February 22. https://www.business-standard.com/article/pti-stories/farmers-from-nepal-get-organic-farming-training-in-india-119022201030_1.html.