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The U.S. Government's Global Hunger & Food Security Initiative

Cereal Systems Initiative for South Asia

Annual Report

(October 2020-September 2021)

CSISA

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iDE

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List of Acronyms and Abbreviations

2WT	Two-wheel tractor
%DI	Percent disease index
%DLA	Percent diseased leaf area
A2F	Access to finance
AAS	Agricultural Advisory Society
ACCL	Auto Crop Care Limited
ACDI-VOCA	Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance
ACIAR	Australian Center for International Agricultural Research
AIRN	Agriculture Inputs Retailers' Network
AIS	Agricultural Information Services
AKC	Agriculture Knowledge Center
AMMI	Additive Main Effect and Multiplicative Interaction
APSIM	Agricultural Production Systems Simulator
ATT	average treatment effect on treated
ATU	average treatment on untreated
BADC	Bangladesh Agriculture Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BMD	Bangladesh Meteorological Department
BpLB	*Bipolaris* leaf blight
BRRI	Bangladesh Rice Research Institute
BWMRI	Bangladesh Wheat and Maize Research Institute
CBO	Community-based organization
CCAFS	Climate Change, Agriculture and Food Security
CEs	choice experiments
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
CSRD	Climate Services for Resilient Development
DAE	Department of Agricultural Extension
DSR	direct-seeded rice
Embrapa	Brazilian Agricultural Research Corporation
EWS	early warning system

FAW	Fall Armyworm
FtF	Feed the Future
FtF-ZoI	Feed the Future Zone of Influence
GoN	Government of Nepal
GWRDB	Groundwater Resources Development Board
HRS	Healthy rice seedlings
HSD	Honestly significant difference (test)
IAL	Ispahani Agro Limited
IARI	Indian Agricultural Research Institute
ICIMOD	International Centre for Integrated Mountain Development
iDE	International Development Enterprises
IFPRI	International Food Policy Research Institute
IGP	Indo-Gangetic Plains
ILSSI	Innovation Lab for Small-Scale Innovation
INGO	international non-governmental organization
IPM	integrated pest management
IRRI	International Rice Research Institute
IVR	interactive voice response
IWM	integrated weed management
JRIP	Joint Rice Implementation Program
KISAN	Knowledge-Based Integrated Sustainable Agriculture in Nepal
LSP	local service provider
ML	machine learning
MoALD	Ministry of Agriculture and Livestock Development
MoLMAC	Ministry of Land Management, Agriculture and Cooperative
MoP	Muriate of potash
MOT	Mitigation options tool
NAMEA	Nepal Agricultural Machinery Entrepreneurs' Association
NARC	Nepal Agricultural Research Council
NARES	National Agricultural Research and Extension Systems
NSAE	Nepalese Society of Agricultural Engineers
ODK	Open Data Kit
OFRD	On-farm Research Division
NPR	Nepali rupee
NSAF	Nepal Seed and Fertilizer project
PCFE	per capita food expenditure
PMAMP	Prime Minister Agriculture Modernization Project

PQR	premium quality rice
PSA	public service announcement
pSIM	Parallel System for Integrating Impact Models and Sectors
RDC	Rice and Diversified Crops Activity
SAAO	Sub-Assistant Agricultural Officer
SI	sustainable intensification
SIIL	Sustainable Intensification Innovation Lab
SP	Service provider
SRFSI	Sustainable and Resilient Farming Systems Intensification in the Eastern Gangetic Plains
TOT	Training of Trainers
TSP	Triple superphosphate
USAID	United States Agency for International Development
WMRI	Wheat and Maize Research Institute
WRF	Weather Research and Forecasting
ZoI	Zone of Influence

Executive Summary

With the support of the United States Agency for International Development (USAID) and the Bill and Melinda Gates Foundation (BMGF), 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), the International Water Management Institute (IWMI) and the International Rice Research Institute (IRRI), in addition to numerous public and private sector partners. CSISA is about bridging the divide between research and impact. In rural Bangladesh, India and Nepal, CSISA:

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

USAID supports CSISA's activities in Nepal and Bangladesh, while BMGF supports work ongoing in India. These efforts are made possible through the cooperation of a multidisciplinary team including agronomists, systems analysts, data scientists, behavioral economists, livestock specialists, agricultural engineers, sociologists, and pest and natural resources management experts, among others. Over time, CSISA has developed into a more comprehensive applied research-for-development program, with many additional and synergistic investments by USAID/Washington, the USAID Missions in Nepal and Bangladesh, and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), in addition to Michigan State University's Borlaug Higher Education for Agricultural Research and Development (BHEARD) program, to deepen the scope and impact of CSISA's work. As such, CSISA has evolved well beyond its origins as a primarily agronomic research initiative to embrace interdisciplinarity as a prerequisite for understanding and efficiently responding to the challenges faced in South Asia's cereal-based farming systems.

This report focuses on the current third phase (2015–2021, CSISA III) of the 'base' or 'original' set of CSISA investments.[2] This phase focuses on USAID's support to activities in Nepal and Bangladesh, where CSISA supports 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 ensuring a successful exit of some aspects of programming, although the Activity is in discussion with USAID about an anticipated extension into 2022.

[2] CSISA III is primarily referred to as 'the Activity' throughout this report. Based on ongoing discussions, USAID is also anticipated to approve an extension of CSISA into 2022, and potentially beyond.

Bangladesh Highlights

Key highlights from CSISA's work in Bangladesh during the October 2020–September 2021 reporting period include:

Expanded collaboration with the Bangladesh Rice Research Institute (BRRI): During the reporting period, CSISA depended on collaboration with BRRI by supporting novel new research to develop a weather-forecast based early warning system for rice blast disease. This effort is based on CSISA's early warning systems for other diseases, including wheat blast, detailed below. In addition, CSISA collaborated with BRRI on a range of experiments focused on optimizing management methods for direct seeded rice and expanding farmers' update of high-value, 'premium quality' aeromatic rice varieties released by BRRI. The latter was accomplished through additional market systems collaboration with rice value chain actors, most specifically a range of small seed companies and millers who worked to expand farmers' cultivation of new varieties in areas that farmers had no previous experience.

Healthy rice seedlings for higher yields: Healthy rice seedling (HRS) awareness-raising activities, including video screenings, leaflet distribution, training and establishing community seedbeds, conducted during the last reporting period, have resulted in increased grain yield of 7%–10% for farmers who were able to implement appropriate seedbed management practices. Studies conducted by CSISA in the reporting period indicate that over 130,000 farmers have now adopted the principles of HRS in their fields. During the reporting period, and in collaboration with DAE and seed companies, CSISA also assisted farmers in establishing community-based seed beds in Jashore (136), Dinajpur (48) and Faridpur (15).

Building resilience to the threat of wheat blast disease: A major success in this reporting period was the formal launch of a weather forecast-based early warning system (EWS), which the Activity has worked with government bodies – Bangladesh Wheat and Maize Research Institute (BWMRI), Department of Agricultural Extension (DAE), Bangladesh Meteorological Department (BMD), and Embrapa (the Brazilian Agricultural Research Corporation) – and which took for several years to achieve. The wheat blast early-warning system – found at www.beattheblastews.net – now has 6,400 agricultural extensions positioned to receive alerts in Bangladesh. CSISA's unique partnerships and value addition also resulted in the endorsement of the EWS by Embrapa in Brazil, where wheat blast disease has been a significant problem for decades. Embrapa's endorsement means that the EWS, which was developed for Bangladesh but with the help of Brazilian scientists, will now also be used widely by extension agents throughout Brazil. In addition, In collaboration with the Bangladesh Wheat and Maize Research Institute (BWMRI) and Department of Agricultural Extension (DAE), CSISA conducted farmer's participatory block-wise intensive seed multiplication campaigns of BARI Gom 33, a blast resistant wheat variety. CSISA bore the cost of distributing 25 t of BARI Gom 33 seed, then handed over to DAE, which continued distribution to 1,223 farmers in the Feed the Future Zone of Bangladesh in the 2021-22 winter cultivation season.

Expanding the use of agro-metrological advisory services: In partnership with the Bangladesh Meteorological Department, CSISA also worked closely with the DAE and national research partners to release Agvisely, an agro-meteorological services tool that provides location-specific advice to rice, wheat, maize, potato, lentil, and mung bean farmers, as well as farmers cultivating a range of fish in ponds. Agvisely covers the phenological states of these crops and species in each of Bangladesh's 492 sub-districts, providing real-time advice. Throughout FY2021, the Activity worked to register 5,900 users, covering more than 90% of the extension staff who are active mobile users within DAE. Beyond Agvisely, CSISA also expanded the use of interactive voice response (IVR) service, which provides real-time weather alerts to farmers. In this reporting period, the Activity expanded the reach of the service to 10,000 mung bean farmers in preparation for the 2021 harvesting period (March–June 2021). The IVR system warned farmers in coastal Bangladesh within the FtF zone of forecasted heavy rainfall and storm events, which cause large yield losses each year, and advisories to farmers to accelerate their harvest.

Government endorsement of lentil disease early warning systems: With efforts beginning in 2019, CSISA developed a weather forecast-driven early warning system for precision application of fungicide ('on-time-no-less-no-excess-frequency') to control *Stemphylium* blight (SB) disease. The SB early warning system (SB-EWS) is a potential replacement for the conventionally prescribed, blanket, calendar-based three-time fungicide application. In collaboration with the Bangladesh Agricultural Research Institute (BARI), CSISA has tested the SB-EWS in collaboration with 120 farmers in Bangladesh and Nepal. In September of 2021, CSISA facilitated a workshop with key governmental partners on the performance of the SB-EWS, with the Bangladesh Agricultural Research Council and BARI endorsing its use by the DAE. CSIA is now in the process of training DAE on how to independently manage and sustain the use of the EWS to support lentil farmers across Bangladesh. A similar endorsement is anticipated in Nepal soon.

Aiding in the fight against Fall Armyworm: CSISA's co-support of the USAID/Bangladesh Mission and Michigan State University funded Fighting Fall Armyworm (FAW) Activity in Bangladesh has been extremely successful. Although this Activity targeted working with DAE to scale-out trainings for at least 33,000 people, these targets have been significantly exceeded. To date, 187,000 farmers and people have been reached with FAW IPM information as a result of cascade trainings and one-to-one interactions between DAE and farmers that were catalyzed and encouraged by the Activity.

Integrated weed management: CSISA's action research partnerships with BRRI and a range of weed control product companies have aimed to identify low-toxicity but effective herbicides that are PERSUAP approved and that can be effective in integrated weed management (IWM) programs in rice. Since 2019, the Activity also began working with private sector organizations and DAE to scale- out efficient and profitable IWM options to control weeds in transplanted rice in the Activity domain area. Despite the COVID-19 challenges, during the reporting period, CSISA, in collaboration with private sector partners Auto Crop Care Limited (ACCL) and AIRN, continued efforts in this area. In partnership with ACCL and DAE, CSISA established 200 on-farm demonstrations for the summer *aman* season so farmers could be trained on best IWM options. Although there were no IWM field demonstrations in the winter *boro* 2020/21 season, CSISA and ACCL, carried out several awareness-raising activities, including sharing CSISA findings/results with DAE, linkage programs with private sector organizations, and leaflet distribution. Based on these and similar efforts, Bangladesh's land area under comparatively safer herbicides as part of IWM strategies has increased by at least 11,700 ha in CSISA's working areas since 2019.

Nepal Highlights

Some of the highlights from CSISA's work in Nepal during the October 2020–September 2021 reporting period are as follows:

Expanding access to rural entrepreneurial opportunities and creating markets for repatriated migrant workers affected by the COVID-19 pandemic: Following the onset of the pandemic, tens of thousands of Nepali migrant workers were repatriated from India to Nepal, where they faced economic hardship and few job opportunities. During the reporting period, CSISA worked to educate 13 banks and farmer cooperatives on the benefits of agricultural machinery, and how machinery can be used as part of a profitable business. These banks and cooperatives subsequently began lending to returnee migrants who, with CSISA's technical backing and support, became interested in purchasing machinery and offering farm machinery services for land preparation, irrigation, harvest and post-harvest activities to farmers on an affordable fee-for-services basis. By the end of the reporting period, a total of USD $243,348 had been loaned by these institutions and cooperatives to 108 returnee migrants who have now begun new businesses in Nepal as machinery services providers. Many of these return migrants find their farmer clients on the five Facebook groups that CSISA provisionally established to raise awareness of machinery services provision. These Facebook groups now have a combined membership of 13,469 people and are used for buying and selling a range of agricultural goods and services in Nepal.

Boosting farm machinery mechanics' skills: Machinery breakdowns can result in significant lost business for machinery service providers and serious delays in planting and harvesting that can hamper farmers' yields. During the reporting period, CSISA created an inventory of a total of 238 mechanics spanning the working districts in which the COVID-19 Response and Resilience Activity (which is a buy-in to the wider CSISA program supported by the USAID/Nepal Mission) is working within the FtF Zone and facilitated training for 150 of these mechanics in the principles of COVID-19 safety, and how to repair land preparation equipment while limiting the risk of COVID-19 infection spread among mechanic shop staff and to clientele. Data collected by the Activity showed that advanced mechanics could service a total of 1,659 farmers in the reporting period.

Big impact from mini-tillers in Nepal's mid-hills: Since 2011, CSISA has supported the widespread adoption of mini-tillers in the Nepal hills, working with private sector actors such as Nepal Agricultural Machinery Entrepreneurs Association (NAMEA), as well as the Department of Agriculture (DOA) and the Ministry of Agriculture and Livestock Development. Mini-tillers are one of the few scale-appropriate farm machineries used for land preparation in Nepal's hills.

Increasing marginal farmers' access to harvesting services: During this reporting period, CSISA Nepal developed a voucher scheme to sensitize vulnerable (with emphasis on poor, women) farmers to the benefits of mechanized reaper services for harvesting wheat and assuring social distancing. The scheme linked farmers and service providers with the expectation that the farmers' cost-savings would create buy-in and lead to systemic change. The activity drew down investment costs for mechanized wheat harvesting service provision through a carefully implemented voucher scheme, targeting extreme poor and women farmers in six districts in Activity areas around the FtF ZoI, western Nepal (Kapilvastu, Dang, Banke, Bardiya, Kailai, and Kanchanpur). The voucher system implemented subsequently registered the farmers with a unique randomized identity number and QR code. The activity then mobilized 50 reaper service providers and registered them to provide wheat harvesting services to the farmers under the voucher scheme. The objective was to facilitate farmer access to harvesting machines in COVID-19-affected areas, by providing a discounted service charge. After harvest, CSISA surveyed the 725 farmers to assess their satisfaction with the service and likely future need; 92% of the respondents stated their intention to utilize mechanized harvesting services in the future, citing time-saving (reported by 98%) and cost-saving (71%) benefits. Crucially, these respondents strongly indicated their willingness to pay for the full costs of harvesting without access to a voucher scheme. As a result of these successes, similar voucher efforts are now being deployed to harvest the *kharif* rice crop among other groups of identified resource-poor farmers.

Big impact from mini-tillers in Nepal: This technology was introduced by CSISA in 2011 and validated in farmers' fields. Since then, CSISA has continued to partner with the private sectors to increase commercial availability and use of mini-tillers. These small 5-9 horsepower tractors are used for land preparation and weeding. Since this technology is more appropriate for smallholder farmers, the adoption of mini-tiller is rapidly increasing. During this reporting period, CSISA staff analyzed the overall growth trends of mini-tillers from the data provided by NAMEA and the impacts of mini-tillers across household gender shows that mini-tiller adoption is rapidly increasing in Nepal's hills and presents growth trends in increasing order. In 2011, there were <100 mini-tillers used in Nepal's mid-hills, but in 2021, over 6,000 mini-tillers were sold by NAMEA associated machinery businesses and adopted by the country's farmers. The mini-tiller's rapid success is attributable to CSISA's continual support to the private sector to achieve its upscaling. Based on the number of mini-tillers that NAMEA has sold, CSISA estimates the area under mini-tiller in maize-based systems in Nepal to be around 15,000 ha.

Mentoring and building the technical capacity of extension staff of rural municipalities for expanding spring season rice production frontier in Nepal: The Government of Nepal has prioritized the expansion of the country's area under rice and its production in order to meet the population's growing demand. The opportunity to achieve this goal in the main monsoon kharif season is, however, limited. CSISA has regional experience in understanding spring season rice, and so the Activity is working to enhance the technical capacity of rural municipality extension staff as part of collaborative activities with KISAN-II and governmental partners in the Joint Rice Implementation Program (JRIP). During the last reporting period, CSISA provided spring rice crop production, management and machinery-related training to KISAN-II and rural municipalities. During these training activities, the area under spring rice has expanded during this reporting period. CSISA also conducted spring season rice crop cuts to understand crop establishment-related challenges to rice production in this season.

Aiding in the fight against Fall Armyworm: As part of its work to extend awareness and skills in FAW management, CSISA organized two days of 'Training on Fall Armyworm Management and Safe Handling of Pesticides' for agrovet association representatives in Lumbini Province (3–4 March 2021), in partnership with the Plant Quarantine and Pesticide Management Center (PQPMC), Directorate of Agriculture Development of Lumbini Province, USAID Nepal's Nepal Seed and Fertilizer (NSAF) Project and iDE Nepal. This was followed by virtual trainings of Prime Minister Agriculture Modernization (PMAMP) staff on FAW management in Banke, Dang, and Lumbini after COVID-19 restrictions prevented in-person training. Also during the reporting period, CSISA reached out to more than 2,300 farmers from 134 villages across four municipalities in Dang using phone surveys to assess the extent of knowledge and practices on FAW. Nearly 15% of respondents reported having experienced FAW attack in maize during the summer kharif 2019 maize season, while a higher proportion (39%) reported pest attack more generally infestation in maize during the same period. This increased substantially in kharif 2020, with nearly all (95%) reporting pest infestation in maize, and around 81% reporting FAW attack. Among those who had previously suffered any kind of maize pest attack, only 16% (baseline) and 19% (endline) said that they recorded the level of pest presence in their crop before deciding upon the type of control measure that needed to be implemented. This underscores the urgent need to train farmers on how to make use of field scouting to enable appropriate pest management decisions.

Eyes in the sky, boots on the ground: CSISA has also been collaborating with PMAMP to design and implement elite techniques that utilize a remote sensing tool to estimate the area and yield of commodity crops. In 2020 in the Dang Maize Super Zone, the Activity initiated work in maize crop area estimation, in coordination with the PMAMP Project Implementation Unit, and quantified the area under maize (please see CSISA III Annual Report 2020). In 2021, collaboration continued with the PMAMP Project Management Unit to facilitate their institutional use of remote sensing assessments to estimate the area and yield of cereal crops in districts across Nepal's Tarai. CSISA also organized a week-long basic training/orientation on GIS and remote sensing for 14 PMAMP officers (August 2021), which provided them with preliminary ideas on the work methodology. This was followed by a second-level orientation to PMAMP officers (September, 2021). PMAMP has anticipated institutionalizing the remote sensing assessment methodology in the near future, after strengthening the capacity of the relevant personnel.

New irrigation technologies: During this reporting period, CSISA continued its efforts to support the development of low-cost irrigation technology, focusing specifically on developing a low-cost drilling rig in coordination with local drillers in Bardiya district. After demonstrations, field surveys and development of the technological design, the Activity guided well-drillers in the installation and operation of the equipment and facilitated a co-creative learning experience to generate their feedback and assess their interest in further deploying and developing the technology. After several weeks of training and practice under the guidance of CSISA staff, two well-drillers expressed a professional interest in acquiring the new technology for use in their private business enterprise. These well drillers then facilitated the drilling of 25 additional wells.

Documenting CSISA's scientific and extension contributions:

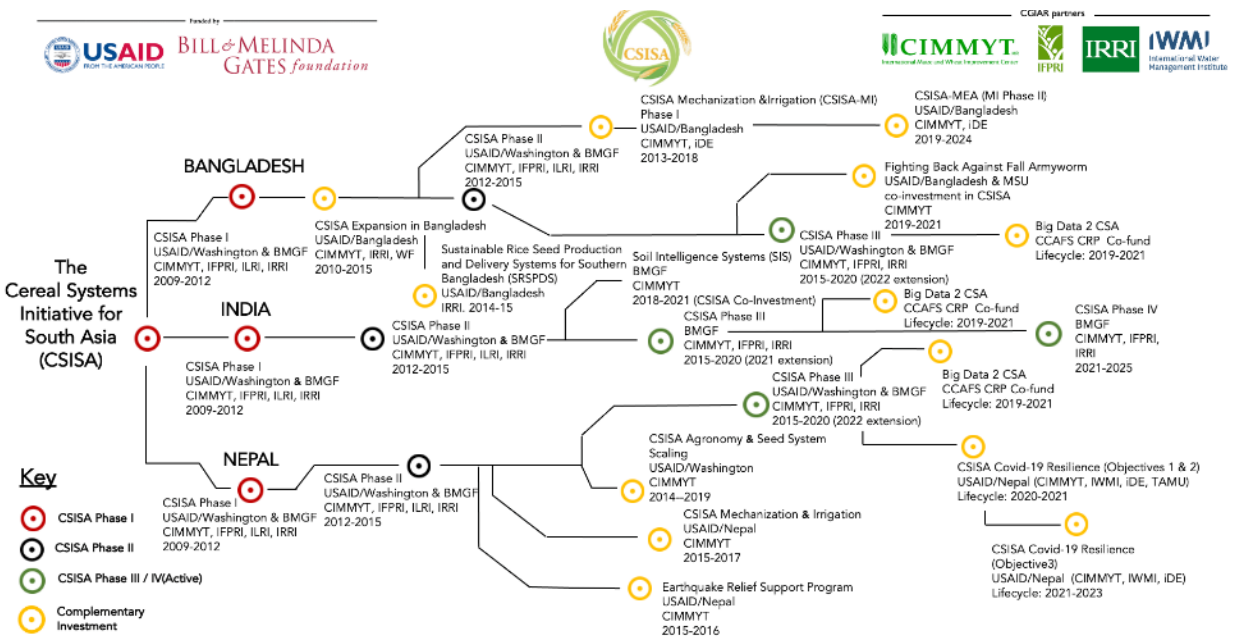
In addition to the above research into real-world development outcomes and impact, CSISA worked during the reporting period to scientifically document its efforts and to publish a range of technical and extension materials. Between 2020-2021, scientists and development professionals working in CSISA have published 43 peer-reviewed papers, one book, seven book chapters, seven research reports and policy briefs, ten extension manuals or primers, five educational videos, and one infographic. Details on these publications can be found in Annex I.

Context, Approach and Theory of Change

Ever since the food price crisis of , agricultural research and development in the developing world has received renewed public sector, 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 well over half a billion people. As time has gone on, interests of governments and international donors have also shifted to embrace more complex agri-food systems issues in an integrated, systems-oriented context. Nevertheless, investments in agriculture have been less adept at supporting transformative change than many development planners had hoped. While progress has been made in addressing some of the systemic weaknesses which contribute to low rates of rural development, many key problems continue to persist:

- Many national **research organizations** narrowly construe their mandates and are only partially oriented towards farmers and the private sector as clients of research outputs. Research tends to still be commodity-specific, and focused mainly on production, with less emphasis to other disciplines that can assist in providing insights crucial for overcoming agricultural development challenges
- **Resilient** farm practices, nutrition, and rural livelihood strategies are insufficiently considered in comparison to technical interventions that focus mainly on yield improvements for singular commodities.
- **Agricultural extension** primarily focuses on single technologies or generalized 'packages of practices', which are not always underpinned by rigorous or participatory field evaluations, and that often lack strategic targeting efforts.
- **Livelihood** initiatives do a commendable job of reaching underserved communities, including women farmers, but rarely have the technical competence to extend their reach and to interact comprehensively with farmers as managers of diverse production enterprises.
- 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.
- **Rural and 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.
- **Cooperation is still not optimized** in the agricultural research-for-development space. This limits opportunities to leverage skills and harness synergies for development impact.
- Activities at addressing **social equity and gender inclusiveness** are unfortunately more transactional and may lack depth. Initiatives to address social equity and justice in agriculture require integrated sets of action, adequate planning, and adaptive management.

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 increasing costs for rural labor, due in large part by the out-migration of men to urban areas or abroad as they seek more remunerative employment. Despite these challenges, there is considerable promise that the many individual strengths within the innovation system[3] 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 Activity 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.



Above: 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-MEA activity in Bangladesh.

CSISA works with technologies and management practices which fall under the rubric of 'sustainable intensification', to enhance the productivity of cereal-based cropping systems, increase farm incomes, and reduce agriculture's environmental footprint.[4] As a science-driven and research impact-oriented initiative, the Activity is positioned at the intersection of a diverse set of partners in the public and private sectors, occupying the crucial middle ground where

[3] 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.

[4] Pretty and Bahrucha (2014) define sustainable intensification as '…. a process or system where agricultural yields are increased without adverse environmental impact and without the conversion of additional non-agricultural land. The concept does not articulate or privilege any particular vision or method of agricultural production. Rather, it emphasizes ends rather than means…. The combination of the terms 'sustainable' and 'intensification' is an attempt to indicate that desirable 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).

research meets development. As such, while most CSISA team members are scientists, each is committed to developing and ensuring pathways by which research products and technologies can be pushed into real-world use and impact by farmers. The Activity 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 sectors, to raise the awareness of farmers and other stakeholders of 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.

With USAID's focused support, 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 (1) prioritizing scaling efforts, and (2) working through national partners to address policy constraints to increase the productivity and resilience of smallholder farming systems.

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

1. Bangladesh – Achievements

A. INNOVATION TOWARD IMPACT

A1. Reducing risk to facilitate uptake of sustainable intensification practices

A1.1 Direct-seeded rice to address labor and energy constraints to precision rice establishment

In South Asia, researchers have long encouraged a shift from the most dominant agronomic method of rice production crop establishment – widely referred to as puddled transplanted rice – to dry direct-seeded rice (DSR). DSR can dramatically reduce production costs, and improve and reduce the environmental impact of rice production. However, for farmers who transition from transplanted rice to DSR, significant changes in management practices and agricultural machinery are often needed. DSR is established without standing water in the field and through machine-aided sowing rather than transplanting. In combination, this saves labor, water, and cultivation costs and can lower greenhouse gas emissions. But while DSR has benefits, farmers tend to emphasize that it also has risks that limit its adoption in South Asia, including Bangladesh. Examples of these concerns include poor and uneven crop establishment, weed management challenges, and a lack of suitable cultivars for DSR. In addition, soils need to be of the right texture, and farmers need to manage irrigation and floodwater depths much more carefully. Rice is also sensitive to cold – particularly early in the winter season. Because of cold injury risks to seedlings during the winter '*boro*' rice season and uncontrollable flooding in the summer '*aman*' season, the research conducted by CSISA on DSR has focused mainly on the pre-monsoon '*aus*' season (usually sown in April–May and harvested in July–August – also known as *kharif*-1). Efforts have also been targeted in select portions of the southwest of the country where soil and hydrological conditions are likely to be better suited to cropping.

Above: Establishment of directly sown rice (DSR) in Bangladesh is often done with specialized machinery. Left: a local service provider sows *aus* DSR, Shailkupa, Jhenaidah. April 17, 2021. *Photo credit: Mohammad Asaduzzaman.* Middle: a local service provider sows *aus* DSR, Faridpur Sadar, Faridpur, April 20, 2021. *Photo credit: Mohammad Haider Ali.* Right: A DSR *aus* field, Shailkupa, June 2021, *Photo credit: Mohammad Asaduzzaman.*

CSISA works on DSR in close partnership with BRRI, the DAE, non-governmental organizations (NGOs), and private sector entrepreneurs (especially mechanized seed drill owners) in the spring *aus* rice season. The primary research activity streams relate to efforts to quantify the impact of DSR on yield profitability, compared to farmers' predominant practices of wet tillage (puddling) and manual transplanting. As the only rice varieties available are developed for puddled transplanted systems and not specifically bred for DSR conditions, CSISA works closely with BRRI to identify the most suitable rice varieties to adapt to DSR conditions for use in the *aus* (monsoon) season. The Activity also arranges public field visit days to on-farm trials to raise awareness of DSR among farmers and other stakeholders. CSISA has made use of field visits from policymakers within the Ministry of Agriculture to boost their understanding of DSR as an option when the season, location, and rice variety are right. CSISA's activities with DSR in the October 2020–September 2021 reporting period are detailed below.

Direct-seeded rice: Performance evaluation study 1

The objective of the farmer-participatory on-farm adaptive trials evaluating the performance of DSR (mechanized line-sown and manually broadcast DSR) compared to farmers' current practice of puddled transplanted rice under different landscape positions was to determine the comparative agronomic and economic performance of different crop establishment options in order to provide evidence of the landscape position most suitable for DSR cropping. CSISA and its partner BRRI jointly implemented these on-farm trials in the *aus* season 2021 (April–August) to confirm the previous two years' results (for which, please see the CSISA Annual Report 2019 and CSISA Annual Report 2020).

The trials were established in three locations (Jhenaidah, Dinajpur and Faridpur) in a split-plot design. The main plot factor was the three rice establishment methods (machine seeding using a power-tiller operated seeder, hand broadcasting, and manual transplanting in puddled soil). The sub-plot factor was three varieties (BRRI dhan83, BRRI dhan 85 and BINA dhan-19). Trials were conducted in three types of land (flood-free high land with no flooding, medium high land which floods <1 month) and low land which floods >1 month). A total of 18 farmers' fields were selected, six for each land type. The crop was sown between 15–20 April and harvested between 1–15 August.

Rice grain yield

The interaction effects of landscape position and crop establishment method on rice grain yields across varieties in all three sites were significant. The table below presents the results of the rice establishment method by landscape position for each site. In Jhenaidah, the grain yields in high and medium landscape positions were similar across all three establishment methods. In low land, however, the highest grain yield (5.01 t ha^{-1}) was recorded using the manual puddled transplanted method. This was 7.5%–10% higher than when DSR methods were used. DSR line-sown by machine and hand broadcast DSR had similar rice grain yields across all three landscape positions. Transplanted rice performed better under low and medium land conditions, and yields were 11% lower on high land compared to low land.

In Faridpur, the manual transplanting method outperformed DSR methods (line-sown by machine and hand broadcast) in yield under all three landscape positions, except for medium land line-sown by machine, where yields were similar to manually transplanted rice (see table, above). Also in Faridpur, manual transplanting and hand broadcast DSR methods performed similarly across all three landscape positions. However, DSR line-sown by machine performed best on high and medium land, and its yield declined in lowland conditions.

In Dinajpur, manually transplanted rice yields were 8%–13% higher than DSR sown in-line by machine and 10%–20% higher than rice hand broadcast across all landscape positions. The exception was DSR sown in-line by machine on high ground, where yields were similar to the manually transplanted method (see table below). In Dinajpur, DSR rice yields did not differ by landscape position. Manually transplanted rice yields were similar under medium and lowland landscape positions, but under highland conditions were 17%–19% lower than in medium and lowland conditions.

Rice grain yields (t ha^{-1}) as influenced by landscape position and crop establishment method across varieties in the *aus* season 2021 in Jhenaidah, Faridpur and Dinajpur in Bangladesh.

Establishment methods	Landscape positions: High		Medium		Low	
			Jhenaidah			
Line-sown by machine	4.62	A a	4.85	A a	4.57	B a
Hand broadcast	4.57	A a	4.71	A a	4.66	B a
Manually transplanted	4.44	A b	4.67	A ab	5.01	A a
			Faridpur			
Line-sown by machine	4.89	B a	5.15	A ba	4.11	B b
Hand broadcast	4.75	B a	4.92	B a	4.72	B a
Manually transplanted	5.40	A a	5.59	A a	5.72	A a
			Dinajpur			
Line-sown by machine	3.10	AB b	3.76	B a	3.66	B a
Hand broadcast	2.81	B b	3.70	B a	3.70	B a
Manually transplanted	3.37	A b	4.06	A a	4.14	A a

Note: The uppercase letters in a column compare the establishment methods for landscape positions. The lowercase letters in a raw compare the landscape positions across the establishment methods. Means in a column followed by the same letter are not significantly different according to Tukey's HSD at alpha = 0.05.

Across landscape positions and establishment methods, the rice grain yield varied across sites and varieties. At all sites, the variety BRRI dhan83 produced the highest grain yields (4.96, 5.56 and 3.69 t ha^{-1} in Jhenaidah, Faridpur and Dinajpur, respectively) followed by BRRI dhan 85 and BINA dhan-19 (see table, below).

Grain yields (t ha^{-1}) of three newly released *aus* rice varieties across three landscape positions and three crop establishment methods in the *aus* season 2021 in Jhenaidah, Faridpur and Dinajpur, Bangladesh.

Varieties	Jhenaidah		Faridpur		Dinajpur	
BRRI dhan83	4.96	A	5.56	A	3.69	A
BRRI dhan 85	4.65	B	5.02	B	3.60	AB
BINA dhan-19	4.42	C	4.50	C	3.49	B

Means in a column followed by the same letter are not significantly different according to Tukey's HSD at alpha = 0.05.

Production costs

The production cost varied among sites, landscape positions and rice establishment methods, but not by variety type. In general, production costs declined in the following order at all three sites: highland > medium-land > lowland (see table below). Among rice establishment methods, production cost declined in the following order at all three sites (based on an average over landscape position and varieties): manually transplanted rice > hand broadcast DSR > line-sown DSR by machine. With DSR, the production cost was USD 41–96/ha lower with rice line-sown by machine compared to hand broadcast. Compared to manual puddled transplanted rice, the reduction in production cost with DSR line-sown by machine was USD 205, USD 127 and USD 145/ha in Jhenaidah, Faridpur and Dinajpur, respectively. With hand broadcast DSR, these reductions in production cost values compared to transplanted rice were USD 134, USD 86 and USD 49/ha in Jhenaidah, Faridpur and Dinajpur, respectively.

Production cost as influenced by landscape position (averaged over establishment methods and varieties) and rice establishment methods (averaged over landscape positions and varieties).

Landscape positions	Production cost (USD ha^{-1})					
	Jhenaidah		Faridpur		Dinajpur	
Highland	631	A	616	A	873	A
Medium-land	582	B	570	B	684	B
Lowland	524	C	583	B	620	C
Establishment methods						
Line-sown by machine	487	C	534	C	645	C
Hand broadcast	558	B	575	B	741	B
Manually transplanted	692	A	661	A	790	A

Means in a column followed by the same letter are not significantly different according to Tukey's HSD at alpha = 0.05.

Labor use

Averaged across locations and landscape positions, the highest amount of labor required was for manual transplanting (81–98 person-days/ha^{-1}) followed by hand-broadcast DSR (59–79 person-days/ha^{-1}). It was lowest in DSR line-sown by machine (51–64 person-days/ha^{-1}). Overall, labor use was 27%–34% lower using DSR compared to manually transplanted rice.

Implications

The results from this study during the 2021 *aus* season indicate that DSR performed better in high and medium landscape positions, and that transplanted rice performed better in medium and low landscape positions. The yields of machine-sown DSR were similar to those of manual-transplanted rice in the medium landscape position and slightly lower in the low landscape position. Hand-broadcast DSR performed similarly to DSR line-sown by machine across all sites and landscape positions. Economic data indicated that higher costs are needed for more intensive production practices on higher landscape positions. The similarity in yields of machine-sown DSR and hand-broadcast DSR suggests that the latter can be encouraged by extension services in areas where DSR machines are not widely accessible to smallholders. However, further efforts would be needed to strengthen the DSR service provision model for encouraging mechanized DSR, and take advantage of the further reduction in production cost observed by machine-sown DSR. The 2021 *aus* season results confirm the findings of the previous *aus* seasons 2019 and 2020.

Machinery and weed management are the two most important considerations when planning the large-scale dissemination of DSR. Firstly, the current machinery used for the establishment of line-sown DSR often does not perform well. The most widely available DSR machines have a fluted roller seed metering system which does not provide sufficiently precise seeding and crop establishment. To overcome this and achieve good, uniform establishment requires a more precise planter with an inclined plate or other precision seed metering mechanism. Farmers and extension workers also lack proper knowledge of effective DSR weed management, which is critical to success. In future activities, additional work on these two issues is needed. BRRI will publish the current study results in their Annual Research Review book and is planning more work on DSR. At some sites during the study, especially Dinajpur, DSR weeding was carried out entirely by women, probably because in the DSR field the soil stays dry (not puddled and flooded as is the case with transplanted rice), which women report feeling more comfortable working in. Large-scale adoption of DSR *aus* may create an income-generation opportunity for female laborers, who usually do not have enough work during the *aus* rice-growing season, though confirmatory research on this topic is required.

Direct-seeded rice: Performance evaluation study II

In October 2020, CSISA initiated a dialogue with Bayer Crop Science to gauge its interest in working to raise awareness of weed control products and varieties suitable for DSR technology in Bangladesh. This led to the planning of collaborative activities for the spring *aus* season in 2021. CSISA and BRRI's collaborative research on DSR during the 2019 and 2020 *aus* seasons had highlighted the importance of sowing date optimization for DSR, in response to which, during this reporting period the Activity conducted on-farm activities to assess the effect of sowing date and establishment methods on DSR yield and productivity.

However, Bayer Crop Science rice hybrids are mostly appropriate for the summer *aman* season and not well-matched for the spring *aus* season (because of their relatively longer duration for the *aus* season), so the trial just used BRRI's most recently released inbred and hybrid varieties. The study was established in the 2021 *aus* season in two locations (Jheneidah and Gazipur) in a split-split plot design with three replications. The main plot factor was the two-crop establishment methods (line-sown DSR and transplanted rice). The sub-plot factor was two PQR varieties (BRRI dhan 85 and BRRI hybrid dhan 7), and the sub-sub-plot factor was four sowing dates (15 March, 30 March, 14 April and 29 April).

Grain yield of performance evaluation study II

The yields under both establishment conditions were higher at the Jheneidah site than at Gazipur, irrespective of variety. At Jheneidah, hybrid variety (BRRI hybrid dhan 7) gave a higher yield (1.0 t/ha; 20%) than the inbred variety (BRRI dhan 85), irrespective of planting date and establishment method. For BRRI dhan 85, the yields of the last three sowing dates were similar for both establishment methods (see table below), with the lowest grain yield from the first sowing date (15 March). BRRI hybrid dhan 7 followed a similar trend under DSR. For TPR, however, yields of the first (15 March) and last sowings (29 April) were significantly lower than the second (30 March) and third (14 April) sowings. These results indicate that the optimum sowing window for DSR in the *aus* season in Jhenaidah is 30 March–29 April.

Rice grain yield of BRRI dhan 85 and BRRI hybrid dhan 7 as influenced by establishment methods and different sowing dates in Jhenaidah, Bangladesh

Establishment methods	Jheneidah							
	BRRI dhan 85				BRRI hybrid dhan 7			
Sowing date	DSR		TPR		DSR		TPR	
15 March	3.85	Bb	4.43	Ba	4.87	Bb	5.87	Ca
30 March	5.07	Ab	5.65	Aa	6.47	Aa	6.81	ABa
14 April	5.32	Aa	5.77	Aa	6.03	Ab	6.91	ABa
29 April	5.14	Aa	5.38	ABa	5.71	Aa	5.93	BCa

Note: uppercase letters in a column compare sowing dates for establishment methods. Lowercase letters in a row compare establishment methods across a sowing date. Means in a column followed by the same letter are not significantly different according to Tukey's HSD at alpha = 0.05. DSR – line-sown dry direct seeded rice. TPR – manually transplanted rice.

At CSISA's Gazipur site, based on the average over-establishment method and planting date, hybrid variety BRRI hybrid dhan 7 produced a higher yield (1.3 t/ha; 37%) than inbred variety BRRI dhan 85 (Table 9). Among planting dates, inbred variety BRRI dhan 85 produced a higher yield when planted on 30 March and 14 April (3.8 to 4.0 t/ha) compared to 15 March and 29 April planting dates (2.7 to 3.4 t/ha) (see table, below). Similarly, BRRI hybrid dhan 7 produced maximum yield during the planting window 30 March–14 April, for both DSR and transplanting methods. Across all planting dates, DSR and transplanting methods did not differ in grain yield, except with the early planting date (15 March), where transplanting produced a higher yield than DSR.

Rice grain yield of BRRI dhan 85 and BRRI hybrid dhan 7 as influenced by establishment method and sowing date, in Gazipur, Bangladesh

Establishment methods	Jheneidah							
	BRRI dahn 85				BRRI hybrid dhan 7			
Sowing date	DSR		TPR		DSR		TPR	
15 March	2.69	Bb	3.39	Ba	3.49	Bb	4.19	Ba
30 March	3.99	Aa	3.97	Aa	5.05	Aa	5.21	Aa
14 April	3.83	Aa	3.78	Aa	5.15	Aa	5.56	Aa
29 April	2.76	Ba	2.66	Ca	4.19	Aba	4.41	Ba

Note: The uppercase letters in a column compare the sowing date for establishment methods. The lowercase letters in a row compare establishment method across sowing dates. The means in a column followed by the same letter are not significantly different according to Tukey's HSD at alpha = 0.05. DSR: line-sown dry direct-seeded rice; TPR: manually transplanted rice

The preliminary results found that in Jhenaidah the best time for DSR sowing appears to be 30 March–29 April, and in Gazipur, 30 March–14 April. Across all sites, establishment methods and sowing dates, BRRI hybrid dhan 7 had a 10%–30% higher yield than BRRI dhan 85. The results of this study will run the scenario to extrapolate results to other locations using the ORYZA rice crop model. To validate the results of the current finding, the study may be continued in the next *aus* season.

Direct seeded rice awareness-raising activities

In addition to on-farm research activities, additional awareness-raising activities were planned for the *aus* 2021 season; however, most of these were suspended due to COVID-19 restrictions.

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

Since the 2016 outbreak of wheat blast disease that affected 15,000 hectares across Bangladesh, CSISA has collaborated with international and national partners to develop appropriate agronomic and varietal recommendations for integrated disease management. Further outbreaks of wheat blast in South Asia – a region where people consume over 100 million tons of wheat each year – could have an enhanced impact on food stability and income security. In 2016, wheat blast struck South Asia unexpectedly, with crop losses in Bangladesh averaging 25 to 30 percent, threatening progress in the region's food security efforts. Estimates are that blast could reduce wheat production by up to 85 million tons in Bangladesh, equivalent to $13 million in foregone farmers' profits each year when an outbreak occurs. This section of the report provides updates from the reporting year on advances made in this work.

Institutional adoption of the wheat blast early warning system

In response to the first appearance of wheat blast disease in Bangladesh in 2016, the CSISA and a previous USAID supported activity (the Climate Services for Resilient Development in South Asia (CSRD) project) teams collaborated with the University of Passo Fundo (UPF) and the Brazilian Agricultural Research Corporation (Embrapa, Brazil's national research and extension organization) to develop a preliminary wheat blast predictive model driven by weather data. Collaboration with Embrapa was strategic in that wheat blast has its center or disease origin in South America, and Embrapa scientists had worked on wheat blast management for decades before the disease was found in South Asia.

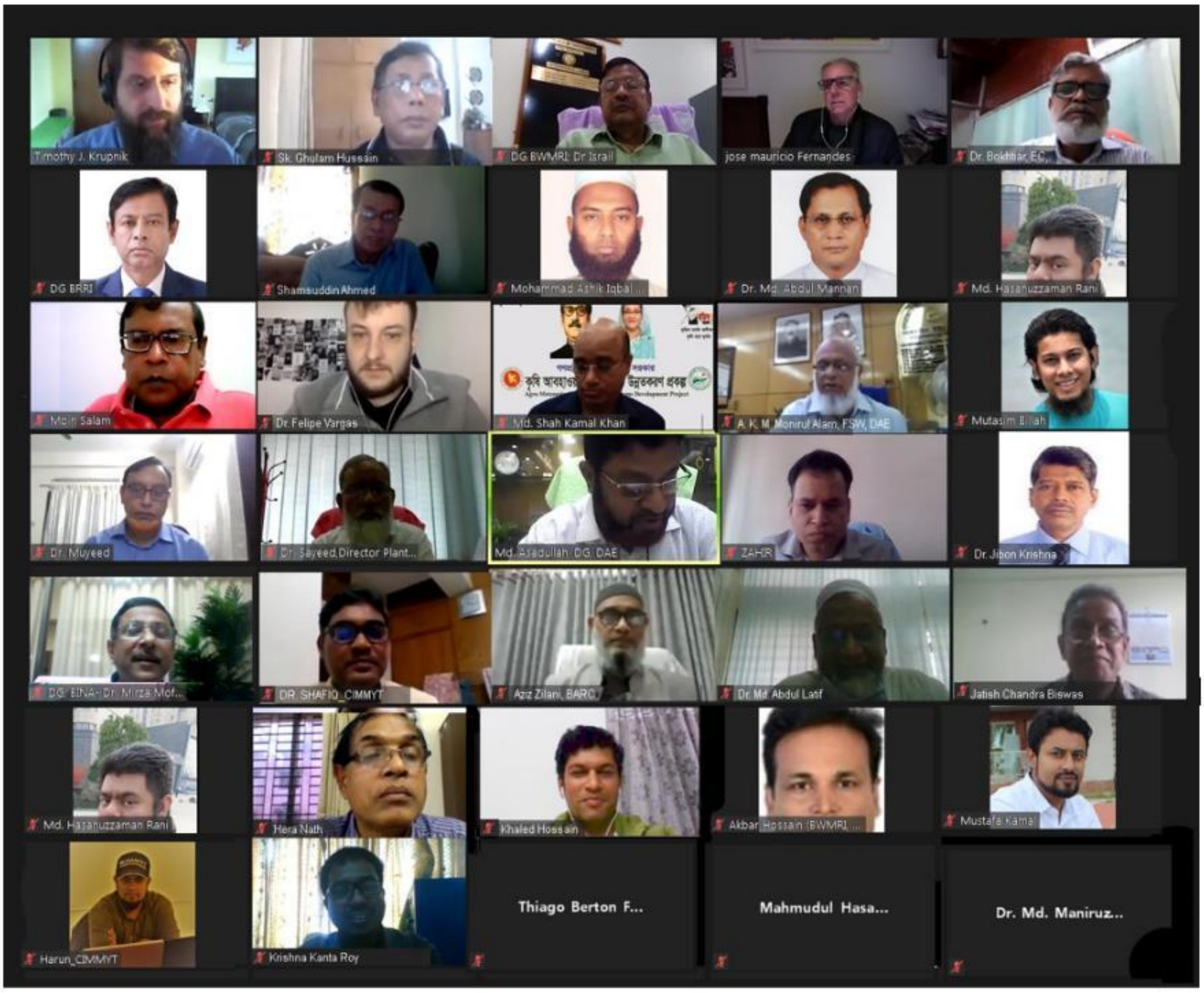
DAE validated a released beta-version of the predictive model-driven and from 2018 used it to advise farmers of the disease forecast for better-bet disease management since 2018. This was followed by a validation workshop held in December 2019 at BARC, with the system officially accepted by DAE, BWMRI and BMD, and formally endorsed by the Ministry of Agriculture (see www.Beattleblastews.net). Subsequently, CSISA facilitates training for DAE master trainers in the use of the wheat blast advisories that the early warning system (EWS) provides, and by the end of February 2020, more than 800 extension agents had been trained and began to receive alerts in their designated working territory whenever a risk of wheat blast outbreak was predicted[5]. In the 2020–21 wheat season, more than 6,500 extension agents were enrolled in the system, and 2,273 alerts for locations at risk of outbreak were sent via SMS to users in 13 *upazilas*.

In the second half of the 2020-21 reporting period, CSISA organized a high-profile virtual workshop to disseminate findings on the wheat blast early warning system (31 May, 2021). Participants included 35 scientists from NARES and Extension System and Embrapa and the University of Passo Fundo, Brazil, as well as the Chairman of BARC, Directors General of DAE,

[5] In consideration of the wheat growing season, alerts are restricted from January to April which corresponds to the wheat phenological stages in Bangladesh, from heading to maturity.

BRRI, BARI, BWMRI, Director of BMD, and the CIMMYT Country Representative. The workshop's main focus was on wheat blast disease ecology and epidemiology, how the predictive model works, user enrollment in the system and their experiences, and future strategies were discussed. Although wheat blast has not occurred on the same scale as in 2016, the outbreak risk remains high. All the participants showed appropriate awareness and concern, with a strong emphasis on strengthening EWS at the national level. As part of its ongoing work, CSISA contributes to the maintenance of the EWS system and has enrolled another 7,500 extension officers, who are now primed to receive automatic advisories by email and/or SMS if there are future outbreak risks. Additional options for improving the system under consideration by the CSISA research team and governmental partners include delivering blast warnings directly to farmers using IVR technology in at-risk locations, although this option is more costly and requires governmental co-investment to support sustainable delivery.

These efforts also attracted the attention of BRRI, who approached CSISA in late 2020 following the workshop and requested a research collaboration to adapt the wheat blast EWS to predict outbreaks of rice blast. The collaboration is now underway with BRRI's Department of Plant Pathology. Scientists from both teams have assembled a comprehensive dataset of more than 3,500 GPS reports of rice blast from recent years that are being analyzed to assess if data can be used to generate reliable rice blast outbreak warnings.



Above: Screenshot of participants attending the Wheat Blast Early Warning System virtual workshop.

Spotlight on wheat blast model early warnings in Bangladesh and Brazil

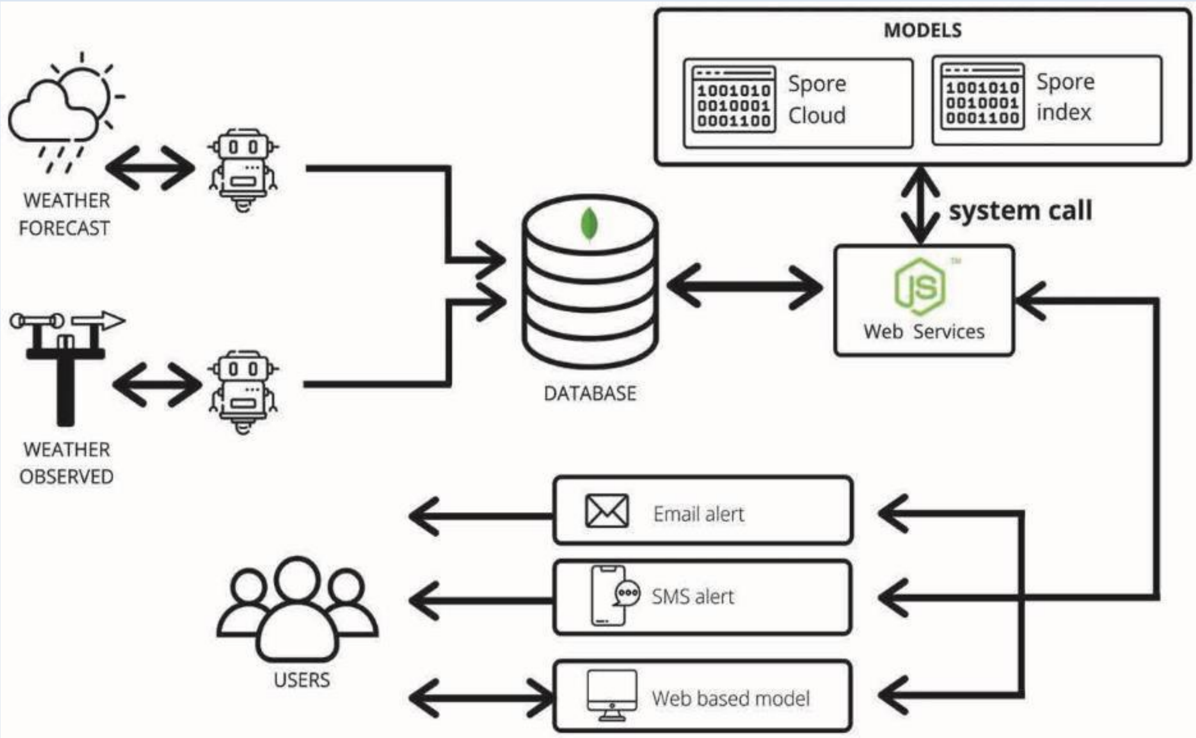
Recognizing the strong dependence of wheat blast epidemics on seasonal weather (which varies across regions and seasons within a region), CSISA considered that a prediction system that operates at large would be helpful to anticipate the risk of outbreaks early in the season. It developed an early warning system (EWS) for wheat blast, consisting of a computerized framework integrating several geographic, climatic, and biological layers. The EWS has four components: (1) weather data, (2) a sporulation favorability index, (3) a spore cloud density prediction model, and (4) the disease alert distribution system.

An entire set of hourly meteorological data, including air temperature, precipitation, solar radiation, and relative humidity, is needed to predict wheat blast risk. Dynamic data collection and disease simulation were implemented in the system every 24 hours according to the task schedule in the Linux Cron (the latter being a long-running process that executes commands at specific dates and times). The first step is to process the weather data delivered by each weather station stored in the database. Secondly, numerical weather data forecasting the next 120 hours is processed from each cell corresponding to the wheat-growing areas in the specific region. The historical 60-day observed weather data serves to identify wheat blast risk factors, including sporulation index and spore cloud density (the latter is simulated as the density spores in a 1 m^3 area over the crop canopy, subject to assumptions of current air uptake, atmospheric diffusion, and wind shear, all of which can affect and reduce spore longevity).

The wheat blast EWS is available at http://beattheblastews.net. Its current implementation integrates weather databases, and scripts for specific submodules developed using different programming languages. For example, the spore index was implemented using the R programming language based on previous work, and the spore cloud model was implemented using C++ based on a generic disease model. All the submodules are integrated, and information on infection risks and crop management advisories are delivered to end-users via e-mail, SMS, and the web. The model diagram is presented in Figure 1.

This EWS has been made operational in Bangladesh and Brazil. In Bangladesh, to more accurately identify and map risk areas, three-hourly Weather Research and Forecasting (WRF) model outputs are supplied by the Bangladesh Meteorological Department at an 18-km^2 grid resolution for all wheat-growing areas of the country. WRF forecasts are generated on a three-hourly rolling basis for five days into the future and combined with an automatic weather station network for observed data. These are used to drive the wheat blast predictive model, with advisories generated at this spatial and temporal resolution when the model indicates sufficient risk. In Brazil, the Eta Model output is provided by CPTEC/INPE (https://www.cptec.inpe.br) at a 20-km^2 grid resolution for all wheat-growing areas. These are used to generate time- and location-specific advisories on a five-day forecast basis. The model adequately described the observed epidemic and non-epidemic years in Brazil and Bangladesh.

More than 6,000 agriculture extension officers are currently using the wheat blast EWS in Bangladesh. In Brazil, the system has been included on digital platforms already in place in some wheat-growers cooperatives, who then spread alerts through their website or in-house applications. Finally, CSISA hopes that the system will give farmers in both countries time to take preventative measures against wheat blast, as without such action, outbreaks can massively reduce crop yields.



Above: Schematic of the wheat blast-early warning system operational in Brazil and Bangladesh.

Effect of cultivar mixtures on wheat blast

Following the emergence of wheat blast disease in Bangladesh in 2016, CSISA began working in collaboration with BWMRI and Bangladesh Agricultural Research Institute (BARI) to identify sources of resistance and develop resistant varieties, explicate the epidemiology of the disease, and find the best control measures to mitigate wheat blast in Bangladesh. As a part of this collaborative work that included additional projects led by CIMMYT but supported by the Australian Center for International Agricultural Research, in 2017 a blast resistant, zinc-enriched variety, BARI Gom 33 (which carries a wild wheat chromosome segment referred to as 2NS that confers blast resistance), was released and fungicide recommendations developed to reduce the disease intensity. However, excessive fungicide spraying can lead to the growth of the pathogen by developing resistant genetic characteristics against fungicide. Research findings indicate that a field with genetically similar plants may create a more conducive environment for disease development. Mixing the number of cultivars grown together in a single field could however confer some level of protection. Studies show that mixing different varieties of grain crop can reduce disease intensity.

In many cases, mixing cultivars also increase yield as well as helping to stabilize the crop. This is because of the dilution of spores, the barrier effect caused by resistant cultivars, induced resistance, disruptive selection, and compensation effects. Without using fungicide (or by using a minimum amount), this is an option to manage wheat blast disease. Lastly, although considerable efforts to multiply BARI Gom 33 are underway, it will take a number of years before sufficient seed is available to provide to farmers at scale.

With this in mind, CSISA conducted a cultivar mixture trial experiment to identify mixture combinations suitable to reduce wheat blast disease and to discover to what extent fungicide can control blast in a conducive environment and under high disease pressure. Mixtures are a potentially feasible option in Bangladesh, given that following harvests, groups of farmers often grain of multiple varieties before selling them. Unlike in rice production, wheat varieties are also commonly mixed during milling into flour.

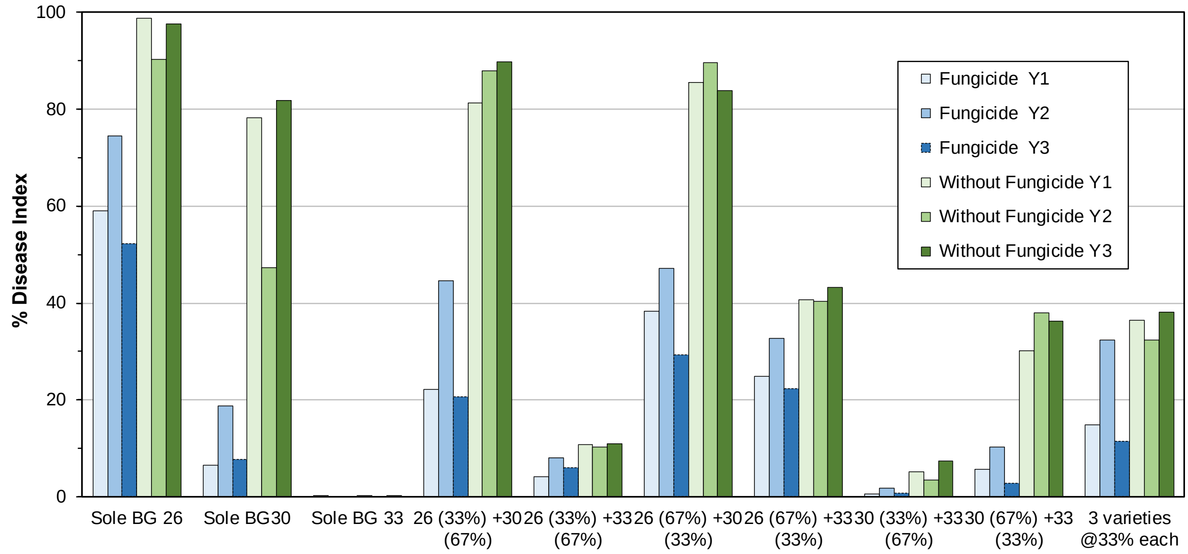
The reporting period was the third year of a trial that started in the 2018–19 season. It was initiated in the winter wheat-growing season of 2020–21 at the same location as the previous two years (for earlier findings, please see CSISA Annual Reports 2019 and 2020). As in previous years, three wheat varieties – BARI Gom 26 (blast susceptible), BARI Gom 30 (blast tolerant), and BARI Gom 33 (blast resistant) – were selected for testing in seeding mixtures with different seed densities. Ten sub-plot treatments – six two-variety mixtures with (i) 33% + 67% and (ii) 67% +33% seed densities, one three-variety mixture (33% + 33% + 33%) and 3 sole varieties – were prepared and sown on 25 December, 2020. The experiment followed a split-plot design with five replications, where the main plots were divided into fungicide and without-fungicide treatments surrounded by three border rows of blast-susceptible BARI Gom 26, and inoculated with spores at seven-day intervals starting from the early reproductive stage of the crop. The fungicide Nativo 75WG was sprayed five days after each inoculation in the fungicide main plots. The trial was conducted under a misting irrigation system. In the 2020–21 season, the experiment was harvested on 28 March 2021. It recorded wheat blast incidence and severity percent from 30 randomly tagged plants three times, at growth stages 75, 80, and 85 days after seeding. The percent disease index (%DI) was calculated using the percentage of blast incidence and severity. The trial also partially investigated *Bipolaris* leaf blight (BpLB), the most common wheat disease in Bangladesh. *Bipolaris* leaf blight data was recorded three times at the above growth stages from the flag leaves of 30 randomly tagged plants and converted to percent diseased leaf area (%DLA).

The results indicated that years, main plots, treatments and their interactions significantly affected the blast disease index. In case of BpLB, the main plot and treatment interaction has significant differences over the years. Yield is significantly differentiated when interacted with treatments. Among the 10 sub-plot treatments, the highest yield and lowest %DI were recorded in sole BARI Gom 33, and the lowest yield and highest percent disease index in sole BARI Gom 26 when fungicide was applied or not over the years. The sole BARI Gom 30 treatment was an average performer for both the above parameters in

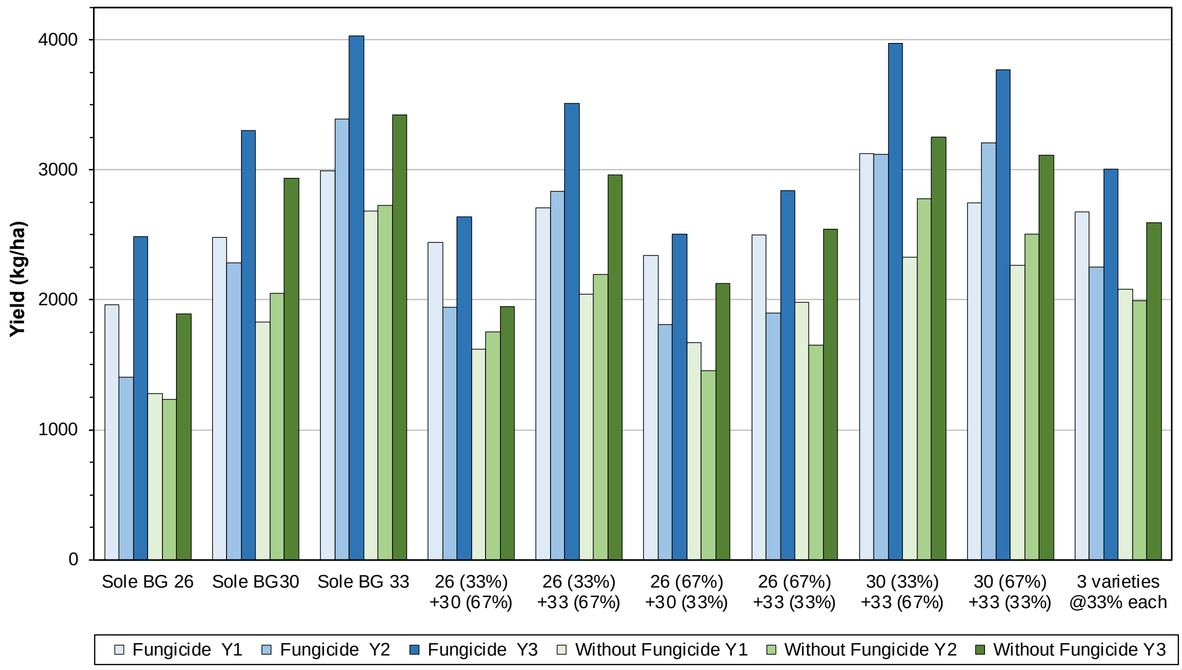
Analysis of variance showing different levels of significance among different treatments over disease index and yield

Sources of variation	Prob > F		
	Blast disease index	BpLB diseased leaf area	Yield
Year (Y)	0.0421*	0.0002*	<.0001*
Main plot (MP)	<.0001*	<.0001*	<.0001*
Treatment (T)	<.0001*	<.0001*	<.0001*
Y x MP	<.0001*	0.8451	0.1842
Y x T	0.0302*	0.6782	0.0133*
MP x T	<.0001*	<.0001*	0.6555
Y x MP x T	0.0095*	0.5633	0.8902

both situations in three years. The percent blast disease index was significantly lower than sole BARI Gom 26 in both conditions but higher than BARI Gom 33 over time.



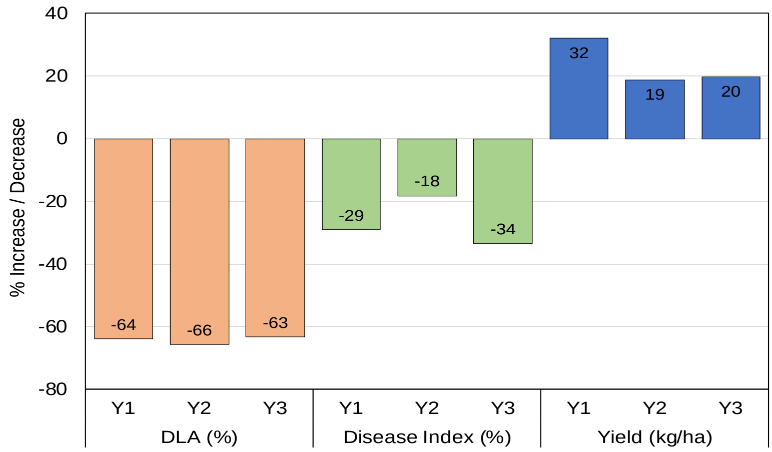
Above: Interaction effect of fungicide treatments and years on % Disease Index.



Above: Interaction effect of fungicide treatments and years on yield.

Among the mixtures, the highest yield was recorded in 30(33%)+33(67%) seed densities, followed by 30(67%)+33(33%) in both fungicide and without-fungicide conditions. Their percent disease index was lower than BARI Gom 30 in both conditions, but similar to BARI Gom 33 when fungicide was applied, and slightly higher when not applied. In both conditions, the third-highest yield was recorded in the 26(33%) +33(67%) mixture, significantly higher than sole BARI

Gom 26 but lower than sole BARI Gom 33. Fungicide spraying reduced the BpLB and the disease index for wheat blast, and increased grain yield.



Above: Effect of fungicide on % diseased leaf area (DLA) BpLB, % blast disease index and wheat yield over years.

The three years of results indicate that the blast-resistant BARI Gom 33 that carries the 2NS gene is the best variety for yield and disease control in both 'fungicide applied' or 'not applied' situations. However, this is a newly released variety and seed is not yet adequately available at the farmer level. Given these circumstances, the results of the three years of trials indicate that mixing BARI Gom 30 seed (33% or 67%) with BARI Gom 33 (67% or 33%) and BARI Gom 26 33% with BARI Gom 33 can be effective in reducing wheat blast and BpLB disease infection and maintaining a desirable yield levels for farmers unable to secure sufficient amounts of BARI Gom 33 to plant their entire field. These results will be disseminated for review and potential endorsement by the Ministry of Agriculture as an alternative method of wheat blast disease management that can be used by farmers unable to access sufficient quantities of BARI Gom 33. Further information on progress towards this goal will be provided in the next semi-annual report.

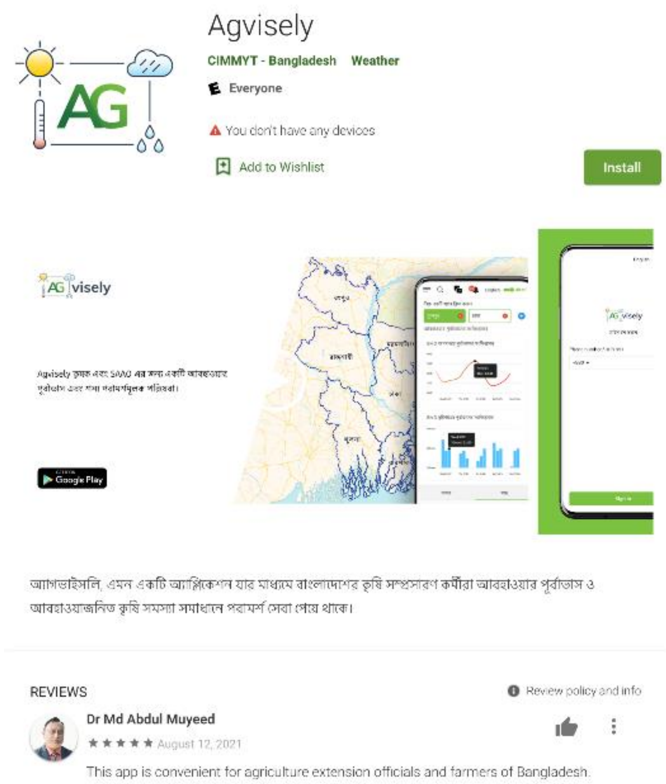
2. Adding value to extension and agricultural advisory systems

A.2.1 Strengthening the foundations of agro-advisory through knowledge organization and data integration

Building farmers' resilience using actionable climate services: national partnerships result in large-scale use of the Agvisely decision support tool

Agvisely is an agro-meteorological services tool developed to support frontline DAE extension officers, especially SAAOs, by providing a national climate information service to increase agricultural resilience to climate risks in Bangladesh. Agvisely integrates location-specific meteorological forecasts generated by the Bangladesh Meteorological Department (BMD), based on which it automatically generates agricultural advisories at the *upazila* level. Each crop has a specific threshold point at its different phenological stage, above or below which it is stressed or damaged. Using temperature and precipitation forecasts for the next five days at the *upazila* level, the thresholds for the likely phenological stage of each crop are compared to the forecasted values. If the weather forecast is above or below the thermal threshold, the anticipated impact on the crop will be detrimental or damaging and the advisory for mitigating the impact is automatically triggered. Similarly, based on the forecasted rainfall amount, an advisory for mitigating its impact is automatically triggered. In this way, the SAAOs receive an advisory that can suggest to farmers what measures they should take to mitigate extreme environmental issues. In November 2019, Agvisely was endorsed by concerned government agriculture research and extension departments of Bangladesh as an official agro-meteorological advisory tool for SAAOs to advise farmers at the grass-root level. The application was also linked to the DAE, Bangladesh Agro-Meteorological Information Systems (BAMIS) and BWMRI website homepages. Meanwhile, CIMMYT developed a database of around 6,400 SAAOs with active mobile phone numbers. Its purpose was to phone them to register, popularize and ensure greater application use during the COVID pandemic.

During the 2020-21 reporting period, CSISA then rearranged a series of virtual meetings (20–29 June, 2021) with all the cadre officers and SAAOs. For the first time in DAE's 14 working regions, the Agvisely application registration process was demonstrated to participants to ensure ease of understanding and experience-sharing. Although it was the last month of the current fiscal year, in most of the meetings, either the Director General or Director (Field Service Wing) from DAE attended as chief guest and the respective Additional Director of that particular region as special guest. Participants in these meetings then went away and instructed their field-level workers to use and validate the application at the field level. These virtual sessions witnessed highly active participation from DAE field officials, with a total of 2,600 DAE personnel attending. Among them, almost 90% registered themselves successfully for Agvisely (or did so with the help of colleagues who had already registered), which was confirmed by monitoring the administration panel on the app.



Above: Google play store screenshot where the Agvisely application can be downloaded for free use on mobile phones

Currently, Agvisely has more than 5,900 registered users, covering more than 90% of the SAAOs who active mobile users are, as supplied by DAE. CSISA has received very positive responses from the participants, who expressed their pleasure to be among the first to use an auto-generated climate-smart advisory app in Bangladesh. Those who have started to use the application have been told that it is already making a positive impact at the farmer level; they are now looking for more specific (that is, at the union level) and longer forecasts. In some regions (more specifically, in the north eastern '*haor*' (low-lying elevation) and coastal areas), SAAOs and higher-level officials have expressed strong appreciation of the forecast's accuracy and have recommended adding some new parameters (tide and thunderstorm) if possible. Zoom participants from almost every part of the country recommended adding new crops based on their local relevance, including disease and pest advisories. In response, the technical team added two new major oil and fiber crops (mustard and jute, respectively), meaning that nine major crops and pisciculture options, including indigenous fish culture, water temperature, and management, are now available in both Bangla and English versions. Participants were also very appreciative of the simplified registration process, which used their mobile numbers (previously, an active email address was mandatory). Keeping in mind the target group, the technical team has been working on improvements to the Android-based mobile application, which was released in such a manner that users can access it easily from remote locations where internet facilities are scarce. The Activity recently released the app on the Google Play Store for easy download, and uploaded the video, "How to do redistricted for the Agvisely application" on the CSISA YouTube channel. To obtain feedback directly from the user level, a help and feedback section was introduced in the application form. This enables the user to share their experience, comments, or feedback on any issue (e.g. weather forecast, crop advisory) directly with the team by using the application. A recently-formed Agvisely advisory panel comprised of CSISA staff and governmental partners regularly checks the feedback and follows up with senders to improve the app.

Stempedia: development of a weather forecast-driven early warning system for lentil crop diseases

Spotlight on lentil disease management

- With efforts beginning in 2019, CSISA developed a weather forecast-driven early warning system for precision application of fungicide ('on-time-no-less-no-excess-frequency') to control *Stemphylium* blight (SB) disease.
- The SB early warning system (SB-EWS) is a potential replacement for the conventionally prescribed, blanket, calendar-based three-time fungicide application.
- CSISA and BARI has tested the SB-EWS and it proved its merits in 120 field tests in Bangladesh and Nepal.
- Lead researchers of the National Agricultural Research and Extension System of Bangladesh endorsed the system. A similar response is expected from Nepalese research leaders.
- The utility of SB-EWS has been communicated to stakeholders.
- Ownership and maintenance of the SB-SWS are being transferred to national agencies in Bangladesh and Nepal. During the transfer process, CSISA PIII will take a backstopping role.

Background

Lentil is a minor but essential crop in many cropping systems in South Asia, contributing to land productivity and providing low-cost nutrition to the resource-poor. The crop's productivity is constrained in the region, particularly due to *Stemphylium* blight (SB), a fungal disease which causes yield loss of up to 60% in severely infected crops. Management of SB – only possible through manipulation of genotypes – is limited, as varieties with full resistance to the disease are not commercially available (for discussion, please see CSISA Semi-Annual Report 2021).

Stempedia activities conducted in the 2020-21 reporting period

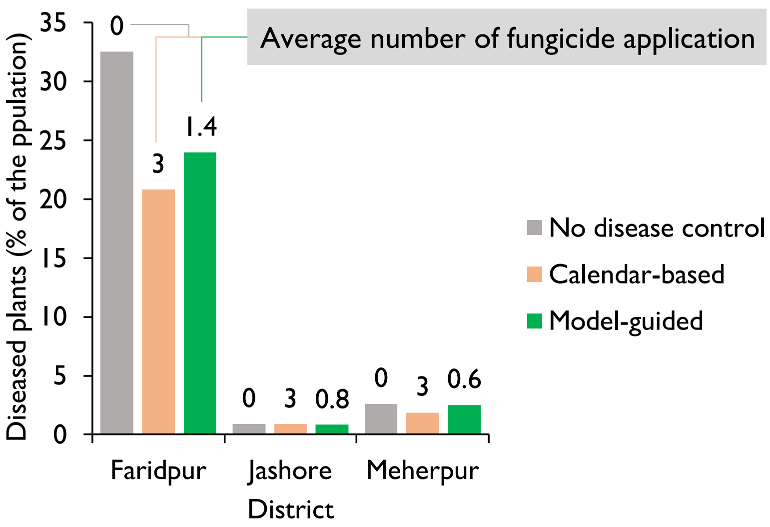
During the reporting period, activities focused on seven aspects of SB modelling work, described below. COVID-19 restrictions seriously disrupted engagement, including field operations, physical meetings, face-to-face consultations, and office and field visits. Nevertheless, the Activity fulfilled most of the planned activities with little compromise to quality.

Apprising top national agricultural research and extension leaders and decision-makers of SB disease and potential benefits of the SB-EWS: To disseminate information about SB and CSISA's proposed solution to its effects, CIMMYT and CSISA organized a national seminar (23 November 2020) at the Bangladesh Agricultural Research Council (BARC) in Dhaka, Bangladesh. CSISA's work in lentil was presented to 18 research and extension management leaders of Bangladesh. The seminar was attended by, among others, the Executive Chairman of BARC, Director General of BARI, Director General of the DAE and Director of the Bangladesh Meteorological Department (BMD). The participants expressed their appreciation of the modelling work, and suggested CSISA to field test the SB-EWS-based advisory with farmers during the 2020-21 season in Bangladesh and Nepal.

Formalizing partnerships with key national agencies: During the reporting period, CSISA formalized partnership agreements with NARC and the On-farm Research Division (OFRD) of BARI to field test the SB-EWS advisory in the 2020-21 season in Nepal and Bangladesh, respectively.

Developing and setting up the SB-EWS: The SB-EWS was initially developed in MS-Excel. The five-day projected weather forecast was obtained from either BMD in Bangladesh, the Department of Hydrology and Meteorology (DHM) in Nepal, or online weather forecast sites (https://www.weatheronline.co.uk/ ; https://www.weather-forecast.com/). The Stempedia model was run for each field-testing site using sourced weather data to determine the frequency and timing of fungicide application.

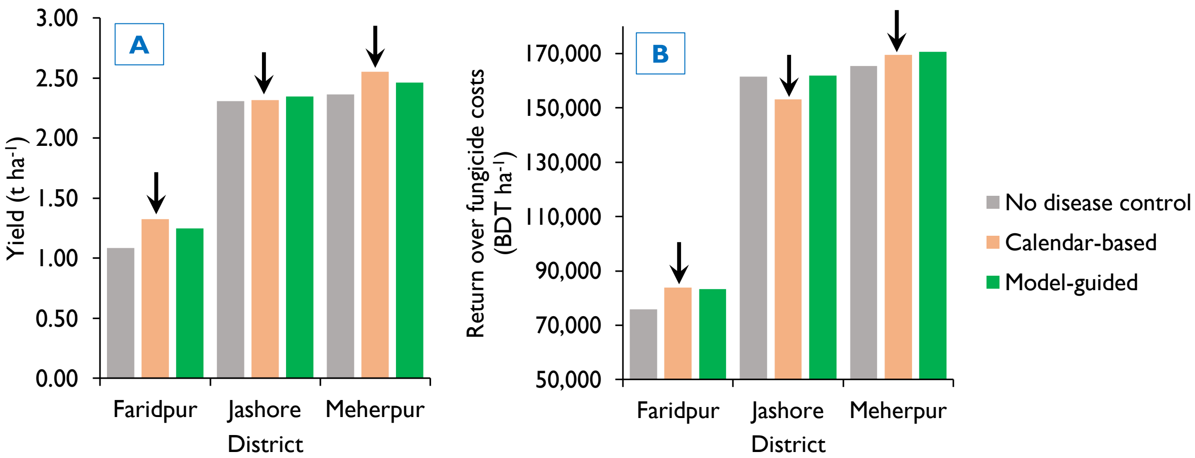
Undertaking field operations in implementing the SB-EWS in farmers' fields in partnership with national agencies: Following a developed protocol, the Activity field-tested the SB-EWS in 120 farmers' fields, 20 each in Faridpur, Jashore and Meherpur districts of Bangladesh, and Dang, Dhangadhi and Nepalgunj districts of Nepal.



Above: Comparison of lentil disease status in farmer fields in three districts of Bangladesh during the 2020–21 cropping season under three scenarios: (1) no fungicide application (current farmer practice), (2) three calendar-based fungicide applications, and (3) SB-EWS guided fungicide applications.

The experiments used to validate the forecasting system compared three scenarios: (1) no fungicide application (as per farmers' practice), (2) three calendar-based fungicide applications, and (3) SB-EWS guided fungicide application. The test used fungicide recommended by the national agencies, and disease and yield measurement were carried out according to protocol. Data were analyzed and key findings from Bangladesh are presented below.

Under a relatively high disease scenario (Faridpur district), (1) application of fungicide reduced the disease compared to no fungicide application, and (2) three calendar-based fungicide applications reduced the disease more than the SB-EWS-based, 1.4 fungicide applications. Such variation in disease reduction was less evident under moderate (Meherpur district) or low (Jashore district) disease scenarios.



Above: Comparison of lentil disease yield (A) and margin (B) in farmers' fields in three districts of Bangladesh during the 2020-21 cropping season under three scenarios: (1) no fungicide application (current farmer practice), (2) three calendar-based fungicide applications, and (3) SB-EWS guided fungicide application. The arrows show responses from three calendar-based foliar fungicide applications.

Lentil yield was higher after the calendar-based fungicide application in a relatively high disease (Faridpur district) or moderate disease (Meherpur district) scenario, but not under a low disease (Jashore district) scenario. Compared to the SB-EWS forecast, the calendar-based fungicide application resulted in a lower margin (when compared to fungicide costs) in the low disease scenario but similar margins in the moderate and high disease scenarios. Taken all together, the SB-EWS forecast reduced the frequency of foliar fungicide application, while producing similar or higher margins than calendar-based fungicide application.

A communication campaign to influence stakeholders: During the SB-EWS field tests, local farmers, and scientists from BARI in Bangladesh and NARC in Nepal frequently visited the field. The OFRD of BARI, a national partner of this work, organized three large gatherings of farmers and other stakeholders in Faridpur, Jashore and Meherpur districts of Bangladesh. Over 80 farmers participated at each gathering, together with regional and district-level extension officers, and elected local government representatives. Moin Salam, CSISA's lead consultant working on lentil diseases and Wasif Faisal, CIMMYT's Research Associate, communicated with stakeholders for several hours during the gatherings to deliver the message 'Follow the SB-EWS advisory': apply fungicide to control lentil Stemphylium disease only if required and only according to the frequency and timing as required.

Lentil *Stempedia* Model Piloting, National Endorsement and Plan of Action for Early Warning System Guided Advisory on *Stemphylium* Blight Risk & Fungicide Application

Above: Participants and attendees of the national workshop, "Lentil Stempedia Model Piloting, National Endorsement and Plan of Action for Early Warning System Guided Advisory on Stemphylium Blight Risk & Fungicide Application", 9 August, 2021, BARI, Joydebpur, Bangladesh. *Photo credits: Tim Krupnik and Md. Washiq Faisal.*

Above: CSISA delivers the message to stakeholders: by following the SB-EMS-based advisory, apply fungicide to control Stemphylium disease only if required and only according to the appropriate frequency and timing, with safety precautions adhered to. Pirojpur union, Meherpur, Bangladesh (13 September 2021). *Photo credit: Harun-Or-Rashid.*

Plan of activities for the rest of the year: The SB-EWS is in the process of being handed over to DAE in Bangladesh for ongoing use and maintenance. A similar initiative regarding ownership of the system in Nepal is under consultation. These are (1) finalizing the transfer of the SB-EWS to DAE in Bangladesh, (2) organizing meetings to secure the national endorsement of SB-EWS in Nepal, and (3) finalizing the transfer of SB-EWS to a national agency in Nepal.

A.2.2 Building precision nutrient management approaches around scaling pathways

This activity was deemphasized by CSISA after funding shortfalls and delays experienced in 2017 and 2018 that resulted in the departure of scientific staff leading the research. Since then, only limited work on precision nutrient management has been conducted in Bangladesh. As such and as indicated in previous reports no major activities were undertaken in this work package during the reporting period.

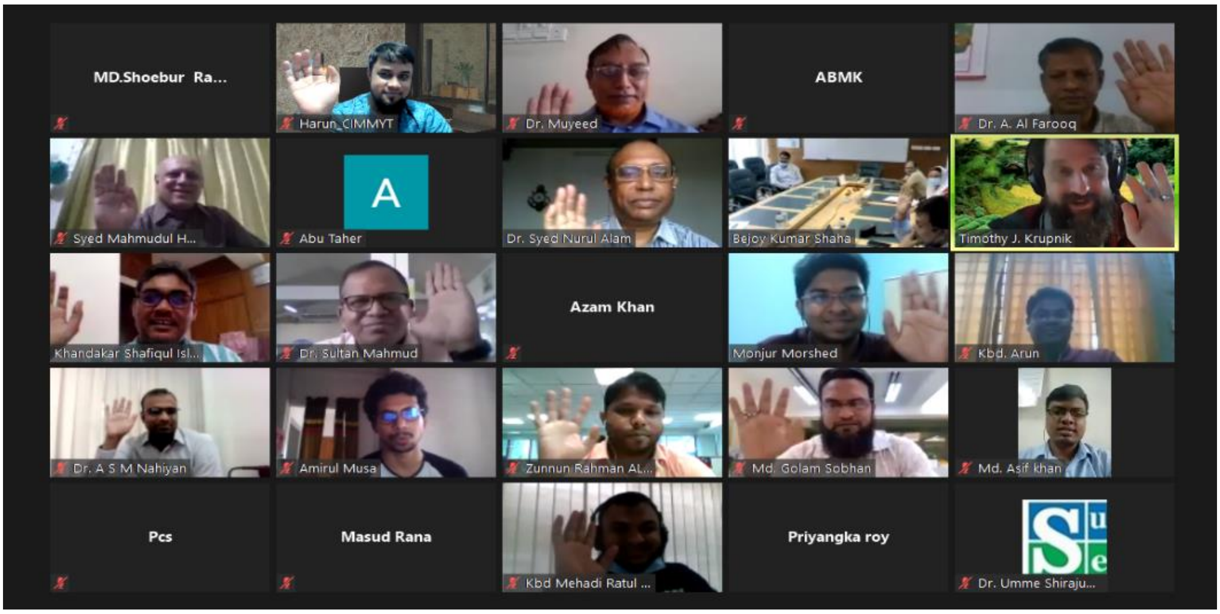
A.2.2 Aiding the Fight Against Fall Armyworm in Bangladesh

Fall Armyworm (FAW) is an invasive Lepidopteran crop pest native to the Americas, that has migrated to Africa and then to Asia, and has been in the process of colonizing Bangladesh since late 2018. FAW feeds on more than 80 species of plants, but maize (*Zea mays)* is its preferred host. The arrival of FAW in Bangladesh caused considerable concern – particularly within the Ministry of Agriculture – as maize has grown to be the country's second most widely grown cereal crop of significant economic importance to farmers, exceeded only by rice. In response, and supported by the University of Michigan and USAID/Bangladesh, the Fighting FAW Activity was initiated in 2019 as a synergistic project cooperating with CSISA and with national research and extension partners, in addition to the private sector, to mitigate the impact of the pest on farmers' income, food security and health. The project's design involves co-financing from CSISA Phase III to support activities in Bangladesh. Some of the key achievements that CSISA and the Fighting FAW Activity have accomplished in the last twelve months that involved cost-shares between the Activities include the examples provided below. The information below provides updates primarily on activities completed in the second half of the reporting period (from April – September of 2021). Details on the significant outputs and outcomes from this activity in the first half of the reporting period (October 2020 – March 2021 can be found in the [previous semi-annual report](#) and in the [Fighting FAW Activity semi-annual report](#)).

Overall achievements of the Fighting FAW Activity in association with CSISA: Although this Activity targeted working with DAE to scale-out trainings for at least 33,000 people, these targets have been significantly exceeded. To date, 187,000 farmers and people have been reached with FAW IPM information as a result of cascade trainings and one-to-one interactions between DAE and farmers that were catalyzed and encouraged by the Activity.

Virtual training workshop: master trainer training program on FAW for private company personnel: In collaboration with the Government of Bangladesh, the Fighting FAW Activity was assisted by CSISA in organizing a virtual "Master Trainer Training for Private Sector Partners to Respond to Fall Armyworm in Bangladesh" for private companies involved in the pesticide business, and maize seed production and marketing (17 June 2021). A total of 31 staff attended from 13 seed and agro-chemical companies completed the training.

Technical support for the private sector in responding to FAW: Bio-pesticides as an integral part of IPM are natural substances derived from plants, animals, bacteria, and certain minerals which possess pesticide-like qualities. One effective and relatively safe pesticide against FAW is the biological pesticide *Spodoptera frugiperda nucleopolyhedrovirus* (sold under the brand name 'Fawligen, SfNPV', produced by the Texas-based AgBitech and commercialized locally registered by IAL). Fawligen, SfNPV is a highly specific natural pathogen and kills the FAW larvae upon its ingestion. It is a highly cost-effective biological pesticide against FAW, and is non-toxic and non-hazardous, with residue and a low or no environmental and human toxicity risk. The Fighting FAW Activity, which was co-supported by CSISA, worked to support the expanded use of biopesticides during the reporting period.



Above: Screenshot of 'Master Trainer Training for Private Sector Officials to Respond to Fall Armyworm' Bangladesh, 17 June, 2021. *Photo credit: Md. Harun-Ur-Rashid.*

Commercialization of new biological and low-toxicity pest control products: With market and technical guidance from the Fighting FAW and CSISA activities, IAL launched marketing campaigns for Fawligen in the districts of Chuadanga, Jashore, Manikgonj, Dinajpur, Rangpur and Bogura districts in the first year of its commercial availability. In Dinajpur district, the total sales volume was much higher than in other areas – a total of 3,800 farmers purchased Fawligen in Bangladesh, of whom 1,850 (48.68%) were from Dinajpur. The reason for this is that from November 2021–March 2021 in Nashipur (in Dinajpur district), BWMRI, DAE, CSISA and the Fighting FAW Activity organized a series of FAW training programs for extension officials. IAL also organized several training programs for dealers/retailers, developing awareness which was reflected in a rise in sales.

Establishing a new biological product in the market takes time, and a comparatively low sales volume was initially expected. In addition, because FAW is a relatively new pest in Bangladesh, many farmers tend to be reluctant to implement any management strategy until the infestation becomes very high, when it becomes difficult to control with Fawligen alone. As a result, despite the initial success from Fawligen's commercialization, some doubt remains among farmers about the product's efficacy. The price of Fawligen is also high compared to other available chemical and biological pesticides, and for that reason, CSISA and the Fighting FAW Activity are working with IAL to adjust prices so the product can be fully market competitive and profitable. An additional constraint to marketing Fawligen in the region is the lack of cool storage facilities at the dealer level (Fawligen is a temperature-sensitive product that needs to be stored in the deep freeze under 4 °C, as its efficacy rapidly reduces in environment temperatures). As such, opportunities for pre-bookings of Fawligen by farmers prior to the cropping season are now being explored as a way to reduce dependence on cold storage.

While IAL has reported a number of challenges in marketing the product but remains very positive about its scope for market expansion, for the following reasons:

- The product is safe, non-toxic, and non-hazardous.
- There is little chance of resistance development by FAW (this is the main weakness of other chemical and other biological pesticides).
- In combination with other bio-pesticides such as *Emamectine Benzoete* or *Celestrus Angulas* the efficacy of Fawligen increases severalfold, meaning that only 2–3 sprays throughout the season efficiently manages the FAW population.
- The Government of Bangladesh emphasizes the commercial availability of biological pesticides like Fawligen, meaning that the expansion of the marketing of Fawligen is aligned with the government agenda.
- During this reporting period, the Activity has undertaken an extensive awareness and educational program on FAW management practices for farmers and retailers in the targeted areas. IAL reported positively that they expect the sales volume to increase in these areas in the upcoming year.

The Fighting FAW Activity and CSISA also supported Syngenta Bangladesh Limited (SBL) to develop markets FORTENZA® Duo, a seed treatment insecticide that delivers insect control.

To raise awareness and disseminate knowledge of this product, SBL established 50 demonstrations in 6.5 hectares of land with the collaboration of BWMRI and DAE in some of the pocket maize-growing areas in Bogura, Rajshahi, Rangpur, Dinajpur, Kushtia, Comilla, Dhaka and Mymensingh districts. These demonstrations are intended to build confidence among its internal sales force, as well as building awareness among farmers about the positive results of the product. SBL's efforts in promoting its new product will support growers to buy this new product. SBL also arranged training for maize growers in Bogura, Rajshahi, Rangpur, Dinajpur, Kushtia, Comilla, Dhaka and Mymensingh districts (November 2020–May 2021), which attracted a total of 6,900 maize growers (see graphs, above). SBL ensured COVID-19 distancing protocol was observed. This is a new product, requiring extensive collective effort to build greater awareness among growers while creating access to updated FAW management information and its dissemination among farmers, to create demand for Fortenza among farmers and DAE officials and increase the volume of sales in the forthcoming year.

Educational materials co-produced by CSISA and the Fighting FAW Activity yield impact in South East Asia: In late 2020, an video on biological control of FAW for farmers in Bangladesh completed in partnership with CABI, which is also active in FAW response in South Asia. The video on biological control of FAW can be found here. Since production, the video has been widely used by the Department of Agricultural Extension (DAE) in trainings. Importantly, the biological video was also further adapted by CABI in March through April of 2022 and is now being used in Vietnam and Thailand having been translated in the Vietnamese and Thai languages.

FAW population and crop damage monitoring continues: Manual observations of FAW populations in Bangladesh remains ongoing through the Bangladesh Fall Armyworm Monitor in collaboration with DAE. During winter season 2020–21, which extended beyond the first six months of the reporting period, FAW monitoring data recordings were done from maize fields across 259 unions of 199 sub-districts of 25 districts and during kharif maize 2021, 85 unions of 55 sub-districts of 7 districts that the level of FAW infestation in Bangladesh has been more severe in the 2020-21 winter season than the previous 2019-20 season. These data are represented on updated versions of the open-access data FAW Monitor for Bangladesh, and on a detailed dashboard developed for research purposes. This is likely due to generally higher temperatures in a number of locations and the lack of late season rainfall.

The roll-out of monitoring in the 2020-21 season, however, was significantly slowed due to the COVID-19 crisis, and likely was affected by the modality employed by the Activity of re-training DAE staff on monitoring. Although staff did complete the virtual refresher training, internet connectivity issues and also the slow deployment of traps and pheromone in the winter season meant that it took well into January for the majority of DAE staff to begin monitoring. The slow implementation may also have been due to leadership changes within the extension department that affected the speed of activities. As of February -March, most of the sub-districts and unions required for effective monitoring were reporting data each Monday, which continued till the end of kharif 2021 maize season.

Above: Farmers in Dinajpur scouting for FAW damage in their fields in Dinajpur, Bangladesh, in January of 2021. *Photo credit*: *Zakir Hussain.*

As maize is not only the host plant of FAW and it can attack more than 82 crops, monitoring of FAW infestations has also been done in another four crops, cabbage, tomato, tobacco and rice. Non-maize monitoring was being done by the scientists and scientific staff of BARI and BRRI at different locations throughout Bangladesh.

So far, the highest plant damage observed in the winter 2020-21 rabi season was recorded in tobacco with the highest incidence rate of 5.2% in the younger or seedling stages, (last year it was around 11%), followed by infestation in tomato (2.9%; last year it was around 2.8%) and cabbage (0.5%, last year it was around 1.2%). No attack was observed yet in winter season boro rice, however many FAW male moths were captured in the pheromone traps set in the rice fields, especially higher number of catch was recorded in the farmers' rice fields surrounded by maize.

Advances in research on FAW in Bangladesh: Research on integrated pest management of FAW is ongoing in partnership with the Bangladesh Agricultural Research Institute, Bangladesh Wheat and Maize Research Institute, and the Bangladesh Rice Research Institute. Focus areas include screening studies to evaluate the effectiveness of new pest-control materials, and on agroecological management methods for FAW.

- Field efficacy studies revealed that among the five tested bio-pesticides two new biopesticides, *Bacillus thuringiensis (Bt)*+Spinosad (Minchu plus) and *Bacillus thuringiensis* var. Kurstaki (Bio-Bt-K) showed higher effectiveness in reducing FAW infested plants as well as cob damage.

- Four species of parasitosis were found parasitizing FAW life stages in the studied area. Among them, two were egg parasitosis and identified as *Telecoms remus* and *Trichogramma pretiosum* and one was larval parasitoid *Cotesia* sp and another was egg-larval parasitoid *Chelonus* sp. The identification was done using available taxonomic keys. However, the parasitoids identification will be confirmed by molecular analysis. *Trichogramma pretiosum* was identified first time in Bangladesh. The average egg mass parasitism rate by *Telelomus remus* was 22.38%, while it was 7.60% by *Trichogramma pretiosum*. Larval parasitism was 4.00% and 4.72% by *Chelonus* sp. And *Cotesia* sp., respectively.
- A study was conducted on parasitization efficiency of *Telenomus remus* and *Trichogramma pretiosum* on eggs of *Spodoptera frugiperda* in IPM laboratory at Entomology division BARI, Gazipur during February – April 2021. Parasitism and emergence rates and the duration of the egg-to-adult period of *T. remus* and *Trichogramma pretiosum* were investigated following 48-h exposures of these parasitoids to egg mass of *Spodoptera frugiperda.* The duration of egg to adult and the frequency of parasitism and emergence, adult longevity, sex ratio was studied. Results from the no-choice test indicate that the parasitism efficiency of *Telenomus remus* wasps was recorded 95.91%. Adult emergence rate from the parasitized eggs was 86.75% with 80.11% female. Egg-to-adult period of *T. remus* in fall armyworm eggs was 14.69 days and adult female survive up to 9.00 days, whereas the parasitism efficiency of tested *Trichogramma pretiosum* wasps was recorded 84.12%. Adult emergence rate from the parasitized eggs was 73.31% having 81.67% female. Egg-to-adult period of *Trichogramma pretiosum* in fall armyworm eggs was 10.0 days and adult female survive up to 8.67 days. These studies confirm that *Telenomus remus* and *Trichogramma pretiosum* can parasitize FAW eggs very effectively in the field and can be used in the IPM program for FAW's effective natural management.
- Multi-locational data suggest that maize intercropping with cowpea reduces FAW infestation on maize in the winter season, although cob infestation did not differ significantly among the treatments. However, more return from intercrops was the extra benefit and due to that, economic returns are higher in the intercrop plots than mono crop plots.
- Considering higher efficacy and marginal benefit-cost ratio (MBCR), an IPM package comprising of seed treatment with Fortenza 60 FS + intercropping with radish + alternate spraying of Fawligen and bio-pesticide Tracer 45 SC starting from visible plant infestation at 15-day interval + spraying of Tracer 45 SC at visible cob infestation, was identified a s a viable option for management of FAW.
- Research has shown that FAW can complete its life-cycle on rice, although further research is needed to assess if this could be a risk under field conditions outside the lab.

New FAW response efforts in Bangladesh: With the support of the USAID/Bangladesh Mission, CIMMYT entered into a partnership with Virginia Tech University and the FAO in Bangladesh as a consortium partner on a new FtF IPM Activity that commenced activities in September of 2021. This new project, which will run until 2023, provides additional emphasis on FAW management. As such, exempting specific research that was conducted in previous work co-supported by CSISA through the Fighting FAW activity, future outputs from CIMMYT's work on FAW in Bangladesh will be reported as part of the FtF IPM Activity.

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 profitability of crops. Communicating this to farmers and providing access to advise on appropriate and proven agronomic practices through easily understandable extension materials is an important means to scale out these practices among the communities they are designed to reach. CSISA has produced a range of extension materials 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 factsheet on wheat blast mitigation.

Extension advice on how to grow more healthy and productive rice seedlings reaches more than 130,000 farmers in the reporting period

Healthy rice seedling (HRS) awareness activities, including video screenings, leaflet distribution, training, and establishing community seedbeds, conducted during the last reporting period, have resulted in increased grain yield of 7%–10% (for details, see CSISA Annual Report 2020). Since March 2020, however, COVID-19 restrictions meant that these activities were suspended, except for the preparation of community seedbeds for mechanized transplanting (either of mat or tray nursery seedlings) and community-based ideal seedbeds for manual transplanting. These were established in the winter *boro* 2020/21 and summer *aman* 2021 seasons. In collaboration with DAE and seed companies, CSISA assisted farmers in establishing community-based seed beds in Jashore (136), Dinajpur (48) and Faridpur (15), ranging in size from 30 to 50 *decimals*.

In February 2021, the CSISA team conducted a telephone survey to determine the status of adoption by farmers of HRS-raising practices, using a series of structured questions on the retention and use of knowledge they might have gained through the Activity's mass media campaign. Of the 662 farmers surveyed, 480 reported having seen a video promoting HRS and had raised HRS (for details, see the CSISA semi-annual report 2020-21). Respondents had earlier been registered to have viewed the HRS videos during the mass media campaign and received HRS leaflets. Extrapolating these results and summing data from reporting periods, over 130,000 farmers in Bangladesh have now adopted the principles of HRS in their fields.

The survey results also showed sustained adoption of HRS agronomic practices among rice farmers, with adoption rates increasing remarkably after seeing the HRS video in terms of seed bed preparation, use of young seedlings, use of quality seed, and conducting seed germination tests.

Above: Left: a community seed bed for manual transplanting in Jashore Sadar, Jashore in the *boro* 2020/21 season. *Photo credit: Sharif Ahmed.* Right: a mat-type community seed bed for mechanical transplanting at Damurhuda, Chuadanga in the *aman* 2021 season. *Photo credit: Hafijur Rahman.*

B1.2 Rice-fallow development and intensified cropping patterns

Since the inception of CSISA's third phase, the Activity has focused work on coastal 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 – can be reliably brought into production using management practices that rely on approaches aligned with the goal of increasing cropping intensity. CSISA therefore conducts strategic research on pathways and approaches to encourage fallow land intensification, including de-risking crop production in the central coast of Bangladesh. Major activities conducted in the reporting period focused on mung bean cultivation – which is particularly well suited to replace fallows and has an emerging market of significance in Bangladesh – are discussed below.

Replacing fallow land with mung bean in Bangladesh: Large-scale trials of new commercial Rhizobium inoculant

Enhancing mung bean productivity through Rhizobium inoculation under rice-fallow stress-prone environments of southern Bangladesh: This applied research on-farm study was conducted with the private sector – specifically with the company ACI – with the aim of generating precise product performance data needed for the popularization of mung bean *Rhizobium* inoculation. While inoculants are available in Bangladesh, farmers' access to and understanding of these biological products are limited. In response, this new private sector partnership will expand the *Rhizobium* culture business model to improve soil health sustainability and orient farmers on the use and benefits of culture inoculation. Patuakhali Science and Technology University (PSTU), with support from Wageningen University and Research (WUR) and the Resilient and Climate Smart Agriculture project, also joined the partnership aiming at collaboratively testing the viability of inoculation for mungbean. This on-farm experiment executed the three treatments in 127 farmers' fields in two districts (Patuakhali and Barguna). The treatments were (1) farmers practice (T1), (2) farmers practice + *Rhizobium* inoculation (T2), and (3) BARC nutrient recommendation + *Rhizobium (T3).*

The study results clearly demonstrated that with a relatively small additional investment of BDT 397 (approximate USD 4.5 ha^{-1}), the use of Rhizobium culture inoculation boosted mung bean yield by 22% over traditional farming practices without inoculation. An additional approximate

2% cost increase in mung bean production is also unlikely to be a burden for resource-constrained smallholder farmers, while investment in inoculation can increase gross margin by an average of 29%. Conversely, when farmers also apply fertilizer with inoculation, with an investment of BDT 5,195 ha^{-1} (approximate USD 62 ha^{-1}), yield and profit potential increase further, but with significantly higher investment costs.

Enhancing mung bean productivity and profitability by practicing Rhizobium culture inoculation and improved fertilizer management in Southern Bangladesh (an aggregation of 127 on-farm field trials)

Treatments	Grain yield (kg ha^{-1})	Fertilizer / inoculation cost (BDT ha^{-1})*	Production cost (BDT ha^{-1})	Gross margin (BDT ha^{-1})
Farmer's practices (T1)	607 c	521 c	15,125 c	39,106 c
T1+ inoculation (T2)	738 b	918 b	15,444 b	50,438 b
T2 + Recommended fertilizer	916 a	6,113 a	20,639 a	61,097 a

CSISA implemented and monitored trials jointly, involving the committed interaction of farmers, researchers, and private sector personnel during the crop season. This increased the impact on the farmer community, enhancing their understanding of the Rhizobium culture and its importance to harnessing higher yields and gross margins. The process has already started to build the confidence of farmers while at the same time encouraging the private sector to consider larger investment and the expansion of their business through Rhizobium culture and fertilizer use. The Activity also expects that the results of these large on-farm trials will attract the kind attention of researchers, development leaders and policymakers, and encourage them to work together to produce the most appropriate strategy for Southern Bangladesh and its promotion of mung bean production in rice-fallow systems. The expansion of mung bean cultivation, coupled with improved efficient management, will ensure the increased availability of a nutritious protein source in Bangladesh.

Building farmers' resilience to weather shocks and replacing fallow land with mung bean in Bangladesh: Protecting against crop damage with climate services

Mung bean is a highly profitable legume crop, widely cultivated in the southern central coastal region of Bangladesh (especially Patuakhali, Barguna and Barishal districts). However, every year during the harvesting period (mid-April to the end of May), heavy rain and storm events cause large yield losses (and thus income loss) to mung bean farmers. In response, CSISA partnered with a now closed EKN and Mott MacDonald funded pilot project that ran from 2018-2020 that built an interactive voice response (IVR) system for mung bean farmers in some coastal areas of Bangladesh (Patuakhali and Barguna districts). This IVR system provides real-time weather alerts warning farmers to harvest their mung bean ahead of forecasted heavy rainfall events that could damage their crop. The system is interactive in that farmers can push-dial to select from a range of menu options to listen to other types of agronomic advice on mung bean, and to learn about mung bean markets. Any farmer with a phone can also dial 0960 450 0060 at any time to hear to updates from the system. CSISA has continued to work with this system, iteratively improving and expanding its use in coastal Bangladesh. Details on work during this reporting period can be found below.

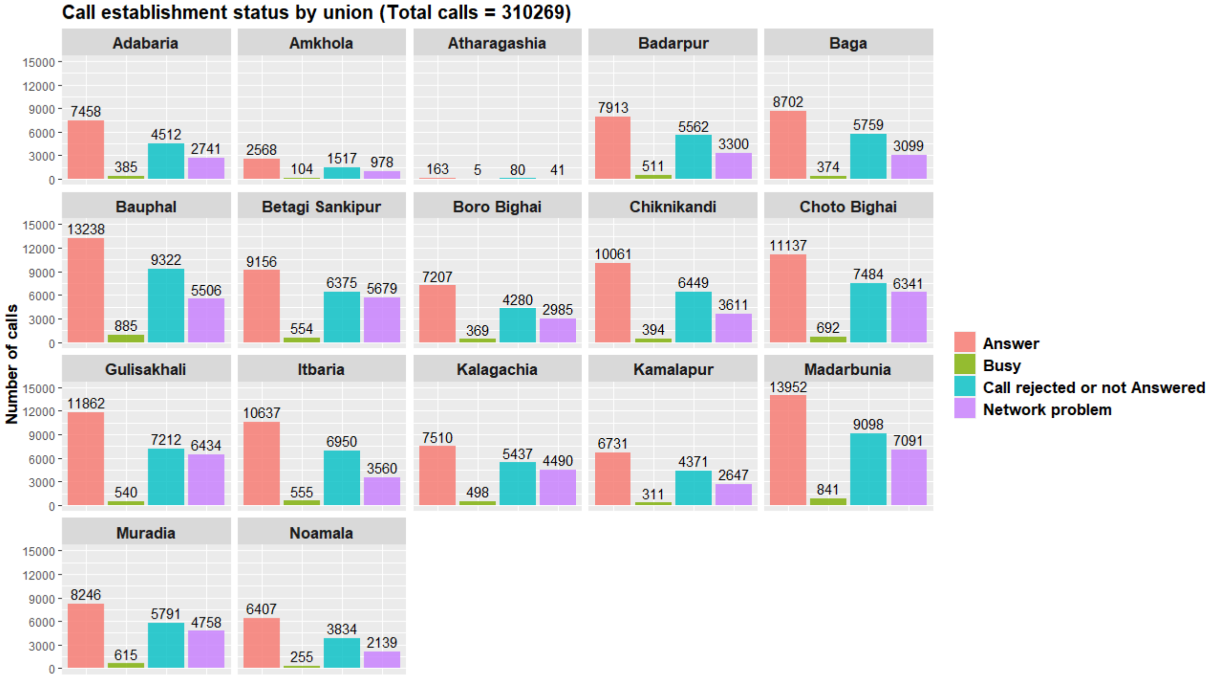
Expanding IVR services in the 2021 mung bean harvest period: The CSISA research team randomly selected an additional nine unions in Patuakhali and Barguna districts to reach more than 10,000 mung bean farmers and 70 DAE government extension agents with IVR advisories to provide them with mobile voice alerts to heavy rainfall during the mung bean season (March–June, 2021). The IVR service covered farmers and extension agents from 17 unions during the 2021 harvest period (for details, please see the [CSISA III Semi-Annual Report October 2020–March 2021](#)).

Collecting information of an additional 10,000 mung bean farmers with farmers mung plot's GPS points by ODK: Information was gathered from 10,690 mung bean farmers (500 women, 10,190 men) (8 February–22 March 2021), after enumerator training facilitated by CSISA in the first week of February, 2021, at the Patuakhali Community Development Centre (CODEC) training center. For details, please see [CSISA III Semi-Annual Report, 2021)](#).

Above: CSISA-trained enumerators survey mung bean farmers using the ODK form, Hazikhali village, Madarbunia union, Patuakhali district, 28 February, 2021. *Photo credit: Golam Morshed Rokon.*

Analyzing rainfall forecasts vs. observed rainfall during the 2021 mung bean harvesting season: CSISA has installed 52 rain gauges in 17 unions and trained 51 male mung bean farmers to collect rainfall data from March–June 2021 (for details, please see [CSISA III Semi-Annual Report, 2021](#)). During the mung bean harvesting season (April–June 2021), the rainfall forecast model predicted heavy/very rainfall events for nine days, light rainfall events for 18 days, and no rain event for 36 days in 17 selected unions. CSISA analyzed the observed rainfall data collected from 52 rain gauges in the 17 unions. Findings showed that an average of 73% of rainfall forecasted was correct, matching the actual rain events. Among the 17 unions, Gulisakhali had the highest forecast accuracy (77% in 2021), followed by Atharagashia, Betagi Sankipur, Baga and Choto Bighai unions (each with 75% forecast accuracy) (please see Annex 4).

Summary of IVR calls about rainfall forecasts issued during the 2021 mung bean harvesting period: During the harvesting period 8 April–7 June, 2021, CSISA issued a total of 310,269 IVR calls to 10,485 mung bean farmers (671 women, 9,814 men) in 17 selected unions. The IVR system had been ready from March 2021; however the team issued no IVR calls in March as there were no rain forests and mung bean was in its immature stages of growth. At the start of harvesting, the model forecast mainly no rain, and the team issued IVR calls conveying 'no rain' information twice a week to avoid farmer anxiety.

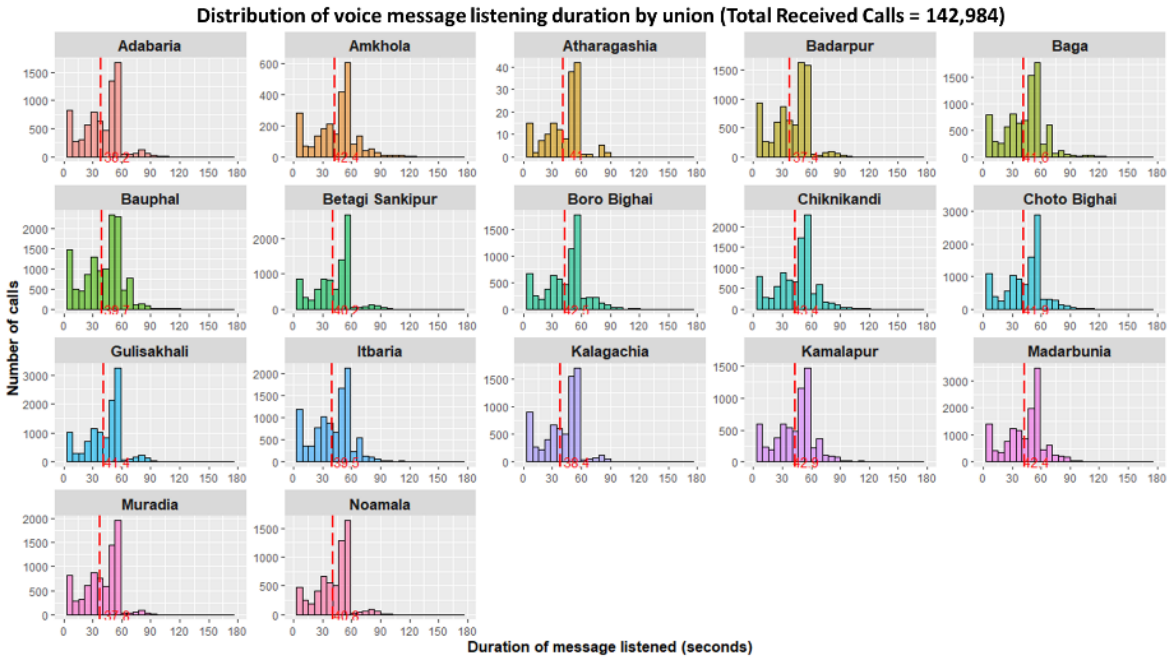


Above: Number of IVR munt bean harvesting alerts provided to farmers in 17 unions during mung bean harvesting season, 8 April–7 June, 2021.

On 25 May and 26 May, the forecast model predicted heavy/very heavy rainfall events in the 17 unions, due to the deep depression over the Bay of Bengal (this became Cyclone Yaas on May 26, 2021) and the team issued a voice message alerting farmers and government extension agents to heavy/very heavy rainfall events. Cyclone Yaas made landfall in Patuakhali and Barguna districts on 26 May, so IVR calls were not issued on this day to avoid the risk of advising farmers to harvest crops during a life-threatening extreme weather event. The call-back system was also activated for the mung bean farmers.

The CSISA research team analyzed the IVR call data and found that of the 310,269 location - specific advisory IVR calls automatically generated by the system, 142,948 (46%) were successfully received and listened to by farmers. The remaining 167,321 (54%) failed to reach the end-user. The number of calls received was higher in Maderbunia, Bauphal, Gulisakhali, Choto Bighai and Itbaria unions during the 2021 mung bean harvesting season. The main reason for call failure was network failure (56%); other reasons were 'call rejected/no answer' (39%) and 'mobile number busy' (5%). Farmers can call the IVR system any time to hear updated messages, and around 16,838 incoming calls were received during the mung bean harvesting period (8 April–7 June, 2021).

The graph below shows the duration of time that farmers who took the call listened to IVR messages in 17 selected unions, in May 2021. This ranged from 1 to 138 seconds, including when the message was listened to repeatedly. The length of the whole voice message included advisories varied from 40–72 seconds, depending on recipient gender (as advisory type is tailored to be gender-specific and sensitive), forecast communication style, and location (messages are customized according to these factors). Most farmers listened for an average of around 40.47 seconds, indicating that the majority listened to the call in its entirety before hanging up.



Above: Listening duration of farmers to IVR messages in 17 unions, 8 April–7 June, 2021. The dotted vertical line of each histogram indicates the average listening duration (in seconds) by farmers to voice messages, by union.

Above: CSISA research team conducting telephone survey of mung bean farmers remotely, using an online Google survey form

Monitoring and evaluation of the 2021 climate-smart IVR pilot: CSISA began a telephone survey of a total of 1,800 mung bean farmers from 17 unions, to monitor and evaluate the IVR study, after the 2021 mung bean season. Of the 1,800, 900 were randomly selected from the IVR call group; the rest were from the control group who had received no IVR calls during the mung bean harvesting period. The Activity decided to survey those farmers who had received no IVR calls this year to examine and compare the two groups in terms of the yield benefits to each. Because of the COVID-19 pandemic, the survey was conducted remotely by telephone, starting on 18 August, 2021. At the time of writing, 15 CSISA staff members from different parts of the country have surveyed 750 (60 women, 690 men) mung bean farmers who received IVR calls and 325 (30 women, 295 men) farmers from the control group. The remaining (725) telephone surveys are expected to be completed by October 2021, with results presented in the next semi-annual report.

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

Smallholder farmers are the engine of food system transformation in developing countries, and their integration into high-value chains is critical to achieve rapid transformation and improve local livelihoods. A carefully designed, quality-oriented value chain also creates opportunities for small-scale actors such as traders, retailers and processors, across the value chain. CSISA has therefore been working to integrate and incentivize smallholder farmers and other small-scale value chain actors into emerging value chains for premium quality rice (PQR) in Bangladesh. CSISA's PQR workstream focuses primarily on expansion activities through developing strategies and collaborative business planning with value chain stakeholders, as well as research to facilitate a business environment where the benefits from high-value PQR products are distributed evenly across the value chain. The Activity works to develop producer groups to cultivate PQR, and to assure the supply of quality seed to these producers through innovative private sector grants, wherein producer groups are linked to seed companies through business expansion mode, ensuring the supply of quality seed through linking these seed companies to BRRI for regular breeder seed supply. CSISA is also working to create direct linkages with midstream value chain actors such as millers and marketing firms, and conducting research on introducing quality incentive pricing, while investigating the nutritional and grain quality benefits of PQR. Key activities conducted on PQR in the reporting period are detailed below.

2020-21 activities focused on Premium Quality Rice: During the COVID-19 pandemic, which continues to hamper the life and economy of Bangladesh, CSISA has engaged creatively with various stakeholders and producer groups to facilitate PQR expansion and market development activities. In this reporting period, the CSISA Jashore field office undertook activities to expand PQR rice in the FtF zone through partnership with local, reputable seed companies, millers and other service providers. An integral part of this engagement is developing an innovative partnership model with seed companies, by ensuring (1) the flow of good quality PQR seed, (2) accountability-sharing in area expansion through seed company business portfolios, and (3) the linking of farmer/producer groups to these seed companies. The Activity also formulated kick-start seed distribution for newly released PQR varieties, using a private sector grant initiative channeled through seed companies and millers. It provided training on seed production and preservation technologies to all the staff of six seed companies[6]. As such, CSISA provided training to DAE staff (SAAOs) at the *upazila* level on PQR rice production best management practices,

[6] (1) Uzirpur Organic Multipurpose Cooperative Society Ltd (UOMCSL), Narail, (2) Modern Agro Private Ltd., Chuadanga, (3) One X Crop Care's Square Seed Company, Meherpur, (4) Konica Seed Company Ltd, Damurhuda, Chuadanga, (5) Friends Seed, Maheshpur, Jhenaidah, and (6) Adarsho seed company, Shailkupa, Jhenaidah.

with the remit to convey this message to farmers. The result has been that Khulna Division and other CSISA areas created a decentralized, local public-private partnership engagement that attracts different value chain stakeholders (including farmers, seed companies, millers and traders) as well as public institutions (DAE).

CSISA's target was to facilitate increased production and commercial sale of PQR in Jashore hub areas during *boro* 2020/21 and *aman* 2021. To achieve this, the Activity entered into cooperative business agreements and provided the six selected companies with an incentive of 10% of their PQR seed volume, with the remaining 90% sold by the companies to farmers. The companies distributed the incentive seed among farmer groups free of cost. Some provided an integrated service model (including mechanized transplanting and harvesting) and sometimes purchased the produce from the farmers at a fair price. CSISA's catalytic role with the seed companies, DAE and farmer groups in *boro* 2020/21 and *aman* 2021 has had a very positive impact, achieving about 264% of PQR grain production targets in the CSISA Jashore hub areas. The season-wise activities are provided below.

PQR activities in the Jashore area: In *aman* 2021, CSISA provided 3 t of PQR seed (2 t of BRRI dhan 75, 1 t of BRRI dhan87) to 6 local seed companies as a kick-start. The companies then distributed this seed among 607 farmers aligned with 6 auto rice mills. 40 farmer groups followed a community seedbed approach to produce seedlings (using manual and mechanical transplanting methods) in 8.5 ha. As a result of CSISA's facilitation, the seed companies sold 17 t of BRRI dhan 75 and 18 tons of BRRI dhan 87 seed for the *aman* 2021 season. This covered approximately 915 ha of land (447 ha for BRRI dhan 75; 461 ha for BRRI dhan 87). Estimated paddy production is 10,720 t (BRRI dhan 75 – 1,787 t; BRRI dhan 87 – 8,933 tons) on seed company land near to auto rice mills. CSISA also facilitated linkages between local seed companies and BRRI, as a result of which, five seed companies received 230 kg of BRRI dhan 75 and 140 kg of BRRI dhan87 breeder seed from BRRI.

Planned face-to-face meetings and workshops with millers, traders and farmer groups within the reporting period were suspended due to imposed travel and health-related restrictions resulting from the COVID-19 pandemic and extended lockdowns. Sharing meetings with DAE, seed companies and farmer groups was not completed according to the CSISA DIP plan. Only a few sharing meetings and training with DAE were possible, by maintaining COVID-19 safety protocol. As such, achievement of targets were lower than anticipated.

Summary of 2020 Premium Quality Rice outputs in the Jashore working area of Bangladesh.

PQR variety	tons sold during *aman* 2021	Hectare coverage	Estimated paddy production (t)
BRRI dhan 75	17	447	1,787
BRRI dhan 87	18	461	8,933

Above: Partnering with CSISA: seed company One X Crop Care's Square distributes PQR seed to contract farmers at Meherpur. *Photo credit: Harun-Or-Rashid.*

Above: A farm machinery service provider picks mat seedlings (BRRI dhan 50) to transplant using a rice transplanter, Sadhuhati, Jhenaidah. *Photo credit: Mustafa Kamrul Hasan.*

Above: A woman's farmer group collect PQR seed (BRRI dhan 75) from 'Mobile seed sale center of UOMCSL', Narail. *Photo credit: Md. Atikuzzaman.*

Above: A mat-type PQR seedbed using plastic trays for BRRI dhan 75, Shailkupa, Jhenaidah. *Photo credit: Anarul Haque.*

PQR activities in Rangpur division: Since 2019 the CSISA Dinajpur field office has worked with different stakeholders (lead farmers, auto rice mills, private seed companies, LSPs and DAE) to facilitate the expansion of PQR in Rangpur Division. By the end of 2021, the Activity will have provided technical and value chain support to its stakeholders to facilitate and create market linkage between producer groups and auto rice mills. To achieve PQR scale-up and its long-term sustainability in the region, CSISA works as a catalyst, taking a holistic approach with the private sector (seed companies, auto rice mills/private companies), farm services providers and lead farmers through formal engagement and partnership with DAE. During the reporting period, CSISA established partnerships through agreements with two private seed companies (Srizon Agro and J.R Agro) and informal linkages with BRAC Seed and Agro Enterprise, and ACI Seed, to ensure an adequate supply of PQR seed in the region. In collaboration with the two seed companies and DAE, the Activity identified and formed 21 new PQR groups, including three contract farming PQR groups organized by an auto rice mill (582 farmers: 115 women and 467 men) during the summer *aman* 2021.

Above: BRRI dhan 50 production block, Fathejongpur, Chirirbandar, Dinajpur. *Photo credit: Kanilal Roy.*

Above: BRRI dhan 50 seed storage in the *boro* 2020/21 season: a farming family using plastic bags in Khosalpur, Dinajpur. *Photo credit: Kanilal Roy.*

Above: Local services provider harvests BRRI dhan 50, using a combine harvester, Chapra, Saidpur, Nilphamari. *Photo credit: Bappy Mohonto.*

Above: A contract farmer group formed by CSISA partner, Shamsul Haque auto rice mill. The farmers are in their BRRI dhan 75 production block, *aman* 2021, Tupamari, Nilphamari. *Photo credit: Bappy Mohonto.*

During the reporting period, CSISA formed 85 PQR groups (with a total of 2,168 farmers) and has established formal linkage with three auto rice mills (Dui Bhai mill in Thakurgaon, Shamsul Haque mill in Nilphamari and Bengal mill in Dinajpur) to ensure a premium price for the PQR production groups. This facilitated the distribution of 1,500 kg of PQR seed (BRRI dhan 75 and BRRI dhan 87) in the *aman* 2021 season and 3,640 kg of BRRI dhan 50 seed in the *boro* 2020-21 season to kick-start PQR production in new areas, again through the two selected local seed companies and in collaboration with DAE. In *aman* 2021, with CSISA's support, the two seed companies sold 15 tons of PQR seed, and BRAC and ACI sold 8 tons. In addition, Rangpur Bivag Krishi and Grameen Unnoyon project (DAE) and BRRI, Rangpur distributed 6 tons of PQR seed in the CSISA Dinajpur working area. To ensure the continuation of PQR production, 32 farmers from the PQR groups stored 1.2 tons of BRRI dhan87 seeds during the 2020 *aman* season, later using PQR seed for their own cultivation and selling the stored seed to their neighboring farmers in the 2021 *aman* season. Considering total PQR seed distribution/sales (31.7 tons) by CSISA stakeholders in *aman* 2021, PQR land coverage in Rangpur Division is about 1,050 ha, with PQR production predicted to be about 5,200 t.

Impact of COVID-19 on activities: The CSISA Dinajpur field office was unable to achieve 12 out of the 20 training of trainer (TOT) batches planned for farmers' groups leaders, private seed companies, millers and SAAOs on better bet agronomy practices of PQR production according to the DIP plan. Instead, the Activity conducted 37 informal meetings with small groups of stakeholders to provide them with key information. COVID-19 safety measures were observed throughout.

PQR activities in the Faridpur area: During the reporting period, the CSISA Faridpur field office worked closely with two local seed companies (Insaf Seed and Nur Seed). An agreement between CSISA and the companies at the beginning of the *boro* 2020/21 season motivated them to produce PQR seed. The Activity facilitated BRRI dhan 50 breeder seed from BRRI, with both companies receiving 40 kg and using it for seed multiplication to expand commercial availability of seed.

Both companies also sold 4 tons of BRRI dhan 50 seed from BADC to their farmer groups – Insaf Seed has 29 and Nur Seed has 12 farmer groups, working as contract growers for seed and paddy. During the *boro* 2020/21 season, CSISA provided the companies with an incentive of 2 tons of BRRI dhan 50 (800 kg to Insaf Seed, 1,200 kg to Nur Seed) to give to their farmer groups free of cost. Insaf and Nur also provided the groups with training and support on quality seed and grain production.

Above: BRRI dhan 50 seed production field of Insaf company. *Photo credit: Hera Lal.*

Above: Healthy seedling production of PQR variety BRRI dhan 75 for mechanical rice transplanting, *Photo credit: Hera Lal.*

Most of the farmer groups receiving seed took a community approach to produce seedlings. Total land coverage for the BRRI dhan 50 was 280 ha, with tentative production around 1,350 tons, and two companies purchased all the BRRI dhan 50 grain, either as seed or paddy, at a premium price. Paddy was sold to two auto rice mills in Faridpur. In the *aman* 2021 season, CSISA again worked with the same two seed companies and DAE to expand the use of PQR varieties (BRRI dhan 75 and BRRI dhan 87). This time, the CSISA Faridpur office provided 1.5 t of PQR seed (1 tons BRRI dhan 75, 0.5 tons BRRI dhan 87) as an incentive to the farmer groups working with the two companies. In the same season, the seed companies also sold 15 t of PQR seed (from BADC) among their farmer groups and other farmers.

CSISA also conducted a sharing meeting with SAAOs on PQR expansion. In the *aman* 2021, the total land coverage under CSISA facilitation was 905 ha, with predicted production around 4,100 tons. CSISA's catalytic work with the seed companies and DAE is expected to have met the target of 100% of 5,000 t of PQR production within the last two rice growing seasons of the reporting period. Final outcomes of this work will be provided in the next semi-annual report following harvest.

PQR value chains: rice branding – a win-win situation for farmers and consumers: To expand the market size and improve the efficiency of the rice value chain, CSISA has initiated the branding of a few selected varieties of PQR. This section examines a few different types of rice grain, Miniket, the name given to a popular group of rice varieties with thin and medium-thin grains. Miniket accounts for more than 60% of the PQR market Bangladesh. The brand name and dominance of Miniket *chal* is however slowly decreasing due to mass media campaigns and increased awareness of it being a mixture of varieties, which has lowered consumer demand.

Conversely, BRRI dhan 63 is a long-slender grain type that is gaining popularity due to its higher yield and lodging resistance. Its grain size and shape are almost the same as BRRI dhan 50; however, it has no aroma. In 2020, BRRI dhan 63 was produced in 50,866 ha and total *chal* production was 206,786 tons, according to the DAE. Its yield is 10% higher and its crop-life cycle is 10 days shorter than BRRI dhan 50. At the start of the reporting period there was no specific brand name for BRRI dhan 63, which traders and millers often confused with BRRI dhan 50. It is generally marketed simply as basmoti/Bangla basmati, which consumers were increasingly complaining has no aroma, mainly attributing this to mixing by traders and millers.

Above: left: packaging for 'Soru Balam' rice, financed by the CSISA branding initiative; right: BRRI dhan 63 *chal* packaged in the rice mill under the brand 'Soru Balam'. *Photo credit: Monjur Rahman.*

CSISA recognized that giving BRRI dhan 63 its own branding had strong market potential if proper market linkage was established across the value chain, targeting different market segments. Branding would also reduce the admixture of BRRI dhan 50 and may improve the quality, consistency and brand value of Banglamoti (BRRI dhan 50). To achieve this, CSISA initiated a brand development plan for BRRI dhan 63, promoting it under the brand name 'Soru Balam', through millers and traders across the Activity's hubs and regions covering the Dhaka market. Major activities included identifying millers, developing a business strategy for the branding, linking millers with traders in different markets, and developing a feedback mechanism to facilitate the planning of a future expansion strategy (due to COVID-19 restrictions, the CSISA team and business development specialist could not execute the whole plan).

After the last *boro* harvesting (2020–21 season) of the reporting period, the Activity started work with Mannan Enterprise in Jhenidah to brand BRRI dhan 63 and facilitate a supply of quality rice from the field. CSISA provided financial assistance for branding, including preparing branded print bags as packaging. Crucially, it also facilitated market linkage between traders from Jhenidah, Faridpur and Dhaka city and Mannan Enterprise rice mill to sell the newly branded rice. The result was that the mill sold 25 t of Soru Balam. With the rising popularity of Soru Balam and market demand for it, the expectation is that the admixture with BRRI dhan 50 (Banglamoti) will be reduced. The promising experience of launching the Soru Balam brand has led CSISA to extend its branding and commercialization activities to BRRI dhan 75 and BRRI dhan87.

Above: stakeholders meet to discuss the branding and marketing of BRRI dhan 75. *Photo credit: Monjur Rahman.*

PQR on-farm research in partnership with BRRI: During the reporting period, as part of the expansion and sustainable production of PQR varieties in Bangladesh, CSISA conducted three on-farm research interventions in partnership with BRRI. These are summarized below.

Research activity 1: Determination of the effects of rice seedbed sowing date, seedling age, and rice growth duration on the yield of popular premium quality rice varieties for *aman*

This experiment was conducted in the *aman* 2020 season (June to December 2021) in three regions: Dinajpur, Gazipur and Jhenaidah. The major objectives were (1) to determine the effects of sowing dates, seedling age and transplanting dates for popular premium varieties with differing growth duration, and (2) to generate rice crop data for simulation modeling using ORYZA v3 to determine the optimum transplanting window, sowing time and seedling age. The experiment targeted yields, aiming to develop associated management recommendations for increased rice yields and higher water productivity in different regions of Bangladesh. BRRI completed this experiment for *aman* 2020 in the three locations, in collaboration with CSISA staff. The main plot factor was three PQR varieties (BRRI dhan 75, BRRI dhan87, and BRRI dhan34) and the sub-plot factor was five seed bed-sowing dates (20 June, 5 July, 20 July, 4 August and 19 August, all in 2020). The sub-sub plot factor was seedling age (20 days, 30 days and 40 days).

Rice grain yield differs significantly among locations and varieties. The short duration varieties (20-day old seedlings with seedbed sowing between 5–20 July) produce a higher yield; for medium-duration varieties, 20 day-old seedlings with sowing dates ranging from 20 June to 20 July produce high yields. For long-duration types, 20–30-day old seedlings with sowing dates ranging from 5 July to 4 August produce higher yields. To confirm the results of this trial, the second season trial has already been established in all three locations in the ongoing *aman* season. Results will be presented in the next semi-annual report.

Above: A trial field during *aman* 2020, Vatoi, Jhenaidah, *Photo credit: Sharif Ahmed*.

Research activity 1.2: Determination of the effects of rice sowing date, seedling age, and rice growth duration on yield of popular premium quality rice varieties for *boro*

The experiment was established in the 2020/21 *boro* season (November 2020 to June 2021) in the same three locations as mentioned above for *aman* (Dinajpur, Gazipur and Jhenaidah) using a split-split plot design with three replications. The main plot factor was three PQR varieties (BRRI dhan 63, BRRI dhan 50 and BRRI dhan9 2). The sub-plot factor was five sowing dates (16 November, 1 December, 16 December and 31 December in 2020, and 14 January in 2021). The sub-sub plot factor was seedling age (35 days, 45 days and 55 days). Overall, 35–45-day-old seedlings with sowing dates between 16 November to 16 December produced higher yields for both short and medium duration rice varieties. For long duration varieties, a higher yield emerged from the sowing dates between 16 November and 1 December. To confirm the results of this study, a second season trial in *boro* 2021–22 is required.

Research activity II: On-farm trials in different regions of the country to validate the results for PQR varieties predicted by ORYZA v3 model in research activity I

In each of the Northern, Central and South-Western regions of the country, the Activity conducted participatory on-farm trials with the PQR varieties used in the trial described above, in 30 farmers' fields (10 fields for each variety) at each site during *boro* 2020–21 (November 2020 to June 2021). In all locations, BRRI dhan 92 produced the highest yield, followed by BRRI dhan 63 and BRRI dhan 50. The grain yield data are presented in the figure below and will be further used in validating the ORYZA crop model for PQR in the *boro* season. Running the ORYZA model needs crop, soil and weather data; to extrapolate these results to other sites also needs long-term weather data. The data of research activities 1.1 and 1.2 are under process to be modelled using ORYZA.

Research activity III: Determine the effects of nutrient management practices on premium quality rice (PQR) variety/(s) for improved yield, grain quality, and milling traits.

This on-farm research activity was planned to observe the impact of potassium (K), zinc (Zn) and silicon (Si) nutrients on grain yield and quality traits (including milling and aroma) on PQR varieties. In the 2020–21 *boro* season, on-farm trials were conducted in 90 farmers' fields in the country's Northern, Central and South-Western regions (30 fields at each site). Three PQR varieties (BRRI dhan 50, BRRI dhan 63 and BRRI dhan92) were tested in this study with nine nutrient management practices. The trials followed these specific nutrient management treatments:

Above: Surveying rice consumers to determine their investment preference, part of the activity to develop improved PQR value. *Photo credit: Sharif Ahmed.*

1. Recommended dose of fertilizer (RDF)
2. RDF + 1 foliar spray of 0.5% K$ at heading (50% panicle exertion) (0.5% KH)
3. RDF + 2 foliar spray of 0.5% K at (i) panicle initiation (PI)* and (ii) at heading (50% panicle exertion) (0.5% KPI)
4. RDF + 3 foliar spray of 0.5% K at – (i) active/maximum tillering (ii) PI* and (iii) heading (50% exertion) (0.5% KT)
5. RDF + 1 foliar spray of 0.5% Zn-EDTA@ at heading (50% exertion) (0.5% ZnH)
6. RDF + 2 foliar application of 0.5% Zn-EDTA at (i) PI and (ii) heading (50% exertion) (0.5% ZnPI)
7. 7. RDF + 3 foliar application of 0.5% Zn-EDTA at (i) active/maximum tillering (ii) PI and (iii) heading (50% exertion) (0.5% ZnPT)
8. RDF + foliar application of 0.25% Si at PI (0.25% Si PI)
9. RDF + foliar application of 0.5% Si at PI (0.50% Si PI)

The effect of foliar spray on grain yield results was very inconsistent across the site, varieties and treatments. A solid conclusion can be drawn only after the analysis of soil data and grain quality. All the grain samples for *boro* 2020–21 were sent to the BRRI grain quality analysis laboratory for further analysis. This study continues in the ongoing *aman* season using three PQR varieties (BRRI dhan34, BRRI dhan 75, and BRRI dhan 87) and the same foliar spray treatments. Results will be presented in the next semi-Annual report.

Assessing and advising on PQR grain quality and nutrition: a value chain study

For this study, CSISA conducted choice experiments and 'games' with value chain players to estimate the agronomic contributions to productivity and supply of PQR, and identify incentives that would support and intensify PQR adoption.

This activity attempted to identify PQR varieties and explore if traditional and aromatic rice varieties (TARV) can achieve the best results or whether some other modern varieties possessing the same quality standards as those of PQR. It also studies production optimization of PQR and works to develop an inclusive supply chain and market linkages with millers and traders, so that smallholders are not left out in this transformed food value chain.

Decision choice experiments and hypothetical intensification pathways: During the reporting period, CSISA also continued implementing decision choice experiments begun in the previous reporting period but that had been delayed by COVID-19. In October 2020, the Activity completed its survey of 1,420 farmers and 200 millers in Dinajpur, Sherpur and Jhenaidah, and the final clean data was handed over in December 2020. A hypothetical investment game was conducted with the sample farmers to evaluate their ability to efficiently allocate production-enhancing inputs in PQR cultivation, emphasizing the lack of sufficient and robust extension information. Some preliminary results from the miller surveys show that when asked about what characteristics they preferred while buying PQR from suppliers, they said moisture content (which they checked manually) (92%), followed by chaffiness (87%) and grain health (75%). However, when selling on PQR, what mattered, according to millers, was aroma (82%), purity of the grain (78%) and grain colour (71%).

Typical responses by survey participants

Respondents	How would you define PQR?
Paddy trader	Chaffiness; consistency of the grain in length, size and color; purity of the grain and moisture content
Wholesaler	Food cooking quality , Good taste (95%), Aroma and Consistency of the grain in length, size and color
Retailer	Aroma; Consistency of the grain in length, size and color ; Fine and slender grain

The paddy trader, retailer and wholesaler surveys and experiments were rolled out in March 2021. Enumerator training was conducted from 14–19 February, 2020 in Rajshahi, where the enumerators then pre-tested the survey instruments. A total of 200 paddy traders, 125 wholesalers and 275 retailers were interviewed in Dinajpur, Sherpur, Jhenaidah, Kushtia and Dhaka city. Significant delays caused by Covid-19 meant these surveys and choice experiments were concluded in June 2021, and the final clean data was handed over in August 2021. Data analysis is still underway at the time of writing; the short table below presents some initial survey results, indicating the response of paddy traders, wholesalers, and retailers when asked about the characteristics of PQR.

The final part of these choice experiments will be administered to urban consumers. Enumerator training for this was conducted in September 2021 in Rajshahi, where the survey instruments were also pre-tested. The survey will be rolled out in October 2021 among 1,200 consumers in Dhaka, Kushtia, Dinajpur and Jhenaidah.

Nutritional and grain quality assessment of PQR as a function of processing, value chain handling and cooking techniques. During the reporting period, CSISA continued using grain samples from different nodes of the PQR value chain in Bangladesh to develop a comprehensive assessment of grain quality, including nutritional and sensory parameters as a function of production, processing, value chain handling, and cooking techniques. The first step in this activity involved collecting paddy/grain samples, barcoding them and shipping them to the Centre of Excellence in Rice Value Addition (CERVA), IRRI South Asia Regional Centre (ISARC), India, a process which required a phytosanitary certificate and import permits from the Indian Council of Agricultural Research (ICAR).

There were significant delays in this process due to the challenges imposed by COVID-19, especially the onset of the second wave in India during March–April 2021. CSISA completed the analysis of the first set of 487 samples from farmers and millers in February 2021. Grain quality analysis involved estimating four groups of quality parameters: textural, cooking, sensory and nutritional qualities. Some results from the analysis of the first batch of farmer and miller samples revealed that the mean gel consistency is between 33% to 66%; most PQR has a soft gel consistency. The average iron content of PQR is 10.56 ppb and zinc content are 16.97 ppb; the samples collected from millers had a slightly higher iron (11.18 ppb) and Zn (18.68 ppb) content.

A second batch of grain from farmers and millers containing 150 samples arrived at ISARC in February 2021 and is being analyzed at the time of writing. The third batch of grain from paddy traders, retailers and wholesalers containing 137 samples reached ISARC in August 2021. The final batch of 1,419 samples is in Bangladesh, waiting for clearance for a phytosanitary certificate. These samples are expected to arrive at ISARC by November 2021.

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 in 2017 and 2018 that resulted from the uncertainty in Activity funding. 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 (CCAFS) 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.

Big data and large-scale agronomy diagnostics

To modernize and refine their crop-cut data collection process used to estimate regional yields for key crops, DAE expressed an interest in digitalizing the survey system to harmonize crop-cut activities. In response, CSISA has been working to support and coach DAE to conduct thousands of crop cuts and production practice surveys for *boro* and *aman* rice, executed by the DAE field level SAAOs. As part of this data-driven initiative and its project programming, DAE has purchased and distributed thousands of internet-enabled Android phones and tablets that used by front-line extension workers across Bangladesh. Harnessing this opportunity for digital agriculture, CSISA and the CCAFS project described above are collaborating to develop a robust platform that can build improved surveys, carry out cloud-based analysis, and provide a dashboard representation of research results (beta version of the dashboard available here.

Starting in late 20219, CSISA facilitated the training of 125 SAAOs in using the digital survey tool Open Data Kit (ODK), using android devices to implement surveys and crop cuts with farmers. Over the next two years, DAE conducted a total of 17,483 crop cut and crop production management surveys across key hear and rice growing districts of Bangladesh. The data were immediately uploaded to a cloud using the tablets maintained by DAE, with the resulting data being made available to CSISA (see table, below). In the *aman* 2020–21 season, more than 100% of targets for data collection have been achieved; data for four out of six crop seasons have been collected and by the end of the year, DAE plans to have collected data on yield and management practices from 4,500 wheat farmers. All data were entered using internet-enabled devices and ODK, and uploaded to the CSISA server for semi-automated analysis using the Big Data Monitoring tool developed by CSISA.

On 16 March 2021, the Activity held a virtual coordination meeting with DAE representatives (Assistant Directors and Deputy Directors from Jashore, Faridpur, Rajshahi, Dinajpur and Rangpur districts). Discussion centered around the current status of collected data and a review of descriptive analysis of the data, as well as progress and strategies on upcoming crop cut surveys and how to further improve input data quality. Participants learned how they could check incoming data quality using a web-based dashboard. Our ultimate goal is to identify the best options to enable farmers to maximize productivity and profitability while minimizing greenhouse gas emission, to generate advisories for better-bet practices in agricultural management which DAE can deploy as part of their regular extension support.

CSISA had planned to conduct large, national-scale debriefs on use of these data assets with senior DAE and research officials during the second half of the reporting period. COVID-19 inducted lock-downs however hampered these efforts. At the time of writing, the workshop is being planned for the first half of November 2021. Outcomes will be reported on in the subsequent semi-Annual report.

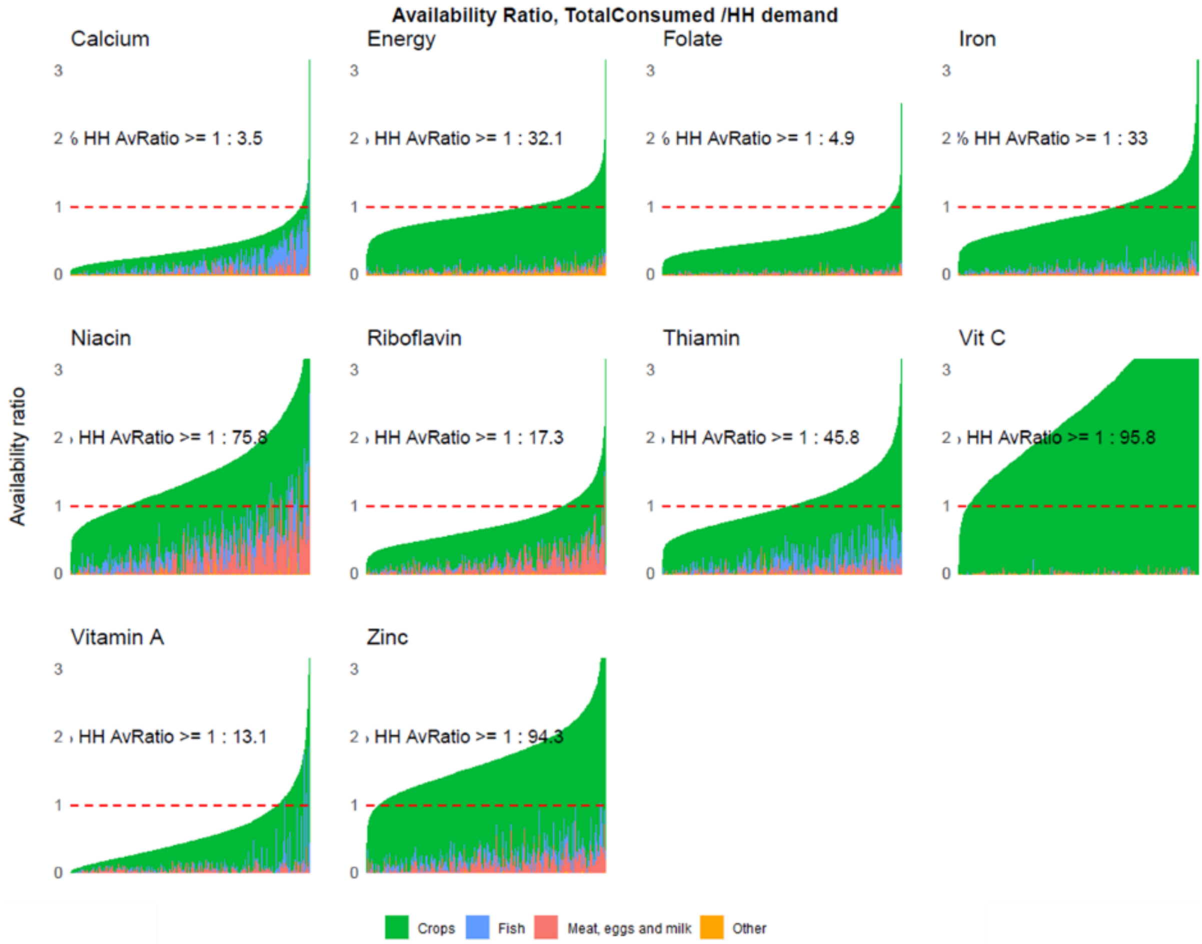
Innovative modeling and ex-ante research on integrated farm and household nutrition systems through collaboration with the Nutrition Innovation Lab

Background: AgSyst2N: a study linking 'Agricultural Systems to Nutrition' is being developed through a partnership with the FtF Innovation Lab (Friedman School of Nutrition Science and Policy) for Nutrition (with team members Dr. Patrick Webb and Dr. Robin Shrestha, Dr. Shibani Ghosh, Dr. Katherine Heneveld), Tufts University. This collaboration lies at the intersection between nutrition, and agronomic and food security perspectives, and aims to understand, assess and ultimately improve the links between agricultural systems and nutrition among smallholders in Southern Bangladesh. The research builds on an existing dataset from a comprehensive household survey by Innovation Lab for Nutrition (ILN) of 3,000 farm households (with detailed food production and consumption data from male members/household heads, mothers/female caregivers (aged 15–49) and children aged under 5 across Dhaka, Barisal, and Khulna divisions in Bangladesh, covering the 102 unions of the FtF zone baseline survey.

Activities: Research activities in the 2020-2021 were directed towards understanding (1) the contribution of different sources of food and nutrients to Bangladesh's farming households and (2) the identification of critical nutrient deficits and the main food sources (among crop, livestock and fish products, either produced or purchased) that contribute to closing the nutritional gaps of rural households in Southern Bangladesh. Quantitative analysis of consumption of food items at the farm household level, including their source, is based on the seven-day recall data provided by a female member of the family (collected between January and April 2016). Using the nutrient content information from the Food Composition Table (FCT) for Bangladesh and the survey data, an extensive nutrient acquisition dataset was created at the household level.

Balances for satisfaction of nutrition needs of farm household were calculated, taking into account gender and age of household members and the nutrient demand based on the Dietary Guidelines for Bangladesh (Nahar et al 2013). The figure below shows the availability ratios for different nutrients and the source of those nutrients. More than 75% of the sample households are deficient in Calcium (96.5%), Folate (VitB-9) (95.1%), Riboflavin (VitB-2) (82.7 %) and VitA (86.9%). In addition, more than 25% of the households are also deficient in Energy, Iron and Thiamin (VitB-1). Over 95% of households have sufficient Vitamin C and zinc.

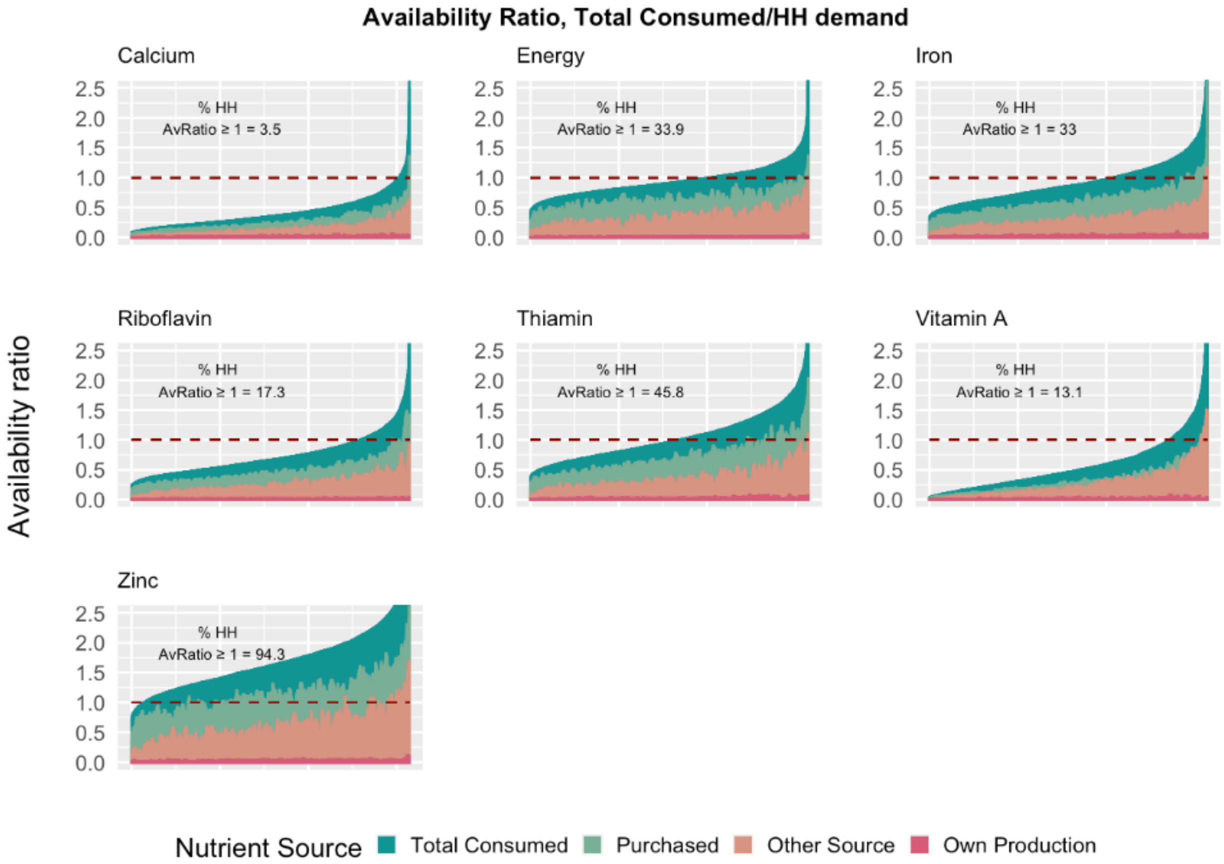
These results have immediate policy relevance. In addition to identifying generalized patterns of nutrient deficit, the variability of nutrient availability also indicates the need to create spatially explicit national level nutrient deficit data that can be used for targeting nutritional interventions.



Above: Distribution of availability ratios for different nutrients and the source of these nutrients.

In addition to the contribution of purchased nutrients, those from other sources of nutrients (such as food support and gifts) that are important when compared to those produced within the farm (see figure below). This also indicates renewed attention to food from commons, social safety nets and non-monetary exchanges, which are usually not given adequate importance in nutritional interventions.

Some of the main food items and agricultural products contributing to nutrient availability for rural farm households in Bangladesh were also investigated. Cereals (parboiled rice) are the main source of energy, iron, zinc, thiamin, riboflavin, niacin and folate. Vegetables (gourd, *saag*, onion, eggplant, potato) are the main contributor of Vitamin A and Vitamin C, and an important source of Folate. Fish and meat or livestock-derived products are the most important source of Calcium and an important source of Riboflavin, Thiamin and Niacin. Spices provide an important sources of Iron. More than 85% of all nutrients is purchased. These data suggest that the possibilities of improving nutritional availability through enhanced nutritional messaging which encourages increased production and consumption of specific food groups could be a suitable pathway for agriculture-nutrition intervention programs.



Above: Contribution of purchased nutrients and those from other sources to the nutrient consumption of rural households in Southern Bangladesh.

Future activities: Activities in 2022 will be directed towards the assessment, using an *ex-ante* assessment tool (production-consumption balance model), of the contribution of specific interventions such as sustainable intensification of crop, fish and livestock and identify specific nutrition targeted interventions (including the biofortification of crops, home garden cultivation of specific produce, markets) to improve the nutritional security of specific types of rural household. The analyses would certainly contribute to the better efficiency of development interventions, especially sustainable intensification and nutrition-smart strategies for FtF in Southern Bangladesh. CSISA and INL aim to have a model ready for *ex-ante* assessment before the end of 2021. COVID-19 did not affect the progress of this work as it was being carried out based on an existing dataset and following remote work modalities as a desk-based analytical study. The Activity expects at least one peer-reviewed article based on these critical results to be submitted in 2021.

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 the inception of CSISA's third phase in 2016, CSISA has worked closely with public and private sector partners, taking a catalytic role to develop and raise awareness among Bangladeshi farmers about the multiple benefits of adopting integrated weed management (IWM). Principles of IWM include:

1. Carefully monitoring fields, identifying problems, selecting appropriate control measures, and minimizing the economic impact of weeds on the crop.
2. Working to prevent weeds from establishing or multiplying, emphasizing controlling the production and spread of weed seeds or weed parts that reproduce vegetative.
3. Considering and integrating cultural, mechanical/physical, biological (including use of weed competitive cultivars) and chemical control options as needed.
4. Where possible, reducing and minimizing the use of herbicides, particularly those which are highly toxic.

In collaboration with BRRI, CSISA has identified the most effective and profitable IWM options for transplanted rice through on-farm research in 2016–17 and 2017. These results identified the careful and safe application of Mefenacet+Bensulfuron methyl as a pre-emergence herbicide, followed by either Bispyribac-sodium or Penoxsulam as post-emergence herbicide, followed by one hand-weeding. This combination responds to the labor constraints experienced by farmers while also using fewer toxic products than those typically applied in rice production in Bangladesh, particularly for higher-yielding crops. Building on these research results and in close partnership with the private sector, the Activity has worked to develop awareness and market demands for these products.

CSISA pioneers public-private sector partnerships in appropriate and safer weed control products

Partnering with BRRI meant that CSISA has been able to identify the best IWM options for transplanted rice. Since 2019, the Activity also began been working with private sector organizations and DAE to scale-out efficient and profitable IWM options in order to control weeds in transplanted rice in the Activity domain area. Despite the COVID-19 challenges, during the reporting period, CSISA in collaboration with private sector partners Auto Crop Care Limited (ACCL) and AIRN, continued efforts to (1) make safe and cost-effective herbicide molecules and safety equipment available in local markets, (2) disseminate outreach materials such as IWM leaflets, and (3) conduct IWM demonstrations at farmers' fields in Jashore, Faridpur and Dinajpur in the 2020 *aman* season (July to December 2020). In partnership with ACCL and DAE, CSISA established 200 on-farm demonstrations for the *aman* season on best IWM options in its domain areas (100 farmers' fields in Jashore region, 50 farmers' fields in each of the Faridpur and Dinajpur regions. In the demonstrations, rice grain yields were similar in IWM and farmers' management practices. Although yields were similar, weed management costs were USD 35-70/ha lower and net income was USD 60-100/ha higher than when farmers' management practices were followed (for details, please see the last CSISA Semi-Annual Report).

Although there were no IWM field demonstrations in the winter *boro* 2020/21 season, CSISA together with ACCL carried out several awareness-raising activities, including sharing CSISA findings/results with DAE, linkage programs with private sector organizations, and leaflet distribution.

During the reporting period, CSISA's target was to facilitate partnerships resulting in farmers' use of IWM techniques on10,000 ha of land (6,000 and 4,000 ha in Jashore and Dinajpur, respectively). To achieve this, CSISA, in partnership with ACCL staff, conducted 22 batches of formal knowledge-sharing meetings (with a total of 506 participants) on IWM options, involving LSPs, lead farmers, input dealers, and SAAOs in its working areas of Dinajpur and Jashore regions (see photos, below).

Above: (right) Private sector representatives leading knowledge-sharing on the best IWM options for transplanted rice, with LSPs, SAAOs and lead farmers, in *aman* 2021 season, Noyerhat, Rangpur. (left) A similar meeting during the *boro* 2020–21 season, Dinajpur. *Photo credits: Kanailal Roy.*

Sales volume of (USAID-approved) low toxic herbicide in the CSISA working areas: Since 2019, CSISA in partnership with the private sector and DAE has conducted awareness-raising activities on the safe use of herbicide and use of comparatively low toxic herbicide (USAID-approved) for farmers, based on the best IWM options identified via BRRI and CSISA collaborative trials. These IWM options were Mefenacet + Bensulfuron methyl (as a pre-emergence herbicide) followed by either Bispyribac-sodium or Penoxsulam (as a post-emergence herbicide), followed by one need-based hand weeding/mechanical weeding. In 2019, pre-emergence herbicide Mefenacet + Bensulfuron methyl in the Jashore region area was marketed by Haychem Bangladesh Ltd and post-emergence penoxsulam was marketed by ACCL Ltd. In Dinajpur areas, both pre- and post-emergence herbicides were marketed by ACCL. ACCL started marketing herbicides in 2020 and it was available in both Jashore and Dinajpur sites. To assess the adoption of these relatively safe and effective herbicides, their sales volume was estimated. In 2018 (prior to CSISA's start of demand creation and and awareness-raising activities with the private sector), the sales volume of Mefenacet + Bensulfuron methyl was 2,580 kg and that of Penoxsulam was 168 kg in CSISA's

Jashore and Dinajpur working areas. In 2020, Mefenacet + Bensulfuron methyl sales volume increased by three times to 7,882 kg and sales of Penoxsulam increased to 226 kg in CSISA's working areas Jashore and Dinajpur. Based on the recommended dose of Mefenacet + Bensulfuron methyl (0.6 kg ha^{-1}) and Penoxsulam (0.02 kg ha^{-1}), areas under Mefenacet + Bensulfuron methyl increased from 4,310 ha in 2018 to 13,137 ha in 2020 (an increase of about 8,800 ha compared to 2018). Similarly, areas under the use of Penoxsulam increased from 8,400 ha in 2018 to 11,300 ha in 2020, an increase of 2,900 ha in the CSISA working domain areas of Jashore and Dinajpur[7]. Based on these results, areas under these safer herbicides have increased by at least 11,700 ha in CSISA Activity domain areas.

Identifying high-yielding and weed-competitive rice cultivars as a tool in IWM to reduce reliance on herbicides: High-yielding and weed-competitive cultivars offer a low-cost, environment-friendly option to include in the IWM strategy for weed control, with the potentiality to reduce herbicide use in rice production systems. In Bangladesh, limited information is available on the weed-competitive ability of high-yielding rice varieties which farmers currently cultivate. To address this, CSISA in partnership with BRRI since 2018, has been jointly conducting both on-station and on-farm research activities to identify high-yielding and weed-competitive rice varieties under transplanted conditions.

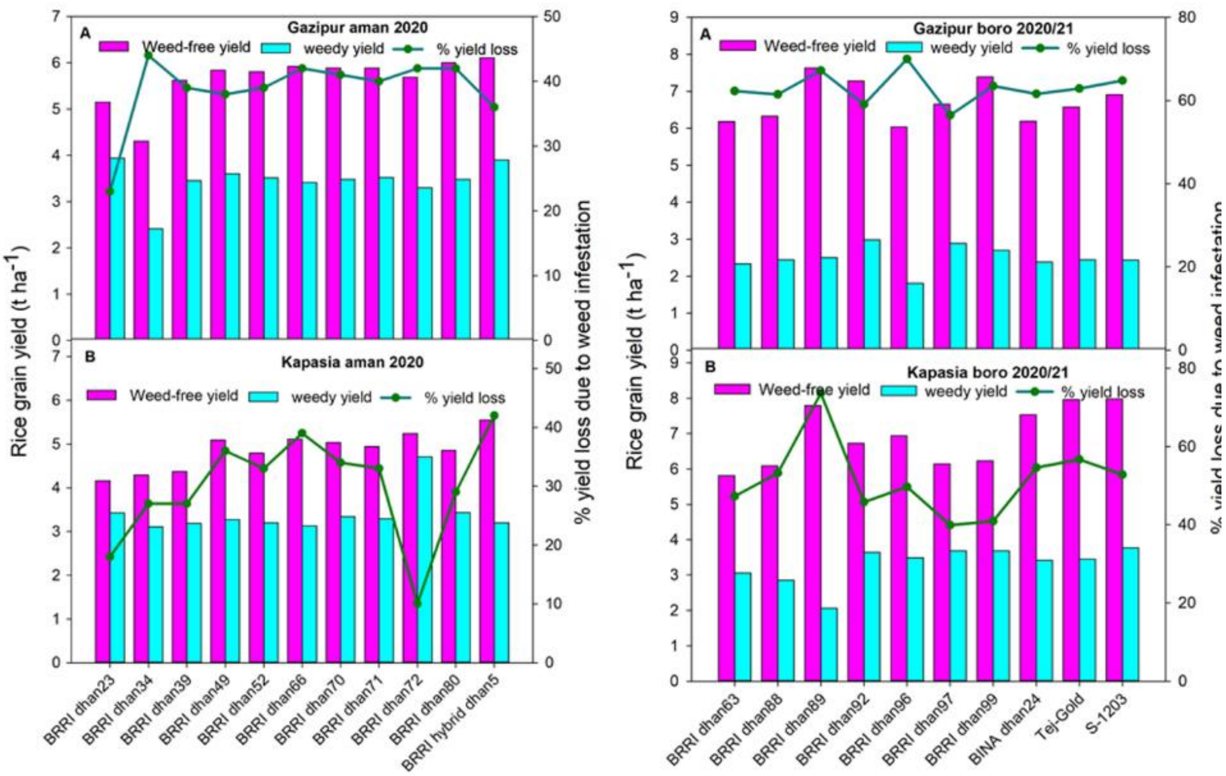
During the reporting period, the Activity conducted two season trials (*aman* season trial: July to December, 2020; *boro* season: December 2020 to May 2021). Both trials were conducted in two locations. In *aman*, 11 popular high-yielding varieties (10 inbreeds and one hybrid) and in *boro* 10 popular high-yielding varieties (8 inbreeds and 2 hybrids) were evaluated for their ability to compete with weeds. Mean rice grain yield data for both seasons are presented in the figure below**.**

In a*man*, experimentally induced yield losses due to weed competition ranged from 33%–42% in Gazipur and 10%–42% in Kapasia. Among the varieties, BRRI dhan23 was found to be the most weed suppressive and high yielding, at both on-station (Gazipur) and on-farm (Kapasia) sites, with yield reductions of 18%–23% due to full-season weed competition. At the on-farm sites, BRRI dhan 72, BRRI dhan 34 and BRRI dhan 39 were also found to be weed suppressive but not at the on-station site. Hybrid rice BRRI hybrid dhan5 produced the highest yields under weed-free conditions, and similar or higher yields than inbred varieties under weedy conditions; however, yield loss due to weed competition was 36%–42%.

In *boro*, weed infestation reduced the rice grain yield by 56%–70% in Gazipur and 40%–73% in Kapasia. Under weed infestation conditions, the highest grain yield was recorded from the variety BRRI dhan92 (2.98 and 3.64 t ha^{-1} in Gazipur and Kapasia, respectively). The grain yield of BRRI dhan 92 under weedy conditions was 45%–58% lower than that of weed-free conditions, indicating that even this variety incurs a significant yield reduction due to weed competition. In Gazipur, the highest yield under weed-free conditions was recorded from the variety BRRI dhan 89; however, under weedy conditions, its yield was 67% lower than the weed-free yield. In Kapasia, the highest yield under weed-free conditions was recorded from the hybrid variety Tej-Gold; under weedy conditions, its yield was 56% lower than the weed-free yield. These results

[7] Note: these results are based on the sales volume of just two key companies, and other companies also market these products.

suggest the need further to improve the weed competitiveness of these varieties by, for example, manipulating crop geometry (closer spacing) and integrating with early mechanical weeding.



Above: Mean rice grain yields of different rice varieties under weed-free and weedy plots and percentage yield loss due to weed infestation at on-station (Gazipur) and on-farm (Kapasia) sites in the *aman* season 2020 and *boro* season 2020/21. Left: *aman* season (A. on-station, Gazipur; B. on-farm, Kapasia). Right: *boro* season (A. on-station, Gazipur; B. on-farm, Kapasia).

C1.2 Accelerating the emergence of mechanized solutions for sustainable intensification

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

In its first two years of its third Phase (2015 and 2016), the CSISA Activity worked intensively to establish 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-Rangpur Division 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.

Since this time, budgetary flow to CSISA has remained somewhat uncertain, with disbursements often coming late. This has slowed progress in some areas, including mechanization. In particular, the ebb and flow of funding has complicated the Activity's ability to enter into joint business arrangements with partners companies. Without certainty on fund flow, it is risky – both from the perspective of CSISA and from the private sector – to invest in large-scale commercialization activities. As such, mechanization activities in Rangpur Division have still not been fully resumed, and are unlikely to before the completion of the Activity, unless funding levels and consistency can be restored. Staff involved in CSISA Phase III nonetheless continue to cooperate and jointly implement the USAID Bangladesh Mission-funded CSISA Manufacturing and Extension Activity (CSISA-MEA), which began in October 2019 and is described briefly below.

CSISA III's synergistic support to the expanding CSISA Manufacturing and Extension Activity (CSISA-MEA)

Building on the successes of the CSISA-Mechanization and Irrigation (CSISA-MI) Activity, which ran from 2013–19, and which emerged from the set of USAID/Washington core investments in CSISA, the Feed the Future Bangladesh Cereal Systems Initiative for South Asia Mechanization Extension Activity (CSISA-MEA) began on 1 October 2019.

The Activity underwent some modifications during the reporting period and now has three main intervention areas:

1. Build the capacity of the agricultural machinery manufacturing sector to produce high quality, competitive pricing of agricultural machinery and spare parts through providing training in manufacturing skills and technical advice on manufacturing processes and machinery systems, and by facilitating improved access to finance.
2. Support agricultural machinery marketing companies to expand new agricultural machinery technology marketing into southern Bangladesh and Cox's Bazar district and improve after sales services to include training for machine operators and mechanics, and spare parts supply systems. Support banks to develop improved systems for the financing of agricultural machinery purchases
3. Support firms in the agricultural machinery, production and food industry to provide machinery solution providers (MSPs) with access to a wider range of labor-saving machinery than currently available, and to other services such as input supply and crop marketing services. This will allow LSPs to sell farmers the services they need, from planting through to marketing. Particular emphasis will be given to developing new or existing agricultural service provision businesses managed especially by women and youth.

Some of the key achievements of CSISA-MEA in the reporting period are described below[8]

Partnering with the private sector to accelerate access to appropriate agricultural machinery: During the reporting period, the Activity initiated and signed agreements with 13

[8] Monitoring and evaluation data are reported separately for CSISA Phase III, CSISA-MEA, and CSISA COVID-19 Response and Resilience. Although all part of the broader CSISA program, their quantitative data are reprted to USAID indepentently each year.

companies (including two banks) and an international NGO. These agreements were designed as 'Joint Venture Agreements' supporting markets and manufacture of new agricultural machinery, provision of financial services, expansion of machinery and spare parts dealerships, and to initiate machine and spare parts manufacture in Bangladesh's ZoI and also the Zone of Resilience in Cox's Bazar District. Under an innovative JVA, BRAC Bank Limited, worked during the reporting period to develop systems for financing agricultural machinery manufacturing and marketing. Similarly, IDLC Finance Limited entered into a JVA with the Activity to support ABLE SMEs with training to develop their capacity in financial management and business planning, both of which are crucial for SMEs to demonstrate their solvency when applying for loans to support their businesses. A new JVA was signed with a lead firm (Janata Engineering) that covered enhancement of its machinery manufacturing capacity through training its workforce in modern technology and Occupational Health & Safety (OHS). Agreements were signed with three regional seed companies (Konika Seed Company, Ali Seed Farms, Uzirpur Organic Multipurpose Cooperative Society Limited (UOMCSL) in Jashore, and INSAF Agro Ltd in Faridpur), to support them to train growers of rice seedlings for rice transplanters, and to encourage the use of rice transplanters.

Above: Mini-combine harvesters are increasing in popularity in the Feed the Future Zone of Bangladesh. CSISA-MEA works to assure appropriate after sales services and training for combine operators through private sector partnerships. *Photo credit: Abdul Momin.*

Partnering with 104 agriculture-based light engineering (ABLE) enterprises. Of 104 ABLE enterprises the Activity engaged with during the reporting period, 85 have signed agreements with CSISA-MEA and have 53 received workforce and business management training. Following the signing of the agreements, 5 "kick-off" meetings were held to explain CSISA-MEA's activities and its role in providing support to ABLE SMEs to develop their capacity to expand their businesses. The remaining 22 will begin formal engagements from October 2021 forward.

Access to smart finance for improved services. Businesses cannot develop and expand their capacity to manufacture agricultural equipment and spare parts without financial investment, either from their own savings or from financial institutions providing loans. A key activity in this reporting period has therefore been to improve access to finance for ABLE enterprises. First, CSISA-MEA developed systems for assessing the credit worthiness of ABLE SMEs and then linked them with banks interested providing loans to enterprises with the best credit worthiness assessments. As a consequence, the Activity facilitated the disbursement of 23 loans worth USD 547,294 through seven financial institutions (BRAC Bank, IDLC, IPDC, Jamuna Bank, Janata Bank, Agrani Bank and MIDAS) to 13 partner ABLE enterprises and by two financial institutions (BRAC MFI and VPKA Foundation) and to two machinery dealers and six machinery solution providers (the latter for machinery purchases to commence or enhance their businesses).

Above: Pre-season combine harvester servicing facilitated by joint venture agreements held between CSISA-MEA and leading agricultural machinery firms in Bangladesh. *Photo credit: Abdul Momin*

Action into impact. A CSISA-MEA impact survey showed that during the reporting period, a total of 41,148 farmers (13% woman) purchased mechanized land preparation, irrigation and harvesting services from a total of 1,514 machinery solution providers (MSPs) (22 irrigation, 1,286 power tiller-operated seeders, 81 combine harvesters, 117 reapers and eight rice transplanters). These services covered 13,642 ha, representing 93% of the Activity's annual target. Activities supported through CSISA-MEA agreements with companies resulted in 193 MSPs purchasing a total of 110 combine harvesters, 51 reapers, 13 rice transplanters, 14 fodder choppers, one mini combine harvester and four power tiller operated seeders. After subtraction of government subsidies, these purchases were worth USD 1,779,235.

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

C2.1 Coping with climate extremes in rice-wheat cropping systems

C2.2 Early wheat for combating heat stress in Bangladesh

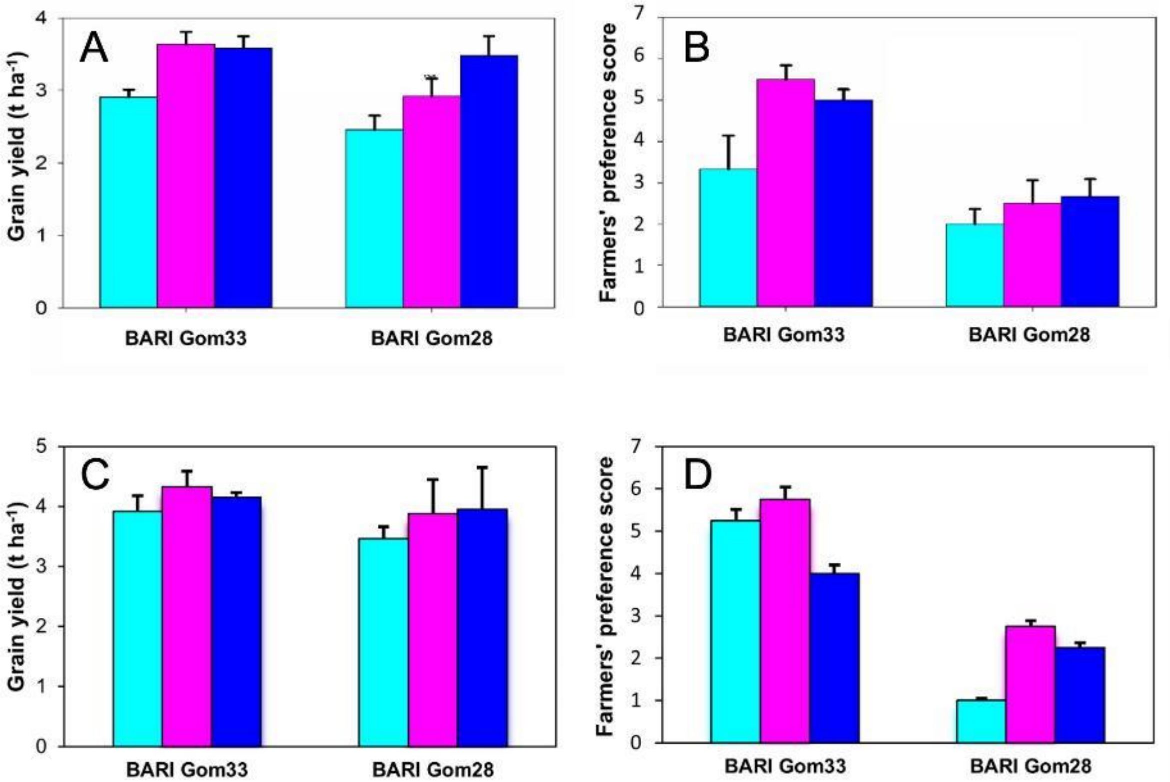
Resilience-enhancing early wheat sowing in the last* rabi *season

Wheat is Bangladesh's second key cereal crop and plays an important role in the country's food security. However, the country's production is much lower than in the rest of the world, with area and production not increasing adequately in line with population growth or changes in eating habits, despite having several high-yielding cultivars. An important reason for reduced yields is that farmers cultivate wheat under late-sowing conditions after harvesting monsoon rice in the *aman* season. Late-planted wheat is routinely subject to heat stress, especially during the grain filling period, which is responsible for its lower yield compared to optimum-sown wheat. Research shows that temperatures above or below optimum (12°–25°C) change the crop's phenology, growth, and development, leading to a reduction in yield. Also, when wheat is sown after 30 November, for each day yield is reduced at the rate of 36 kg/ha/day. CSISA introduced this intervention to raise farmers' awareness of the drawbacks to late sowing and sensitize them to ways of beating heat stress and producing resilient wheat.

In the 2020–21 reporting period, CSISA planned activities to raise awareness among different relevant stakeholders of the benefits of growing wheat at the optimum time. Remarkable progress was made in early-sown wheat, even though COVI-19 restrictions meant that some important tasks could not be accomplished. These are the successful initiatives completed during the reporting period:

- 31 farmer groups with a total of 551 farmers were established timely line-sowing of wheat due to a social media campaign run by the Activity.
- CSISA's videos on the early sowing of wheat was delivered to DAE personnel in 32 *upazilas*, who shown it in their SAAO and farmer meetings at the beginning of the season.
- CSISA conducted 16 virtual meetings with *upazila* agriculture officers on the benefits of the early-sown wheat.
- The Activity facilitated six trainings for 150 farmers (20% women) on the production technology of newly released wheat varieties.
- 9.82 ha of land was brought under relay cropping of wheat into a monsoon season rice field prior to its harvest, involving 42 farmers (21.5% women), in response to observing the benefits of relay cropping in the last reporting period.
- To increase awareness and extend cultivation of early-sown wheat, CSISA distributed 25,000 leaflets, 15,000 factsheets, 200 banners, 400 festoons, and 1,500 stickers, and arranged miking in 33 *upazilas*. An advertisement promoting the early sowing of wheat was published in 4 different local newspapers, and information about it aired on two radio channels for a total of 10 days.
- CSISA organized 12 Farmer Field Days, attended by district and regional level DAE officers and NARES scientists. A total of 733 farmers (37.5% women) participated.

- A video on the benefits of early-sown wheat was shown 708 times (December 2019–January 2020) to a total of 132,358 farmers (19% women), with 21,351 of these being farmers who regularly cultivate wheat. A total of 9,224 individuals applied improved technologies and covered 1,590.29 ha of land with the support of US government funding (Source: CSISA M&E team).
- 16 trial plots comprising 4.4 ha of land were established to observe the performance of seed rate (150, 180 and 210 kg/ha) between two different wheat cultivars (BARI Gom 28 and BARI Gom 33) in a relay cropping practice following monsoon season rice. (for results, see below).



Above: Effect of different seeding rates and varieties on performance of relay wheat with aman rice in Jashore and Faridpur. (A) wheat grain yield, Jashore; (B) farmers' preference score, Jashore; (C) wheat grain yield, Faridpur; and (D) farmers' preference score, Faridpur. Preference scores were collected with a range from 6 to 1. The trial had 6 treatments combinations for each replication (farmers field). Farmers provided the highest score of 6 for the best treatment combination, and the lowest score of 1 for the poorest treatment combination.

Detailed research on the response of new wheat varieties to different seeding dates

Optimum seeding time is an important management strategy for increasing wheat production in short and mild winter conditions like Bangladesh. Temperature above optimum leads to hider the physio-biochemical activities of plants; too early sowing produces weak plants with poor root systems, while late-planted wheat shortens the duration of the life cycle for escaping high-temperature stress at the flowering to the grain-filling stage. In the last few years, BWMRI has released some new wheat seed varieties, developed through testing in optimum sowing conditions (15–30 November) and late sowing conditions (20–25 December). The performance of these varieties following an intermediate sowing time and location-specific performance is not known. This multi-year experiment was conducted in three Agro-Ecological Zones of Bangladesh (BWMRI, Dinajpur; RWRC, Rajshahi; RARS-BARI, Jashore) in four consecutive wheat seasons (2017–18, 2018–19, 2019–20 and 2020-21), and has now been completed.

The aim was to evaluate their performance under different sowing dates, to discover the optimum sowing time, variety location interaction and wheat blast response for a specific variety. In the first two seasons, testing evaluated six existing elite wheat varieties (BARI Gom 26, BARI Gom 28, BARI Gom 30, BARI Gom 31, BARI Gom 32 and BARI Gom 33), in the third year (2019–20), seven wheat varieties (the previous six + newly released WMRI Gom 1) and in the fourth year (2020–21) seven wheat varieties (BARI Gom 26, BARI Gom 30, BARI Gom 32, BARI Gom 33, WMRI 1, WMRI 2 and WMRI 3), in five sowing conditions (25 November–4 January) at 10-day intervals. Under the environmental condition of Dinajpur, it was found that all of the wheat varieties sown at optimum sowing condition (25 November) produced the maximum yield. They also escaped wheat blast disease in all four years in all locations. Yield of all varieties decreased when sown late in all three locations in all four seasons. No incidence of wheat blast was recorded in Dinajpur, but in Rajshahi and Jashore wheat blast was found with the last three sowings (15 December, 25 December and 4 January) in the first two seasons. The study also recorded wheat blast in all sowing conditions in Rajshahi and Jashore in the third and fourth seasons.

In terms of yield performance, BARI Gom 30 performed the best in all sowing conditions and under late-sown heat stress conditions in Dinajpur, followed by BARI Gom 32, BARI Gom 33, WMRI 3, WMRI 2 and WMRI 1 (Annex 5). In the environmental conditions of Rajshahi and Jashore, BARI Gom 33 performed the best, followed by BARI Gom 30, BARI Gom 31, WMRI 3, WMRI 2 and BARI Gom 28. The highest severity of wheat blast in Rajshahi and Jashore was observed in BARI Gom 26, while the lowest severity was found in WMRI 3 and BARI Gom 33. Varieties WMRI 3, BARI Gom 30, BARI Gom 32 and WMRI 2 also experienced comparatively lower severity of the disease when exposed to high disease pressure under late sown conditions in all three locations. After four years of observation, the CSISA research team and BWMRI provisionally conclude that there is a variety of location interaction with yield and disease incidence. As such, location- and sowing date-specific variety recommendations will be needed for optimal cropping. These results will be shared with DAE in the next reporting period and are anticipated to form the basis of new management recommendations to be provided to farmers throughout Bangladesh.

Although no incidence of wheat blast was recorded in the environmental conditions of Dinajpur in all five sowing conditions, this could be due to the region's cooler climate. In Rajshahi and Jashore, blast infection was found in the last three sowings (15 December, 25 December and 4 January) in the first two seasons (see figures, above). In the third and fourth seasons, wheat blast was recorded in all sowing conditions in Jashore and only in the last sowing (4 January) in Rajshahi (see figures below). The highest wheat blast severity and incidence were recorded with BARI Gom 26 in the Rajshahi and Jashore locations and the lowest with BARI Gom 33 and WMRI 3. BARI Gom 30, WMRI 3 and BARI Gom 32 were tolerant to blast and have a lower level of incidence and severity (see figures). After three years of observation, the conclusion is that there is a remarkable variety of location interaction for yield and disease incidence, and that location-specific variety recommendations might be worth considering to achieve production increase. Key conclusions that are to be shared by BWMRI with the DAE for endorsement and development of extension recommendations include:

- Under the environmental conditions of Dinajpur, all the wheat varieties sown at the optimum sowing time (25 November) produced the maximum yield and escaped wheat blast. In this seeding, Wheat blast did not appear in the other two locations.
- The yield of BARI Gom 30 was the highest in Dinajpur, irrespective of seeding dates, followed by BARI Gom 32 and BARI Gom 33. In the environmental conditions of Rajshahi and Jashore, BARI Gom 33 performed better, followed by BARI Gom 30, BARI Gom 31 and BARI Gom 28.
- Yield of all wheat varieties decreased when sown late in all three locations in all three seasons. The lowest yield was recorded with the January 4 seeding, irrespective of years and locations.
- The highest wheat blast severity and incidence were recorded in BARI Gom 26 in both Rajshahi and Jashore locations, and the lowest in BARI Gom 33. BARI Gom 30 and BARI Gom 32 were tolerant to blast and had a lower level of incidence and severity.
- Although no incidence of wheat blast was recorded in the environmental conditions of Dinajpur in all five sowing conditions, this might be due to the cooler climate. In Rajshahi and Jashore, blast infection was found in three sowings (15 December, 25 December and 4 January) in the first two seasons, while in the third and fourth seasons wheat blast was recorded in all sowing conditions in Jashore and in only the last sowing (4 January) in Rajshahi. In the fourth year, wheat blast was recorded in all sowing conditions in Rajshahi and Jashore.
- After four years of observation, the conclusion is that there is a remarkable variety in location interaction for yield and disease incidence. Location-specific variety recommendations may be required for yield increases.

2. Nepal – Achievements

A. INNOVATION TOWARD IMPACT

A1. Reducing risk to facilitate uptake of sustainable intensification practices

A1.1 Direct-seeded rice to address labor and energy constraints to precision rice establishment

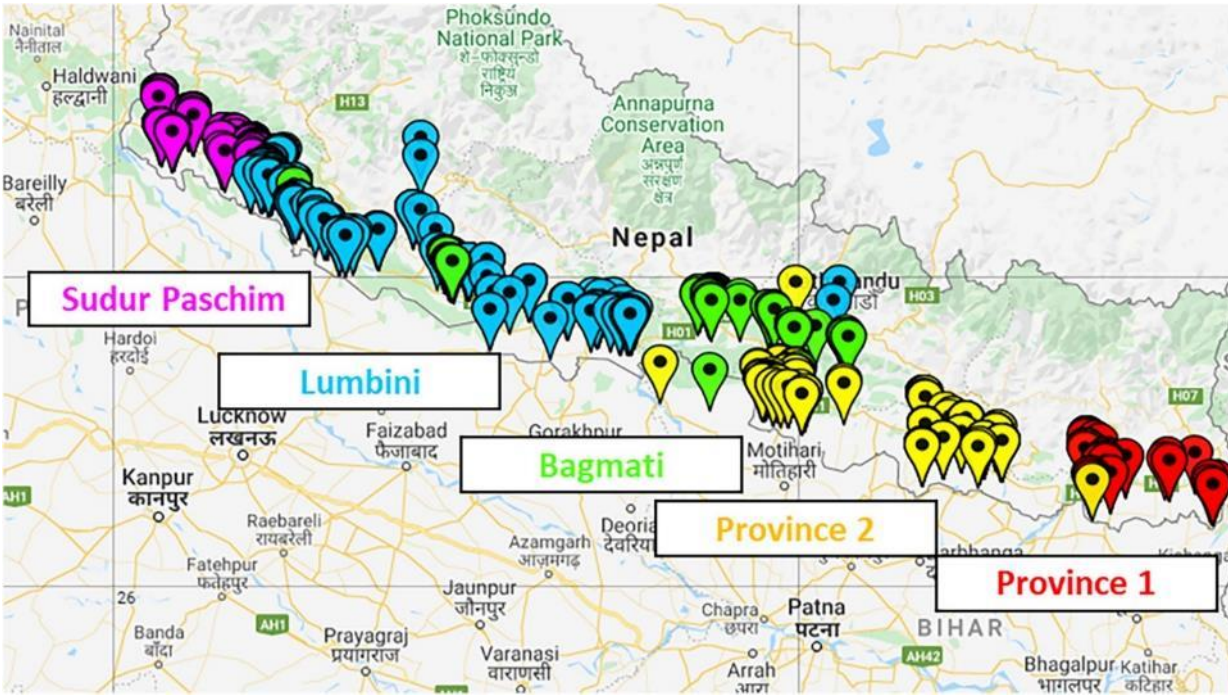
Background: Rice is Nepal's major staple crop, with average annual per capita rice consumption around 135 kg. However, rice productivity is the lowest in South Asia – due to the scarcity of labor and the high cost of cultivation – and Nepal relies heavily on rice imports from neighboring countries. In 2020, it imported 900,000 t of rice, to the value of USD 190 million. To overcome the bottlenecks of labor and high cultivation costs, CSISA has been promoting direct seeded rice (DSR), working with National Agricultural Research and Extension Systems Institute (NARES) and development partners, including the USAID/Nepal supported KISAN-II and Prime Minister Agriculture Modernization Project (PMAMP)[9], to increase awareness of the benefits of DSR and facilitate farmers to cultivate it. DSR has the potential to overcome the acute labor shortages created by labor out-migration and address energy constraints related to rice establishment. As an alternative to transplanting rice, DSR requires a great deal less labor, and is a water and energy-efficient technology. However, the rate of DSR adoption by farmers is constrained by several factors. So far, farmers have adopted only around 350 seed drills needed to plant DSR. This is a relatively lower number than many research and extension services would prefer, with most purchases supported by different programs, mainly in the form of governmental subsidy. Studies indicate the significant advantages of DSR in rice-based cropping systems in Nepal, and the reasons for the slow adoption of DSR seed drills are largely unknown.

Activities during the reporting period: During the reporting period, CSISA worked to identify constraints and address the primary bottlenecks of DSR seed drill adoption, during this reporting period CSISA analyzed the data collected from the previous year and also the research paper in [link to journal paper]. The study was jointly conducted by the CIMMYT/CSISA and the Australian Center for International Agricultural Research (ACIAR)- supported Sustainable and Resilient Farming Systems Intensification in the Eastern Gangetic Plains (SRFSI) project, to accelerate awareness of DSR and its adoption. The study focused on DSR seed drills, and the eight other machines that CSISA has been involved in market facilitation for Nepal's rice system.

As discussed in the CSISA Semi-Annual Report for 2020-21, this study opted for a stepwise framework to understand the reasons for the slow adoption of DSR and other SI technologies in Nepal Tarai. The data for this study came from the 1,569 farmers in Nepal Tarai, including FtF

[9] The Prime Minister Agriculture Modernization Project (PMAMP) is Nepal's largest agricultural development initative supported by the government, planned and executed in in conjunction with the Agricultural Development Strategy. One of its main goals is **to promote commercialization of agriculture through development of infrastructure and technology**. CSISA has worked with PMAMP in a technical advisory capacity since 2016.

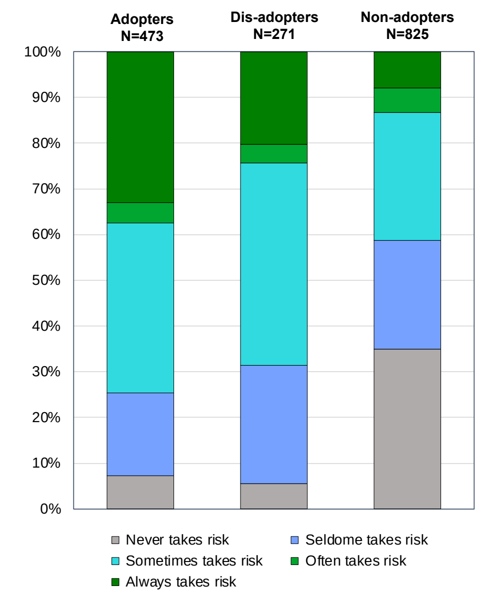
ZoI operation districts. The locations of sample households are presented in the figure below. The stepwise framework consisted of four phases designed to understand the reasons behind the adoption and dis-adoption of the DSR technology. The first phase started with the farmers' "exposure phase," where farmers are exposed to the DSR and other SI technologies. This was followed by the "progression phase" dealing with farmers' adoption, the third, "continuation phase" and finally the "utilization phase." In each phase, farmers were asked to provide information related to DSR (for example, about seed drills) and other SI technologies, their utilization, and, if not adopting and/or dis-adopting the SI technologies, their qualitative reasons. While most of the assessment results were presented in the previous reporting period, this report discusses the major reasons for the slow adoption of the DSR seed drills in Nepal Tarai in the current reporting period.



Above: Survey locations for DSR seed drills and other farm machinery assessment in Nepal's Terai.

The major results of this study suggest that the current activity has not led to the substantial closure of DSR seed drill farmer exposure gaps, nor to ownership of machines sufficient to enable accessible fee-for-hire service provision. The study found that farmer exposure gaps were substantial in all machines, indicating that current demonstration programs may not be achieving their targeted outcomes. The primary reason for limited progress towards the sustained adoption of DSR and eight other SI machines was the lack of service providers. This lack is a manifestation of limited machinery ownership, indicating that current broad subsidy programs to facilitate procurement are also not achieving their intended outcomes. There are, however, substantial pools of potential adopters and a concentration of supply-side constraints. This indicates that with targeted interventions, rapid rural mechanization is possible in Nepal Tarai in the near future.

This reporting period also included an analysis of DSR seed drill data collected in previous years. Although a plethora of studies suggests significant benefits of DSR adoption, only a limited number of farmers have adopted DSR technology in rice-based systems in Nepal and benefit from it. To understand further and identify a rapid upscaling strategy, CSISA is working to identify the reasons for farmer dis-adoption and non-adoption of DSR seed drills in the FtF ZoI and Nepal Tarai. The Activity carried out an analysis of recent survey data, to understand the reasons for dis-adoption and non-adoption, in addition to the access to seed drills, mentioned in the previous section. The analysis produced some interesting findings, suggesting that farmer risk-aversion behaviors might provide an explanation. The results show that farmers who never take risks in technology adoption are more likely to be 'non-adopters' and those who seldom/sometimes take risks likely to be 'dis-adopters' of the DSR seed drill. Farmers who often take risks in technology adoption are likely similarly to adopt the DSR seed drill. These results are intuitive to target DSR technology in Nepal Tarai and align with general risk-aversion theories, where risk-taking farmers benefit from technology adoption, while farmers who are risk-averse are likely to require support through initiatives such as credit, market access for herbicides, and information about irrigation pumps. These are key to the success of DSR. The results suggest that the risk-takers should be targeted for DSR promotion, and that this will facilitate the rapid spread of DSR seed drill used in the FtF ZoI and Nepal Tarai.



Above: Propensity to risk taking by farmers of different categories (DSR seed drill adopters, dis-adopters and non-adopters).

Dissemination of research results: SRFSI and CSISA supported the Modernization of Agriculture for a Prosperous Nepal workshop (18–19 June, 2021), jointly organized by MoALD and DAE, and with 200 participants. CSISA presented the DSR seed drill assessment findings with its national partners, including NARC, Department of Agriculture (DOA), Ministry of Agriculture and Livestock Development (MoALD), provincial agricultural ministries, Agricultural Knowledge Centers (AKCs) and PMAMP, as well as private sector stakeholders including NAMEA. The workshop also presented a short video abstract of the paper (link to video abstract). The workshop was broadcast live in Nepal by national television stations NTV and Krishi TV. CSISA also held rigorous discussions with its national partners and the private sector on how to increase farmer access to DSR seed drills in Nepal Tarai, and hence its adoption. To achieve increased access, large government-led projects such as PMAMP support the farmers and service providers by engaging private sector organizations, such as NAMEA, to purchase the drills, which they will then lease out. CSISA continues to work with PMAMP, as well as provincial government and private sector representatives, to facilitate the upscaling of DSR in Nepal's Tarai, particularly in the FtF ZoI.

Other efforts to expand awareness of DSR: During the reporting period, CSISA also coordinated with PMAMP, the Rice Super Zone Kanchanpur, and Agriculture Knowledge Center of Kailali and Kanchanpur districts to arrange the airing of a radio jingle that promotes DSR as an option for transplanted rice. In March and April, 2021 it was broadcasted by two FM stations in Bardiya, five in Kailali and two in Kanchanpur. Due to COVID-19, the Activity was obliged to drop training of trainers on DSR for local government agriculture technicians, but technical support was provided to service providers on DSR seeding. As a result, in Bardiya and Kanchanpur districts, 64 and 10 farmers respectively adopted DSR technology, extending it to a total of 110 ha.

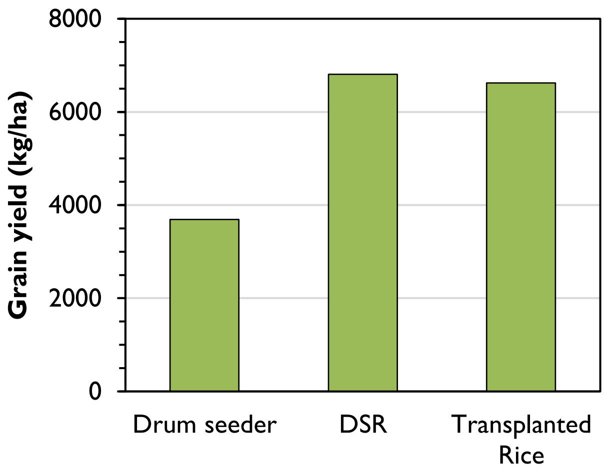
Above: Farmers sharing their learning on DSR technology in the DSR field of Ashareram Badayak (left) and Khadga Chaudhary (right), Belauri-6, Hattibojha, Kanchanpur, Nepal. *Photo credit: Lokendra Khadka.*

During its third phase, the Activity has been providing technical facilitation to machinery service providers and key farmers. It has been found that a skilled service provider, well-levelled land with drainage facilities and weed management are crucial to the successful production of rice using DSR technology. Radha-4, Sarju-52 and Bahuguni-2 varieties of rice were found to be suitable for DSR cultivation in Kailali and Kanchanpur. Due to COVID-19 restrictions, the Activity was unable to implement workshops planned with local government, provincial ministry and other related stakeholders in Nepalgunj and Dhangadhi.

In collaboration with MoALD's PMAMP-Maize Super Zone in Dang, the Activity organized five awareness campaigns on FAW identification, scouting and management (November 2020–March 2021). The field-based campaigns reached out to five farmer groups involved in commercial maize farming and focused on timely management of the pest starting from the 3-4 leaf stage of the maize crop. The campaigns were successful in establishing the concept of field scouting by farmers at regular intervals throughout the crop season to manage any pest damage within the threshold level and ultimately reduce the number of sprays per season. In continuation of these campaigns, the PMAMP-Maize Super Zone has been organizing a series of field-based practical orientation and technical support services to maize growers in FAW in their command area, by integrating with other agronomy and mechanization support activities.

Mentoring and building the technical capacity of extension staff of rural municipalities for expanding spring season rice production frontier in Nepal: The Government of Nepal has prioritized the expansion of the country's area under rice and its production in order to meet the population's growing demand. The opportunity to achieve this goal in the main monsoon *kharif* season is, however, limited. CSISA has regional experience in understanding spring season rice, and so the Activity is working to enhance the technical capacity of rural municipality extension staff as part of collaborative activities with KISAN-II and governmental partners in the Joint Rice Implementation Program (JRIP). During the last reporting period, CSISA provided spring rice crop production, management and machinery-related training to KISAN-II and rural municipalities. During these training activities, the area under spring rice has expanded during this reporting period. CSISA also conducted spring season rice crop cuts, to understand crop establishment-related challenges to rice production in this season.

As a result of the training activity conducted in spring rice production in the previous reporting period, a total of 200 ha of additional spring rice area has expanded in the FtF ZoI, with the majority of the area located in Bardiya and Kanchanpur districts (we expected a higher area for spring season rice, but due to COVID-19 restrictions imposed by local governments this expansion is less than expected). An additional approximate 500 ha of spring rice expanded in the FtF ZoI, with support from CSISA to PMAMP Rice Zones and Super Zones. CSISA staff also carried out crop cuts on spring season rice in farmers' fields (early June, 2021) to understand the productivity potential for spring rice within FtF ZoI. Crop establishment for spring rice – particularly for DSR – has been challenging in the ZoI. The overall objective of these crop cuts, therefore, was to understand the productivity differences of spring rice across different crop establishment methods. The results are presented in the figure.



Above: Productivity of spring rice across different crop establishment methods. All the farmers questioned used the Hardinath-1 rice variety, released by NARC and recommended for the spring season.

The results from the crop cuts indicated that although several farmers reported problems with DSR and crop establishment, DSR and manually transplanted rice had similar yields, of 6.8 and 6.6 t/ha, respectively. The lowest yield (3.7 t/ha) was with drum seeder use for spring rice production. Although governmental partners continue to maintain interest in this technology, these results clearly indicate that it should not be promoted as a mechanism for DSR. This reporting period's results also showed that the problems farmers reported were due to the early spring sowing of DSR – generally in the second week of February – increasing the chance or poor germination due to cold injury, leading to poor crop establishment and yield performance. Farmers who waited until the first week of March and then sow DSR reported better yield performance, similar to transplanted spring season rice.

Transplanted rice is costly because it requires a huge amount of labor to uproot and then transplant the seedlings. This high cost of cultivation presents a major challenge, and CSISA is promoting DSR on the basis that it reduces the labor burden on farmers and increases profitability. Overall, the crop cuts data showed that the timely seeding of DSR (the first week in March) substantially improves spring season DSR crop establishment, yields better productivity, reduces labor costs and increases profitability.

Above: Farmers in Sudur-Paschim Province, Nepal, transplanting rice manually, which is highly labor-intensive. DSR does not require transplanting and thus substantially reduces labor costs, increasing profitability. It also greatly reduces the burden on women farmers, freeing their time to pursue more remunerative and important economic and social activities. *Photo credit: Peter Lowe.*

A.2.2 Aiding the Fight Against Fall Armyworm (FAW) in Nepal

Fall Armyworm integrated pest management (IPM) training

Fall Armyworm's (FAW's) threat to the maize crop and the maize growers has remained constant in Nepal after its official detection in 2019. Since the arrival of FAW in Nepal, CSISA has been collaborating with related stakeholders to improve farming communities' capability to manage the pest using an integrated pest management (IPM) approach. A CSISA-led training, 'Fall armyworm management and safe handling of pesticides' was organized in Dang (3–4 March 2021), targeting key agro-dealers in Lumbini Province, in close collaboration with government and non-government partners.

The participating agro-dealers from different dealers were acquainted with the basics of FAW identification, and its pragmatic management approaches in smallholder maize growers' fields. They also gathered detailed knowledge of the pesticides registered and recommended to combat FAW and their safe handling practices. As a training outcome, the participating agro-dealers have reported to have better access to registered pesticides available in the market with improved value chain linkages with the national importers. The agro-dealers have been able to maintain a good stock of several pesticides suited for FAW management.

Above: Technicians in field training on Fall Armyworm identification and monitoring, Kapilvastu. *Photo credit: Jyoti Rai.*

Due to COVID-19 lockdowns in the second half of the reporting period in Nepal, virtual training was organized by PMAMP-Gulmi (May 2021) to train 17 agriculture technicians from different local municipalities in the district, where FAW had a devastating impact on summer maize in 2021. CSISA delivered technical support to train the technicians, instilling practical know-how on scouting, monitoring, and managing FAW. The Activity also provided technical support in virtual training programs organized by KISAN II in Banke and Dang clusters, targeting local-level technicians. Altogether, more than 125 agriculture technicians from local municipalities and Activity partners were trained in Lumbini Province in the reporting period, with technical backstopping from CSISA.

Broadscale awareness on the invasion of FAW and its management during COVID-19 restrictions: In further work to combat FAW, the Activity collaborated with MoALD's PMAMP-Maize Super Zone in Dang to organize five awareness campaigns on FAW identification, scouting and management (November 2020–March 2021). These field-based campaigns reached out to five farmer groups involved in commercial maize farming and focused on timely management of the pest, starting from the 3–4-leaf stage of the maize crop. The campaigns successfully established among farmers the concept of field scouting at regular intervals throughout the crop season. This manages pest damage within the threshold level and ultimately reduces the number of sprays per season. In continuation of these campaigns, the PMAMP-Maize Super Zone organized a series of FAW-related, field-based practical orientation and technical support services to maize growers in their command area, by integrating with other agronomy and mechanization support activities. Further details on experiments conducted by CSISA in agricultural extension on FAW are found in Section D of this report.

B. SYSTEMIC CHANGE TOWARDS IMPACT

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

On-farm maize demonstrations and evaluations in new PMAMP sites

New technologies suitable for smallholder farmers are regularly being introduced in Nepal, and tested and validated for local conditions. During the reporting period, a new prototype of two-wheel tractor drawn maize planter, introduced by DKAM Microsystems, was tested in fields in Dang, in 12 demonstration events, integrated with the best management package of practices. CSISA and PMAMP-Maize Super Zone facilitated the dealer-led events. With the satisfactory performance of the maize planter, the Maize Super Zone has decided to include this machine in its subsidy schemes, and in the virtual meeting organized by PMAMP (18 February 2021), the same message was delivered by the Activity to Lumbini Province's other maize zones. In the latter half of the reporting period, DKAM Microsystems imported eight new maize planters, keeping them stocked in order to capitalize on potential demand. It has planned further demonstrations and advertising for commercial sales with CSISA's technical support in nearby districts.

Above: Demonstration of 2WT maize planter prototype, Dang, February 2021. *Photo credit: Sagar Kafle.*

Cropping systems and value chain intensification with mung bean

Mung bean is a comparatively new crop in the Tarai of Nepal. In April 2021, CSISA provided technical support to the Ekataa Mung Bean Block, a 100-ha area of commercial mung bean production. It facilitated a training of trainers on mung bean production technology and its plant protection measures in Suklaphata municipality-10, Jhalari, Kanchanpur (12–13 April, 2021) for 75 participants (65 women, 10 men), organized into smaller groups to maintain COVID-safe protocol. The Activity also facilitated training on machinery calibration for mung bean seeding (10 April) and linked the machinery seed drill service providers with farmers. It also worked with the Agriculture Knowledge Center (the local government agriculture office) to allocate a budget for the development of pockets and blocks of mung bean. As a result, the Center developed five mung bean pockets (10 ha each) and two blocks in Kailali and Kanchanpur.

Household consumption of mung bean is consequently increasing. This is important because mung bean can be a source of protein for smallholder and resource-poor farmers that lack access to animal-sourced foods. In the Ekaata Mung Bean Block, farmers used nearly 60% of their mung bean production for self-consumption, selling 35% and preserving 5% as seed. This indicates the increasing nutrient status of the farmer's diet, income generation and increased soil fertility. As most of the women farmers in the district are engaged in mung bean production, mung bean also empowers women by increasing their income. During the reporting period, CSISA planned a range of mung bean product-making activities to promote small-scale industry; however, COVID-19 restrictions compelled the cancellation of this program.

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

Media campaigns to increase the use of mechanized maize seeding

Due to COVID-19 lockdowns during this reporting period, CSISA did not carry out a direct program as a media campaign or any similar program to increase mechanized maize seeding. However, several TOT programs for agricultural engineers and government agricultural technicians were conducted, providing advice to partners on selecting seed drills for different purposes, including maize seeding.

Results of the media campaign conducted in 2019 in Banke and Bardiya in collaboration with the Agriculture Knowledge Centre (AKC) indicated that in this reporting period, awareness campaigns led to an increase in mechanized maize seeding by 50% (from 67.5 ha to 102 ha). Of the 12 groups/programs that AKC supports, seven purchased maize seed drills in Banke and Bardiya after the campaign. Interest in the maize seed drill from groups like these will encourage AKC to include it on it wish list. Due to COVID-19 lockdowns, however, CSISA team was unable to visit the areas where seed drills have been purchased to carry out monitoring and support mechanized maize seeding. However, most of the groups have successfully completed seeding, resulting in an increase in area of 50%. Further information will be supplied in the next semi-annual report.

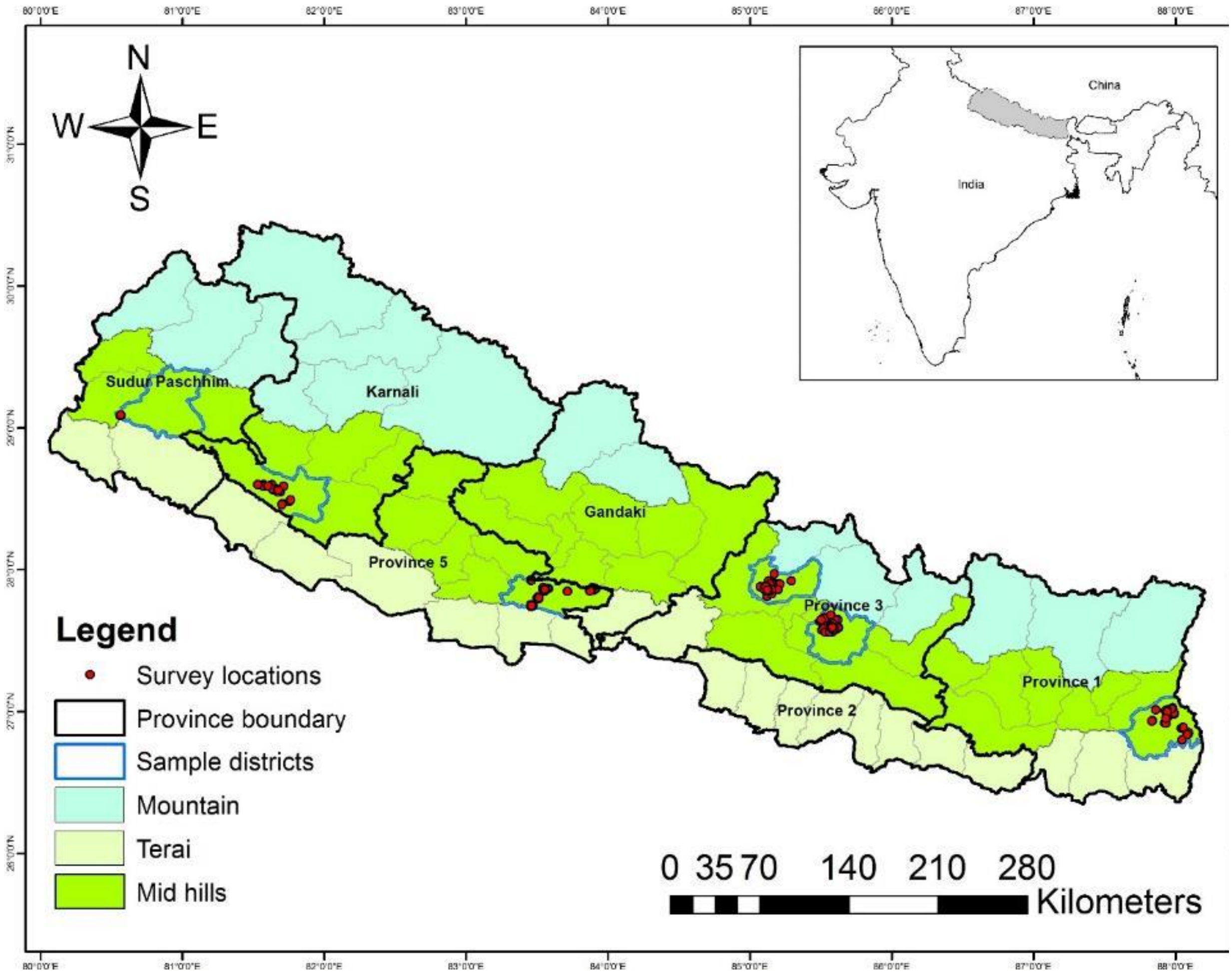
B1.2 Income-generating maize production in neglected hill and plateau ecologies

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

Maize productivity in Nepal is half (2.5 t/ha) the global average of 5.5 t/ha. As a result of this low productivity, Nepal regularly imports over 0.6 million tons of maize grain annually from its neighbor, India. The emerging poultry industries located in Nepal's Tarai are the major consumers of this maize import. Although Nepal's maize area is around one million ha, almost 80% is located in the country's hilly regions (or Midhills). In the Midhills, however, maize is primarily used for household consumption and only partly for livestock feed, with low productivity due to lack of high-yielding cultivars and low input use, including inorganic fertilizers.

During this reporting period, CSISA analyzed datasets on the impact of the adoption of maize hybrids in the Nepal Midhills region. In earlier reporting periods, to overcome the challenges of access to high-yielding maize cultivars, CSISA has worked in the Midhills to facilitate the expansion of seed and input markets with maize hybrids that have a higher genetic yield potential than open-pollinated and traditional cultivars. It also worked to link those farmers growing hybrids to markets where maize can be sold for a profit, justifying investment in higher seed and input costs, while also providing much needed income to farmers. Until 2015, farmers in the FtF ZoI did not have access to these hybrid cultivars, and in 2016, CSISA along with National Maize

Research Program (NMRP), expanded the domains of elite hybrid maize cultivars in the FtF ZoI and many other Midhill areas. This domain expansion of maize hybrids has resulted in the rapid adoption of high-yielding hybrids – it is estimated that almost 10% of the Midhills area is now under hybrid maize. However, until recently there has been no empirical evidence to demonstrate the impact of hybrid adoption on maize productivity, profitability and welfare outcomes. The locations of the study area are presented in the figure below. The next section presents the major highlights of the findings.



Above: Study locations for hybrid maize adoption and impacts on rural livelihoods in the Midhills region of Nepal.

This section presents additional findings from the study of impacts of hybrid maize adoption (for previous results, please see previous reports). Overall, adoption of hybrid maize was profitable for farmers, who enhanced their productivity, profitability and per capita food expenditure. However, these impact results were highly heterogenous. Relatively small farms owing ≤0.3 hectares of land mostly benefited in terms of productivity and profitability gains; only larger farms (>0.3 hectare) benefited in terms of gains in welfare outcomes, such as per capita food expenditure. CSISA analyzed the data to identify whether increasing market access increases the welfare of small farming households from hybrid maize adoption. The impact results across different farm sizes and market access are presented in the table below.

These results suggest that despite very small farms (≤0.3 hectare) being highly productive, increasing their market access for maize grown did not significantly improve household welfare outcomes such as per capita food expenditure. The trend was similar for hybrid maize non-adopters, had they adopted hybrid maize. This indicates that a certain level of farm size may be required for significant technology to impact rural livelihoods. With very small farms (≤0.3 hectares), profitability at the household level is minimal, and insufficient to improve farmers per capita food expenditure. These results highlight the importance of the multiple layering of technologies, such as including fertilizers, crop management practices, and other factors, which might have a stronger effect.

Differential impacts of hybrid maize adoption across farm size and market access in the mid-hill region of Nepal.

Farm size categories with market access		Average treatment effect (Std. error)		
		Maize productivity (kg/ha)	**Gross margin (NPR/ha)**	**PCFE (NPR)**
ATT				
Small farms [≤0.3 ha]	low market access [>4.0 km distance]	2,740*** (156)	44,121*** (2,961)	1,057 (777)
	high market access [<4.0 km distance]	2,395*** (166)	54,130*** (3,577)	93 (876)
Large farms [>0.3 ha]	low market access [>4.0 km distance]	1,825*** (85)	37,345*** (2,306)	2,851*** (417)
	high market access [<4.0 km distance]	1,867*** (123)	24,929*** (2,579)	2,823** (1,151)
ATU				
Small farms [≤0.3 ha]	low market access [>4.0 km distance]	1,927*** (122)	21,824*** (2,833)	4,144** (904)
	high market access [<4.0 km distance]	1,561*** (211)	25,705*** (5,061)	130 (930)
Large farms [>0.3 ha]	low market access [>4.0 km distance]	756*** (113)	9,207** (3,945)	5,958*** (1,076)
	high market access [<4.0 km distance]	1,240*** (124)	5,611 (3,678)	9,396*** (1,616)

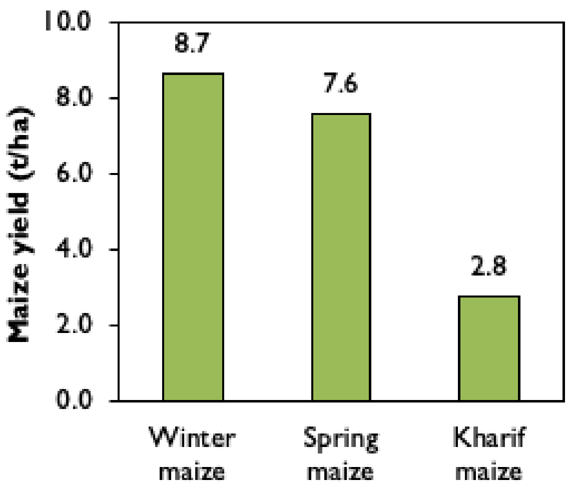
***, ** Statistically significant at 1% and 5% levels, respectively. ATT stands for the average treatment effect on the treated (adopters), and ATU for the average treatment effect on the untreated (non-adopters). Exchange rate 1 USD = NPR 104, during the survey year 2017. PCFE indicates per capita food expenditure; 'high market access' refers to farmers households located within a 4 km radius of markets; 'low market access' means farmers households located more than 4 km radius away from markets.

The details of this impact assessment were submitted for publication during the previous reporting period; the article is under peer review and will be shared via the CSISA website when accepted. These results were also presented at the 31st International Conference of Agricultural Economists, 17–31 August, 2021, organized by the International Association of Agricultural Economists and held virtually due to COVID-19 restrictions. Over 5,000 researchers attended the conference, where CSISA's scientific contribution was well-acknowledged.

Collaborations introducing winter-maize in cropping systems boost maize productivity in PMAMP's operational areas

CSISA has supported PMAMP from its inception in 2016 to incorporate winter maize into traditional rice-lentil, rice-wheat and rice-fallow cropping systems. As part of its work to expand winter maize, the Activity works closely with the PMAMP Maize Super Zone in Dang district, Lumbini Province. The Zone is expanding the winter maize areas, with an additional 500+ ha of winter maize area so far in the Dang district since 2016. Expansion has grown over the years from just 10 ha of hybrid maize area in 2016 to over 500 ha in 2021. To generate information on winter, spring and kharif season maize productivity, PMAMP and CSISA regularly conduct maize crop cuts. Resulting data are used to advise partners how to best approach improvements in the agronomic management of maize.

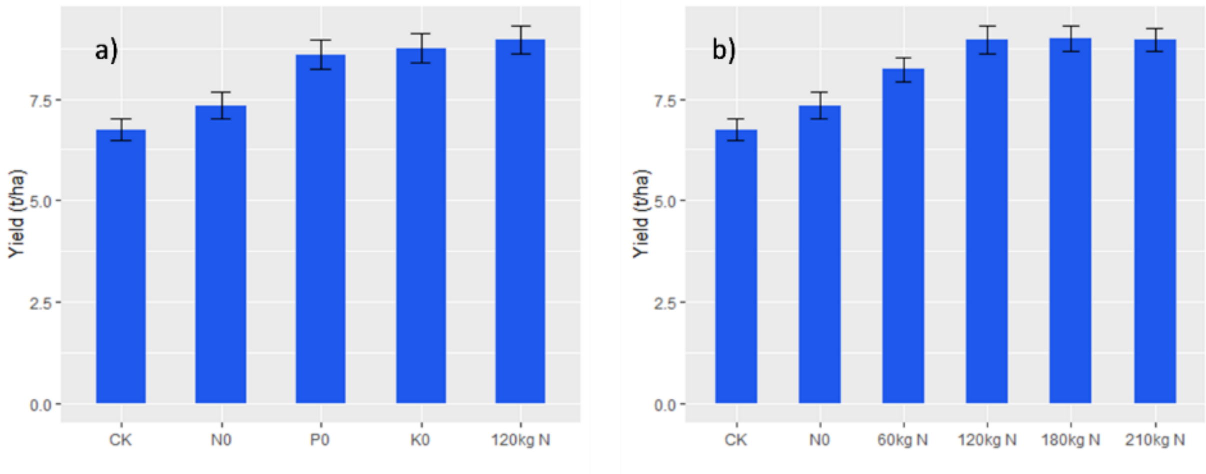
The figure to the right presents the comparative yield performance of seasonal maize, extrapolated from data PMAMP and CSISA have collected. Crop cuts were conducted in 86 farmers' plots in Dang district, where 43 were growing winter maize, 15 were growing rainy season maize and 28 were growing spring maize. Data analysis showed that farmers growing winter maize obtained the highest yield (8.7 tons ha^{-1}) compared to spring maize (7.6 tons ha^{-1}) and *kharif* maize (2.8 tons ha^{-1}). It should be noted that winter maize in this area is a new crop compared to the traditional *kharif* maize and spring maize. These comparative seasonal hybrid maize yield performance results indicate that farmers in the PMAMP working areas are benefiting substantially from winter maize production.



Above: Comparative yield performance of different maize-growing seasons in the maize super-zone areas, Dang district, Nepal. Data source: PMAMP.

Coordination with the Nepal Seed and Fertilizer project (NSAF) to enhance fertilizer use efficiency in maize systems in Nepal

During the reporting period, CSISA continued to collaborate with the USAID/Nepal supported NSAF Activity to enhance fertilizer use efficiency in maize-based systems in Nepal. In the previous reporting period, CSISA analyzed the data from maize-based systems to determine the nutrient use efficiency of hybrid and open-pollinated varieties in the Nepal Midhills region. The results showed the higher nitrogen use efficiency of hybrid maize compared to open-pollinated maize varieties. Farmers can quickly overexploit the soil by not ensuring sufficient levels of fertilizers, the most immediate being nitrogen, and as they do not apply adequate fertilizer doses, nutrient mining from soil could affect long-term soil productivity. This highlights the importance of balanced fertilizer application. These results were shared with NSAF during the 2020-21 reporting period for dissemination to farmers, farmers' cooperatives, and agricultural input dealers throughout Nepal's FtF Zone. The NSAF team continues to conduct experimental fertilizer rate demonstrations and trials in farmers' fields to identify the optimum dose of fertilizer required for maize production in the Nepal hills. Some of these preliminary results are presented in the figure below.



Above: (a) Maize yield response under different fertilizers from the omission plots. The *y* axis represents maize yield and the *x* axis represents different level of nutrients. CK indicates the check plots/control plots managed by farmers; N0 indicates zero Nitrogen but application of other fertilizers as recommended; P0 indicates zero P but the application of other fertilizers; K0 represents zero P but application of other fertilizers; 120 kg N represent 120 kg of N with additional fertilizers. (b) Maize yield response under different levels of Nitrogen fertilizer, other nutrients (P, K2O) remaining constant.

The results from the collaborative NSAF demonstration and farmers' field trials data show that farmers applying 120 kg of nitrogen in maize obtain the highest yield in combination with the recommended phosphorus (50 kg/ha) and potassium (30 kg/ha). The omission trials data (presented in the left-hand graph, above) also indicate that when P, K and N are limiting factors, maize productivity is lower than the ample dose (that is, 120 kg of N) and the recommended dose of Phosphorus and Potassium. If either one of these elemental nutrients are limited, the productivity is lower than when 120 kg/ha of N are applied.

These results highlight the importance of balanced nutrition in maize. The right-hand figure above presents maize yield performance across different levels of N. It shows that application of N beyond 120 kg did not improve maize productivity; applying more fertilizer beyond 120 kg of N is thus a waste of resources. These results from NSAF also support CSISA findings (presented in the previous reporting period) on the importance of balanced fertilizer to enhance maize productivity and sustain long-term soil fertility. CSISA will continue working with NSAF to coordinate and assist it in providing fertilizer recommendations for maize-based systems in Nepal.

Utilizing remote sensing to estimate maize area in Dang

CSISA has also been collaborating with PMAMP to design and implement elite techniques that utilize a remote sensing tool to estimate the area and yield of commodity crops. In 2020 in the

Dang Maize Super Zone, the Activity initiated work in maize crop area estimation, in coordination with the PMAMP Project Implementation Unit, and quantified the area under maize (please see CSISA III Annual Report 2020). In 2021, collaboration continued with the PMAMP Project Management Unit to facilitate their institutional use of remote sensing assessments to estimate the area and yield of cereal crops in districts across Nepal's Tarai. CSISA also organized a week-long basic training/orientation on GIS and remote sensing for 14 PMAMP officers (August 2021), which provided them with preliminary ideas on the methodology of the work. This was followed by a second-level orientation to PMAMP officers (September, 2021). PMAMP has anticipated institutionalizing the remote sensing assessment methodology in the near future, after strengthening the capacity of the relevant personnel.

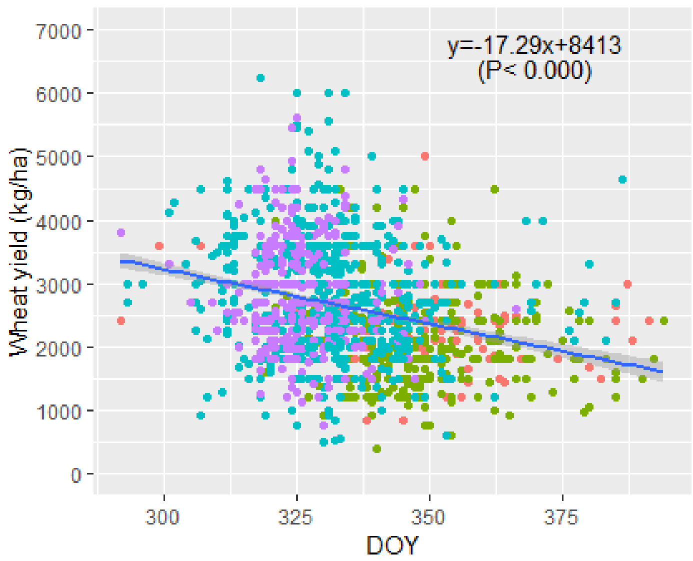
B2. Bringing participatory science and technology evaluations to the landscape and back again

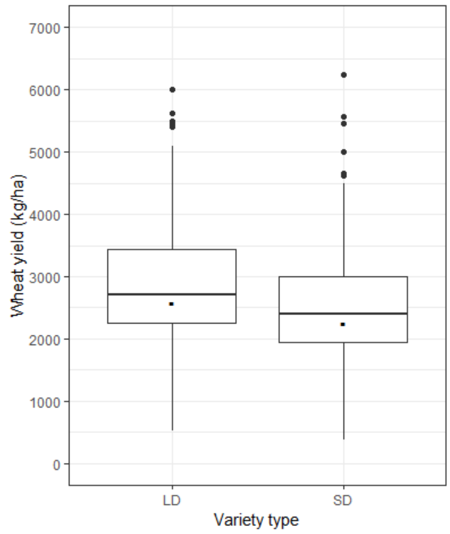
B 2.1 Increasing the capacity of the National Agriculture Research and Extension System to conduct participatory science and technology evaluations

Sharing survey findings to NARES and include them in program implementation

CSISA has been working with national partners, including PMAMP and NARC, to generate near real-time data on different crop management practices for rice, wheat and maize. These data is collected using handled, internet-enabled tablets on the ODK platform and analyzed immediately after being deposited on the CSISA server. Major findings are delivered to PMAMP to be incorporated in its programs or before a crop is planted. In the previous reporting period, CSISA shared wheat survey findings with PMAMP and other national partners. In this reporting period, the Activity organized discussion sessions to assess the possibility of National Wheat Research Program (NWRP) developing long-duration wheat varieties, which observational data suggest would enhance wheat productivity when coupled with early sowing.

The current wheat breeding program is largely focused on developing short-duration maturing wheat varieties due to the decreasing winter season window, climate change and rising temperatures. However, survey results from CSISA and PMAMP show that short-duration wheat varieties might not yield high productivity, and during this reporting period therefore, CSISA organized a discussion with PMAMP and NWRP (27 July, 2021) to showcase the importance of long-duration wheat varieties and early sowing. For example, a delay of just one day in wheat sowing after November 28 reduced wheat productivity by almost 20 kg per hectare per day (see figure below, left) and the adoption of long-duration varieties with early sowing increases wheat productivity by 0.5 t/ha (see figure below, right). From the discussion, the NWRP Coordinator realized the importance of early sowing of long-duration wheat varieties and will now consider duration as one of the major attributes in their wheat-breeding programs. The current wheat varieties developed by NWRP are mostly short- and mid- duration maturing – there are no long-duration maturing varieties. As a result, farmers from Nepal's Tarai go to the bordering districts of India to purchase long-duration maturing varieties.



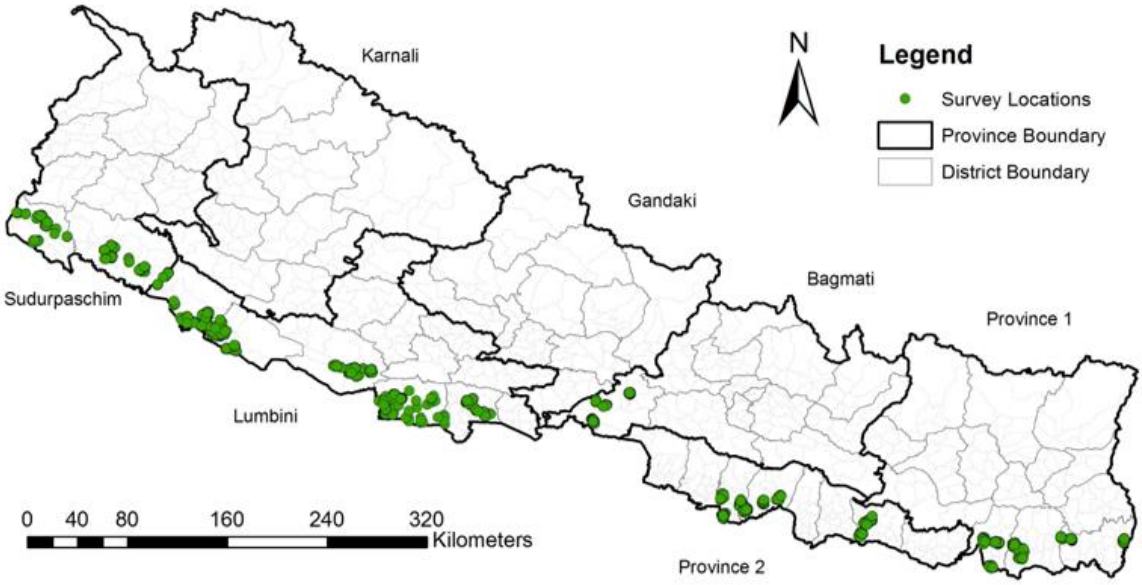


Above: Left: negative slope of wheat sowing date (DOY: Julian days of year) with productivity indicating importance of early sowing. Right: higher wheat productivity of long-duration (LD) wheat varieties compared to the short-duration (SD) varieties.

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

In collaboration with PMAMP and NARC, CSISA collaborates with a CCAFS supported project on Big Data to carry out regular rice and wheat crop cuts and surveys. In this reporting period, PMAMP and NARC collaborated with CSSIA and CCAFS to conduct wheat crop cuts in April, 2021, with a follow-up survey in June and July, 2021. Rice results were presented in the previous reporting period; this report therefore largely discusses wheat crop cut analysis and results. Considering rice, however, prior to summer *kharif* rice transplanting time, CSISA organized a virtual meeting (May, 2021) and shared the rice crop cut and survey results with PMAMP and Nepal's agricultural knowledge center (AKC) staff. NARC supported the dissemination of the findings described in the previous semi-annual report. Due to COVID-19 restrictions, the survey results were shared via Zoom.

The following sections conversely highlight the initial results of the recent wheat crop cuts and production practice survey, analyzed using a machine learning approach. The figure below illustrates the distribution of the samples and selected districts. The results showed that average wheat productivity in the survey areas was around 3.08 t/ha. The distribution of wheat yields across the provinces is presented in the figure below (left), while the right-hand figure presents the drivers of wheat productivity. These were analyzed using a machine learning approach, which data-driven analytics on the drivers of productivity that are helpful for advising extension program implementation. The machine learning results show that fertilizer (e.g. P, K) and the sowing date are the major factors affecting wheat productivity in Nepal's Tarai. These three variables should therefore be prioritized in order to close the country's wheat yield gaps.



Above: Districts and sample locations of the recent rice and wheat crop cuts and production practice survey, completed in January and June/July 2021 jointly by PMAMP and CSISA.

The survey results also showed that the current nitrogen application rate is around 80 kg/ha, significantly lower than the recommended dose of 100 kg/ha. Nepal faces a constant, severe shortage of fertilizers; these are imported and COVID-19 restrictions have aggravated availability issues further. Moreover, the current P2O5 application rate is around 19 kg/ha, far below the recommended dose of 50 kg/ha. The analysis also shows that farmers need to apply sufficient doses of N and P_2O_5 in order to achieve higher yields and close the yield gaps, and that one of the major reasons for low wheat productivity is the late sowing of wheat.

Farmers can substantially increase productivity if they sow their wheat before the end of November, but they report that the main reason for sowing wheat late is the late harvesting of rice. As the majority of rice varieties grown in Nepal are long-duration maturing generally harvested in November, farmers have no option but to sow wheat late. The analysis shows that research and development initiatives in Nepal need to work at the cropping systems level, so that farmers will adopt short-duration maturing rice varieties, allowing them to harvest their rice and sow wheat early, thus taking advantage of cropping systems. These survey results will be presented to CSISA partners, including NARC, PMAMP, and stakeholders in PMAMP's Wheat Super Zone focused working areas during October 2021, to encourage them to consider these factors in their programs in the coming November wheat-sowing time.

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

During the reporting period, CSISA worked to extend its awareness and use of rice IWM management techniques by building the capacity of agrovets and government technicians. The Activity organized virtual trainings on rice IWM in collaboration with MoALD and NSAE during June of 2021. The 90 participants were agriculture technicians/officers and agricultural engineers, primarily from PMAMP. Follow-up monitoring results indicate that in rice production, farmers are adopting CSISA-promoted technologies (e.g. brown, mechanized weeding) in Kailalai and Kanchanpur districts.

Above: (right) Brown manuring of DSR as part of an IWM approach, adopted by a farmer in Belauri-8, Kanchanpur. (left) A two-wheeled tractor being experimentally used to weed rice, Belauri-6, Kanchanpur. *Photo credits: Hari Acharya.*

Manual weeding of rice is labor intensive, which reduces profitability. However, the cost of cultivation can be reduced by the application of appropriate herbicides. In this reporting period, CSISA provided technical assistance to 120 agrovets on the right dose, time and method of herbicide application. Due to COVID-19 restrictions, a workshop on these topics with government partners was unable to be implemented at the field level.

C.1.2 Accelerating the emergence of mechanized solutions for sustainable intensification

Machinery specifications and service provider training

During this reporting period, CSISA conducted comprehensive capacity building training for more than 30 participants on appropriate-scale mechanization from all of Nepal's seven provinces (6–10 April, 2021). This was achieved with technical support from the Agricultural Mechanization Promotion Centre (AMPC), including the Center for Agricultural Infrastructure Development and Mechanization Promotion (CAIDMP), NARC, and Nepalese Society of Agricultural Engineers (NSAE). Participants were from various affiliated organizations, including PMAMP, MoLMAC, Directorate of Agriculture Development, and NSAE.

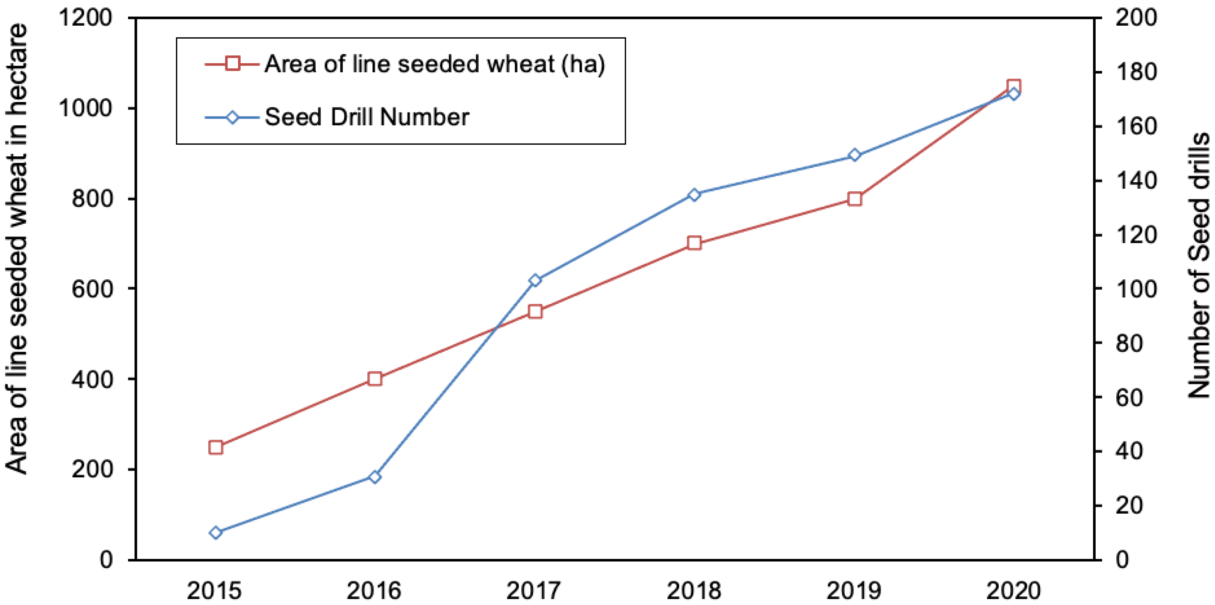
The main aim of the training was to share CSISA's experience to facilitate the future selection of appropriate machinery for extension and support participants in the different procurement processes, focusing mainly on specification preparation of the machinery. It included information on the availability of farm machinery in Nepal, and brief repair and maintenance tips for the mini-tiller and power tiller, two important machines currently provided by Nepal government organizations to farmers under a government subsidy. It also included a tour of the Agriculture Machinery Testing and Research Center (AMTRC) with demonstrations of the laser land leveler, and harvesting and seeding machinery. The training included irrigation activities, with an introduction to an irrigation pump set and shallow tubewell promotion. It also covered agriculture mechanization policy and research on extension work.

Above: Participants in capacity building training, facilitated by CSISA Nepal. *Photo credit: Bishal Shrestha*.

Scaling mechanized wheat seeding through service providers and PMAMP

Outside of periods constrained by COVID-19 lockdowns, during this reporting period CSISA conducted TOT programs for agricultural technicians within PMAMP. Trainings were part of efforts to disseminate knowledge on mechanization in wheat production, including line wheat seeding machinery. The first TOT trained 21 agriculture technicians (3 women, 18 men) in Madhuwan-4, Bardiya district (6 December, 2020). Another five-day TOT program was conducted at AMPC, Dhanusha (6–10 April, 2020) to 27 PMAMP agricultural engineers from all over Nepal. Through these efforts, CSISA assisted technicians associated with more than 30 active machinery service centers (individual and custom hire centers).

Above: Government agriculture technicians learning about the wheat seeder in the field, Madhuwa-4, Bardiya district. *Photo credit: Subash Adhikari.*



Above: Increasing trend in seed drill numbers and area of wheat seeded in four districts of Western Tarai in the last six years (2015–20).

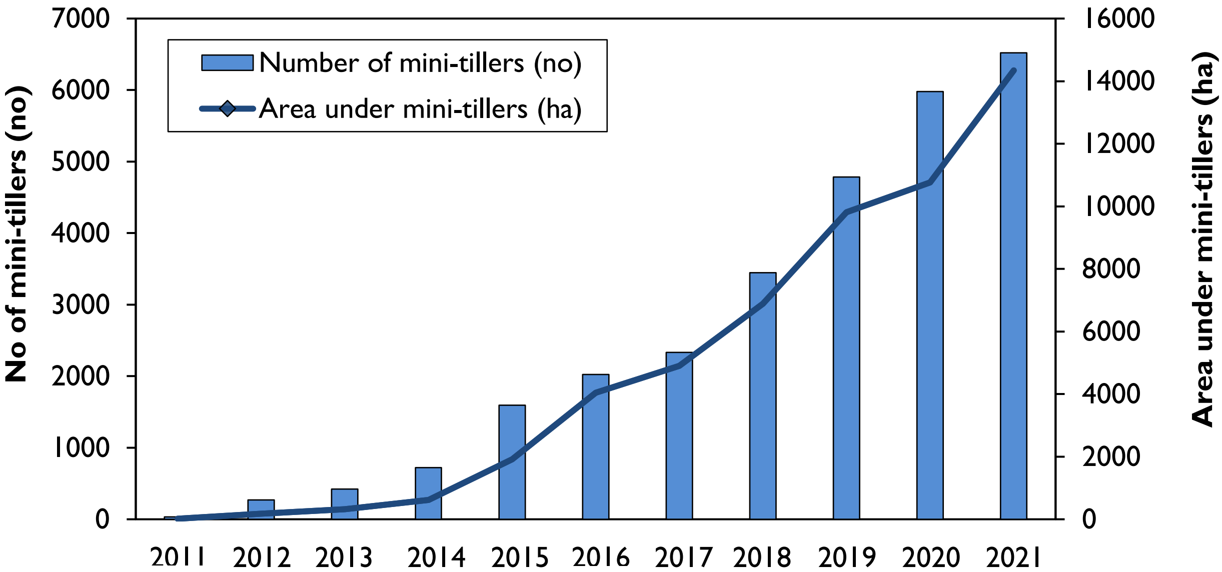
Area under mechanized wheat sowing has been steadily increasing as a result of these and similar efforts. During the early wheat sowing period of 2020, the total mechanized wheat seeding area was around 1,050 ha, with 172 seed drills operational in Banke, Bardiya, Kailali and Kanchanpur districts.

C1.3 Commercial expansion of scale-appropriate machinery and associated service provision models for reapers and seeders in Nepal

Nepalese smallholder farmers often use two-wheel tractor (2WT) power tillers to cultivate their fields. Since 2016, CSISA Nepal has provided technical assistance to machinery value chain actors to increase demand for 2WT-mounted seed drills in Dang and the surrounding districts they serve. The Activity is now studying their adoption and spreading awareness of other labor-saving machines for carrying out the range of farm operations.

Impact of mini-tiller adoption on maize productivity, profitability and household food security across household's gender cohort in Nepal

Since 2011, CSISA has supported the widespread adoption of mini-tillers in the Nepal hills, working with private sector actors such as Nepal Agricultural Machinery Entrepreneurs Association (NAMEA), as well as the Department of Agriculture (DOA) and the Ministry of Agriculture and Livestock Development. Mini-tillers are one of the few scale-appropriate farm machineries that are used for land preparation in Nepal hills. This technology was introduced by CSISA in 2011 and validated in farmers' fields. Since then, CSISA has continued to partner with the private sectors to increase commercial availability and use of mini-tillers. These small 5-9 horsepower tractors are used for land preparation and weeding. Since this technology is more appropriate for smallholder farmers, the adoption of mini-tiller is rapidly increasing.



Above: Annual growth trends of mini-tillers from inception in 2011 to 2021 in the Midhills of Nepal (note that growth of mini-tillers has also been considerable in the Tarai, though data are not shown here).

During this reporting period, CSISA staff analyzed the overall growth trends of mini-tillers from the data provided by NAMEA, and the impacts of mini-tillers across household gender cohorts the figure above shows that mini-tiller adoption is rapidly increasing in Nepal hills, and presents growth trends in increasing order. In 2011, there were <100 mini-tillers used in Nepal's mid-hills, but in in 2021 over 6,000 mini-tillers were sold by NAMEA associated machinery businesses and adopted by the country's farmers. The mini-tiller's rapid success is attributable to CSISA's continual support to the private sector to achieve its upscaling. Based on the number of mini-tillers that NAMEA has sold, CSISA estimates the area under mini-tiller in maize-based systems in Nepal to be around 15,000 ha.

CSISA's scientists also analyzed data collected from previous years to discover the impacts of mini-tillers across household gender cohorts (see table, below). The results show that male-headed households are largely benefited from mini-tiller adoption for land preparation in maize while the impacts of adoption on female-headed households is comparatively and unfortunately more limited. Male-headed households gained higher maize productivity (607 kg/ha) than female-headed households (442 kg/ha). Male-headed households are also benefited from a typically higher gross margin from maize, and mini-tiller adoption made them more food secure than female-headed households. These results indicate that female-headed households are less benefited from this technology than male-headed households. The major reason for this could be due to operational difficulty associated with mini-tillers. The results suggest that more capacity development programs should target female-headed households to increase their mini-tiller operational skills to take advantageof technology adoption. This is a crucial insight, as a range of FtF Implementing Partners and other development programs have begun promoting mini-tillers in Nepal, as a supposed gender-neutral or women-friendly technology. The data conversely and strongly indicate that targeted capacity development efforts will likely be needed to achieve significant women's empowerment outcomes from mini-tillers.

Impacts of mini-tiller adoption on maize productivity, profit (gross margin), and household food security across household gender cohorts in the mid-hills of Nepal.

Strata	Outcome variables	Adopters	Control	ATT
	Maize yield (kg/ha)	3334.57	2727.32	607.26*
Male-headed	Gross margin (NPR/ha)	23075.45	587.93	22487.52***
households	Food self-sufficiency (%)	45	24	24***
	Maize yield (kg/ha)	3355.52	2913.90	441.62
Female-headed	Gross margin (NPR/ha)	26320.23	20612.49	5707.75
households	Food self-sufficiency (%)	40	13	27

* and *** indicate statistical significance at the 10% and 1% levels, respectively. ATT stands for the average treatment effect on the treated (adopters).

Initiating next steps towards scale-appropriate farm mechanization Nepal with the public and private sector, via virtual meetings during lockdown

CSISA organized a virtual digital conference on the 'Importance and Role of Scale-Appropriate Machinery in COVID-19 Response, including Gender Sensitiveness and Awareness' (21 June, 2021); 140 stakeholders with extensive experience in Nepal/Asia were invited. The 139 attendees included national and international experts/researchers in agricultural mechanization, agronomists, GESI experts, agriculture engineers, members of academia, practitioners, field-based staff, scientists, agriculture senior officials, policymakers, civil society members, Activity staff, and private sector companies, including NAMEA. The main purpose of the online conference was to raise awareness of the demand for machine-based land preparation, planting and harvesting services in COVID-19-impacted districts. Invited to present on the effects of the crisis on smallholder farmers and subsequent recovery activities were federal government ministries and departments from FtF districts: PMAMP, international non-government organizations (INGOs), community-based organizations (CBOs), private sector companies, NARC) and Agriculture Knowledge Center staff, particularly from FtF districts. All the presenters shared their experiences, achievements and what they had learned during the recovery activities carried out in the FtF ZoI. One common factor was that these activities have contributed greatly to the recovery process towards securing the income and livelihood of the affected populations.

During the meeting, Dr. Hari Bahadur K.C., Joint Secretary, MoALD, highlighted the difficulties of using machinery in the hilly regions of Nepal, which can be abandoned when farmers find them difficult to use. He noted the importance of analyzing their usability before starting an initiative, and that Nepal farmers are very skilled in land preparation mechanization. He identified the lack of technical manpower needed for repairs and maintenance as the main constraint faced by the agriculture machinery sector. In his closing remarks, Mr. Rewati Raman Paudel, Secretary of the Ministry of Land, Agriculture and Cooperatives, Lumbini Province, Nepal, stated the conference was timely and very useful. He highlighted that scaling-out a range of key mechanization options is highly important for a country like Nepal in the context of its agricultural labor shortage.

Above: Participants of the CSISA Nepal virtual conference, 'Importance and Role of Scale-Appropriate Machinery in COVID-19 Response, including Gender Sensitiveness and Awareness', 21 June 2021.

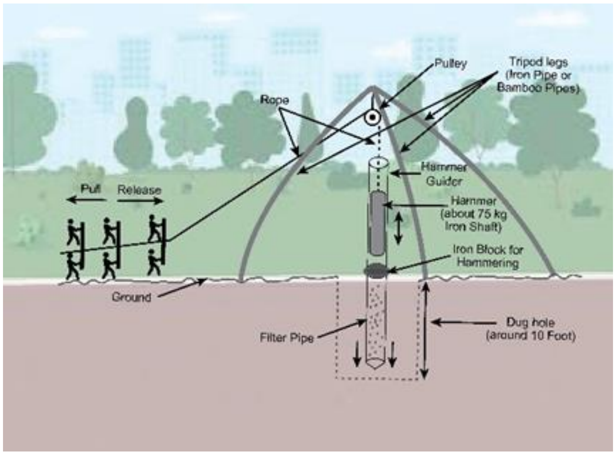
C2. Managing risk by coping with climate extremes

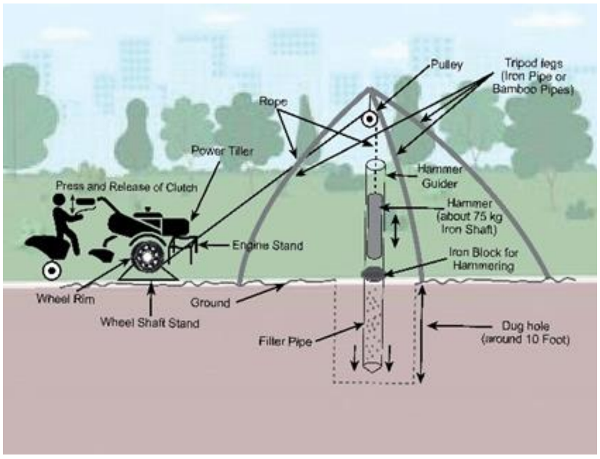
Climate change and extremes are increasingly challenging South Asian agriculture, particularly the more extreme temperatures and increasingly erratic, difficult-to-predict monsoon rainfall. This heightens the importance of farmers having access to irrigation, to buffer against drought stress and provide flexibility for early planting that otherwise depends on monsoon rains and residual moisture. Previous research conducted by CSISA and its partners found that the high cost of irrigation, combined with smallholder farmers being reluctant to pay for irrigation when rain is likely in the near future, inhibits rice productivity in Nepal's Tarai, CSISA has focused on overcoming these constraints. In response to these challenges, the workstreams below focus on options to increase affordable access to irrigation and knowledge products that can help farmers in Nepal's Tarai overcome climate extreme induced productivity constraints.

Partnerships to reduce irrigation prices through technology development

During this reporting period, CSISA continued its efforts to support the development of low-cost irrigation technology, focusing specifically on developing a low-cost drilling rig in coordination with local drillers in Bardiya district. The rig is having been cooperatively designed with research partners in the public and private sector to substantially reduce the drudgery and labor required to construct shallow tubewells, which accounts for a large portion of irrigation borewell construction costs, as manual well-drilling usually requires crews of 10 people or more.

CSISA initiated this work in 2017 and after extensive field testing and improving the equipment, has now conducted several successful water table borings, employing different professional well-drillers in Bardiya district. After demonstrations, field surveys and development of the technological design, the Activity guided well-drillers in the installation and operation of the equipment, and facilitated a co-creative learning experience to generate their feedback and assess their interest in further deploying and developing the technology. After several weeks of training and practice under the guidance of CSISA staff, two well-drillers expressed a professional interest in acquiring the new technology for use in their private business enterprise. In response, CSISA organized an official handover (April, 2021) of one piece of prototype boring technologies to each of them, in an effort to kick-start commercial use of this innovation.





Above: Left: manual drilling method (current method used in Nepal). Here, average cost of drilling a 40 ft deep x 4" diameter well is NPR 29,429 (n=13); average labour used per day is 7.5 men (for drilling) plus one *mistri* (mechanic); average days needed for drilling the bore is 4.38 days using the labor mentioned plus one *mistri* and no additional charge. Right: power tiller drilling method (newly developed in Nepal). Average cost of drilling a 40 ft deep x 4" diameter bore is NPR 18,700 (n=14). Average labour needed is 0.3 man/day (for drilling) with one *mistri*; average days needed to drill the bore is 2.17 days using the labor mentioned plus one *mistri*, with an additional charge of NPR 3,300 for the power tiller.

These well drillers then facilitated the drilling of 25 additional wells (see [link to the original map]() of new well locations) and conducted a survey (September 2021) to better understand the economic performance of this technology among 14 and 13 adopters compared to non-users (the latter of whom used the conventional using manual well boring method). Survey results suggested a significant reduction in the need for labor (a considerable reduction from 7.5 to 0.6 pers-n-days), when a two-wheel tracto engine was used to assist in in boring under the new method reduction in the time needed to bore a set (from 4.38 to 2.17 days), and reduction in overall cost of boring by 36.45% (see table, below). At the same time, the new boring method increases the benefit to the service provider, whose charge is increased by NPR 1,000 per boring and who earned an additional NPR 3,300 per boring from the use of the two-wheel tractor engine to power the boring process.

Further analysis of the scaling potential of this technology is needed, but these initial figures highlight the potential for improving water security and the adaptive capacity of smallholders in Nepal Tarai. CSISA is currently preparing a factsheet with a video to increase awareness of, and demand for this technology. These activities contribute to resolving infrastructure bottlenecks for timely and adequate irrigation provision, identified by previous CSISA research as key to bolstering agricultural productivity and resilience.

Using pump-testing diagnostics to build public support for a strong private sector

Research published by CSISA during the reporting period in *Agricultural Water Management* journal focused on the intensification of groundwater irrigation as central to goals of improving food security and reducing chronic poverty faced by millions of rural households across the eastern Indo-Gangetic Plains (EIGP) of Nepal and parts of eastern India. At present, levels of groundwater use and access in the EIGP lag far behind other areas of South Asia despite abundant available groundwater resources. A key reason for prevailing access constraints is the dependence on diesel pump sets for accessing groundwater, which are typically unsubsidized and therefore expensive to purchase and operate. To date, efforts to reduce access costs have focused almost exclusively on how to incentivize the adoption of alternative electric or solar-powered pumping technologies, which are viewed as being cheaper to operate and less environmentally damaging due to their lower operational carbon emissions.

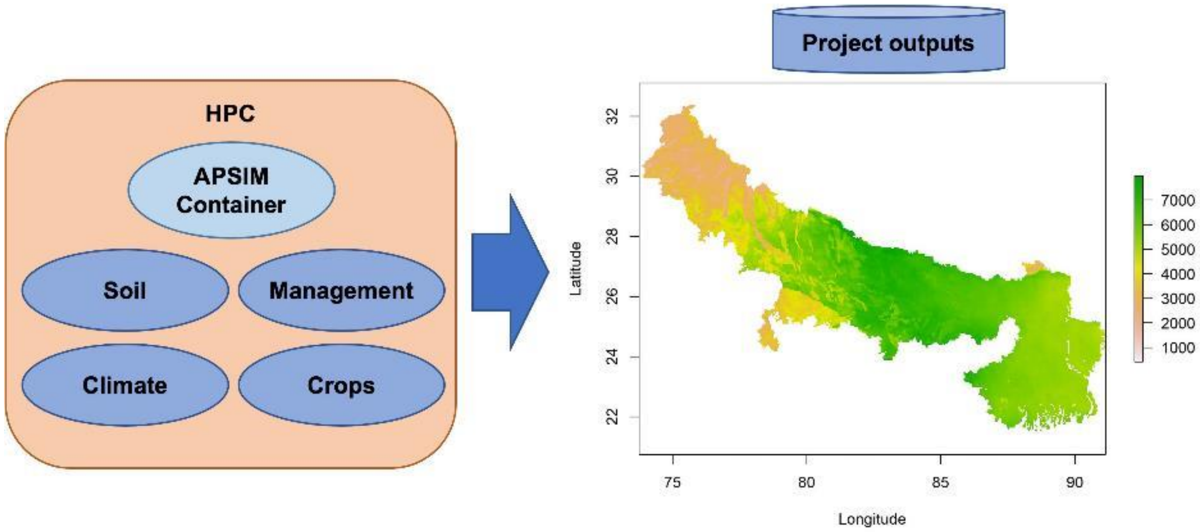
In contrast, there has been little attention paid to identifying opportunities to make existing diesel pump systems more cost-effective for farmers to operate in order to support adaptation to climate change and reduce poverty. The study used evidence from 116 detailed in-situ pump tests along with interviews with pump set dealers, mechanics and farmers in the Nepal Tarai to assess how and why fuel efficiency and operational costs of diesel pump irrigation are affected by farmers' pump set selection decisions. The results suggest that costs diesel pump set irrigation can be reduced significantly by supporting and incentivizing farmers (e.g., through equipment advisories, improved supply chains for maintenance services and spare parts) to invest in newer low-cost, portable and smaller horsepower pump set designs that are more effectively matched to local operating conditions in the EIGP than older Indian manufactured engines that have historically been preferred by farmers in the region. Moreover, efficient diesel pump sets can support the transition to low-carbon technologies.

Above: Setup of pump testing rig during one of the 116 *in-situ* irrigation tests conducted as part of the CSISA study published in *Agricultural Water Management* journal. Inset image shows a close-up view of the fuel injection from the graduated measuring cylinder into the pump engine. *Photo: Subash Adikhari.*

Moving these research results into action, CSISA continues to collaborate with small-scale private machinery workshops to establish national testing protocols for machinery technologies, including irrigation pumps. Although discussions with partners during the reporting period were limited due to COVID-19 lock-downs, there remains considerable interest in building the capacity of machinery testing centers to strengthen their foothold in scale-appropriate technologies, including shallow tubewells and small pumps. To this end, CSISA will continue to collaborate with pump testing centers that have also agreed to further strengthen the partnership through the development of pump-testing and promotion strategies, by which the centers can support local government in the selection of adequate irrigation equipment specifically suited to the local environment and uses. These programs are also aimed to build trust with farmers, who currently face information asymmetry and often rely on the limited experience of their neighbors, families or even contacts in India for making investment decisions that are often not well-suited to their water system. Such interventions can help to unlock potential for intensified irrigation water use in the EIGP, contributing to goals of improving agricultural productivity and resilience to climate extremes while also strengthening farmers' capacity to invest in emerging low-carbon pumping technologies.

Developing a regional crop simulation framework to support spatio-temporally targeted advisories

Climate change, population growth, and persistent food insecurity require agricultural systems to become more productive and resilient1 - especially in smallholder-dominated cereal-based systems where adaptive capacity is low. In Nepal, as within the wider Indo-Gangetic Plains (IGP), significant regional climatic gradients, as well as management practices and constraints, strongly impact farmers' decision-making. Alongside this, poor understanding of the interaction between management decisions on the timing of crop planting activities, and a host of operational constraints, limit the development of spatially targeted crop management advisory systems. CSISA has developed a regional crop simulation framework to address this bottleneck. This is based on the parallel System for Integrating Impact Models and Sectors (pSIMS) and the Agricultural Production Systems Simulator (APSIM) crop model. During the reporting period, a study was conducted to assess the impact of different planting strategies on yield patterns, resilience and water use, with an initial focus on rice in Nepal and the wider Indo-Gangetic Plains.



Above: Average potential rice yield in kg/ha when planting rice at the monsoon onset in the Indo-Gangetic Plains (IGP), showing that this planting strategy is highly productive in the middle and Eastern IGP to which Nepal belongs.

This long-term, regional modelling study assessed the impact of rice planting strategies on resource-use trade-off and temperature stresses. The results from this assessment demonstrate that the outcomes of different planting strategies diverge across the IGP. Synchronizing rice planting with monsoon onset improves rice-wheat system productivity and resilience over the eastern IGP, indicating that monsoon forecasting can be a promising service for farmers in this sub-region. However, the east-west progression of the monsoon and seasonality in temperatures restricts the application of this strategy to the northwestern IGP, with limited scope to improve both the productivity and sustainability of 276 the rice-wheat system. Secondly, this study demonstrated the need to consider rice-wheat cultivation as an integrated multi-cropping system in which interventions, such as planting dates strategies, must be evaluated from a systems perspective that includes the full crop rotation. The study, which is currently under peer-review, advises that explicit management factors and considerations of future climate scenarios should be further investigated to support programmatic targeting of interventions at the regional scale of mega-environments, as well as within the large east-west climatic gradient encountered in Nepal's Tarai. In concert, strengthening the knowledge base on the spatio-temporal interplay of crop systems management and the climate system.

Building linkages between local governments and advances in regional climate forecasts

Monsoon patterns and onset are notoriously hard to predict. Nevertheless, recent advances in earth system sciences and climate dynamics have significantly improved the understanding of the monsoon, and skills in forecasting its onset. Several actors including the European Centre for Medium-Range Weather Forecasts (ECMWF) are continually improving operational datasets to support seasonal forecasts, including monsoon forecasts for South Asia. Currently, the International Centre for Integrated Mountain Development (ICIMOD) supports the ongoing development of a regional and country-specific drought outlook and seasonal climate forecasts. CSISA has already informally partnered with ICIMOD in to inform outreach strategy for advisories related to climatic factors such as timely plantings and irrigation deployment.

In the next step, CSISA is collaborating with the local Government of Nepal Agricultural Knowledge Centers[10] to develop outreach strategies that can be put into place. These partners currently lack the expertise and capacity to interpret the results of model outputs and seasonal forecast systems, as these are relatively technical and require domain knowledge to be interpreted. Given the significant value these can provide for local partners, CSISA organized a meeting with ICIMOD to strengthen further cooperation between ICIMOD's drought outlook and seasonal forecasts and local organizations. At the virtual meeting on 16 March 2021, ICIMOD and CSISA discussed potential collaboration avenues. They agreed to host a capacity-building workshop for local government partners to be trained on ICIMOD's regional forecasts' INTERPRETATION and use. Participants also agreed that CSISA will facilitate these linkages and contribute agronomic expertise as part of the translation process from model output to specific crop management advisories.

However, the COVID-19 wave that followed (April–June, 2021) stalled this workshop. CSISA then coordinated with ICIMOD and other colleagues to assess the seasonal forecasts for the 2021 monsoon season, and co-developed crop planting and irrigation advisories accordingly. Due to the good rainfall characteristic of 2021's monsoon season, these advisories could support farmers in timely planting in anticipation of good and timely rains. Timely planting ensures that crop growth takes place within favorable temperature regimes and low irrigation requirements are maintained. Doing so allows farmers to reap good rice harvest and provides sufficient time for early wheat planting after rice is harvested – a key prerequisite to increase wheat productivity too in the subsequent season. The advisories were broadcast through eight different FM stations in four different languages to enable inclusive exposure to necessary information and reach smallholders of different ethnic and social groups, increasing resilience of climate shocks and variability in an inclusive manner. Conversely, capacity building workshops have been postponed due to COVID-19 complications, although efforts will resume towards this goal prior to the *kharif* season in 2022.

[10] There are 52 Agricultural Knowledge Centers in Nepal, established by the Ministry of Agriculture Land Management, Agriculture and Cooperative (MoLMAC) to disseminate up-to-date agricultural information to the farmers and implement agriculture program of Provincial Ministries.

3. Policy Reform – Achievements

D1. SEED SYSTEMS

Bangladesh

As described in the 2018-19 Annual Report, activities in Bangladesh around seed system policy reform were phased down due to transitions in the CSISA's leadership within the International Food Policy Research Institute (IFPRI) and Activity funding uncertainties. These are described in the Executive Summary and 'Challenges Faced During the Reporting Period' sections of previous CSISA reports.

Nepal

Assessing varietal turnover gaps: The Indian Agricultural Research Institute (IARI) set up a business incubation center to foster partnerships with small and medium-sized seed companies and startups to propagate and market newly released varieties of rice and wheat seeds. CSISA had planned to engage with the IARI center to understand if a similar public-private model can be replicated in Nepal. This involved in-person discussions and visits to assess the situation in Nepal and to facilitate interaction between stakeholders from partner organizations in Nepal and IARI. However, a serious secondary outbreak of COVID-19 and subsequent lockdown and travel restrictions in both countries prevented the initiation of this workplan[11].

D2. SCALE-APPROPRIATE MECHANIZATION

Bangladesh and Nepal

CSISA is conducting a process evaluation around subsidy and credit policies and programs for agricultural equipment in Bangladesh. However, given the travel restrictions due to the pandemic and the associated ethical concerns and risks of carrying out primary data collection, the planned study has been postponed until the next reporting period. Discussions around this have been initiated with regional partners and subject matter experts in Bangladesh. Secondary data sources, such as Bangladesh Integrated Household Survey (BIHS) datasets, are being used for all three rounds (2011–19) to assess the penetration of select agricultural machinery in the FtF ZoI and other districts in Bangladesh. The analysis seeks to understand how machine ownership and the cost of land preparation has evolved over the years. Its findings will be used to prepare a policy brief and/or journal article, and as part of a 2022 workshop planned by the USAID/Bangladesh Mission supported FtF CSISA Mechanization and Extension Activity (CSISA-MEA)

D3. SOIL FERTILITY MANAGEMENT AND FERTILIZER MARKETS

Bangladesh and Nepal

Based on the policy work around soil fertility management and fertilizer policies in Bangladesh and Nepal from the previous reporting period, CSISA had planned a regional workshop in 2021

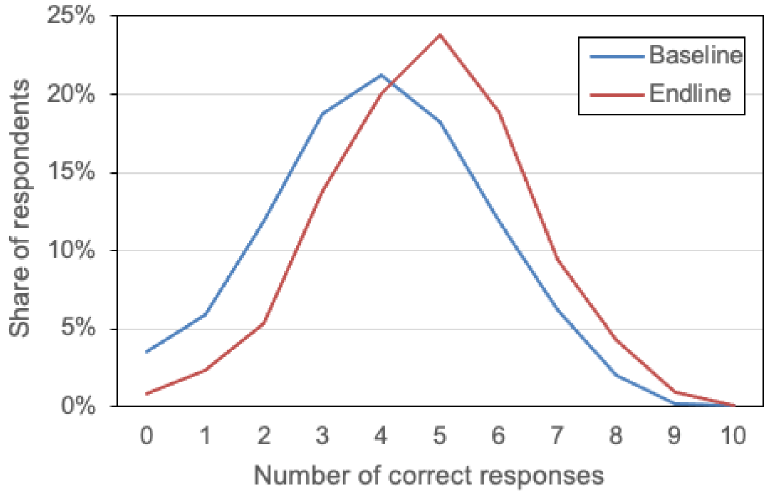
[11] Both India and Nepal experienced a severe second wave of COVID-19 infections between April to July 2021, affecting CSISA work plans during this reporting period.

in Dhaka, Bangladesh. The objective of this event was to reflect on CSISA findings from both countries and highlight the need for evidence generation and extension to encourage balanced fertilizer application by farmers. However, owing to COVID-19 restrictions, the workshop was postponed until the last quarter of 2021 or the first quarter of 2022, contingent on the pandemic.

D4. AGRICULTURAL RISK MANAGEMENT

Nepal

Examining risks and extension options for Fall Armyworm mitigation in Nepal: Adapting to the COVID-19 pandemic, CSISA worked during the reporting period to investigate the potential use of extension approaches including auto-recorded voice calls and phone calls from trained personnel with information on FAW management. Both treatment groups received the same set of information, followed by four weekly SMS reminders on the same topics. The Activity reached out to more than 2,300 farmers from 134 villages across four municipalities in Dang using phone surveys. Around 70% of respondents were women agriculture decision-makers.

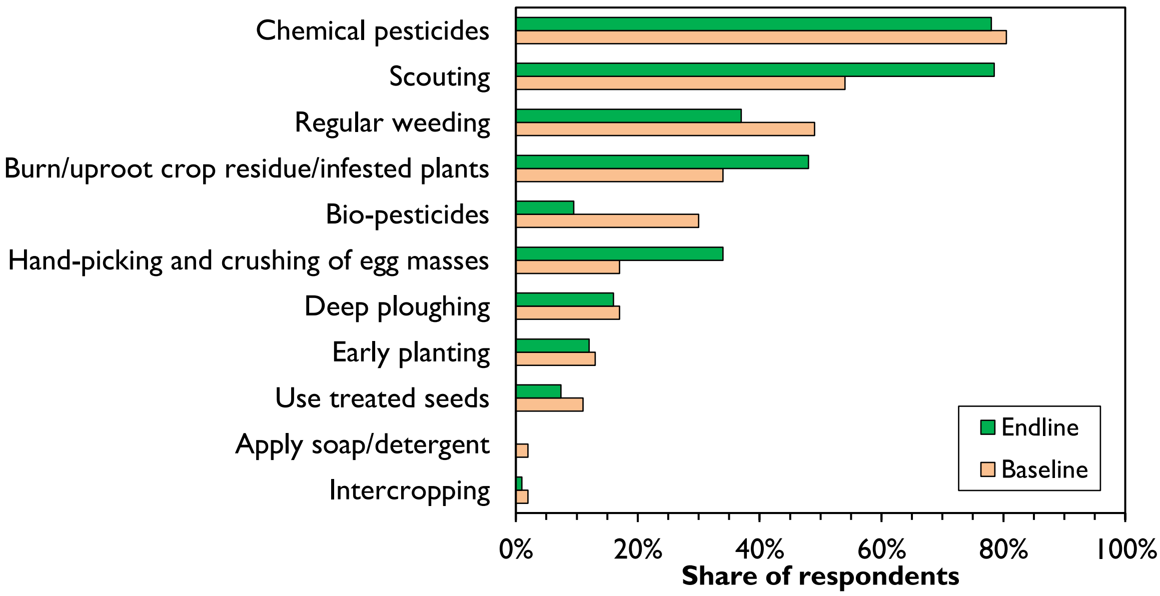


Above: Comparison of test scores on FAW knowledge test between baseline and end line.

Preliminary results suggest more than 80% of respondents in the baseline survey (increasing to 99% in the endline survey) had heard of FAW, and around 33% had heard FAW awareness messages broadcast on the radio. Nearly 15% of respondents reported having experienced FAW attack in maize during the summer *kharif* 2019 maize season, while a higher proportion (39%) reported pest attack more generally infestation in maize during the same period. This increased substantially in *kharif* 2020, with nearly all (95%) reporting pest infestation in maize, and around 81% reporting FAW attack. Among those who had previously suffered any kind of maize pest attack, only 16% (baseline) and 19% (endline) said that they recorded the level of pest presence in their crop before deciding upon the type of control measure that needed to be implemented. This underscores the urgent need to train farmers how to make use of field scouting to enable appropriate pest management decisions.

Out of the 10 questions in the knowledge test on FAW identification, scouting and mitigation, during the baseline survey, only around 21% of respondents answered more than five questions correctly. This increased to 34% during the endline survey. The mean score of the baseline survey was 3.96, increasing to 4.77 in the endline survey. While men and women both demonstrated increased knowledge during the endline survey, the average score for men (baseline 4.24, endline 5.07) was higher than for women (baseline 3.84, endline 4.64) in both rounds. The mean score for respondents in the control arm in the baseline survey was 3.95, and 4.07 and 4.05 in treatment arms 1 and 2, respectively. This increased to 4.61, 4.78, and 4.97, for control arm, and treatment arms 1 and 2, respectively, in the endline survey. Analysis to determine the differential impact of the phone-based interventions is underway and the results will be published in the next reporting period.

In the baseline survey, the primary sources of information for managing pest infestation cited by farmers included agrovets (53%), other farmers (45%), own knowledge (36%), and mass media (25%). The endline survey, conducted while the pandemic curtailed movements and impacted in-person extension approaches, showed a dramatic increase in reliance upon other farmers (71%), and mass-media (50%). Reliance on agrovets had reduced to 47%.



Above: Commonly-used methods/practices to protect maize plants from pest infestation by farmers.

In the baseline survey, around 53% of respondents recalled scouting as one of the practices that should be used to protect maize plants from pest infestation. It is encouraging to note that this increased to 78% in the endline survey. Although the application of chemical pesticides was the most commonly reported control measure, there was a very marginal decline from 80% in the baseline survey to 78% in the endline survey. Most farmers (68%) could not recollect any names of chemical pesticides they used to treat against FAW; however, Spinosad, a biologically based insecticide, was the most commonly used pesticide among those who could recall. More men than women recalled the use of treated seed and bio- or neem-based pesticides as recommended practices to protect against pest infestation in maize. In terms of adoption of other key recommended practices, 70% of farmers said that they followed the recommended time for spraying pesticide to control FAW effectively, while less than 15% followed the recommended practice of spot-spraying pesticide rather than broadcasting. These results indicate that substantial additional work is required to increase knowledge of appropriate IPM practices for FAW among farmers in Nepal. The results of these analyses will be disseminated to partners in webinars planned prior to the upcoming 2022 *kharif* summer maize season. CSISA is also working to include insights from this work in the workplan of the USAID/Nepal Mission supported IPM Activity in Nepal, implemented by Virginia Tech University and iDE, as data indicate a very strong need for enhanced training and awareness raising efforts.

Further learnings from the phone-based experiment: The experience of operationalizing an experiment remotely by telephone and conducting phone-based surveys, especially with a relatively large group of women respondents, has helped gain meaningful and critical insights. One of the major methodological findings from conducting phone surveys was the widespread use of speakerphone by female respondents. This not only violated respondent privacy and precluded us from including sensitive questions in the survey but also affected responses to other seemingly innocuous questions on intra-household decision-making. The behavior of putting the phone on speaker can also be partially explained by the degree of trust in the enumerator – speakerphone use was lower when women are matched with the same enumerators in the second round.

The Activity shared the learnings from this experience on various platforms. They were included in IFPRI South Asia Region's COVID-19 blog series[12], SurveyCTO blog on conducting phone surveys[13] and other IFPRI events[14]. The work was also presented at the International Conference of Agricultural Economists organized by the International Association of Agricultural Economists, gLOCAL evaluation week 2021[15] , and at the Women and Gender in Development Conference 2021 organized by Virginia Tech[16]; the online training organized by ICAR-IARI (March 2021) on "Analytical techniques for impact assessment of agricultural technologies & policies"; and the online training workshop, "Advances in tools and techniques for policy research" organized by AERA and IFPRI (December 2020). The methodological challenges and learnings from operationalizing the FAW experiment remotely during the pandemic were also presented at a Standing Panel on Impact Assessment (SPIA) webinar (April 2021) that focused on the challenges of designing impact assessments around CGIAR innovations.

These findings have important implications for the design and analysis of phone survey data. The early insights have been very impactful and several other organizations, including Michigan State University and World Bank, included questions on speakerphones in their own COVID-19 survey modules. Importantly, in addition to CSISA, this work received financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned and administered through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Fund for International Agricultural Research (FIA), grant number: 81235251, with additional support from the CGIAR Research Program on Policies, Institutions, and Markets, the USAID supported Gender, Climate and Nutrition Integration Initiative (GCAN) and the CGIAR GENDER Platform.

[12] https://www.ifpri.org/publication/just-call-away-learnings-phone-surveys-india-and-nepal.
[13] https://www.surveycto.com/case-studies/ifpri-covid19-phone-surveys/.
[14] Gupta, S., Alvi, M. Hello, can you hear me? Impact of speaker phones on responses in phone surveys during COVID-19. Working Paper. Presented at IFPRI RISE.
[15] https://www.glocalevalweek.org/event/collecting-data-women-and-girls-remotely-lessons-field.
[16] Poster presentation, "Not just a call away: Reaching women through phone surveys in India and Nepal" http://view.ceros.com/ifpri/a-phone-call-away-web/p/1.

Impact of COVID-19 among maize farmers in Nepal

In recognition of the prevailing conditions, the baseline and endline surveys for the FAW experiment also included questions on the impact of COVID-19 on farmers' livelihoods, agriculture extension, farm input accessibility, and economic impact including remittance inflow dynamics from migrant workers. CSISA reached out to 2,300 maize growing farmers in Dang, Nepal in two rounds of telephone survey. It also undertook a panel survey, comprising five rounds of data collection (July 2020–August 2021), with a subset of around 500 farmers who were part of the FAW extension experiment (control arm). The broad aim was to understand the gendered impact of COVID-19 lockdown on income and livelihoods, including access to agriculture extension, impacts on agriculture productivity, food security, emotional well-being, and household violence and conflict among poor and vulnerable groups.

Effects of the COVID-19 lockdown on farmers' incomes were prolonged, with more than 80% of households experiencing income loss during the initial months of the lockdown (this later reduced to around 50%). Very few households reported receiving institutional support and many farmers resorted to looking for extra work, borrowing money, and using their savings to cope with income loss. Income shocks have been most acute for migrant households, who struggled to support returned migrants and deal with remittance loss. A considerable share of households experienced food insecurity during various stages of the pandemic. Many households reduced their household expenditure, particularly on food, to cope with this income loss, resulting in food insecurity and lack of dietary diversity. Farmers continued facing issues with accessing agriculture extension and inputs, especially fertilizers during the monsoon cropping season.

In terms of emotional well-being, in the latter part of 2020, around 25% women were depressed according to the Center for Epidemiologic Studies Depression Scale (CES-D). This reduced to around 20% by mid-2021. The likelihood of being depressed for women in maize-producing farm families who worried about not having sufficient food were significantly higher than those who did not. Women were also more than twice as likely to be depressed than men.

These findings highlight the need for policy action to ensure food and income security, especially among marginalized farmers. Lack of access to markets and reduction in both farm income and remittances is likely to reduce investments in agriculture inputs, further trapping farmers in a cycle of low output and productivity. The impacts appear to be exacerbated by the mass reverse migration and loss of remittance income, which is the single most important source of income for the country. Any policy measures to aid the agriculture sector must be centered around creating a safety net for the farmers to ensure continued agriculture investments, with a special focus on marginalized farmers, while simultaneously reflecting on long-term strategies to shield the agriculture sector from any future shocks. The results also highlight the need to account for mental health and wellbeing as part of crisis relief and rehabilitation.

CSISA's findings on the impact of COVID-19 on maize farmers in Nepal[17] were presented at the 6th International Conference on South Asian Economic Development, organized by South Asian University, New Delhi, February 2021. They will also be presented at the Landscape 2021 conference organized by Leibniz-Centre for Agricultural Landscape Research (ZALF) in

[17] Alvi, M., Barooah, P., Kishore, A., and Saini, S. COVID-19 lockdown & maize farmers in Nepal: How the crisis impacted agricultural production, incomes, and farmers' coping strategies. Working Paper.

September 2021. Findings on food insecurity, and emotional well-being during the COVID-19 pandemic were presented as part of Agriculture, Nutrition and Health Academy Week 2021 and the 29th Annual International Association for Feminist Economics Annual Conference, respectively.

CSISA's report on the impact of the pandemic on women's access to agriculture extension was published in the Agricultural Systems journal in 2021[18]. It was also presented at the recently concluded (August 2021) 31st International Conference of Agricultural Economists organized by the International Association of Agricultural Economists; and at the Feed the Future Developing Local Extension Capacity (DLEC) Annual Community of Practice Convening (April 2021). The findings were also discussed at the Tropentag 2021 workshop (September 2021) on reaching women farmers with innovative extension approaches[19].

The overall findings on the impact of COVID-19 among rural households in Nepal are being synthesized to prepare a journal article that will be published in the next reporting period.

[18] https://www.sciencedirect.com/science/article/pii/S0308521X20308969?via%3Dihub.

[19] https://www.tropentag.de/conference/workshops.php#W3.

5. CSISA COVID-19 Response and Resilience in Nepal

The CSISA-COVID-19 Response and Resilience Activity was originally an 18-month (July 2020–December 2021) buy-in from the USAID/Nepal Mission to the wider CSISA program. Its aim is to rapidly and effectively respond to the threats posed by the COVID-19 crisis that undermine the recovery and sustained resilience of farmers in the FtF Zone of Nepal, with two initial Objectives:

Objective I: Enable rapid, targeted, and effective agricultural COVID-19 crisis response through scale-appropriate farm mechanization and rural services provision.

Objective II: Break the smallholder irrigation bottleneck and build rural resilience to the COVID-19 crisis.

Following the second weave of COVID-19 in Nepal during the second and third calendar quarters of 2021, a third objective was added with activities planned that will span from September of 2021 through June of 2023. This objective is as follows:

Objective III: Supporting rapid response and resilience-building from Nepal's second COVID-19 wave.

The passages below provide updates on Objective I and II during the 2020-21annual fiscal year reporting period. Information on planned activities for Objective III is also supplied at the end of Section 5 of this report.

OBJECTIVE I: ENABLE RAPID, TARGETED, AND EFFECTIVE AGRICULTURAL COVID-19 CRISIS RESPONSE THROUGH SCALE-APPROPRIATE FARM MECHANIZATION AND RURAL SERVICES PROVISION

WP 1: Creating jobs for young return migrants as machinery and irrigation service providers and entrepreneurs to support farmers affected by the COVID-19

The poor – particularly the rural poor and smallholder farmers with limited risk-bearing and investment capacity in areas– are disproportionately at risk from the economic effects associated with the COVID-19 pandemic. In Nepal, many rural farm households – which are frequently headed by women affected by previous rural out-migration – experienced the temporary collapse of remittances normally used to purchase inputs and hire farm labor for time-sensitive agricultural tasks. Conversely, more than 3.5 million Nepalis are estimated to work abroad, many in India[20]. During the first wave of the pandemic in 2020, many of these migrants were repatriated due to COVID-19 risks and expulsion from India. The result was an influx large populations of predominantly young men are returning and looking for gainful employment. However, job opportunities were challenged by social distancing policies and potential medium- to long-term mobility restrictions.

[20] MoLE, 2018. Labour migration for employment. A status report for Nepal, Ministry of Labor and Employment, Government of Nepal, Kathmandu, Nepal.

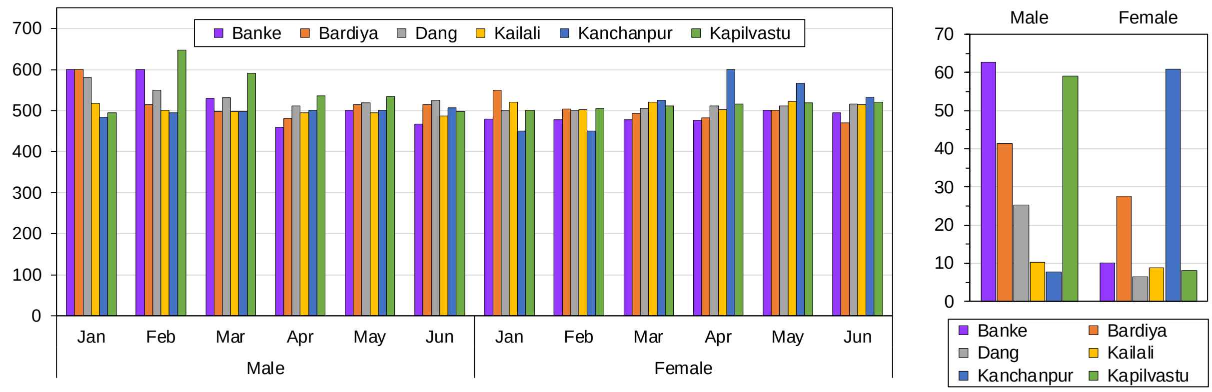
Agriculture in developing nations is largely supported by human labor – often in the form of back-breaking work completed by household members. Many farmers in developing economies also hire labor to support their land preparation, planting, weeding, fertilization, harvesting and post-harvest activities, in addition to management of livestock in many countries. Where social distancing measures and disruptions to markets – particularly for agricultural labor – prevent farmers from managing their fields with the same level of care as prior to the COVID-19 crisis, countries such as these are likely to face challenges in maintaining productivity and economic growth in the agricultural sector. Conversely, in locations where migrants are repatriated to Nepal, parts of the FtF zone could experience large populations of young men returning who will require gainful employment to maintain family income.

In response, Objective 1 aims to develop mechanisms to support longer-term resilience among smallholder farmers and the private sector – emphasizing empowering youth and overcoming challenges faced by women-headed farm households suffering from the economic and social distancing effects of the pandemic. At the same time, the Activity assists in efforts to increase smallholder farmers' understanding of and capacity to protect themselves from COVID-19. This is achieved by disseminating awareness-raising messages on public health and by increasing economic opportunities for return migrants, smallholder farmers, and by encouraging resilience-enhancing irrigation.

Objective 1 responds to these emerging crises by harnessing opportunities to encourage scale-appropriate mechanization, machinery services provision and entrepreneurism, to assure that farmers in COVID-19 impacted districts face fewer risks of delayed planting or harvesting. Focusing attention on land preparation, planting, irrigation, harvesting and post-harvest is crucial, as social-distancing and COVID-19 fear induced labor scarcity and increased labor costs (which have already been observed in several locations). This can have a significant impact on these time-bound farm operations. For example, if sequenced rice and wheat in the same field are delayed in the establishment of the summer rice crop, yield decline can occur in both rice and wheat, the latter due to subsequent postponement of sowing. This can lead to high temperature stress in March and April. Similarly, rapid post-harvest processing and appropriate handling of harvested crops are essential to reduce losses while also protecting against the development of mycotoxins that can threaten human health.

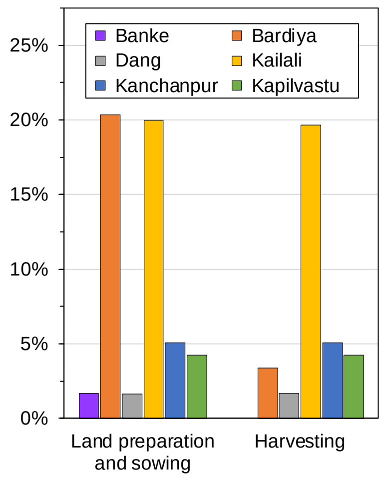
1.1 Gather information and generate data on evidence of labor availability and cost dynamics, and challenges that farmers face in the COVID-19 crisis and post-crisis period

Work Package 1.1 of Objective 1 targets districts that had experienced negative economic impacts as a result of the onset of the COVID-19 pandemic in the FtF ZoI in Nepal. During the reporting period, CSISA conducted rapid telephone panel surveys, on a monthly basis, of farmers and machinery service providers to understand the effect of the crisis on labor costs and machinery services for land preparation, crop establishment, irrigation and harvest. COVID-19 infection data from official source (https://covid19.mohp.gov.np/) indicates that Sudurpashchim Province (Kailali, Kanchanpur) and Lumbini province (Banke, Dang, Bardiya, Kapilvastu) had relatively lower infection rates compared to the national average in 2021. Despite this fact, an increase in male and female wages in May and June months of 2021 was observed compared to March and April 2021, given the lock-down measure started on April 29, 2021. As June to August is an agriculturally lean period in Nepal, the lock-down conditions seemed to have less severe implications on wage rates than expected. The variability of labor prices was observed more among men than women in all surveyed districts except Kanchanpur, indicating that increases in labor prices mainly benefited men rather than women workers.



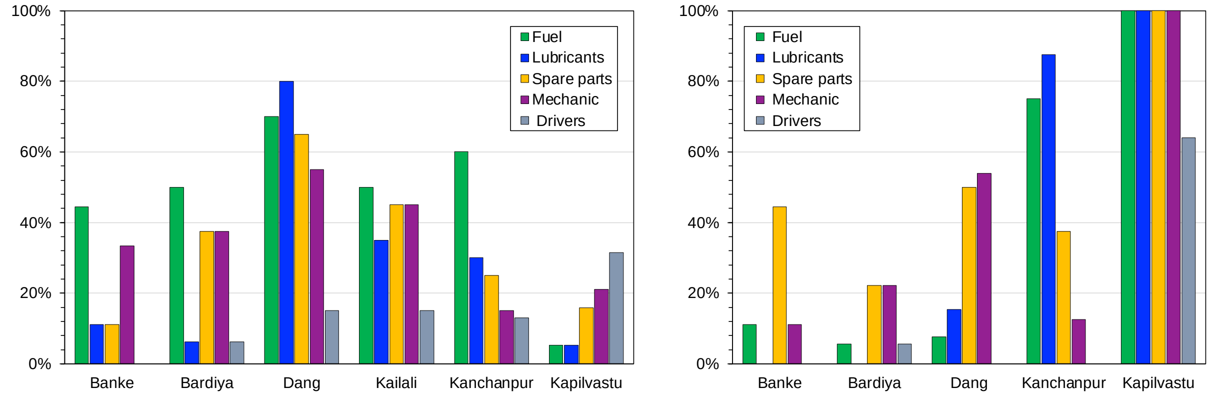
Above: (Left) Labor price dynamics for men and women as well as (Right) Labor price variability (represented by standard deviation) (NPR per day).

CSISA presented the results of the monthly surveys during a virtual conference on the 'Importance and Role of Scale-Appropriate Machinery in COVID-19 Response, including Gender Sensitiveness and Awareness' (21 June, 2021), with 139 attendees, and participants from PMAMP, INGOs, the private sector, NARC and AKCs. It was conveyed that farmers who faced labor shortage paid NPR. 600 to 800 per day, which pointed to the fact that significant cost saving can be realized by shifting to machinery services (40-50%). During surveys, farmers also reported shortages in machinery labor availability in Bardiya during Winter crop preparation and sowing (December 2020-January 2021) as well as in Dang during the winter harvesting period (March-May 2021). Machinery service providers reported challenges in access to fuel, spare parts, lubricants, mechanics as major constraints. Access to machinery operators was also an issue in some districts during December 2020 and January-2021. During the winter harvesting season (March to May 2021), machinery services related issues reduced in severity in all districts compared to the winter planting season, except in Kapilvastu. Regional differences in constraints need further assessment. The lock-down from end of April, 2021 again changed this scenario. Given the shortage in machinery services reported by the recurrent surveys, CSISA conducted a detailed survey on performance of mechanization service centers (MSCs) of Nepal during the months of July and August of 2021. Detailed information governance and leadership, machinery portfolio, customer



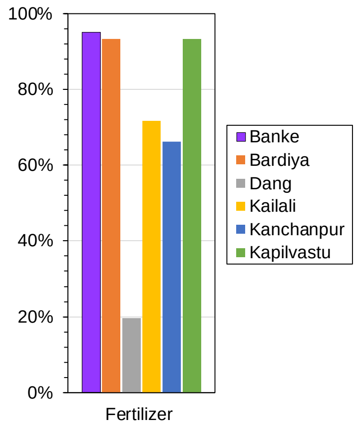
Above: Machinery shortage during planting and harvesting period (% of farmer surveyed).

management, financial management, operational management are collected to prescribe additional measures to ensure the availability of machinery services in the FtF zone.



Above: Issues constraining machinery service during (left) planting period and (right) harvesting period (left) (% of service providers surveyed).

In addition to labor, the major issue reported by farmers was fertilizer shortage. Most of the surveyed farmers (>70%) indicated fertilizer shortages in the summer cropping period except in Dang, with many farmers speculating that shortages were related to COVID-19 lockdowns. This is a serious concern, as fertilizer shortages can impact household food security and farm income, as well as regional food security, especially when combined with machinery and manual labour shortages. All data were used to set the context for the implications of the pandemic on rural labor supply and costs as related to farm management. The surveys will be continued, to gauge the COVID-19 impacts in the FtF ZoI in Nepal.



Above: Fertilizer shortage (% of farmers surveyed).

1.2 Turn problems into solutions by identifying return migrants poised to become rural entrepreneurs

Background: The objective of Work Package I Activity II is to identify at least 108 return migrants(21% youth) who can be supported to become service providers. Returned migrants were identified as a key group in need, as Nepal experienced large-scale mass re-migration from India as workers who had been employed in India were forced to return to Nepal when the pandemic began.

Screening of returnee migrants and identification of core lending beneficiary candidates: The initial strategy was to first identify 500 returned migrants within the Activity's catchment area who could be established as machinery service providers. This was accomplished through two mechanisms (a) broadcasting of radio jingles encouraging returnee migrants to come forward and contact CSISA if they were interested in participating in programs aimed at becoming a machinery service provider, and (b) through snowball telephone sampling in which CSISA researchers called farmers and requested information on known returnee migrants. These efforts produced 557 interested returnee migrant candidates. The pre-vetting process included selection criteria related to geography, past/future migration, and knowledge and interest in agricultural service provision. A psychometric test was developed to determine the likelihood of successful enterprise development, with questions related to investment capacity, business and financial acumen, strategic thinking, risk tolerance and technical knowledge. After its initial application with returned migrants, however, the psychometric testing was found to be ineffective and/or unnecessary as it provided only partial information on the potential of returnee migrants to cooperate with the Activity. As such, it was discontinued in April of 2020.

Instead, the Activity held target group meetings in the form of small, socially distanced gatherings of identified returned migrants, to orient them to the potential opportunities provided by establishing a service provision business, as well as the training and other support that the CSISA COVID-19 Response and Resilience Activity can provide. A subsequent one-and-a-half-day business orientation training for interested returned migrants included a full business model canvas, business plan development, and financing discussion. Where appropriate, the potential entrepreneurs were then connected to banks and cooperatives to gain access to credit and financial services.

The first round of identification and subsequent vetting, meetings and training, resulted in a roster of 272 interested, higher than average possibility candidates within the Activity areas. More than 78% of the candidates were from under-represented/marginalized ethnic groups. Of this high-possibility group, 27% are youth and 4% were women. Despite substantial efforts to identify women candidates, very few females returned migrants appear to be actively seeking employment or business opportunities within the Activity catchment areas, let alone having an interest in participating in mechanization service provision.

Facilitating access to finance: This filtering yielded a list of high-potential returnee migrants that demonstrated the drive and sufficient business knowledge to engage in rural entrepreneurial services provision as an agricultural machinery owner. In addition to these candidates, the Activity identified potential other return migrants on an opportunistic basis in Dang, Kanchanpur, Banke and Kailai districts. The activity then engaged these return migrants in additional trainings and worked with them to select agricultural equipment for which they could apply for loans from banks, or through enrollment in the Government of Nepal subsidy scheme supporting machinery dealers to offer equipment at reduced incentive prices. Importantly, each of the trainings included information on how to maintain COVID-19 safety as part of machinery services provision businesses.

Many banks, however, were initially reluctant to loan to returnee migrants. This is because they were perceived as (a) higher-risk clients that could flea in the event of loan default, (b) lack of adequate collateral for loans, and (c) because banks rarely lend for agricultural machinery, and when they do, they tend to implement a policy in which loanees must have a verified residence within a 3 km diameter area of the bank branch extending the loan. The latter is another risk and transaction cost-reducing measure on banks, so they do not have to expend considerable time, money, and effort locating defaulting clients. Finally, (d) many banks indicated that machinery can breakdown easily, and when not repaired, loanees may not be able to generate business to repay their debts. These criteria, however, are clearly constraints to engaging returnee migrants as service providers.

Above: Suraj Lal Tharu, Rajpur, a returnee migrant laborer from Chhotkirdolatpur, Bardiya displaced from India during the COVID-19 pandemic, showing off the newly purchased four-wheel tractor he acquired through access to finance facilitated by CSISA in March of 2021. *Photo credit: Subash Adikhari.*

To tackle this challenge, CSISA worked during the reporting period closely first with Muktinath Bikas Bank Ltd. (MNBBL), and then later with Nabil Bank, MegaBank, and Century Commercial Bank, to develop risk-reducing financial services arrangements that could facilitate increased access to loans for agricultural machinery. In order to reach agreements, high-profile coordination meetings were held following COVID-19 safety guidelines. A key example was the meeting with CSISA and the MNBBL field office team was conducted on 22 March, 2021 at Nepalgunj, Banke, with the objective of strengthening coordination among the MNBBL and CSISA teams and speeding up loan disbursement to migrant workers. A total of 19 participants from 12 branches in all five districts participated in this program, which was very successful in clarifying the agricultural machinery service provision business model and key machinery types and its attachments that the project is popularizing.

Through such meetings, agreements were reached with MNBBL for (a) CSISA providing returnee migrants applying for loans with repair kits and training in how to maintain and trouble-shoot machinery malfunction, (b) and through the provision of a loan security fund in which CSISA provided funds to buy-down the initial interest rates for loans associated with machinery purchase, and (c) by assuring returnee migrants were sufficiently trained in business skills and linked to farmer clients wishing to purchase machinery services. Transactions with farmer clients were also (d) informed by business models that were developed by the Activity and provided to returnee migrants during the loan application process, to generate maximum amounts of revenue from farmer clients and to optimize seasonal opportunities for services provision following loan securement.

'Seeing is believing' - Access to finance efforts expand following initial successful examples: To increase linkage and coordination with financial institutions offering access to appropriate finance for machinery loans, the Activity is also in the process of courting partnerships with Mega Bank Ltd and Shine Resunga Development Bank, as a result of which the process of signing an MoU has been initiated with Mega Bank to allow its 'Kisan Credit Card' to be utilized as a means of lending for the purchase of farm machinery. Following these initial efforts, the Activity was able to use these successful examples to encourage additional agreements with a range of banks, with 13 financial institutions and cooperatives) now actively engaged in lending for agricultural machinery purchase (these include Aishwarya Cooperative, Bhuwar Bhawani Bahuudeshya Cooperative, Bhuwar Bhawani Multiple Sahakari Sanstha Ltd, Century Commercial Bank, Chharhi Agriculture Cooperative, Kaneshwar Multiple Sahakri Sanstha Ltd, Kumari Bank, Muktinath Development Bank, Nabil Bank, Prabhu Bank, Sakar Multiple Cooperative, Sangrila Development Bank, Shine Reshunga Development Bank Ltd, and Singhabahini cooperative). A total of USD $243,348 has been loaned by these institutions and cooperatives so far, which is over half the value of the USAID/Nepal buy-in for Objective I.

Impact – targets achieved: While it took time to navigate these challenges and come to agreements with banks and returnee migrants, the process has yielded significant impact. At the time of writing, the Activity achieved 108% of its targets, with 108 returned migrants purchasing machinery and entered into rural entrepreneurial business service farmers as a result of CSISA's interventions. Fifty-nine of these obtained credit from bank loans, while 14 also obtained credit through loans from farmer cooperatives. The remainder were able to self-finance machinery purchase with the technical guidance of CSISA. The range of machinery purchase ranged from irrigation pumps , mini-tillers, power-tilers with attachable trailers or reapers, four-wheel tractors, self-propelled reapers, and wheat threshers and combined rice mills.

Finally, as part of these activities, the business model framework supporting business planning for returnee migrants that was developed in consultation with stakeholders was written-up as a training and resource manual. This manual, which was printed both in English and in Nepali, includes detailed financial investment options and business cases supporting returnee migrants to profitably enter into agricultural machinery services provision businesses. The manual was published as Agricultural Machinery Service Provision Business: A business model for return migrant workers.

1.3 Link potential service providers to machinery dealers and financial services

Starting in the first half of the reporting period, the Activity also selected 17 returnee migrants and linked them to a range of agricultural machinery dealers who collaborate with CSISA. The machinery dealers that participated in this program included Krishi Solution in Banke, Swostik Traders in Bardiya, Quality Agro Suppliers in Bhurigaun, Karnali traders in Bardiya, Aayeshaa Power Tiller Mermat Kendra in Joshipur, NB Krishi Auzaar Kendra, and D-KAM Micro system in Kailali, RTC AgroMachinery and Engineering Workshop in Kanchanpur, RK traders in Kanchanpur, and Swargadwari Trade Link, Surya Traders, and Kishan Trade and Link, the latter three in Dang.

Returnee migrant interns were provided with a two-month internship that included sub-dealers/sales agent training and machinery adjustment and maintenance. Following the signature of MoUs between the Activity and machinery dealers, and contractual agreements with the Activity and returnee migrants, these return migrants were supported by the Activity with two months of salary work in machinery dealer shops in high-priority districts. During this time, CSISA also provided basic training on business management and sales, and they also learned about the machinery detailed in Annex 4 of the 2020-21 semi-annual report through their practical employment in the machinery dealer's showrooms.

After the internship training period, which lasted 8-10 weeks, five interns started working full-time with five dealers, one intern has started up as a sub-dealer in Rajapur, Kailali and one is planning to establish a sub-dealership in Dang. An interaction organized jointly with agriculture machinery dealers and interns found that the internship program builds up returnee migrants' confidence to start up a new business and create work opportunities in machinery sales and repair.

Above: Returnee migrants in the internship program at D-KAM Micro system, Tikapur, Kailali, Nepal
Photo credit: Lokendra Khadka.

1.4 Cooperatively develop business models and link emerging entrepreneurs to provide essential services to farmers in COVID-19 affected areas

Background: In Activity 1.4, CSISA works with return migrants entering into the machinery services provision to develop business models through which they can profitably offer land preparation, planting, irrigation or harvesting and post-harvest services to farmers in COVID-19 impacted areas while also reducing overall production costs for farmer clients.

Activities and impact: As of September 2021, 108 returned migrants had established machinery service provision enterprises in their local communities. The Activity facilitated business management training, including detailed demand creation strategies, for over 90% of the service providers to date, and will eventually cover all new entrepreneurs. Training includes distribution of printed business cards and advertising boards outlining the services they provide to display in their communities, as well as general marketing strategies to engage new customers.

During repeated prohibitory orders that prevented travel and in-person field training, CSISA followed remote strategies in order to continue engagement with stakeholders. The Activity facilitated an online meeting with dealers in the target districts around the promotion of agricultural mechanization for service provision, introducing the dealers to the business model. Multiple rounds of radio public service announcements (PSAs, or 'FM jingles') were broadcast to inform and encourage the adoption of scale-appropriate machinery services by farmers within the Activity areas. The messaging was also designed to raise farmers and service providers' awareness of COVID-19 safety precautions to avoid potential outbreak of the disease while carrying out farm activities. These PSAs were broadcast from December to February through eight FM radio stations covering the Activity's five districts.

A voucher scheme was also established to draw down the cost of hiring new machinery services to very poor and women farmer clients in COVID-19 affected areas. As of September, 2021, 725 smallholder farmers have taken advantage of this program and have adopted machinery services for the first time, primarily for harvesting crops at the end of the spring rice/wheat season. Additional information is provided below under activity 2.4.

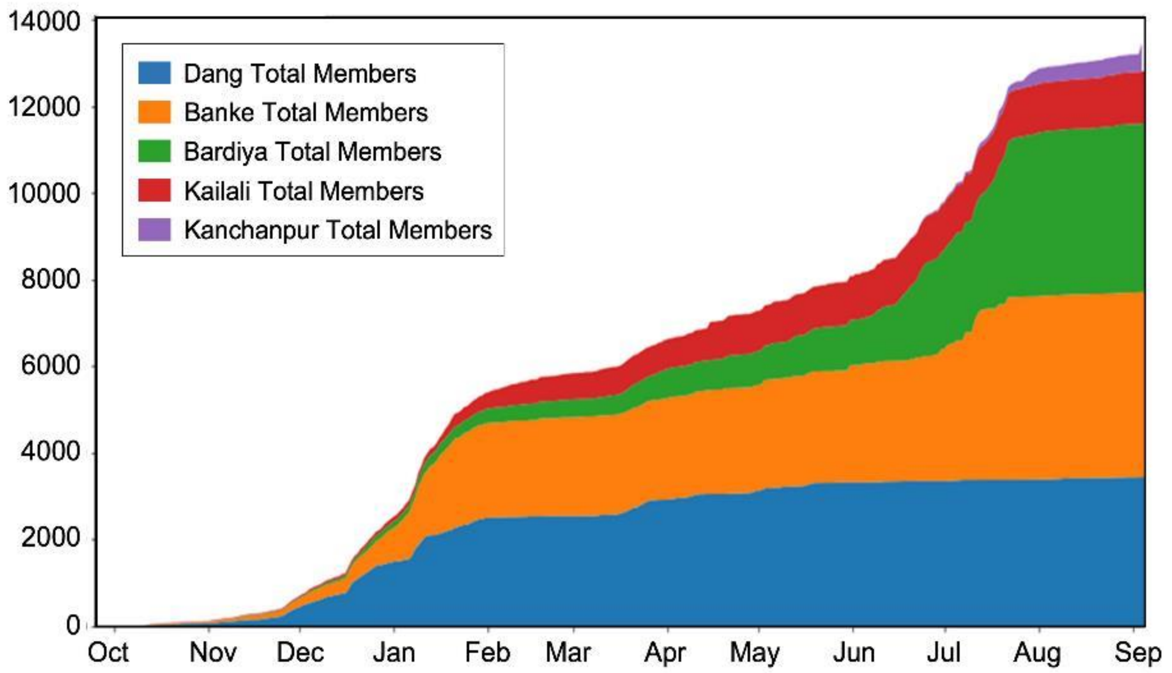
Emerging from this work, future activities to integrate machinery dealers into demand creation activities have been planned for Objective III, which is commencing at the time of writing. A meeting was organized between CSISA-MEA (Bangladesh) and CSISA Nepal teams to share the experience with private sector engagement through Expression of Interest/proposal-based mechanisms. This resulted in planning for a challenge fund model that will include machinery demonstrations and trainings in combination with targeted land use preparation, planting, and harvesting equipment.

Some activities were modified to meet the changing needs of the COVID-19-affected communities served by the Activity. Initial plans to provide mini-grants to dealers for purchase of PPE, for example, were important during the proposal development period, during which PPE was scarce. This was found to be no longer relevant by the time of implementation, as PPE was widely available at affordable costs. Further information on activities in the first half of the reporting period for Work package 1.4 can be found in the semi-annual report for 2020-21.

Spotlight on social media efforts to connect service providers, cooperatives and farmers

In a drive to connect farmers, services providers and cooperatives to facilitate greater communication during COVID-19, CSISA set up five different Facebook groups for Bardiya, Banke, Dang, Kailali and Kanchanpur in October 2020. The objective was to establish an initial platform for information-sharing between farmers, farmer cooperatives, and service providers. There has been a gradual growth in group members and in overall participation within the groups. The service providers have used the platform as an effective way to advertise their services and farmers have been able to make inquiries about the services.

The gradual growth in growth membership can be observed in the graph below. In total, 13,469 members have joined the five groups (4,266 in Banke, 3,893 in Bardiya, 3,444 in Dang, 1,208 in Kailali and 658 in Kanchanpur).



Above: Growth of members across different Facebook groups established by the Activity.

Looking at the trend and the interaction within the groups, Facebook groups appear an effective solution for advertising and communication between various stakeholders. However, there remains a gap between the total number of women and men who are group members, with currently only 286 women in the four groups compared to 12,432 men[21]. The focus for the future is therefore to increase women's membership, which will be tackled in the next reporting period.

[21] Gender data from Kanchapur is not available, as Facebook only generates this after total membership exceeds 1,000.

1.5 Beating back breakdown of agricultural machinery through deployment of COVID-19-safe mobile mechanics

Background: The number of weeks during the calendar year in which machinery service providers can assist farmers with land preparation, planting, and harvesting services is limited. This is a consequence of the tight-time windows within the calendar that farmers need to focus their work on within the confines of agricultural seasonality. As such, any machinery breakdown can have significant negative consequences. In response, CSISA is working to overcome lost workdays for machinery services providers – who are increasingly crucial during the COVID-19 pandemic – by assuring that mechanics are (a) well trained, (b) are available in the service watersheds of machinery service providers, and particularly new service providers who are retuned migrants, and (c) assuring that mechanics are equipped to assist machinery service providers using COVID- 19 safety protocols.

Above: A mechanic repairs a mini tiller as part of CSISA's training for new machinery service providers. The training was provided by existing repair service providers, facilitated by the Activity as a linkage between mobile mechanics and machinery service providers. *Photo credit: Subash Adhikari.*

Activities and impact: During the reporting period, CSISA created an inventory of a total of 238 mechanics spanning the working districts in which the COVID-19 Response and Resilience Activity is working within the FtF Zone, and facilitated training for 150 of these mechanics in the principles of COVID-19 safety, and how to repair land preparation equipment while limiting the risk of COVID-19 infection spread among mechanic shop staff and to clientele. Follow-up studies indicated that although most mechanics were able to operate and provide repair services when and where needed, during the first lockdown period, they were strictly restricted in movement and in the second lockdown for about 1.5 months between April and May 2021. Fortunately, restrictions permitted them to provide services to farmers 15 days before the peak season started.

Data collected by the Activity showed that advanced mechanics were able to service a total of 1,659 farmers in the reporting period. This includes assistance provided in the repair of 235 machines by the 17 returned migrants participating in a sub-dealership/agent traineeship with agricultural machinery suppliers, facilitated by CSISA (see section 1.3 above for details). Learning to repair machinery appears to be one of the primary courses for those who want to be involved in the agricultural machinery business, and so the CSISA training facilitated the trainee to gain skills in machinery repair, in parallel with learning business skills within the supplier's shop. With new learners, simply providing training seems to be ineffective in developing mechanics. For example, women who were new to repair, when trained were unable to establish themselves as a repair service provider/mechanic. This suggests that a traineeship under a supplier/repair workshop, in addition to business development skills, is key to developing new mechanics. Such improvements in activity design will therefore be incorporated into future phases of project activities.

Work Package 2: Minimizing the economic impacts of COVID-19 for very poor and women farmers through linkages to established service providers and custom hiring centers

2.1 Track the availability and movement of agricultural machinery in the FtF zone and advise government, development partners and machinery owners on how to channel services to locations where they are most needed

Background: Nepal benefits from a relatively high concentration of reaper-harvesters and farmers' knowledge of, and demand for harvesting services. In addition to reapers, combines are also increasingly popular for rice and wheat, both of which can experience significant yield losses if left too long in the field because of social distancing or a lack of available labor prevent harvesting. Similarly, land preparation and planting equipment popularized by CSISA is gaining traction.

Progress update and policy influence: During the reporting period, CSISA focused on (a) assisting partners to track machinery availability through telephone surveys and assist in targeting machinery services provided by PMAMP through development partner initiatives and service providers themselves, to areas in COVID- 19 affected high demand districts. (b) CSISA is also working to assess demand for mechanization and irrigation services against the willingness and ability of machinery owners to serve farmer- clients in the context of the COVID-19 crisis. This is accomplished through CSISA's regular interactions with officials at the district, provincial, and federal levels of government. Examples include national-level presentations on appropriate machinery for spring rice establishment held on August 28, 2020, and the supply of suggested machinery lists for the MoALD and KISAN-II backed Joint Rice Implementation Program (JRIP) that was transferred from CSISA to these partners on July 28, 2020 and April 18, 2021.

In addition, CSISA is one of the members of District Project Implementation Committee formed by the JRIP in each project implementing district including Dang and Kapilvastu. In Dang, CSISA participated in three consecutive meetings chaired by the head of AKC-Dang after 23 January 2021 to technically backstop the project. Likewise, three consecutive meetings in AKC-Kapilvastu after the first meeting on 11 October 2020 were also attended by the CSISA representatives. In the meetings, CSISA provided technical information on reliable machineries that are fit for the purpose based on cropping pattern dynamics, land suitability, market availability of machines/spare-parts and potential to adoption and scale up. Firstly, scale-appropriate machines were identified through intensive discussion among the members of the committee and finalized. It was agreed that the small-scale machines like power tiller attached- and self-propelled reapers and seed drills which contribute to resource-conservation are to be promoted. Secondly, the Activity advised downplaying attention to rice transplanters, given their low adoption rates and limited use, as demonstrated from a comprehensive study conducted during the reporting period. Additional recommendations and policy outcomes that resulted from CSISA's engagement with governmental partners can be found in the corresponding section of the 2020-21 semi-annual report.

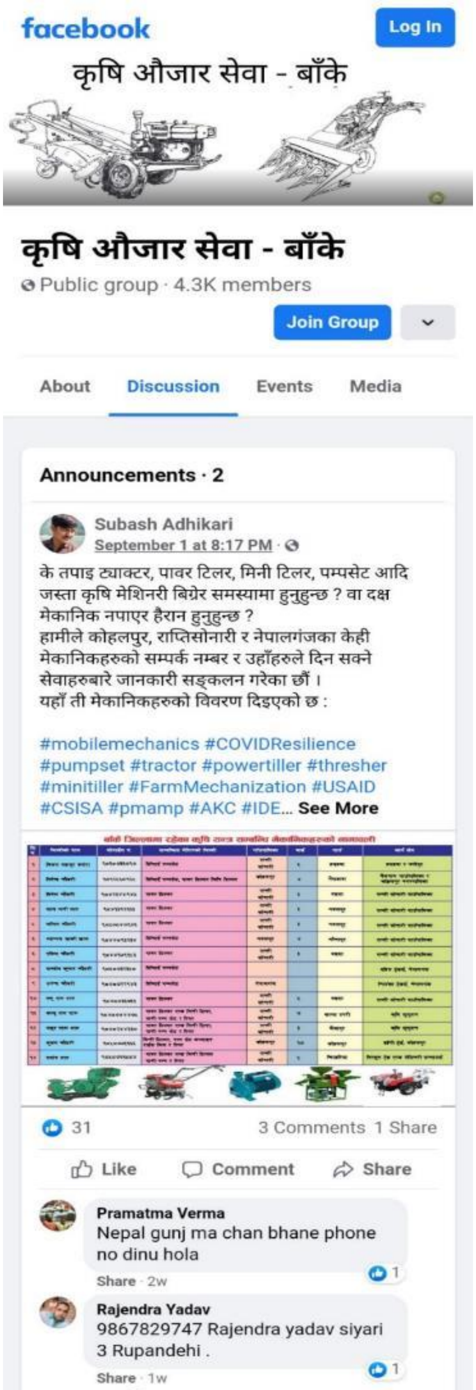
Machinery efficiency tracking and online services booking system: During the reporting second half of the reporting period, the Activity also developed a system to track the availability and movement of agricultural machinery in the FtF zone, in order to channel service providers to locations where they are most needed. This included conducting a telephone survey with farmers to understand the availability status of machinery and machinery operators, and directly linking farmers with service providers in the database.

Collecting the phone numbers of service providers – the main stakeholders acting on requests from farmers – is essential. During the reporting period, CSISA amassed the details of an additional 1,442 machinery service providers in Dang and Kailali districts. This increased the total number of service providers in the database to 4,300 (3314 of them also have a GPS location). Similarly, to understand machinery availability in different areas, 60 farmers from each of five districts (Banke, Bardiya, Kailali, Kanchanpur and Dang) were interviewed during the season when they used machinery.

Tracking machinery availability was a method to link service providers to farmers demanding services in COVID-19-affected districts. Details of an additional 184 reaper service providers were added to the database, making a total of 1,981 reaper service providers in six FtF districts (Kapilvastu, Dang, Banke, Bardiya, Kailali and Kanchanpur). The Activity also facilitated training and demonstrations in harvesting equipment to strengthen new operators to ensure timely repair and maintenance, and demand creation for reapers in new areas.

The Activity also surveyed a sample of 104 machinery service providers from the database to learn about their issues and the availability/use of their machines. When any unavailability was observed, or reported by farmers, CSISA and its partners were able to contact the nearest service provider and facilitate service provision. Service providers were in turn able to provide a quick response by via an online booking system, which was provided to some custom hire centers during the reporting period as a pilot. With the possibility of its future usage in mind, CSISA prepared and distributed a video explaining this free online booking system. Efforts to encourage use of this online system will be further explored in the next reporting period.

The data generated in this workstream is now being used by PMAMP and agricultural policymakers to formulate an effective COVID-19 response and methods, in order to ensure timely, affordable and rapid land preparation, planting, irrigation, harvesting and post-harvest for farmers. This is affected through CSISA's regular interaction with officials at the district, provincial and federal levels of government.



Above: snapshot of a post on mobile mechanics contact information, from Facebook group 'Krishi Aujar Sewa Banke'.

2.2 Link harvesting equipment owned by PMAMP or by farmer's cooperatives, and individual service providers, to farmers demanding services in COVID-19-affected districts

Background: During the reporting period, CSISA prepared its partners for COVID-19 safe and socially distanced harvesting operations and also launched a voucher scheme to assure that farmers in COVID-19 impacted areas who have not previously utilized mechanization services could benefit. The sections below therefore concentrate on work that was done by CSISA to prepare partners to meet farmers' machinery needs in a COVID-19 safe way.

Activities: Between October 2020 to September of 2021, CSISA made use of its established networks and information generated in Activity I to actively link land preparation, crop establishment, and harvesting equipment service providers to farmers demanding services – particularly for the remaining wheat crop and for the *kharif* season rice crop – in a COVID-safe way. During the reporting period, CSISA prepared its partners for COVID-19-safe and socially distanced harvesting operations, and launched a voucher scheme to ensure that farmers in COVID-19-impacted areas who had not previously utilized mechanization services could benefit from them. Outcomes from this voucher scheme – a strategy to link very poor farmers who have never used harvesting machinery with service providers – are discussed briefly below and in greater detail in section 2.4 of this report. More details on the activities conducted in the first half of this reporting period can be found in the previous 2020-21 semi-Annual Report.

On 20 Nov 2020 CSISA enhanced the capacity of individual entrepreneurial service providers of seed drills and laser land levellers who were not part of PMAMP's custom hiring centres, by providing hands-on training to a total of 10 government machinery operator staff and custom hiring center technicians in Sundarpur, Kanchanpur. The training was jointly organized by Sundarpur Agriculture Development Farm and RCT Agro Machinery and Engineering Workshop.

In collaboration with the Ministry of Land Management, Agriculture and Cooperative, Agribusiness Promotion Support and Training Centre and combine harvester suppliers, the Activity f also facilitated training for 34 service providers (including five women) in combine harvester operation and repair (14–28 February, 2021). The aim was to produce operators and mechanics in Nepal, in response to the scarcity of operators- and mechanics, reported as one of the major reasons behind the unavailability of operators during the COVID-19 lockdown. These trained combined harvester service providers have subsequently serviced around 3,000 farmers. Similarly, with the aim of creating demand among farmers for reapers in new areas, and to capacitate newly developed reaper service providers, CSISA facilitated seven different events on the repair, operation and demonstration of reapers. A total of 193 service providers (44 of whom were women) were trained in April of 2021 in five FtF districts.

The voucher scheme was another demand generation activity, initiated among poor people unable to benefit from mechanized harvesting due to the constraint of lack of money. During the 2021 wheat harvest, a total of 725 poor and marginalized farmers were engaged in the scheme and linked with the harvesting services provided by 50 reaper service providers. The detailed report is in the "*Introduction of mechanized harvesting services through a voucher scheme*" and detailed in section 2.4 of this report.

2.3 Improve service providers' access to emergency mechanic's services in COVID-19 impacted districts

Regardless of the quality of agricultural machinery, breakdowns and service interruptions are inevitable. Machinery service providers – who assist farmers during the relatively short time-windows in the agricultural calendar allotted to land preparation, planting, irrigation, harvesting and post-harvest – need rapid access to support from mechanics. Activity III responds by linking competent mechanic repair services to equipment operators who can provide services in COVID-19-affected areas and who may be unfamiliar with local options for spares and repairs.

The original goal of Activity 2.3 was to assist mechanics in the provision of movement permission passes within and across districts, in the event of continued social distancing and movement restrictions during lockdowns. As Nepal was not in lockdown until March 2021, and second lockdown (approximately 1.5 months of strict restrictions in movement between April and May) was over before the repairing season, Activity 2.3 did not need to be implemented. Instead, the CSISA team focused on more general training to mechanics and assurance that mechanics were prepared and able to provide COVID-19-safe services. To directly link new service providers with mechanics, CSISA facilitated nine trainings on repairing agricultural machinery in five FtF districts (August–September 2021). The Activity shared a list of mobile mechanics through Facebook groups (see snapshot of the posting above), which it created to link agricultural machinery stakeholders with farmers. A total of 1,649 farmers were serviced by mobile mechanics that had been trained by CSISA in the reporting period.

2.4 Create demand and facilitate access to machinery services for very poor and women farmers in locations most impacted by the COVID-19 crisis

During this reporting period, CSISA Nepal developed a voucher scheme to sensitize vulnerable (with emphasis on poor, women) farmers to the benefits of mechanized reaper services for harvesting wheat and assuring social distancing. The scheme linked farmers and service providers, with the expectation that the cost-savings that the farmers achieved would create buy-in and lead to systemic change.

Above: A reaper service provider harvesting wheat for resource-poor women farmers using the piloted voucher system in Bardiya. *Photo credit: Pradip Chaudhary.*

The activity drew down investment costs for mechanized wheat harvesting service provision through a carefully implemented voucher scheme, targeting extreme poor and women farmers in six districts in Activity areas around the FtF ZOI, western Nepal (Kapilvastu, Dang, Banke, Bardiya, Kailai, and Kanchanpur). Farmers were selected using the results of wheat crop cuts and a survey conducted in 2017. 725 farmers (304 women) were selected for characteristics of resource poverty, based on (1) landholding of less than 10 *kattha*, (2) never having previously used machines for rice and wheat harvesting, and (3) average income of less than USD1.25/person/day. The voucher system implemented subsequently registered thee farmers with a unique randomized identity number and QR code. The activity then mobilized 50 reaper service providers, and registered them to provide wheat harvesting services to the farmers under the voucher scheme. The objective was to facilitate farmer access to harvesting machines in COVID-19-affected areas, by providing a discounted service charge. This would alert them to the benefits of mechanical harvesting (which saves labor and time costs) and encourage future use.

The scheme issued the 725 registered farmers with a printed voucher covering 50% of the costs associated with harvesting their wheat crop. They used these to hire the registered reaper service providers, who harvested wheat from 210 ha of land, and afterward redeemed the vouchers. After harvest, CSISA surveyed the 725 farmers to assess their satisfaction with the service and likely future need; 92% of the respondents stated their intention to utilize mechanized harvesting services in the future, citing time-saving (reported by 98%) and cost-saving (71%) benefits. Crucially, these respondents strongly indicated their willingness to pay for the full costs of harvesting without access to a voucher scheme. As a result of these successes, similar voucher efforts are now being deployed to harvest the *kharif* rice crop among other groups of identified resource-poor farmers at the time of writing. Updates on this activity will be provided in the following semi-annual report.

OBJECTIVE II: BREAK THE SMALLHOLDER IRRIGATION BOTTLENECK AND BUILD RURAL RESILIENCE TO THE COVID-19 CRISIS

Along with high-yielding crop varieties and broad use of fertilizers, expansion of irrigation has provided a core foundation for agricultural intensification in South Asia since the 1960s. For more than 50 years, development programs to support irrigation in South Asia have been driven primarily by the idea of area expansion. Access to irrigation has become crucial in building farmers' resilience to climate variability and long-term climate change, and specifically to variable monsoon precipitation patterns, drought, and heat stress, all of which can undermine sustained agricultural productivity. Irrigation can also play an important mediating role to assist farmers in stabilizing or even increasing productivity in the face of the COVID-19 crisis. Nepal's irrigation potential is however largely untapped with very low amounts of available water used for irrigation. Only 30 percent of Nepal's irrigated land has year-round irrigation facilities using surface water resources. Groundwater aquifer structure and how and where groundwater can be used to sustainable expand irrigation remains an under-researched area. Given this complicated context, an integrated assessment is needed to assure rational natural and sustainable resources management. Such analysis must also consider the current COVID-19 crisis and its medium- to long-term effects on Nepal's agricultural systems and economic growth, with implications for irrigation development as a pathway to increase productivity and hedge against climatic risks with resilience enhancing irrigation.

In response, Objective II consists of four work packages that culminate in an integrated irrigation sustainability framework to assist in inclusive water resources planning and management in Nepal's FtF ZoI. The first package collects the necessary data to inform a sustainable irrigation planning assessment. The second and third work packages focus on groundwater monitoring and analysis and the social and biophysical targeting of appropriate irrigation interventions. The final work package is the sustainability framework, which will inform COVID-19 crisis and post-crisis water resources development investments aimed at efficient, equitable, and rational use of irrigation.

Importantly, the development of this framework is informed by detailed background research, literature review, and multi-stakeholder dialogue. Options for appropriate response and recovery from the COVID-19 crisis are from participating stakeholders and will be accounted for in the sustainability framework. By integrating these activities and building local capacity in hydrological modeling, sustainability assessment, interpretation of model scenarios for policy formulation and crisis response, the work packages in Objective II aim to prioritize self-reliance by developing the capacity of Nepali stakeholders over time.

Work Package 1: Towards a systemic framework for sustainable scaling of irrigation in Nepal

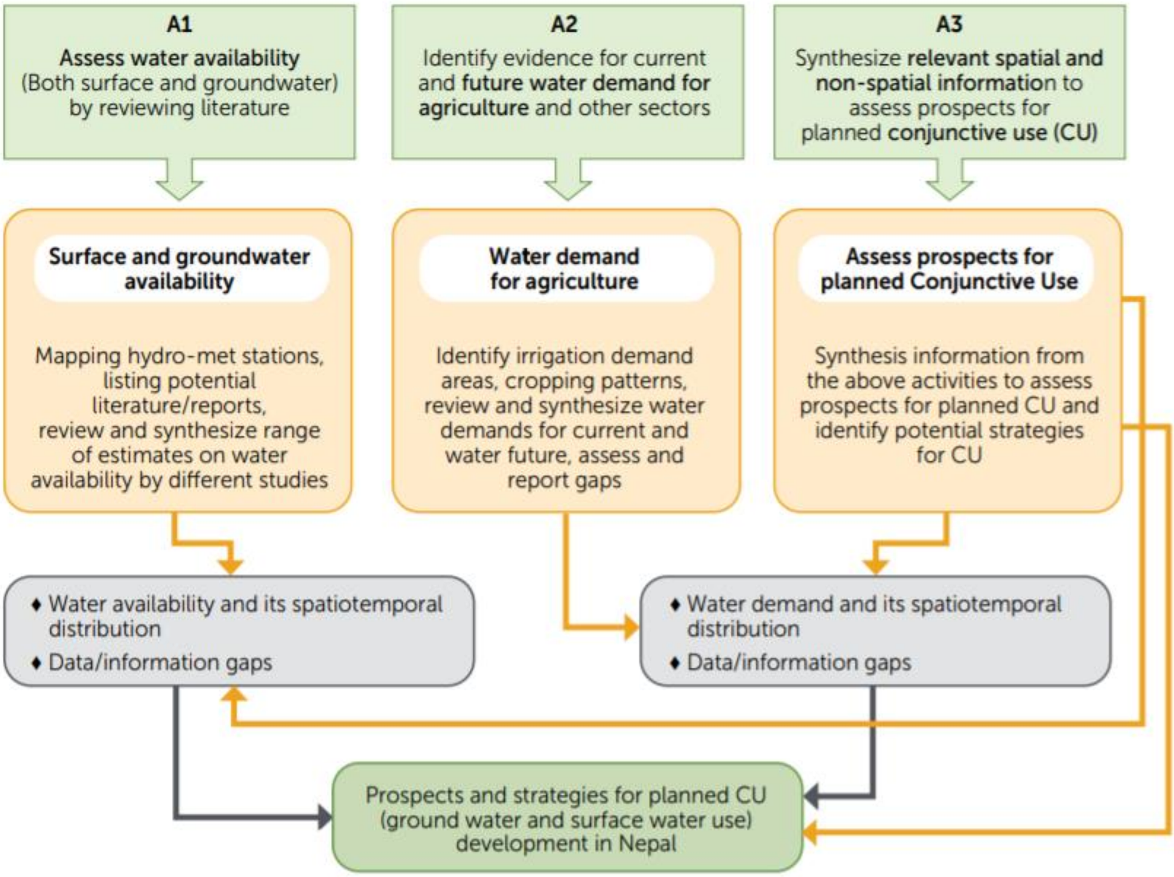
1.1 Develop a sustainable groundwater use framework to support conjunctive use as a response to water access challenges in Nepal

Activity 1 focuses on the biophysical aspects of irrigation development with an emphasis on hydrology. A comprehensive review and analysis of available secondary data and literature with a specific focus in the FtF ZoI of the Tarai was completed in the reporting period titled 'Towards Conjunctive Use of Surface Water and Groundwater Resources as a Response to Water Access Challenges in the Western Plains of Nepal'. The goals of this work carried out following a stepped methodological framework, include:

1. Assess current and future water availability;
2. Evaluate current and future water demands; and
3. Assess the prospects for planned CU in the FtF-ZoI districts (Tarai) and potential strategies for planned CU.

In addition to generating information that can be used for model scenario analyses as described in Objective II Work Package III, this review synthesizes information that can be fed into policy and support for irrigation-related investments by the public and private sectors. A summary of key conclusions from the study on conjunctive use (CU) irrigation planning in the FtF-ZoI region (Tarai districts) is provided below.

Water availability: In terms of surface water, data on key hydrological features (e.g., catchment area, volume of water, water balance components, etc.) are available for nine basins/sub-basins in the region, albeit with varying level of details. Specific discharge across the river systems varies from 18.8 $l/s/m^2$ (Upper Karnali, above Lalighat hydrological station) to 52.1 $l/s/m^2$ (Mohana). Groundwater availability ($MCM/km^2/year$) across the FtF-ZoI districts (Tarai) varies from 0.11 in Dang to 0.48 in Kanchanpur. Aquifer yield is high in Bardiya district (32 lps), followed by Kanchanpur (28 lps) and Dang has relatively lower yield (only 15 lps). From the perspective of planned CU, we need data/information on surface water availability for many southern rivers as well. It requires expansion of hydrological network in those rivers and developing a well calibrated and validated hydrological models.



Above: Methodological framework for biophysical analysis This figure depicts the conceptual framework for biophysical analysis. A rigorous review of available literatures related to water availability, water demand, and water infrastructure development from the perspective of conjunctive use potentials was done. The final research report titled "Towards conjunctive use of surface water and groundwater resources as a response to water access challenges in the Western Nepal of Nepal (FtF-ZoI)" was prepared and finalized after the review from the identified reviewers (policymakers, irrigation development practitioners, agricultural and engineers of the GON and NGOs, and USAID Mission staff in Nepal).

Water demand: It is not at this time possible to map water demand hot-spots, nor it is feasible to overlay such data with water availability (both surface and groundwater) distribution and draw meaningful conclusions in terms of CU planning in the absence of a comprehensive study report on estimates of agricultural and other water demands and their spatio-temporal distribution. A detailed study on estimating water demands and their hot-spots with a higher resolution will address the aforementioned issue.

Status of irrigation development: About 310,260 ha of land within the FtF-ZoI districts (Tarai only) have irrigation facilities. Surface irrigation systems are designed to irrigate nearly 72% of total irrigated land, whereas official groundwater wells cover only 28%. Official groundwater irrigation coverage varies across the FtF-ZoI districts (Tarai only) from 13% (or 9,740 ha) in Bardiya to 53% (or 24,248 ha) in Kanchanpur. Though continued efforts are put by the government sector, development partners, and private sector to expand actual irrigation areas, there are still gaps, and more investments are required to expand actual irrigation areas.

Prospects and potential strategies for planned CU: Co-existence of both surface water and groundwater, under-utilization groundwater resources, and unreliable or inadequate water supply from a surface water system that draws water from rain-fed and spring-fed rivers indicate a good prospect for planned CU in the FtF-ZoI districts (Tarai). The challenges that problematize CU development, however, are mainly related to technical capacity, socio-political realities, inadequate emphasis (especially in terms of allocation of funds) on research-based development practices, and data/information gaps. Addressing the challenges and then translating the prospects for planned CU into reality requires workable strategies, mobilization of actors and resources, and political commitments. Establishing an enabling environment for public-private partnership and community-based investment to attract the private sector for planned CU irrigation programs and a demonstration pilot in this regard to understand what works and what does not could be a starting point in this endeavor.

Knowledge gaps: Literature on CU and groundwater in the Tarai region of Nepal is almost non-existent. Similarly, there is a serious lack of reliable information on the extent of groundwater development, especially for privately operated command areas in the Tarai. Knowledgebase on surface water availability is relatively more, albeit with varying levels of details for different river systems in the region. However, a comprehensive modeling of an entire hydrological system (both surface and groundwater) that covers all areas within the FtF-ZoI region using a coherent method/approach is missing. This point is a key, as appropriate and integrated CU and water resources planning will not be possible without tools, techniques, and data to driver scenario development to aid policy prioritization and decision-making. Furthermore, assessment/estimation of sustainable yield from different layers of groundwater aquifers and their spatial distribution are not well documented in literature. Understanding groundwater recharge process and dynamics are equally important to ensure sustained availability of groundwater for CU, however, information on groundwater recharge and potential recharge areas are not document, thereby adding constraints in designing appropriate inventions for groundwater recharge and source are protection. In terms of water demand, there is a lack of a comprehensive study estimating spatio-temporal distribution of water demands (for current and future periods), water use inventory of surface and groundwater resources, and performance assessment (both technical and economic) of existing irrigation systems. In sum, an integrated study for evaluating various scenarios of planned CU using a set of models to identify the most suitable scenarios for ensuring year-round-irrigation (YRI) at affordable costs on the irrigable lands in the FtF-ZoI districts (Tarai) is needed for CU planning perspective.

This research report is targeted towards the policymakers, irrigation development practitioners, agricultural and engineers of the GON and NGOs, and USAID Mission staff in Nepal to get an insight about the current and future water availability for water, to evaluate current and future water demands and to assess prospects for planned CU in the FtF-ZoI districts (Tarai) and potential strategies for planned CU. Parts of this report will also be used to iteratively develop and complete a sustainability and scaling framework for inclusive irrigation development in Nepal's FtF-ZoI.

A shortened and more precise version of the report is in the process of being developed into a paper for peer-review. The insights generated from this report are being combined with the other activities in Work Packages I, II III and IV to inform relevant policies to support sustainable private and public investments in irrigation.

1.2 Understanding systemic barriers, socio-economic and institutional challenges, and opportunities in scaling water access and irrigation technologies

Background: The limited use of ground and surface water in Nepali agriculture remains largely related to various socio-economic, policy, institutional, investment and gender and social inclusion challenges faced by rural communities. Where these challenges are not systemically analyzed or understood, major opportunities are missed to strengthen water and irrigation access aimed at agricultural development in Nepal. These challenges have likely been exacerbated by the COVID- 19 crisis, and by the necessary national policies put into place to prevent further infection.

Accomplishments in the reporting period: As such, this Work Package, which was completed during the reporting period, made use of a systems approach to assess a range of relevant topic influencing irrigation development, including the broader policy environment, public and private sector interventions in water management, gender and social inclusion, value chains, irrigation machinery and services, and the implications of COVID-19 on irrigation development. The comprehensive report, titled '<u>Understanding barriers and opportunities for scaling sustainable and inclusive farmer-led irrigation development in Nepal'</u>, was released by CSISA in September of 2021

Report overview: The overall objective of this component was to assess systemic barriers, and opportunities in scaling water access and irrigation technologies that can increase resilience and generate income for smallholder farmers in COVID-19 crisis affected districts of the FtF ZoI. To achieve this, the research looked at six key interconnected dimensions that influence scaling of irrigation development in Nepal's diverse societies, livelihoods, and political economy:

1. Lasting drivers in the FtF ZoI and Covid-19 related impacts and responses
2. Policy environment, including governance
3. Agricultural value chains
4. Irrigation equipment and service supply chain
5. Public and private sector interventions in water resources development
6. Gender and social inclusion in policies, agricultural value chains, irrigation equipment supply chains and public and private sector interventions

These elements were studied based on extensive policy and secondary literature review, and interviews with private sector actors, government officials, and cooperatives, after which a comprehensive report titled 'Understanding barriers and opportunities for scaling sustainable and inclusive farmer-led irrigation development in Nepal'[22] was produced within this year. Overall, data collection thereby was carried out mostly through virtual/telephonic means due to the COVID pandemic and related restrictions. The report also underwent rigorous internal and external feedback cycles.

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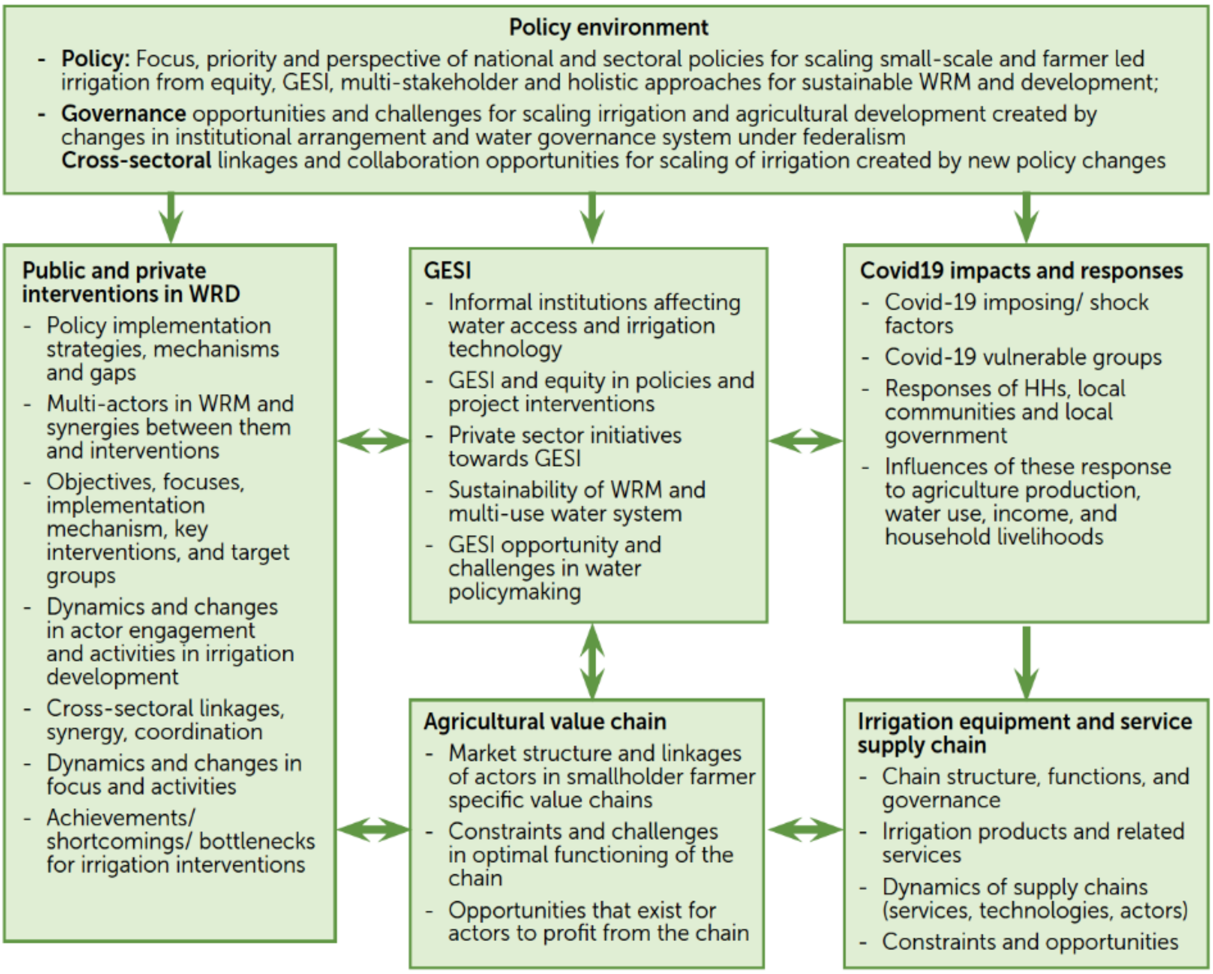
[22] Khadka, M., Uprety, L., Shrestha, G., Minh, T.T., Nepal, S., Raut, M., Dhungana, S., Shahrin, S., Krupnik, T.J., Schmitter, P. 2021. Understanding barriers and opportunities for scaling sustainable and inclusive farmer-led irrigation development in Nepal. The Cereal Systems Initiative for South Asia (CSISA). Kathmandu, Nepal.

As part of data collection and continued collaboration with stakeholders, we also organized three multi-stakeholder workshops (two for province-level on February 10 and 17, 2021 and one for the national level on December 7, 2020) that saw policymakers, private sector actors, and irrigation experts come together virtually to share on irrigation water management, and challenges and opportunities for private actors working in irrigation in the newly federal space.



Above: Analytical framework for scaling irrigation development in Nepal (from Khadka, et al., 2021).

The report concludes that to achieve the vision to improve incomes, nutrition, health, knowledge, and representation and voices of smallholder farmers, especially women, youth and disadvantaged groups through sustainable and inclusive farmer-led irrigation (FLI) development, the following five strategies are essential to focus on:

- Enable a supportive policy and institutional environment and governance mechanisms for the scaling of sustainable and inclusive FLI development along irrigated agricultural value chains and public and private investment
- Capitalize upon private sector investment into irrigation equipment and input supply chains; additionally, mainstreaming GESI in the private sector by partnering with I/NGOs could offer an opportunity to achieve GESI outcomes at the project-implementation level as women's social networks are key to technology adoption

- Enhance adaptive interventions to support small-scale irrigation and FLI development
- Support collaborative scaling ecosystem in responding to dynamics and driving changes needed for scaling FLI development
- Transform the irrigation and agricultural development system (facilitation of inclusive policy process, creation of multi-stakeholder dialogue platforms, institutional capacity development).

The findings were disseminated through virtual multi-stakeholder dialogues at the central and provincial level during the second half of the reporting period. The discussions in the workshops, in turn, has also informed additional analysis and verification of the data and findings of the social component of the research. Based on these efforts, a journal article looking at a systemic analysis of farmer-led irrigation development is also being currently developed.

Work Package 2: Preliminary development of a digital groundwater monitoring system to inform sustainable irrigation development and management strategies

2.1 Identify groundwater wells appropriate for spatially accurate groundwater monitoring

Background and context: Although much is known about surface water resources and hydrological and meteorological linkages between the Tarai, Mid-Hills, and Himalayas, Nepal currently lacks a comprehensive system for groundwater resources monitoring. Seasonal monitoring of groundwater levels is crucial for current and future sustainable irrigation development and increasing farmers' resilience to climatic risks. What little data is available is not centralized and often not available in digital form. Work Package II responds to this crucial information gap through two associated activities to develop and pilot a preliminary groundwater monitoring system.

Activities during the reporting period: As part of the Nepal Digital Groundwater Monitoring Pilot, CSISA and the Groundwater Resources Development Board (GWRDB) of Nepal cooperated to develop a sampling framework for the adequate testing of the data collection methods and devices. The team started by surveying the existing monitoring wells from which GWRDB is currently collecting data. These wells were largely installed as part of a UNDP-supported project in the 1980s and comprise the key monitoring network for GWRDB. In each district there is a total of 20 shallow monitoring wells (<80m) and an additional four deep monitoring wells (>80 m depth). The initial logic behind the siting of these wells is not directly known and COVID-19 restrictions made document recovery through personal travel impossible. However, GWRDB confirmed that they were installed as part of a wider project to characterize groundwater resources, suggesting that substantive investigation to ensure appropriate siting had been conducted. Nevertheless, with an increase in irrigation water use, the adequacy of the current network remains unknown and was earmarked as a key concern that the Activity aims to address.

As a result, in July of 2021 CSISA started facilitating a dialogue among CSISA, GWRDB and Tribhuvan University that aims to strengthen the local capacity for state-of-the-art data collection and analysis through collecting more systematic groundwater data. This is expected to further inform and strengthen Nepal's groundwater monitoring network, thus providing improved data assets as a basis for integrated, adaptive and sustainable water resource management.

Working with the existing monitoring network, the Activity identified the best locations for installing the offline data loggers to collect groundwater levels and provide a 12-hourly temporal resolution. Given that the pilot area exhibits a North-South topological gradient which also guides river morphology, a perpendicular cross-sectional sampling strategy was chosen for installing the offline loggers within the more evenly distributed network of shallow monitoring wells. This approach was documented in the groundwater monitoring protocol that CSISA co-developed and endorsed by the GWRDB. Slight modification to the planned selection wells had to be accepted due to some shallow wells not being amenable to the installation of the offline loggers, for which the closest neighboring well was chosen. Due to COVID-19-related delays, the telemetric online groundwater level loggers were delivered and installed in coordination with GWRDB field staff in late April and started functioning in the second week of May. These have been providing high-frequency real-time data two times per day. There were delays to training activities for GWRDB staff, auxiliary data collection and reading out the data of the installed offline loggers. Consequently, this work could only be initiated after COVID-19-related risks were less prevalent, towards late July and early August. Initial data points suggest that the rebounding of the water table in the region starts with up to more than one month difference, indicating that water availability for rice planting may differ within the district. Better delineating intra-district groundwater zones could thus be a valuable tool for targeting agricultural interventions and advisories.

Above: Installing an offline data logger for groundwater level monitoring in Bardiya, Nepal. *Photo credit: Anton Urfels.*

2.2. Set up and kickstart of a digital groundwater monitoring system

After an online inception workshop and initial stakeholder consultation with participants from a wide variety of backgrounds (14 October 2020), CSISA started the implementation of the groundwater monitoring pilot on the ground. With the well selection in place, the next step was to train GWRDB staff on the procedures for data collection (January and February 2021), conducted in field days by CIMMYT staff. The Head of the GWRDB office, Surendra Maharjan, was replaced in the pilot area by Krishna Upadhyaya.

Slight delays meant an additional training session was needed to update the new GWRDB staff on the activity and data collection methods. The newly appointed chief of the GWRDB office provided excellent support, and his avid engagement helped secure a swift start to the data collection and knowledge transfer. Training utilized the Training of Trainers Manual co-developed and endorsed by CSISA and GWRDB. The Manual is a living document that is updated as the approach is refined and learnings emerge, and has been improved based on the training experience. It has incorporated the current monitoring approaches and this updated version is ready to be used for future training.

Deployment of the online loggers was delayed due to a technical fault in the loggers from ONSET company, which had to be re-ordered. COVID also caused delays in the production and import of the OTT pressure level sensors. These arrived several months later, and COVID-safe installation was completed by the end of the reporting period. To kickstart the digital groundwater system, CSISA organized an online workshop, and invited key critical stakeholders and individuals who had shown interest during previous stakeholder discussions. The workshop (23 February 2021) started with GWRDB Head, Krishna Upadhyaya informing stakeholders about the progress of the activity, sparking a lively discussion on the potential use cases and needs of stakeholders. Critical discussion points included arranging the science-policy interface for the translation of these data into policy guidelines, and enabling better coordination of stakeholders at the district level.

These discussions were followed by a brief presentation of the current prototype of the dashboard. Stakeholders welcomed this with interest, expressing appreciation for the open-data approach and requesting that this be used collaboratively to update the knowledge on groundwater characteristics in Nepal Tarai. Stakeholders further remarked that for policy- and decision-makers, a monitoring system requires a policy framework to guide the development of maps indicating groundwater abstraction risks and potential. Lastly, the data collectors shared their experience, remarking on how they had overcome issues of digital literacy and the reward of contributing directly to better water management. They also remarked that in the future it would be easier to collect data using a mobile phone rather than a tablet, which can be awkward to carry on a bicycle.

By September 2021, the Activity had already collected several data points that document the recharge processes of monsoon rainfall. Bishnu Belbase was appointed the new Executive Director of the GWRDB and met with CSISA (August, 2021) to discuss the current monitoring pilot. This was warmly welcomed, with GWRDB expressing a strong interest in continuing to strengthen and develop the digital monitoring system after the pilot phase ends. The new GWRDB management requested that further training courses on the different monitoring technologies are held before the end of the pilot period, which CSISA agreed to support. Translating groundwater information and science into policy action requires a stronger science–policy interface. To this end, CSISA provided support to ongoing discussions between GWRDB and Professor Moti Rijal, Department of Geology, Tribhuvan University of Nepal, on strengthening groundwater science in Nepal. With these ongoing developments, the groundwater monitoring pilot has attracted significant attention to the value of evidence-based and adaptive groundwater management in Nepal. This has released latent energy among several interested stakeholders to join together to strengthen Nepal's digital groundwater database to support adaptive, sustainable and integrated water resources

Above: Groundwater levels in a subset of monthly monitored groundwater wells, showing variation in both the timing and magnitude of recharge dynamics with the onset of monsoon rainfall in May–September 2021. This image is a screenshot of the preliminary groundwater monitoring online tool developed by CSISA.

Work Package 3: Provide local, district and provincial level assessment of sustainable water use and development options including risks of unintended consequences at a watershed (and basin) scale and communicate assessments effectively through trainings and workshops

3.1 Generating insights into targeting irrigation-led sustainable intensification with machine learning analytics

Sub-Activity 1: Construct machine learning-based prediction models for rice productivity

Using farmer survey data collected in the 2016 and 2020 cropping seasons by CSISA and national partners, including the Nepal Agricultural Research Council (NARC) and PMAMP, a random forest model was constructed to predict rice yields as a function of environmental and agronomic management factors (r^2 = 0.736, RMSE = 676 kg ha^{-1}). Soil properties were estimated from the digital soil maps developed by the USAID-supported NSAF project. In descending order of importance, the top 7 model predictors are shown below. Of these, three factors – soil texture(percentage of sand content), planting date and irrigation number) are strongly associated with field hydrology and crop water stress. In contrast to adjacent rice-growing areas in India, less rice yield variation in Nepal Tarai can be explained by irrigation intensity because here, in general, irrigation utilization is low, with an average of just two irrigation events per season. Additional information on model outputs can be found in the 2020-21 semi-annual report.

Sub-Activity 2: Scenario analysis to understand the spatial distribution and causal factors associated with responses to increased irrigation

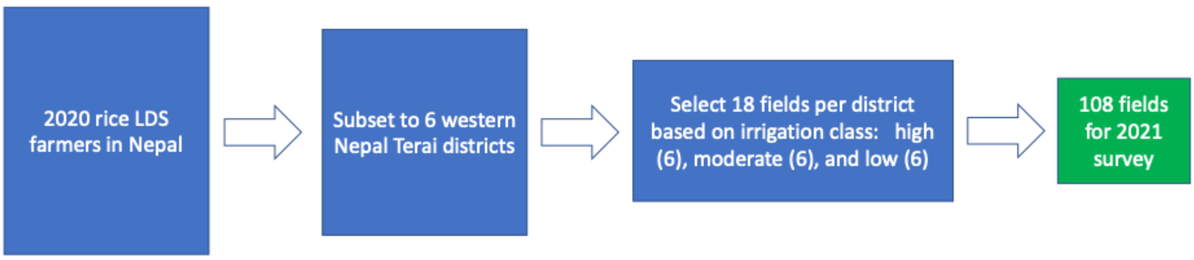
Using the random forest model developed in Objective 1, a set of hypothetic scenarios was run to predict how individual fields would be likely to respond to increased irrigation, and to understand the spatial consistency of responses. A high degree of response heterogeneity was observed between districts, with the Western Tarai generally anticipated to have higher productivity gains than the higher rainfall ecologies in the Eastern Tarai. Hot spot analysis suggests that Kapilvastu, western Banke and Bardiya districts are likely to benefit significantly and consistently from increased irrigation. The analysis also explored the field characteristics associated with responsiveness to irrigation, and identified prior rice yield levels (i.e. < 3.3. t ha^{-1}), soil texture, and past irrigation practices as strong candidates to help guide field level advisories. An additional step explored how investments in soil health (i.e. N and P fertilizers) might influence the value of intensified irrigation for rice. Results suggest that the expected benefits of irrigation will more than double if modest levels of complementary investments in fertilizer are used conjunctively. Just as importantly, the geographic areas likely to respond most favorably demonstrate significant shifts, with Kailali and Chitwan districts emerging as priorities. The results highlight the need to consider fertility and irrigation management in tandem, in order to maximize yield and profitability gains. Additional information on scenarios analyzed can be found in the 2020-21 semi-annual report.

Sub-Activity 3: In areas predicted to be highly responsive to increased irrigation, implement additional field diagnostic surveys that highlight opportunities and constraints that farmers may face in intensifying irrigation.

In light of COVID-19-related staff mobility restrictions, the Activity implemented a telephone-based survey during July-September of 2021 to characterize farmer decision processes, and constraints pertaining to irrigation management in the Western Tarai (Kailali, Kanchanpur, Banke, Bardiya, Kapilvastu and Rupendhehi districts). This survey was implemented every two weeks in order to accurately capture ancillary information on farmer perceptions of the field water balance (e.g. days with continuous flooding) and is based on a stratified sampling plan that accounts for differences in irrigation intensity at the field level from the 2020 growing season (see figure, below). In total, 108 farmers' fields were monitored for irrigation practice and water balance dynamics, for the duration of the 2021 growing season. These data are currently under analysis to highlight additional opportunities and constraints that farmers may face in intensifying irrigation based on the machine learning analyses articulated in Sub-Activity 2 and 3. Further outputs and outcomes from this research will be presented in the next semi-annual report.

Stratified sampling strategy (district then irrigation class) based on population of 2020 LDS farmers

1. Focus on six western Terai Districts that were surveyed in 2020: Kanchanpur, Kailali, Bardiya, Banke, Kapilvastu, Rupendhehi
2. Classify surveyed fields into irrigation intensity classes: high (4 or 5 irrigation events), moderate (2 or 3), and low (1); rainfed fields or those receiving 6 or more irrigations are not considered in the current study.
3. For each district, select 6 fields from the 2020 dataset that fall into the high, moderate, and low irrigation classes for a total of 18 fields per district and an overall sample *n* of 108 fields.



Above: The sampling plan characterizing irrigation practices and field water balance in the rice growing season 2021, Western Tarai, Nepal. Fields sampled were extracted based on machine learning analytical results from the 2020 landscape diagnostics survey for rice conducted by CSISA.

3.2 Integrated crop and hydrological set-up and scenario analysis for sustainable irrigation development

Background: Using insights from Objective I Activity I and II, as well as the data-driven modeling work described above, Work Package 3.2 integrates data sources to develop modeling scenarios that can provide integrated assessments of (s) field, watershed, and basin-level water balances, (c) existing crop productivity estimates, and (c) economic performance of existing farming systems. This is accomplished using SWAT, a basin-scale physically based model which is used to estimate changes in climate, land use and land management on water, soil and nutrients. APEX is a biophysical model which analyzes the productivity and water/nutrient balance of farming systems. FARMSIM, conversely, is a Monte Carlo socio-economic model that assesses the economic and nutrition impacts of different alternative farming systems. The three models applied in an integrated manner, are referred to as an Integrated Decision Support Systems (IDSS), and are widely used by the Texas A&M University led FtF Innovation Lab for Small Scale Irrigation. These tools are being used to assess the impact of different farming systems on agricultural production, environmental sustainability and income and nutrition at different geographic scales.

Research questions: The key research questions being addressed through this work include the (a) what is the scope is for ground and surface water irrigation development in Lumbini and Sudurpashchim provinces? (b) What best-bet crop and cropping systems combinations are suited to irrigation development from both an agronomic and economic standpoint, the latter with emphasis on pump owners and male and female farmers' profit potential, and also on returns to investment in irrigation development at the local, district and provincial levels? (c) What the potential 'safe operating space' for irrigated (groundwater, surface water, and conjunctive use) development in Lumbini and Sudurpashchim provinces, with consideration of assuring reasonable water access to both up- and down-stream water users through appropriate development and options to recharge water upstream and maintain environmental and economic flows downstream? (d) What locations might be 'best-bet' for future irrigation development in consideration of the medium-term effects of climate change?

These questions aim to assess the optimal water use that ensures maximum agricultural production, income, and nutrition without causing significant negative environmental externalities. In doing so, this Activity is working to provide inference on the potential implications of different irrigation development pathways for individual farmers, farmer cooperatives, and water user's associations.

Progress during the reporting period: Soil and Water Assessment Tool (SWAT) was used to assess multiple scenarios on agricultural productivity and environmental sustainability related to the questions above and identify sustainable irrigation development framework in Lumbini and Sudurpashchim provinces of Nepal. Details on this process and preliminary outputs and insights are presented below.

Model setup and calibration: After assembling data[23], the SWAT model was setup for the Mahakali, Karnali, Babai, West Rapti and southern watersheds (Bardiya, Kapilbastu, and Palpa-Rupandehi)

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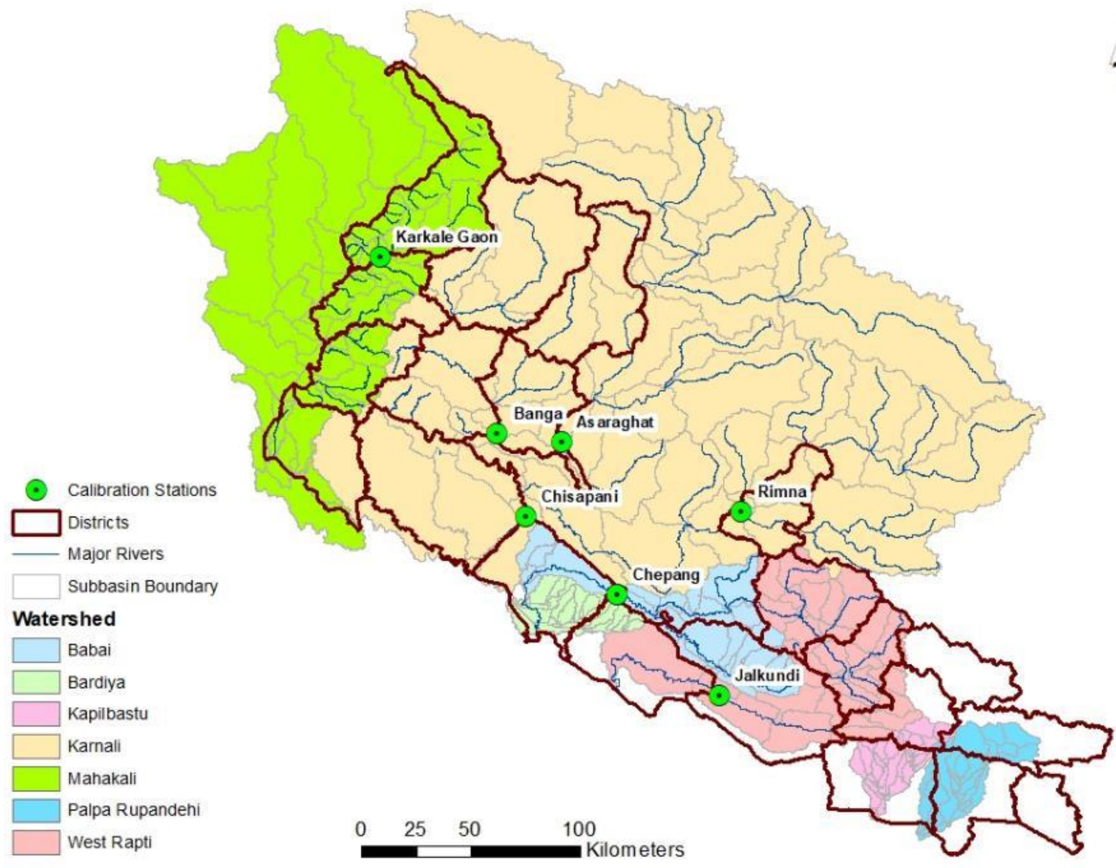
[23] Geospatial data such as Digital Elevation Model (DEM), Land use and land cover (LULC), soil climate and agricultural management data were collected and prepared according to the SWAT model requirement. A void filled Shuttle Radar Topography Mission 2010 DEM of 1 arc-second (30 meters) resolution downloaded from USGS Earth Explorer was used for watershed delineation. LULC data for entire study area was prepared combining crop mask for different crops (rice and wheat) obtained from CIMMYT and available LULC map obtained from International Center for Integrated Mountain Development. Soil

using a DEM, land use and land cover (LULC), soil, climate, and agricultural management data. Four models Mahakali, Karnali, Babai, and West Rapti were calibrated and validated for streamflow using streamflow data obtained from multiple gauging stations located within the watersheds. Calibrated model parameters from these gauged watersheds were transferred to nearby southern watersheds that did not have observed flow data. The models were also calibrated for rice and wheat yield using the district wise national crop production data.

Initial streamflow calibration (1995 to 2004) and validation (2005-2013) for the Mahakali Watershed at Karkalegaon station (gauging station 120) showed reasonable performance based on coefficient of determination (R^2), Nash-Sutcliffe Efficiency (NSE) and Percent Bias (PBIAS) goodness-of-fit evaluations. For example, the R^2, NSE and PBIAS for the calibration were 0.69, 0.68, and 0.81, respectively, while during calibration and the goodness-of-fit values were 0.67, 0.67, and -1.3 during validation. The goodness-of-fit values suggested that the model calibration was acceptable, and the simulated streamflow did not have significant bias. Plots of 5) showed reasonable agreement except for underestimation and overestimation of certain peaks.



Above: Location of Watersheds, Major Rivers, and Calibration Stations in the Study Area.

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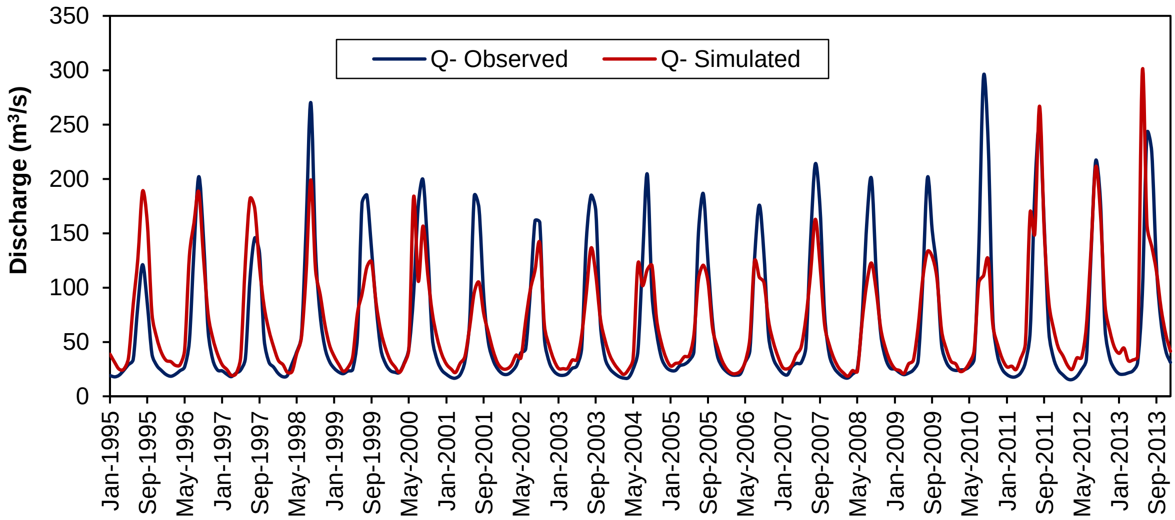
data was prepared from 1 km ISRIC global soil grid in which soil physical and chemical properties were determined using pedotransfer functions. Climatic variables required for model setup such as precipitation , maximum/minimum, temperature, solar radiation, relative humidity, and wind speed for the study area were obtained from Department of Hydrology and Meteorology, Kathmandu. Precipitation data for the study areas was also extracted from the global precipitation satellite grid (Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) as an alternative source and was blended with the precipitation data obtained from DHM. Similarly, streamflow data required for model calibration and validation were obtained from the Department of Hydrology and Meteorology in Kathmandu. Agricultural management practice data such as dates of planting/harvesting, irrigation amount and dates, tillage types and dates, and fertilizer rates and dates were obtained from CSISA survey and expert opinion working in the area.



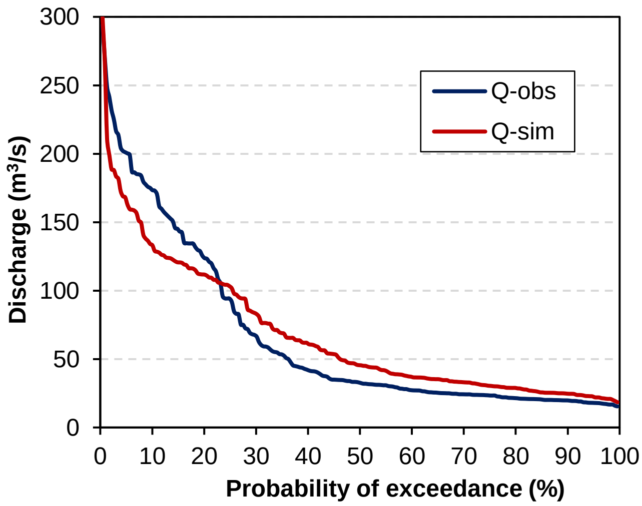
Above: Comparison of monthly observed and simulated streamflow at Karkalegaon Station (Gauging Station: 120) located near Subbasin 10 of Mahakali Watershed.

The Flow duration curve (FDC) at the calibration site of Mahakali Watershed was used to compare streamflow characteristics of observed and simulated streamflow throughout the discharge range, without considering the sequence of their occurrence. These results showed that the model simulated both the baseflows and high flows with reasonable accuracy.

3.3 Integrated crop and hydrological set-up and scenario analysis for sustainable irrigation development COVID-19 response at the local, district and provincial levels

During the reporting period, CSISA designed a one-day interactive multi stakeholder workshop to develop scenarios for analysis based on the results from research conducted in work packages I and 2 of Objective II and the use of modeling results in work package III, with multiple Activity partners.

Participants for the workshop are identified through a series of planning meetings between CSISA and the GWRDB and NARC. The invitation list for the workshop was prepared taking into consideration of gender and social inclusion. The online zoom workshop was organized on June 16, 2021 with 37 active participants. The summary note on the social and biophysical findings were prepared to provide participants in advance of the workshop. As it was an interactive workshop, different online tools such as Mentimeter (https://www.mentimeter.com/) and



Above: Flow duration curve (FDC) for monthly observed (Q-obs) and simulated (Q-sim) streamflow at Karkalegaon Station (Gauging Station 120) located at Subbasin 10 of Mahakali Watershed.

Google Jamboard (https://jamboard.google.com/) were used to facilitate the maximum interaction.

As a first step for the workshop, the background and the definition of drivers that might change the cropping systems and irrigation water use and examples of drivers from the farmer survey were presented to the participants. Then, participants were asked to input the drivers they think are important into Mentimeter. Six major key drivers were identified through voting in Mentimeter, and 12 different storylines (scenarios) were developed through a 2-axis method in the workshop. Owing to the similarities in the scenarios developed, the 12 scenarios were consolidated into 4 scenarios through CSISA internal discussions. Two of these scenarios were already included in the scenarios developed by the CSISA team, so two additional scenarios were added to the list of the scenarios to be simulated on the SWAT model by colleagues at Texas A&M University. The scenarios simulated on SWAT will also provide inputs to sustainability and scaling framework for inclusive irrigation development in Nepal's FtF-ZoI.

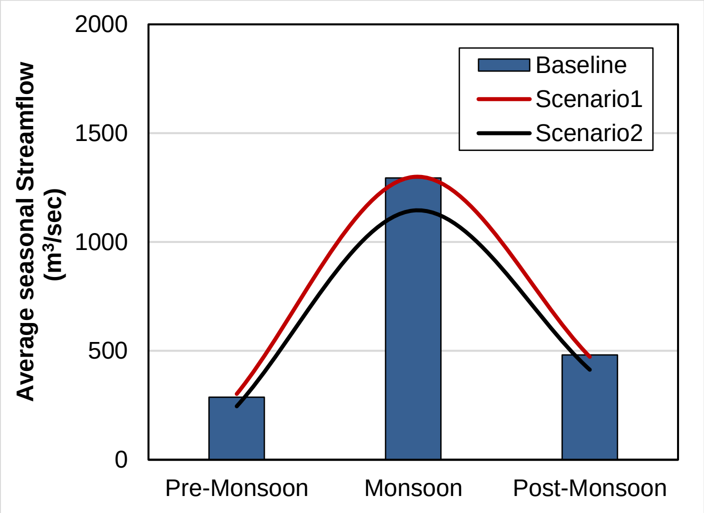
Scenario Analysis: As described above, multiple scenarios were developed and analyzed after series of provincial/national level workshops and meetings with CIMMYT, IWMI and other stakeholders held during the reporting period. Scenarios were developed by combining crop rotation, irrigation and fertilizer management based on water resource availability, crop suitability and diversification potential, market access, interest of stakeholders, etc. The calibrated and validated SWAT model was used to assess the impact of these scenarios on groundwater resource, surface water resource, crop production, and environmental sustainability. Each scenario was implemented in certain districts within Activity areas according to the feasibility of determined based on experience of the expertise working in the field. A final list of scenarios that were analyzed for the respective districts and provinces are summarized below.

List of scenarios in districts and provinces where the practices will be likely implemented

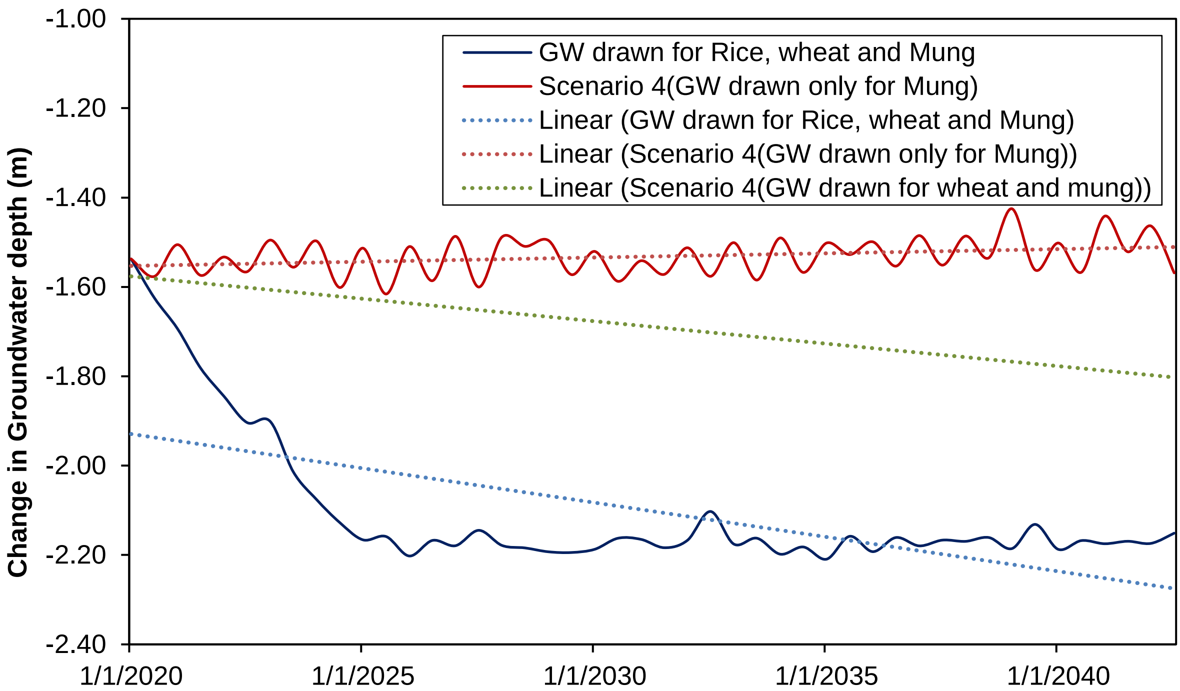
Scenario	Description	Implemented Area
Scenario 1	Closing yield gap in rice-wheat system through irrigation	Dang, Banke and Bardiya (Lumbini Province), Kailai and Kanchanpur(Sudurpaschim Province)
Scenario 2	Vegetables between Khariff and spring rice	Bardiya (Lumbini Province) and Kanchanpur of (Sudurpaschim Province)
Scenario 3	Irrigated maize replaces rainfed lentil and fallows	Dang (Lumbini Province) and Kailali (Sudurpaschim Province)
Scenario 4	Intensified triple cropping instead of double cropping System	Banke (Lumbini Province), and Kailali (Sudurpaschim Province)
Scenario 5	Replacing rainfed rabi crops by horticultural crops	Rolpa and Argakhanchi (Lumbini Province)
Scenario 6	Maximize the groundwater recharge in the mid hills	Dang (Lumbini Province)

The potential impact of scenarios on surface water resources: Most scenario effects on surface water resources were not very significant because very limited water was utilized from the rivers since the scenarios do not consider the development of canal systems as they are expensive to build. The snow-fed perennial rivers like Karnali and Mahakali had sufficient water during the entire year, but the water in rain and spring-fed rivers like West Rapti and Babai were not sufficient for irrigation during pre and post-monsoon season. The average seasonal streamflow for baseline and alternate scenarios 1 and 2 for the Mahakali Watershed is presented below as an example.

The impact of scenarios on groundwater resources: In contrast to surface water, groundwater resources, however, were much more affected by scenarios, based on depletion of groundwater reserve and annual groundwater recharge. Irrigation from groundwater was found to be sustainable for all the scenarios when the water was drawn only during the dry season of the year and were preserved during monsoon season. The supplementary irrigation requirement for monsoon crops like rice must be provided from a surface source like irrigation canals if available. Simulations of the management scenarios for the current and climate change data showed that the rice-wheat-mung bean irrigation scenario caused the highest groundwater drawdown while the mung bean irrigation scenario caused the lowest drawdown for the climate change condition, as shown below.



Above: Change in average seasonal streamflow before and after irrigation was supplied in Mahankali watershed.



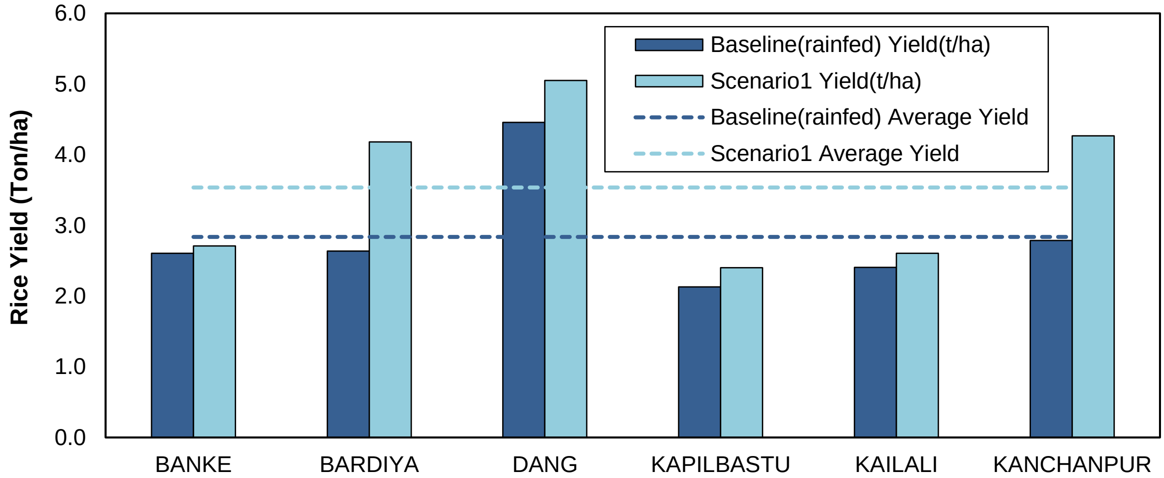
Above: Groundwater fluctuation for Rice-Wheat-Mung bean, Wheat-Mung bean, and only Mung bean systems in subbasins 48 and 49 of Karnali Watershed for climate change conditions.

Potential impact on crop yields: During the reporting period, the CSISA team conducted a preliminary assessment of the potential impact of scenarios on crop yield. This was done by comparing average crop yield and production for different scenarios with that of the baseline scenario. Average yield and total production of crops improved with an increase in sufficient irrigation amount.

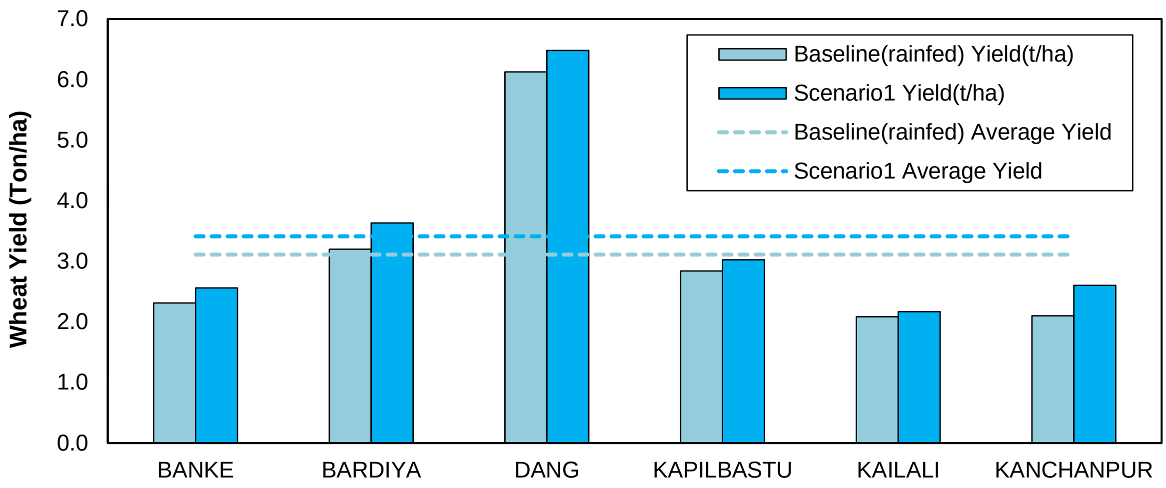
Percentage of increase in rice and wheat yield due to irrigation in Tarai districts

District	%Increase in Rice Yield	%Increase in Wheat Yield
Banke	4%	11%
Bardiya	58%	14%
Dang	13%	6%
Kapilbastu	13%	7%
Kailali	8%	4%
Kanchanpur	53%	24%

In general, crop yield and production for winter and spring season crops were low even after sufficient irrigation and fertilizer was provided because of the short growing period and temperature stress. Moreover, a decrease in crop yield was observed during near and midterm future period due to temperature stress. The increase in average rice yield for different districts in CSISA Activity areas area after by Scenario 1 (Closing yield gaps in rice-wheat systems through irrigation) is presented below as an example.



Above: Average rice yield for baseline and irrigation scenario in different districts studied.



Above: Average wheat yield for baseline and irrigation scenario in districts studied.

At the time of writing, yield and water use sustainability assessments are being modeled for each of the scenarios and under conditions of modeled climate change. The results from this work will be used in developing a sustainable irrigation development framework in Nepal following stakeholder validation workshops, that, if permitted by USAID, will take place in early 2022 (conditional on acceptance of a proposed extension for this work). The sustainable irrigation framework will eventually benefit Nepalese farmers with increased cropped area, agricultural productivity, and identification of high value crops, as described below.

Work Package 4: Sustainability framework for irrigation development in Nepal's Feed the Future Zone completed

4.1 Move towards self-reliance through training and communication of research insights

Background: Work Packages I, 2, and 3 closely involve stakeholders in (a) selection of scenarios for irrigation and multi-use water resources development assessments, and (b) in interpretation and fine-tuning of model scenario outputs, respectively. Activity 4.1 is focused on complementing these efforts through capacity building. Key actions taken during the reporting period include those described below.

On-the-job training and capacity development for irrigation management: Following a call for competitive applications and proposals by candidates that was posted in various newspapers and job advertising websites. A shortlist of 19 candidates was made, and after an intensive interview process, two early-career scientists, one male (Sujan Sapkota), one female (Kiran Dahal), both youth, were selected for a long-term training internship. These interns are now participating formal members of the CSISA team in Work Package III activities and are actively contributing to IDSS modeling through 1:1 coaching and direct participation in the research outlined in Activities II and III. The goal of this work is to provide thorough on-the-job coaching, technical support, and practical learning that will position these early-career scientists to contribute in the long-term towards resilience-enhancing and sustainable irrigation development, while also positioning them as leaders in water resources management and agricultural research.

Capacity development on the Soil and Water Assessment Tool (SWAT): A SWAT beginners Workshop was conducted in Kathmandu from April 19 to April 23. The training was provided to two on-the-job trainees (OJTs) and Activity partners from the International Water Management Institute (IWMI) and International Maize and Wheat Improvement Center (CIMMYT). Among six regular participants, one member was female, and five were male. List of participants of ArcSWAT beginners Workshop is given in the table.

List of participants for the SWAT beginners Workshop (April 19-23)

Name	Institution	Gender
Kiran Dahal	On-the-Job Trainee	Female
Sujan Sapkota	On-the-Job Trainee	Male
Saral Karki	CSISA	Male
Gokul Poudel	CSISA	Male
Nirman Shrestha	CSISA	Male
Naresh Suwal	Khowpa College	Male

Providing special seminars on the Integrated Decision Support System (IDSS): A virtual special seminar on the Integrated Decision Support System (IDSS), including SWATT, was provided on April 22, 2021, to graduate students at the Institute of Engineering, Tribhuvan University, Nepal. The seminar was coordinated by Professor Dr. Vishnu Prasad Pandey of Department of Civil Engineering, Institute of Engineering, Pulchowk Campus, Tribhuvan University and by Dr. Avay Risal of Texas A&M University, both of whom are CSISA collaborators. The seminar covered application of the IDSS to ensure water security, agricultural productivity, environmental sustainability, household income and nutrition.

4.2 Iteratively develop and complete a sustainability and scaling framework for inclusive irrigation development in Nepal's Feed the Future Zone

Background: Conducted in close dialogue with public and private sector stakeholders, this activity is the ultimate product of Objective II and will identify plausible and equitable irrigation and water development pathways for Nepal's Feed the Future Zone. This activity is working to develop a Nepal-specific sustainable and inclusive scaling framework for irrigation development to: (a) cooperatively identify high-potential locations for public and private sector interests and incentives to overcome systemic barriers and strengthen sustainable water governance, thereby working to increase farmer's resilience and de-risk private sector agricultural investments. Such efforts also link the IDSS model setups and run analyses to incorporate learnings on the policy implications of farming practices changes resulting from the COVID-19 crisis and other stresses. This work will also (b) initiate regular multi-stakeholder dialogues to support sustainable irrigation and agriculture development. Activity 4.2 builds on all prior Work Packages and Activities in Objective 2 of the CSISA COVID- 19 Resilience Activity. As described above, the necessary work needed to prepare to begin Activity 4.2 was undertaken during the reporting period.

Activities during the reporting period: The CSISA team designed the table of contents for the sustainability and scaling framework for inclusive irrigation development in Nepal's FtF Zone. The table of contents for the framework was then shared with the team members of CSISA as well as the USAID team for the comments. This structure for the framework was subsequently approved by USAID. At the time of writing, different team members are designated to lead the different components of the framework, which is under development and draws on the outputs and insights of each of the prior work packages, emphasizing SWAT-based scenario analyses.

While the team has already generated the first zero drafts of some of the sections of the framework, delays in modeling and challenges associated with meeting partners and holding scenario validation workshops that resulted from COVID-19 lockdowns and international travel restrictions have slowed progress. Nonetheless, the first completed first drafts had been shared with the team member on one online document for comments and suggestions.

The first draft of the framework, with first revisions, is planned to be finished by the first week of November. It is important to note, however, that the scenarios still need to be validated, ideally through in-person, provincial stakeholder level meetings. These have not been possible due to the above mentioned challenges. Similarly, time will be required for stakeholders to review, comment on, and later validate further iterations of the framework. For these reasons, CSISA is likely to request USAID for an extension of completion of this activity from December of 2021 to March or April of 2022. Additional information on progress and these activities will be provided in the next semi-annual report.

OBJECTIVE III: SUPPORTING RAPID RESPONSE AND RESILIENCE-BUILDING FROM NEPAL'S SECOND COVID-19 WAVE

Background: From April to late September of 2021, Nepal experienced its second large and subsequent third minor waves of COVID-19, resulting in additional and significant threats to agri-food systems and livelihoods. These have occurred due to lockdowns, transportation and marketing disruption, social distancing that has decreased farmers' and value chain actor's ability to interact with each other, and increased infection rates that significantly reduce crucial farm labor availability, especially among marginal and women farmers. At the same time, small and medium scale enterprises throughout the FtF Zone of Influence have suffered economically. National food/nutrition security is also undermined by increased costs for imported staples, the unreliability of cross-border trade, and shortfalls in national production before and during the crisis. The pandemic and resulting lockdowns have also exacerbated the need for reliable and timely information on input and output market access, diseases and pests, insurance, and credit, recognizing the inequalities that limit women's and marginalized groups' access to information and their disproportionate economic burden.

In response, USAID/Nepal has provided an additional $3 million buy-in as part of the wider CSISA portfolio to support rapid response and continued resilience building in Nepal's agri-food systems. These activities – which include (a) immediate response activities that are being put into place from September of 2021 forward until June of 2023, aim to effectively rebuild key elements of Nepal's agri-food systems and marginalized groups in the FtF zone that have been disproportionately affected by the second wave of the COVID-19 crisis. Key areas of intervention focus on provision of access to finance for small- and medium-scale agricultural input and services provision businesses, recovery, and response in the post-harvest value chain, with emphasis on financial products to benefit businesses involved in perishable farm product marketing and distribution, and expansion of digital banking services supporting socially distanced agricultural finance transactions. Emphasis is being placed on reaching smaller businesses that are verified to be women-owned or operated with specialized loan products.

In addition, interventions focus on scaling-out agricultural mechanization services through geographical expansion to new districts in which CSISA is not currently working in as part of Objective I activities, while also working to increase national food security and bolster agricultural economies in times of crisis. Importantly, expansion to the mid-hill district of Surkhet will permit increased response supporting women-headed households with access to machinery services that will benefit given the large number of male family members that may have been affected by COVID or who had previously migrated from these areas leaving women with the disproportionate burden of sole household and farm management. (b) Following the immediate response, activities in the first six months of Objective III implementation (mid-2021 to end 2021) will also seek to foster recovery from the shocks experienced during the second wave. Finally, (c) activities from January 2022 through June 2023 will focus on assuring that recovery is complete, while also building the resilience of key elements of the agri-food system to better withstand future shocks, including but not limited to COVID-19.

Objective III of the CSISA COVID-19 Response and Resilience Activity has four primary Work Packages. Importantly, each Work Package in Objective III commences with a rapid gender and marginalized-group specific analysis that will draw upon findings from existing reports and studies on the impact of COVID-19 on vulnerable groups. Following the rapid analysis, which will be conducted within a two-week period following commencement of the award, the proposed activities in each work package will be adapted and improved to increase responsiveness to concerns of gender and social inclusion in COVID-19 response. Work packages are briefly described below.

Work Package 1: Assuring small- and medium-scale input and services provision business recovery and rehabilitation through access to finance

This work package will develop customized business models for financing and facilitate rapid access to response and recovery loans from financial institutions from the second and third wave of COVID-19, with emphasis on specialized products for women and marginalized groups. The agreements with banks held on behalf of CSISA that were developed as part of Objective I will be leveraged to offer quick opportunities to facilitate access to finance for other agricultural businesses, including agro-vets, agricultural machinery dealers, and businesses associated with agricultural inputs or services owned or operated by women or members of marginalized groups that have suffered from lockdown and COVID-19 induced losses. As such, CSISA will deepen these relationships to develop customized COVID-19 response business models, banks providing input business support loans to small- and medium-scale agricultural inputs, machinery dealing businesses, or agriculturally oriented businesses owned by women or members of marginal communities (or that employ these groups).

Work Package 2: Specialty financial products and services to reduce post-harvest losses in at-risk perishable farm product value chains

This work package will increase response and recovery from the second wave of the COVID-19 crisis for farmers and businesses involved in producing, distributing, and selling perishable and healthy commodities. This will be achieved by developing and deploying specialty financial products from banks and lending institutions suitable for unique perishable value chains. Activities will target at-risk businesses owned by women and/or members of marginalized communities that deal in post-harvest horticultural, drying operations, dairy processing, canneries, essential oils distillers, and packaging operations. An additional sector that may be targeted is dairy marketing cooperatives.

Work Package 3: Digital banking services to support immediate response to businesses and consumers affected by the COVID-19 crisis

Leveraging CSISA's burgeoning partnership with MegaBank, Nepal's only woman-led banking institution, this activity will scale a "farmer credit card" product that will be leveraged within the context of the existing CSISA COVID-19 Response Activity. This QR-coded and mobile digital card (linked to the buyer's mobile phone) can be used to purchase a range of products related to farming, including small machinery at pre-identified vendors - up to a total of $2,000. In card will provide excellent interest rates (currently 5.14% with the government subsidy) and long payback periods. In addition, Nepal's Agricultural Development Bank, or ADBL, has been working to support similar digital financial services that could be leveraged to support immediate response to COVID-19 by facilitating mechanisms for socially distanced money transfer.

Work Package 3 will rapidly increase agro-vet access to digital tools, enhancing the sale and purchase of agricultural inputs and commodities in key locations suffering from the economic shock of the second wave of COVID-19 in the Feed the Future Zone. Digital financial technologies allow farmers to make purchases when they need to make them, and the interest will only begin to accrue after the purchase has been made. This is effectively a guaranteed agricultural loan subject to all the government's advantageous agricultural financing programs. Still, unlike a traditional agricultural loan, it does not accrue interest until a farmer spends the money – i.e., it can sit in a farmer's pocket until the day she needs the money to invest in the next season's planting or harvest. Perceptions of gender, social and ethnic identity are important mediating factors that affect access to technology; in particular, women belonging to disadvantaged communities are generally less educated, have less access to financial resources, and are less likely to have access to technology and associated information than other women and men. Therefore, particular attention will be paid to marginalized groups and women in this Work Package.

Work Package 4: Geographical expansion of socially-distanced and COVID-19 safe agricultural mechanization services

Objective 1 of this project expires at the end of 2021 and is a USAID/Nepal Mission buy-in to the overall CSISA program. This Activity works largely in Kanchanpur, Dang, and Banke districts of Sudurpaschim and Lumbini provinces. With the second wave of COVID in Nepal, it has become clear that additional geographic expansion of activities is urgently needed. In response to lockdown, social distancing, and infection-induced labor scarcity, CSISA will continue to strongly work in these provinces to facilitate agricultural machinery markets and accelerate poor farmers' access to COVID-19 safe agricultural machinery and mechanics services, assuring timely farm operations and increased yields. Under Objective III, Work Package 4, Activity 1, CSISA will expand work on COVID-19 safe agricultural machinery services geographically to include support for COVID-19 recovery and resilience in Bardiya, Kapilvastu, and Surkhet districts. Key activities will therefore be adapted based on these findings, but are expected to include (a) increased purchase of agricultural machinery by returnee migrants and the provision of COVID-19 safe land preparation, planting, irrigation, harvest and post-harvest services, (b) continued support for mobile mechanics services to combat breakdowns and assure timeliness of agricultural operations, and (c) enhanced voucher schemes to permit women and farmers from marginalized groups that have had no previous access to agricultural machinery services to benefit from mechanization services.

As activities have only just commenced at the time of writing, progress in each of Objective III's work packages will be detailed in the subsequent CSISA semi-annual report.

6. Challenges Faced During the Reporting Period

CHALLENGES IN BANGLADESH AND NEPAL UNDER CSISA III

COVID-19 restrictions had a significant impact on implementation of the Activity's work during the reporting period. CSISA made several modifications to workplans and only completed the must-do tasks. There was a nationwide lockdown with strict restrictions on movement 14 April 2021–10 August 2021 in Bangladesh and late April 2021–September 2021 in Nepal. Staff mobility completely ceased and alternative work modalities implemented between April and August of 2021 in both countries.

All in-person training programs, workshops, demonstrations, video shows and other field-related programs were postponed or modified to include small groups of less than ten people and only in open air settings. Staff attended office on a rotational basis and all meetings were moved to virtual platforms. The Activity continued to remain appropriately cautious in engagement with partners in any way other than through virtual meetings. Several key staff in both Nepal and in Bangladesh experienced COVID-19 infection, although have now recovered. A number of staff lost family members, which took a toll on their ability to work effectively. Offices opened up in both countries only under strict COVID protocols. Both countries engaged more private and public sectors actors to complete remaining tasks and only travelled to places where movement was comparatively safe.

Challenges specific to the CSISA-COVID-19 response and resilience activity

Objective 1

- Screening and identifying potential returned migrant workers for CSISA to train as in-service providers remained a challenging and time-consuming task. A majority the Activity contacted wanted a fixed job or to set up an alternative business, including work in the agricultural sector, such as raising poultry or goats, and high-value vegetable farming.
- The Activity made multiple efforts to facilitate A2F for the vulnerable migrant workers, creating linkage with banks to provide financing for agricultural machinery However, the banks' perception of risk of lending in this sector, and the high cost of processing and managing these loans has led them to demand extraordinary levels of documentation and collateral. This interferes with access to credit for potential service providers in rural communities, and has generally resulted in the non-adoption of the new technology.
- A majority of farm machinery types in the past have been promoted in villages through various GoN subsidy programs. As a result, many of the returned migrant workers with the potential to become farm machinery service providers are expectant of a future subsidy and have hesitated to invest.

Objective II

- Challenges encountered under this objective related to (1) data, and (2) COVID-19. There was a lack of reliable hydrological data at multiple stations in the working areas (that is, a lack of (i) recent hydrologic observation data, and (ii) reliable hydrologic data at seasonal river gauges). In addition, communication among different partners was limited by the lack of in-person engagement, compounded by time zone differences affecting virtual meetings. More specifically, COVID-19 reduced the potential for in-person workshops for scenario development among different stakeholders and Activity team members at the local, provincial, and federal levels, and virtual workshops conducted at different levels were not as effective as when done in-person. As a result, planned activities were not finalized
- The Activity would have benefitted more from the face-to-face interactive workshops where the inputs from the stakeholders are important. However, due to COVID restrictions, those workshops were organized online. There was active participation from the attendees however the lack of face-to-face interaction was distinctly realized.
- Virtual workshops also posed challenges to ensure gender-balanced participation. Food-water-energy sector and positions are men dominated in Nepal. It is difficult to secure balanced representation at normal times. Virtual workshops posed additional challenges to that, particularly at the provincial level workshops.
- Language was another constraint that may have limited effective participation from the participations. Government stakeholders are proficient and comfortable expressing views in Nepali. Although translation provision was ensured in the workshops, technical complexities and confusions had constrained effective contribution from the participants in the discussions.
- Difficulty in carrying out in-person workshops for scenario development was a significant challenge.
- Difficulty in coordinating with on-the-job trainees (OJTs) and Activity partners
- Inability to obtain accurate crop yield data as the government statistics on district-wise yield and production of different crops contains a lot of uncertainty.

7. Additional Information

ENGAGEMENT WITH MISSIONS, FEED THE FUTURE PARTNERS AND PROJECT SUB-CONTRACTORS[24]

USAID/Nepal and Mission

The Activity continued to engage with the USAID Bangladesh and Nepal Missions during this reporting period, with new investments in CSISA provided by the USAID/Nepal Mission to the CSISA COVID-19 Response and Resilience Activity. It also supported the Fighting Fall Armyworm Activity and CSISA-MEA (the second phase of the CSISA-MI Activity). The latter was awarded in 2019 by USAID/Bangladesh which works in synergy with CSISA.

Feed the Future partners

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

Rice and Diversified Crops Activity. 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 FtF ZoI 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.

Fighting Fall Armyworm in Bangladesh. Supported by the University of Michigan and USAID, this Activity cooperates with national research and extension partners, Centre for Agriculture and Bioscience International (CABI) and Food and Agriculture Organization (FAO) to strengthen efforts to mitigate impact of the pest on farmers' income, food security and health. It is supported in kind by CSISA Phase III. The Activity works to (1) develop educational materials to help reach audiences with information to improve understanding and management of Fall Armyworm, (2) support DAE in the deployment of awareness-raising and training campaigns, (3) encourage institutional change to improve crop protection and extend integrated pest management, (4) prepare the private sector for appropriate FAW response, (5) support the development of a Bangladesh standing multi-threat pest emergency taskforce, and (6) generate data and evidence to guide integrated FAW management. The Activity spans 2019–21 and was completed on June 2021.

Cereal Systems Initiative for South Asia Mechanization and Extension Activity. Building on the successes of the CSISA–MI Activity, the FtF Bangladesh Cereal Systems Initiative in South Asia Mechanization Extension Activity (CSISA–MEA) began on 1 October, 2019. It has three main objectives, namely, to (1) increase the competitiveness and efficiency of domestic and private sector-led agricultural machinery manufacturing, assembly, use and servicing, (2) enhance institutional capacity for agricultural mechanization through the development of a skilled and youth workforce, and (3) facilitate the widespread uptake of sustainable intensification practices in Rohingya refugee-impacted communities in south-eastern Bangladesh. Through activities

[24] A full list of partners and details can be found in Annex II.

designed to meet these objectives, the Activity aims to address a number of challenges faced by the light engineering sector involved in the manufacture of agricultural machinery and spare parts. These include poor manufacturing processes, use of old and inefficient manufacturing equipment, limited supply of good quality materials, limited access to appropriate financial services, and low levels of workforce skills.

The Nepal Seed and Fertilizer (NSAF) project (2016–21) is a USD15 mio 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: (1) greater climate-smart intensification of staple crops and diversification into higher value commodities, (2) strengthening local market systems to support more competitive and resilient value chains and agricultural related businesses, and (3) 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.

The Feed the Future Nutrition Innovation Lab. The FtF Nutrition Innovation Laboratory pursues applied research that supports the goals of USAID's Feed the Future initiative, builds institutional capacity for analysis and policy formulation in developing countries, and offers scholarships that support individual capacity development through formal degree education in the United States and elsewhere. Tufts University's Friedman School of Nutrition Science and Policy has served as the Management Entity for USAID's Nutrition Innovation Laboratory since October 2010. Tufts manages the activities of the Lab and conducts research in close partnership with several US university partners. CSISA collaborates with the Nutrition Innovation Laboratory in the analysis of survey data and modeling of the intrahousehold nutritional status implications of agricultural development interventions in Bangladesh.

The Feed the Future Sustainable Intensification Innovation Lab (SIIL). Since 2015, Kansas State University (KSU) and International Rice Research Institute (IRRI) in collaboration with Sustainable Intensification Innovation Lab (SIIL) and other national research and development agencies have been working in the coastal zones of Bangladesh. The FtF SIIL is a USAID-funded program that supports research, knowledge sharing, and capacity-building in relation to smallholder farming systems, and increasing ecological intensification for the production of food, fiber, and other products in Asia and Africa. From the fourth reporting quarter of the 2019–20 period, CSISA has initiated a collaboration with the SIIL 'Pathways of scaling agricultural innovations for sustainable intensification in the polders of coastal Bangladesh' project (SIIL-Polder Project: phase II) in screening fodder species for tolerance and growth in salt-affected soils in coastal Bangladesh.

The Feed the Future Innovation Lab for Small-Scale Irrigation (ILSSI). Based at Texas A&M University, ILSSI is a research-for-development project that aims to expand farmer-led, small-scale irrigation, principally in Ethiopia, Ghana, Mali, and Tanzania. Sustainable, profitable, and gender sensitive irrigation contributes to agricultural growth, resilient food systems, and better nutrition and health, particularly for vulnerable populations. Now in its second phase (2019–23), ILSSI is working to identify the best ways to expand the use of small-scale irrigation within environmentally sustainable limits. ILSSI is a part of the U.S. Government's Feed the Future Initiative. With the new CSISA/Nepal buy-in to the CSISA program – with the CSISA COVID-19 Resilience Activity – the ILSSI team has begun to work on hydrological modeling with a focus on working towards the development of a sustainable irrigation development strategy for the FtF Zone in Nepal.

Activity 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 Activity 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 have achieved can be found throughout this report, particularly in the sections for Bangladesh and Nepal.

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:

Bangladesh Rice Research Institute (BRRI) was founded in 1970 and is the country's apex rice research body. BRRI assists the Activity with the following:

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

The Bangladesh Wheat and Maize Research Institute. The Activity's agreement with BWMRI, established in 2019, has established a cooperative and mutually beneficial relationship for carrying out activities with CIMMYT on the following topics:

- germplasm exchange, development, delivery, intensification and diversification
- promoting sustainable intensification-based conservation agriculture crop management and improved seed system farm equipment and machinery
- addressing socio-economic and policy constraints that affect the adoption of new technologies
- mainstreaming gender concerns in research for development
- building the capacity of national scientists and partners through training
- engaging the private sector on value chain and market development to benefit maize and wheat farmer.

- CSISA leverages this agreement and cooperates with BWMRI on all wheat-related work in Bangladesh that the project focuses on.

The Bangladesh Department of Agricultural Extension (DAE). The vision of DAE, under the Ministry of Agriculture, is to provide eco-friendly, safe, climate resilient and sustainable productive good agricultural practices while sustaining natural resources, to ensure food security as well as commercial agriculture, with a view to accelerating the country's socioeconomic development. DAE's mission is to provide efficient, effective, decentralized, location-specific, demand-responsive and integrated extension services to all categories of farmer, supporting them to access and utilize better knowhow to increase sustainable and profitable crop production. CSISA collaborates widely with DAE on a range of initiatives and activities in Bangladesh, detailed in this report.

Syngenta Bangladesh Limited Over 50 years, Syngenta Bangladesh Ltd. is working in agricultural sector in Bangladesh. The Activity signed subgrant agreement on October 2020 and completed on June 2021. The objective of this agreement to promote, educate market actors and farmers and establish demonstration on bio pest control agent-Fortenza.

Ispahani Agro Limited One of the reputed agricultural organizations operating since 2007. Pioneer in Biotech Products - Bio-Pesticides, Bio-based lures, Pheromone Traps, Seeds and Agro processing products. Ispahani Agro Limited worked with the Activity from July 2020 to May 2021 to create demand for Fawligen (bio-rational based pest management), educate market actors and farmers, and participate in national taskforce workshop.

University of Manchester, United Kingdom. Since 2019, CSISA has collaborated in a research capacity with Dr Tim Foster, lecturer in Water-Food Security at University of Manchester, to optimize the technical and social acceptability of irrigation in Nepal Tarai.

International Water Management Institute (IWMI) is a non-profit research organization with headquarters in Colombo, Sri Lanka, and offices across Africa and Asia. Research at the Institute focuses on improving how water and land resources are managed with the aim of underpinning food security and reducing poverty while safeguarding vital environmental processes. With the new CSISA/Nepal buy-in to the CSISA Activity – with the CSISA COVID-19 Resilience Activity – the IWMI team in Nepal has been engaged in working towards the development of a sustainable irrigation development strategy for the FtF Zone in Nepal.

Details of partners' achievements during the reporting period are given throughout the report, principally in Chapters 2 and Chapter 3. Please see Annex 3 for details of Activity subcontractors and key partners.

Annex 1: Publications and media produced by CSISA in 2020-2021

PEER-REVIEWED PAPERS & REVIEWED PUBLICATIONS

1 Nayak, H.S., Silva, J.V., Parihar, C.M., Karkralia, S.K., Krupnik, T.J., Bijarniya, D., Jat, M.L., Sharma, P.C., Jat, H.S., Sidhu, H.S., Sapkota, T.B. (2021) Rice yield gaps and nitrogen-use efficiency in the Northwestern Indo-Gangetic Plains of India – Evidence based insights from heterogenous farmers' practices. Field Crops Research. Accepted: In press.

2 Simon, W.J., Krupnik, T.J., Aguilar-Gallegos, N., Halbherr, L., Groot, J.C.J. (2021) Putting social networks to practical use: Improving last-mile dissemination systems for climate and market information services in developing countries Climate Services. 23: 100248. Available Online: Click here.

3 Emran, S., Krupnik, T.J., Aravindakshan, S., Kumar, V., Pittelkow, C.M. (2021) Factors contributing to farm-level productivity and household income generation in coastal Bangladesh's rice-based farming systems. PLOS One. https://doi.org/10.1371/journal.pone.0256694. Available online: Click here.

4 Foster, T., Adikhari, R., Adikhari, S., Justice, S., Tiwari, B., Urfels, A. Krupnik, T.J. (2021) Improving pumpset selection to support intensification of groundwater irrigation in the Eastern Indo-Gangetic Plains. Agricultural Water Management. 256: 107070. Available online: Click here.

5 Ahmed, S., Kumar, V., Alam, M., Rahman D.M., Bhuiya, K.A., Miajy, A.A., Saha, A., Singh, S., Timsina, J., Krupnik, T.J. (2021) Integrated weed management in transplanted rice: Options for addressing labor constraints and improving farmers' income in Bangladesh. Accepted: *In press*.

6 Sapkota, T.B., Khanam, F., Mathivanan, G.P., Vetter, S., Hussain, G., Pilat, A-L., Shahrin, S., Hossain, K., Sarker, N.R., Krupnik, T.J. (2021) Spatially explicit database on crop-livestock management, soil, climate, greenhouse gas emissions and mitigation potential for all of Bangladesh. Data in Brief. 13:107225. Available online: Click here.

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Annex 3: 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. The second Sub-grant letter for "Purchase of Truthfully Lebel Seeds (TLS) of blast resistant wheat variety BARI Gom 33 for strengthening farmers to farmers seed promotion" in 2020–21.
Bangladesh Rice Research Institute (BRRI)	Development, validation, and refinement of technologies and new research methods, boosting scaling	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	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.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	capacity		Government of Bangladesh's National Agriculture Research System.	
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 Activity in Bangladesh in the Feed the Future zone and Dinajpur hub. The sensitization of DAE agents to 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 Activity continues to collaborate with DAE informally and synergistically, despite funding cuts. The volume of activities was reduced in the reporting period due to the Activity's inability to support large field campaigns and collaborative meetings with DAE. CIMMYT also worked with DAE through CSRD and USAID/Bangladesh mini-grant on wheat blast that closed in September 2019. As a part of project activities, DAE works with CIMMYT to disseminate better bet agronomic practices. In this period, DAE spread messages developed by CIMMYT, BARI and BWMRI on EWS and fighting wheat blast, fighting back against FAW and mung bean cultivation.
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 screenings and training on healthy rice seedlings and early wheat sowing in 2020. The Activity is exploring further opportunities to work with AIS to disseminate better bet practices among farmers.
Bangladesh Meteorological Department (BMD)	Conduct collaborative research and development activities related to weather,	Achieving impact at scale	BMD provides clientele services related to weather and climate to more than 100 national and international organizations. It has a network of meteorological stations across the country, and	BMD completed a sub-grant during 2017–19. After completion, the collaboration continues under the Memorandum of Understanding signed on September 15, 2019.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	agro-climatology and climate services, and undertake programs for strengthening the capabilities and dissemination of useful research findings, advisories and technologies within Bangladesh.		BMD-generated weather forecasts are used in the field of agriculture by GOs and NGOs to provide agro-meteorological advisory services to farmers.	
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.
The 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.
Advanced Chemical	Sale of scale-appropriate machinery,	Achieving impact at	Import of sustainable intensification scale-appropriate machinery and sales through the	The commercial joint venture agreement with this firm was terminated in 2017 due to funding

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Industries (ACI)	fungicides, weed control products and seed. IRRI works with ACI to produce a range of hybrid and open-pollinated rice seeds	scale	private sector, along with a range of chemical and cereal seed products.	uncertainties and fund transfer delays to CSISA from USAID. Since then however, CSISA has maintained active discussions with this partner and could re-establish relations if USAUD can provide clear funding timing and commitments.
Ispahani Agro Limited	Scale-up the commercialization of the recently registered biological product Fawligen, SfNPV, a highly specific natural pathogen as well as other biological products against the invasive pest Fall Armyworm	Achieving impact at scale	The agreement covers 10+ activities (e.g. TOT for sales teams, video development and screening, promotional material development and disbursement, crop consultant program, IPM championship program, educational and marketing campaign, dealers, retailers and farmers training, advertisements such as those put out by road shows) aimed at rapid commercialization of the product.	The 1:1 matched fund agreement with IAL started on August 2020 and ended on June 2021.
Syngenta Bangladesh Limited	Awareness raising to assist in the rapid commercialization of Fortenza 60FS (Cyntraniliprole) a low-toxic seed treating agent against FAW.	Achieving impact at scale	There are several activities specially to provide technical support to Syngenta by training their channel line dealers and village-level sales and commission agents on different aspects of FAW. Also video development and showing, promotional material development and disbursement, dealers, retailers and farmers training etc. included in the agreement that aim for a rapid commercialization of that product.	The 1:1 matched fund agreement with this company began on October 2020 and ended on June 2021.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Auto Crop Care Limited (ACCL)	Commercialization of safe and less toxic herbicide molecules found through on-farm research as well as creating awareness among farmers through on-farm demonstrations, make the safe herbicide molecules available with the local input dealers.	Achieving impact at scale	Sales of less toxic and safe herbicide molecules, including safety equipment increase.	CSISA and ACCL's partnership started at the beginning of the *boro* season 2019–20 (November 2019).
SRIZON AGRO, Saidpur, Nilphamari	In collaboration initiatives through private sector and seed company and CSISA project to expand PQR involving farmers groups targeting total 10000 tons new PQR production aiming a sustainable mechanism after existing CSISA III. This collaboration will focus on 3400 ton new PQR production in	Achieving impact at scale	To increase PQR quality seed production through this seed company, No. of PQR farmers increase through locally PQR seed selling, expansion of PQR new varieties specially BRRI dhan50, BRRI dhan63 in Boro & BRRI dhan34, BRRI dhan75 and BRRI dhan87 in Aman, development of a sustainable development among all stakeholders (Miller, LSP, DAE, private sectors etc.) through CSISA & company collaboration activities.	CSISA and SRIZON AGRO's partnership started at the beginning of Boro season 2020 and continue till now.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	Rangpur, Nilphamri, Dinajpur and Thakurgoan district.			
J.R Agro, Chotokollani, Mahigonj, Rangpur	In collaboration initiatives initiative through private sector and seed company and CSISA project to expand PQR involving farmers groups targeting total 10000 tons new PQR production aiming a sustainable mechanism after existing CSISA III. This collaboration will focus on 3400 ton new PQR production in Rangpur, Nilphamri, Dinajpur and Thakurgoan district.	Achieving impact at scale	To increase PQR quality seed production through this seed company, No. of PQR farmers increase through locally PQR seed selling, expansion of PQR new varieties specially BRRI dhan50, BRRI dhan63 in Boro & BRRI dhan34, BRRI dhan75 and BRRI dhan87 in Aman, development of a sustainable development among all stakeholders(Miller, LSP, DAE, private sectors etc.) through CSISA & company collaboration activities.	CSISA and J.R AGRO's partnership started at the beginning of Boro season2020-21(November, 2021) and continue till now.
One X crop care er "Square Seed"	Premium quality rice (PQR) expansion considering large scale famers, availability of premium quality seeds in local level farmers, sustainable linkage	Achieving impact at scale	This activity increases farmers' profits from rice farming targeting all stakeholder's proper involvement.	Agreement between CSISA and One X crop care er "Square Seed" started on 1 November 2020 and will end on 31 December 2021.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	building among the local level stakeholders.			
Friends Seeds Company Ltd.	Premium quality rice (PQR) expansion considering large scale famers, availability of premium quality seeds in local level farmers, sustainable linkage building among the local level stakeholders.	Achieving impact at scale	This activity increases farmers' profits from rice farming targeting all stakeholder's proper involvement.	Agreement between CSISA and Friends Seeds Company Ltd. started on 1 November 2020 and will end on 31 December 2021.
Konika Seed Company (Pvt.) Ltd.	Premium quality rice (PQR) expansion considering large scale famers, availability of premium quality seeds in local level farmers, sustainable linkage building among the local level stakeholders.	Achieving impact at scale	This activity increases farmers' profits from rice farming targeting all stakeholder's proper involvement.	Agreement between CSISA and Konika Seed Company (Pvt.) Ltd. started on 1 November 2020 and will end on 31 December 2021.
Modern Seeds Agro (Pvt.) Limited	Premium quality rice (PQR) expansion considering large scale famers, availability of	Achieving impact at scale	This activity increases farmers' profits from rice farming targeting all stakeholder's proper involvement.	Agreement between CSISA and Modern Seeds Agro (Pvt.) Limited started on 1 November 2020 and will end on 31 December 2021.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	premium quality seeds in local level farmers, sustainable linkage building among the local level stakeholders.			
Uzirpur Organic Multipurpose Cooperative Society Ltd	Premium quality rice (PQR) expansion considering large scale famers, availability of premium quality seeds in local level farmers, sustainable linkage building among the local level stakeholders.	Achieving impact at scale	This activity increases farmers' profits from rice farming targeting all stakeholder's proper involvement.	Agreement between CSISA and Uzirpur Organic Multipurpose Cooperative Society Ltd started on 1 November 2020 and will end on 31 December 2021.
Adarsho Chashi Ghar	Premium quality rice (PQR) expansion considering large scale famers, availability of premium quality seeds in local level farmers, sustainable linkage building among the local level stakeholders.	Achieving impact at scale	This activity increases farmers' profits from rice farming targeting all stakeholder's proper involvement.	Agreement between CSISA and Adarsho Chashi Ghar started on 1 November 2020 and will end on 31 December 2021.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
INSAF SEED	In a collaborative initiative through private sector/seed company and CSISA project to expand premium quality rice (PQR) involving farmer's groups targeting 5,000 tons seed production aiming a sustainable mechanism after exit of CSISA-PIII project.	Achieving impact at scale	Expand premium quality rice (PQR) involving INSAF SEED farmer's groups through quality PQR seed production and ensure availability in the market.	This agreement to collaborate be effective from 1 November 2020 to 31 December 2021 and may be renewed further up to mutual agreement.
NUR SEED	In a collaborative initiative through private sector/seed company and CSISA project to expand premium quality rice (PQR) involving farmer's groups targeting 5,000 tons seed production aiming a sustainable mechanism after exit of CSISA-PIII project.	Achieving impact at scale	Increase premium quality rice (PQR) through farmer's group of NUR SEED in view to availability of PQR seed through BADC and different seed's agents.	This agreement to collaborate be effective from 1 November 2020 to 31 December 2021 and may be renewed further up to mutual agreement.
NGOs				

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
Agricultural Advisory Society (AAS) (project subcontractor)	Facilitates village screenings of training films and conducts follow-up studies	Achieving impact at scale	The Activity 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 Activity sub-grants to conduct village-level video shows and to train farmers on core CSISA topics. In the previous reporting year, AAS organized a total 1,080 video shows in 921 villages watched by 132,358 farmer audiences. Video content was on healthy rice seedling, early wheat sowing and awareness FAW.
Agro-Input Retailers Network (AIRN) (project subcontractor)	Trains input dealers and retailers	Achieving impact at scale	AIRN was awarded sub-grants in 2018/19 to (1) train AIRN dealers in principles and practices of integrated weed management, and (2) equip them to fight the threat FAW.	Partnering with the Activity, AIRN trained input dealers on the principles and practices of integrated weed management and FAW management. In the reporting year, AIRN provided FAW training to 42 batches (total 1,047) of agro input dealers in 9 districts. Training covered FAW management: an introduction, its life cycle, IPM usage and methods, monitoring system and pesticide use.
Universities				
Department of Crop Sciences, 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 to produce two papers using CSISA data.	Ongoing successful partnership.

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of 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 papers 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	BAU is Bangladesh's largest agricultural university, with strong influence over the next generation of agricultural scientists, many of who will go on to work in BARI, BRRI and DAE.	The relationship with this university continued informally. Increased collaboration on fall armyworm control is under way at the time of reporting.
Tufts university	Modelling linkages of farming systems to nutritional deficiencies in Bangladesh.	Innovation towards impact	Collaboration allows sharing of data and methodological expertise in assessing diets of rural households of southern Bangladesh for nutrition deficiencies and study linkages to farming systems (as well as markets). It offers insights on nutritional outcomes from agricultural investment relevant to national and international programmes and policies.	Active since 2020.
Projects				
Sustainable and Resilient Farming Systems Intensification in	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	Active partnership since 2014

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
the Eastern Gangetic Plains (SRFSI)			International Agriculture Research (ACIAR)-funded project is scaling up these activities. CSISA supports NARC and other SRFSI partners to spread its technologies.	
Cereal Systems Initiative for South Asia – Manufacturing Systems Activity (CSISA-MEA)	CSISA-MEA will support Bangladeshi manufacturing firms to (1) develop well-structured business cases that describe the business problem and opportunities to be addressed, (2) articulate alternative solutions, (3) identify potential costs and benefits, and (4) identify the motivations and incentives for businesses to adopt the most suitable one for them, if any	Achieving impact at scale	The CSISA-MEA project through its Manufacturing Systems Activity will work with micro-, small- and medium-sized businesses in the agricultural machinery manufacturing sector in Bangladesh to research and develop business cases for four distinct scenarios: (1) larger companies with dealership networks that will adopt a business model to assemble machines from parts made by smaller companies (OEM-supplier network), (2) larger manufacturing firms venturing into the domestic manufacture, assembly and/or spare parts production of more complex agricultural machines, such as combine harvesters, (3) all sized firms that will domestically manufacture a wider range of spare parts as a means to reduce dependency on expensive imported parts, and (4) the feasibility of manufacturing for export machines, such as threshers, by all sized firms that must meet export standards. 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 direct-	Active since 2019

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
			seeded rice aligning with CSISA-MEA Objective 4.	
Rice and Diversified Crops (RDC) Activity	RDC is led by ACDI-VOCA and is working to (1) improve food security through systemic changes that increase rural incomes, (2) increase farm productivity, and (3) increase farmers' participation in profitable market systems	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 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.	Active since 2016. CSISA Phase III is in discussions with RDC regarding collaboration on integrated weed management and linkages with the 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 USD100 million.	Active and sanctioned by CIMMYT's host country agreement
Nepal Agricultural Research Council (NARC)	Strategic and applied research on sustainable intensification	Innovation towards impact	NARC is responsible for providing the scientific basis for all state recommendations, their endorsement	Active and long-standing

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	technologies, crop diversification, and crop management practices		and the ownership of emerging sustainable intensification technologies.	
Provincial government	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 government	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
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-	Achieving impact at scale	The rapid expansion of investments in scale-appropriate machinery and support for emerging	Active and long-standing

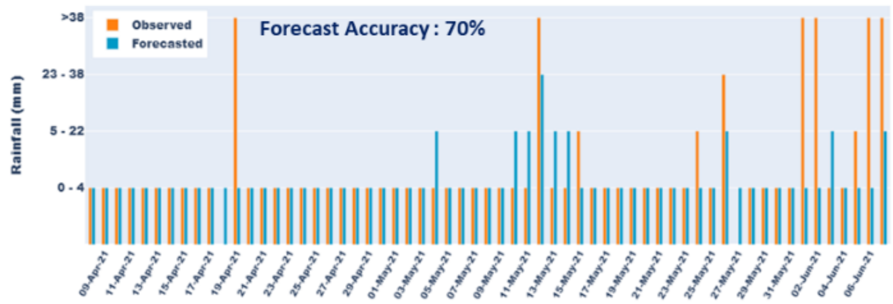
Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	appropriate machinery		service provision markets.	
Dahal (farm machinery importer and dealer)	Introduction and market development of scale-appropriate machinery	Achieving impact at scale	The rapid expansion 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
Muktinath Bikas Bank Ltd. (MNBBL)	Access to finance	CSISA-COVID Response	Developing risk-reducing financial services arrangements that could facilitate increased access to loans for agricultural machinery.	Active since 2020
Nabil Bank	Access to finance	CSISA-COVID Response	Developing risk-reducing financial services arrangements that could facilitate increased access to loans for agricultural machinery.	Active since 2020
MegaBank	Access to finance	CSISA-COVID Response	Developing risk-reducing financial services arrangements that could facilitate increased access to loans for agricultural machinery.	Active since 2020
Century Commercial Bank	Access to finance	CSISA-COVID Response	Developing risk-reducing financial services arrangements that could facilitate increased access to loans for agricultural machinery.	Active since 2020
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	Systemic change towards	Important voice for the private sector with GoN as Agriculture Development Strategy support programs	Active and long-standing

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
	enabling environment and policy dialogue for strengthening seed system and small and medium seed enterprises in Nepal	impact	take shape. Provided input to studies on maize hybrids in Nepal	
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
Tribhuvan University	Strengthening groundwater monitoring and governance and assessing safe operating space from hydrogeological perspective	Coping with climate variability and COVID19 Resilience Groundwater Monitoring	Collaboration with local research institutions establishes strong local science-policy linkage, builds capacity and institutionalizes novel governance mechanisms to strengthen innovations and policy solution networks in a rapidly changing political environment.	Active
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 initiative, is a USD 20 mio 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	Active since KISAN's first phase

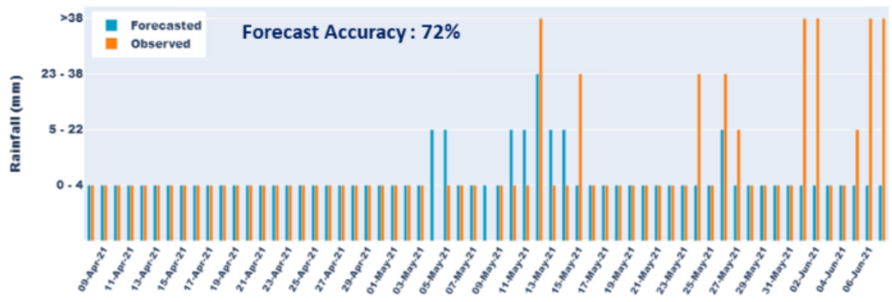
Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of partnership
			and exposes them to CSISA information, materials, and technologies.	
Nepal Seed and Fertilizer Project (NSAF)	Strategic partnership to co-support the large-scale deployment of extension information and technologies	Achieving impact at scale	The USAID Nepal-funded NSAF project (USD 15 mio for 2016–21) 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
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

Annex 4: Below graphs present forecasted vs. observed rainfall events during mung bean harvesting season in seventeen separate unions of Patuakhali district in Bangladesh

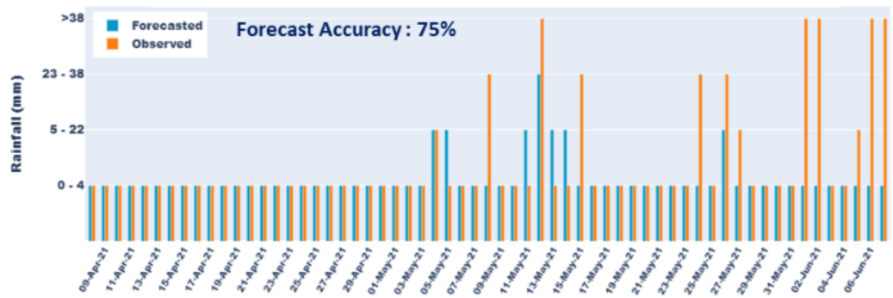
Forecasted Vs Observed Rainfall (Union:Ababaria)



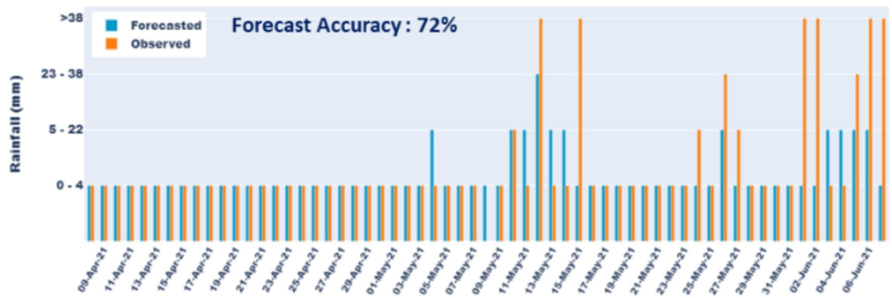
Forecasted Vs Observed Rainfall (Union: Amkhala)



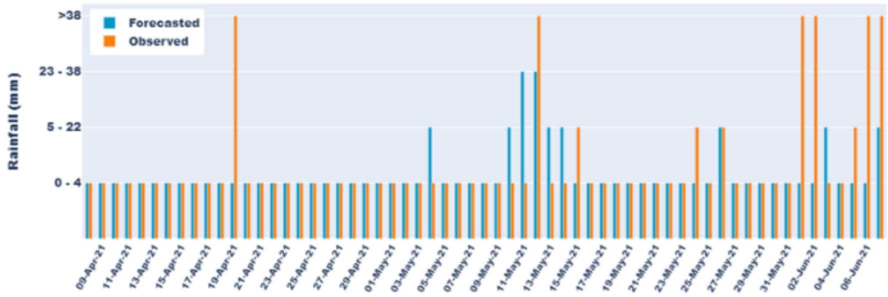
Forecasted Vs Observed Rainfall (Union: Atharagashia)



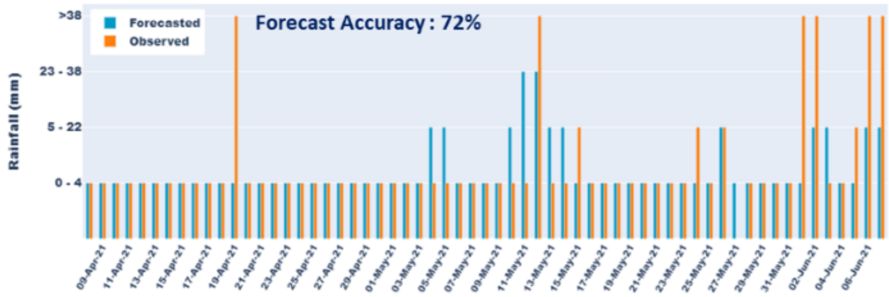
Forecasted Vs Observed Rainfall (Union: Badarpur)



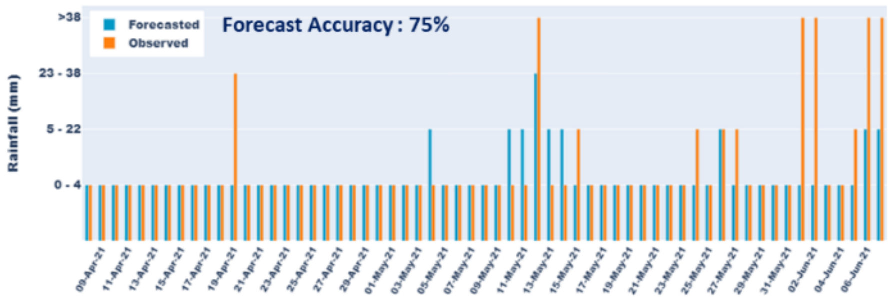
Forecasted Vs Observed Rainfall (Union: Baga)



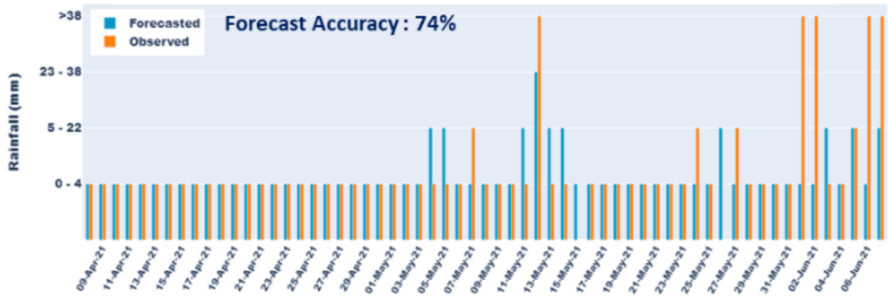
Forecasted Vs Observed Rainfall (Union: Bauphal)



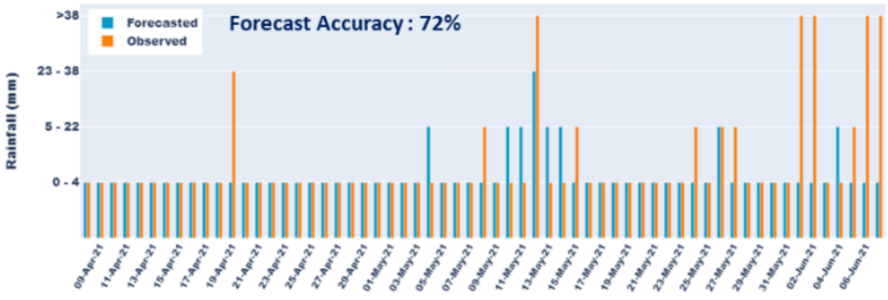
Forecasted Vs Observed Rainfall (Union: Betagi Sankipur)



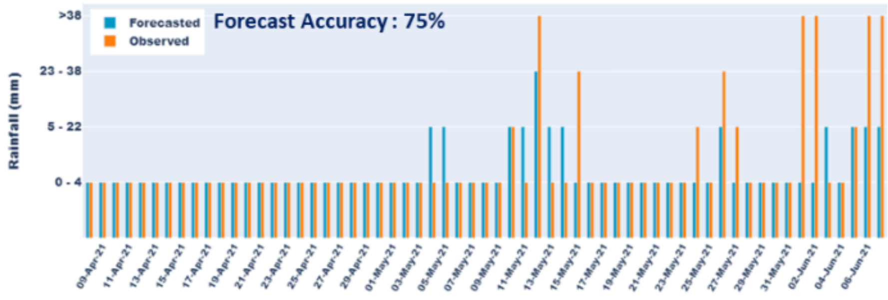
Forecasted Vs Observed Rainfall (Union: Boro Bighai)



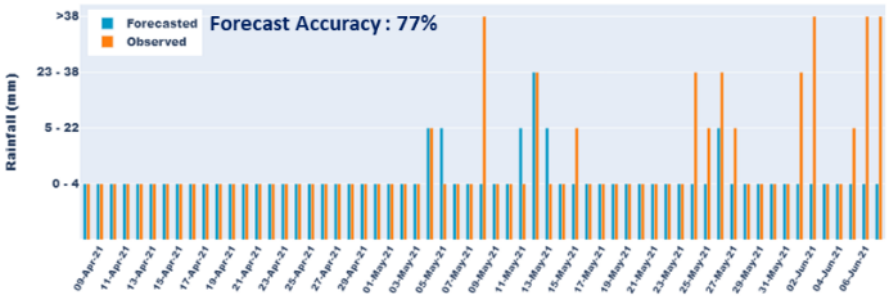
Forecasted Vs Observed Rainfall (Union: Chiknikandi)



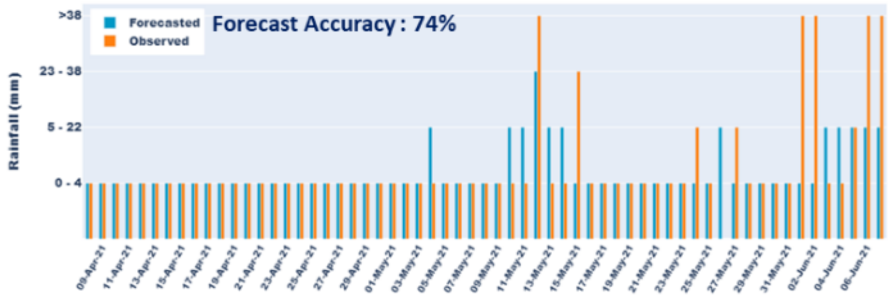
Forecasted Vs Observed Rainfall (Union: Choto Bighai)



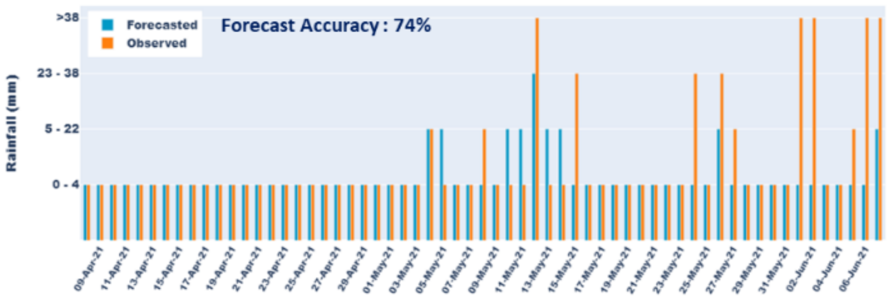
Forecasted Vs Observed Rainfall (Union: Gulisakhali)



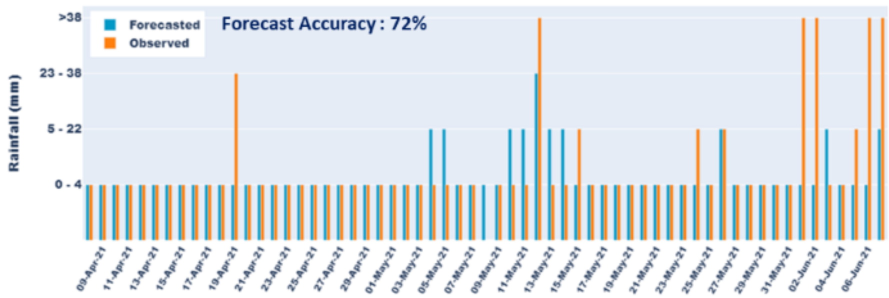
Forecasted Vs Observed Rainfall (Union: Itbaria)



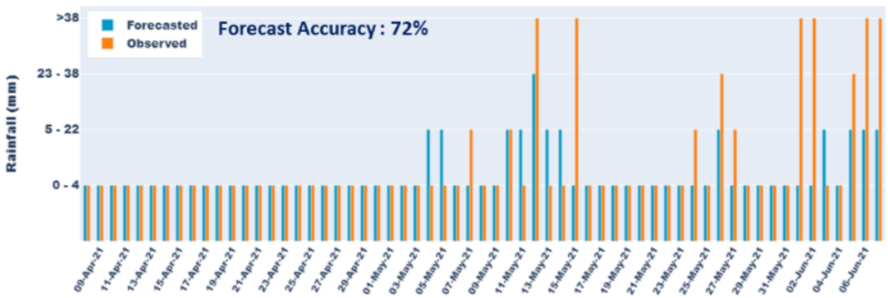
Forecasted Vs Observed Rainfall (Union: Kalagachia)



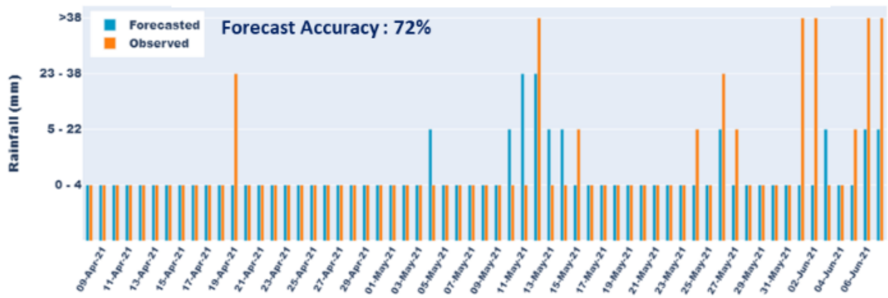
Forecasted Vs Observed Rainfall (Union: Kamalapur)

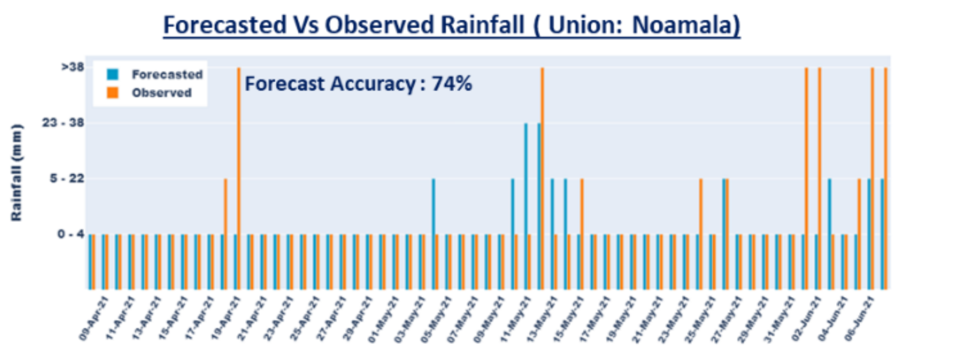


Forecasted Vs Observed Rainfall (Union: Madarbunia)



Forecasted Vs Observed Rainfall (Union: Muradia)





Above: Forecasted and observed rainfall data analysis in seventeen (17) unions during the mung bean harvesting season (April 2021–June 2021).

Annex 5: Results from each year of the mult-locationtrials on the response of new wheat varieties to different seeding dates

Yield of wheat varieties as affected by sowing dates in three locations during the 2017-18 wheat season.

Treatments	Grain yield (kg/ha)							
	V1	V2	V3	V4	V5	V6	Mean	CV (%)
				Dinajpur				
S1	4881.66a	4773.66a	4599.66ab	4481.00a	4804.00a	5153.00a	4782.16A	
S2	4463.66a	3877.00b	5015.00a	4287.66ab	4680.66ab	4696.00a	4503.33A	
S3	3284.66b	3936.33b	4085.33bc	4049.33ab	4217.33b	3977.66b	3925.11AB	9.12
S4	3404.00b	3637.00b	3595.33cd	3775.00b	3288.00c	3246.33c	3490.94B	
S5	2857.33b	2568.66c	3127.66d	2883.00c	3119.33c	3229.66c	2964.27C	
Mean	3778.262B	3758.53B	4084.596A	3895.198AB	4021.864A	4060.53A		
CV (%)	Interaction and sub-plot CV (%) 8.44							
				Rajshahi				
S1	2492.00	2776.66	3108.66	2918.66	3162.00	2707.00	2860.83A	
S2	2536.66	3016.33	2509.00	2909.33	2940.00	2478.66	2731.67A	
S3	3538.00	2809.00	3077.66	2974.33	2946.00	3535.66	3146.78A	15.27
S4	2114.33	2773.66	2999.00	2502.06	2227.66	2650.66	2661.33A	
S5	1703.00	1996.33	1577.66	1608.00	1648.66	1623.33	1692.83B	
Mean	2476.798	2674.396	2654.396	2582.476	2584.864	2599.062		
CV (%)	Interaction and sub-plot CV(%) 35.95							
				Jashore				
S1	2635.66b	2617.33a	2989.66a	2750.00a	2777.33b	2312.66b	2680.44AB	
S2	3185.33a	2527.00a	3085.66a	2941.66a	3535.33a	2656.66ab	2988.61A	
S3	2398.00b	2720.66a	3235.66a	2981.66a	3371.00a	2842.00a	2924.83A	12.80
S4	2398.00b	2720.66a	3235.66a	2981.66a	3371.00a	2842.00a	2924.83A	
S5	1141.66c	1796.00b	2458.66b	1433.33b	2002.00c	1781.66c	1768.89B	
Mean	2351.73B	2476.33B	3001.06A	2617.66AB	3011.33A	2486.99B		
CV (%)	Interaction and sub-plot CV (%) 11.93							

V1, BARI Gom 26'; V2, 'BARI Gom 28'; V3, 'BARI Gom 30'; V4, 'BARI Gom 31'; V5, 'BARI Gom 32' and V6, 'BARI Gom 33'. S1, 25
Nov.; S2, 05 Dec.; S3, 15, Dec.; 25 Dec. and 04 Jan.

Yield of wheat varieties as affected by sowing dates in three locations during the 2018-19 wheat season.

Treatments	Grain yield (kg/ha)							
	V1	V2	V3	V4	V5	V6	Mean	CV (%)
				Dinajpur				
S1	3725.33b	4378.00ab	4598.00ab	4139.33a	4089.00a	4089.00a	4169.78	
S2	4942.67a	5197.00a	5398.00a	4417.67a	4298.67a	4298.67a	4758.78	
S3	4864.67a	4645.67ab	4874.67ab	4279.67a	4979.67a	4979.67a	4770.67	22.92
S4	3893.00b	4089.67b	4002.67b	3887.67a	4155.67a	4155.67a	4030.73	
S5	3517.67b	4006.00b	4425.00b	4585.00a	4197.67a	4197.67a	4154.84	
Mean	4188.67	4463.27	4659.67	4261.87	4344.14	4344.14		
CV (%)	Interaction and sub-plot CV(%) 8.13							
				Rajshahi				
S1	3976.66	3886.66	4193.33	4210.00	4290.00	3661.66	4036.39BC	
S2	4253.33	4555.00	4506.66	4514.00	4170.00	3863.33	4310.56AB	
S3	4466.66	4766.66	4566.66	4100.00	4733.33	4400.00	4505.56A	14.29
S4	3900.00	4133.33	3533.33	3600.00	3833.33	3500.00	3750.00C	
S5	2933.33	3166.66	2966.66	2600.00	3433.33	3100.00	3033.33D	
Mean	3905.996	4101.662	3953.328	3804.8	4091.998	3704.998		
CV (%)	Interaction and sub-plot CV(%) 11.99							
				Jashore				

S1	4863.33	4116.66	3903.33	2231.66	2073.33	2000.00	3198.06A	
S2	3911.66	4038.33	3518.33	2103.33	1173.33	2076.66	2803.61BC	
S3	4300.00	3838.33	2196.66	3248.33	2261.66	1748.33	2932.22AB	13.47
S4	5166.66	3758.33	2763.33	1811.66	2210.00	1726.66	2906.11AB	
S5	4835.00	3288.33	2135.00	1996.66	1570.00	1606.66	2571.94C	
Mean	4615.33A	3808.00B	2903.33C	2278.33CD	1857.67D	1831.67D		
CV (%)	Interaction and sub-plot CV(%) 25.28							

V1, BARI Gom 26'; V2, 'BARI Gom 28'; V3, 'BARI Gom 30'; V4, 'BARI Gom 31'; V5, 'BARI Gom 32' and V6, 'BARI Gom 33'. S1, 25
Nov.; S2, 05 Dec.; S3, 15, Dec.; 25 Dec. and 04 Jan.

Yield of wheat varieties as affected by sowing dates in three locations during the 2019–20 wheat season.

Treatments	Grain yield (kg/ha)								
	V1	V2	V3	V4	V5	V6	V7	Mean	CV (%)
	Dinajpur								
S1	5954.66a	5454.66a	5913.00a	5750.00a	6098.00a	5619.00a	5427.33a	5745.24	
S2	5700.33a	5570.00a	5810.00a	5722.00a	5464.33b	5378.00ab	5555.00a	5599.95	
S3	4218.00b	4678.00b	5007.33b	4380.00b	4510.00c	4960.00b	5148.33a	4700.24	15.12
S4	4106.66b	3860.66c	4685.33bc	3793.66b	4194.33c	4339.66c	4992.00b	4281.76	
S5	3757.00b	3341.33c	4313.00c	3868.66b	4355.66c	4192.00c	3250.66c	3868.33	
Mean	4747.33	4580.93	5145.732	4702.864	4924.464	4897.732	4874.664		
CV (%)	Interaction and sub-plot CV(%) 5.08								
	Rajshahi								
S1	5266.66a	5400.00a	5266.66a	5466.66a	5900.00a	5916.66a	5466.66a	5526.19	13.66
S2	3700.00b	3933.33b	3700.00b	5366.66a	5066.66b	5066.66b	4866.66b	4528.57	
S3	3100.00c	3266.66c	3966.66b	3166.66b	3166.66c	4100.00c	3733.33c	3500.00	
S4	1966.66d	1700.00d	2466.66c	2100.00d	3500.00c	2833.33d	2766.66d	2476.19	
S5	1000.00e	1500.00d	2600.00c	2666.66c	1733.33d	2333.33e	1866.66e	1957.14	
Mean	3006.66	3160.00	3600.00	3753.33	3873.33	4050.00	3739.99		
CV (%)	Interaction and sub-plot CV (%) 6.82								
	Jashore								
S1	4383.33a	5230.00a	4341.66a	4461.66a	5246.66a	4924.00a	4640.00a	4746.76A	
S2	2770.00b	3570.66b	3686.66b	3683.33b	4990.00a	4176.66b	2860.00c	3676.76A	
S3	1416.66c	1762.00d	2163.33d	1705.00d	3093.33b	3186.66c	2048.33d	2196.47B	8.54
S4	2624.66b	2920.00c	3255.00c	2520.00c	3433.33b	2715.66d	3451.66b	2988.62B	
S5	785.00d	725.00e	1560.00e	1303.33e	1313.33c	1915.00e	411.66e	1144.76C	
Mean	2395.93	2841.532	3001.33	2734.664	3615.33	3383.596	2682.33		
CV (%)	Interaction and sub-plot CV (%) 7.50								

In the third year (2019–20) seven wheat varieties (six + newly released WMRI Gom 1). S1, 25 November; S2, 5 December; S3, 15 December; 25 December and 4 January.

Yield of wheat varieties as affected by sowing dates in three locations during the 20-21 wheat season.

Treatments	Grain yield (kg/ha)								
	V1	V2	V3	V4	V5	V6	V7	Mean	CV (%)
	Dinajpur								
S1	5001.00a	5372.33a	4595.00a	4596.00a	4495.33a	4546.66a	4392.00a	4714.05	
S2	4643.00ab	5377.00a	4592.00a	4608.33a	4358.33ab	4388.00a	3971.33ab	4562.57	
S3	4519.66b	4185.00b	4025.33b	3829.00b	4037.33bc	3803.66b	3572.33bc	3996.04	7.20
S4	4054.00c	3996.33b	3713.33bc	3558.00b	3904.33c	3137.33c	3218.00c	3654.47	
S5	3134.00b	3209.33c	3311.33c	1841.00c	2907.00b	2285.33d	2468.33b	2736.62	
Mean	4270.33	4427.99	4047.39	3686.46	3940.46	3632.19	3524.39		
CV (%)	Interaction and sub-plot CV (%) 6.53								
	Rajshahi								
S1	3666.66	4500.00	5000.00	4000.00	4000.00	3666.66	3916.66	4107.14	27.42
S2	4750.00	4083.33	3416.66	3083.33	4000.00	3250.00	4083.33	3809.52	

	Grain yield (kg/ha)								
Treatments	V1	V2	V3	V4	V5	V6	V7	Mean	CV (%)
S3	2416.66	3166.66	2916.66	3083.33	3083.33	3083.33	2833.33	2940.47	
S4	2000.00	2750.00	1916.66	1833.33	1750.00	2000.00	1750.00	2000.00	
S5	1333.33	2500.00	1833.33	1750.00	1583.33	1000.00	2000.00	1714.28	
Mean	2833.33	3399.998	3016.662	2749.998	2883.332	2599.998	2916.664		
CV (%)	Interaction and sub-plot CV (%) 24.09								
	Jashore								
S1	3987.66a	3849.00a	4001.66a	4178.00ab	3964.00a	3696.00a	3977.66a	3950.57	
S2	3669.00a	3474.66a	4018.66a	3339.66c	4535.00a	3921.66a	4097.33a	3865.14	
S3	3628.00a	3563.00a	4096.33a	4768.33a	3970.66a	3373.33a	4256.00a	3950.81	16.56
S4	1958.33b	2722.00b	3170.00b	3869.33bc	2185.00b	2422.33b	3234.33b	2794.47	
S5	655.00c	1852.00c	1673.33c	2548.66b	1459.33c	1265.66c	2440.33c	1699.19	
Mean	2779.59	3092.13	3391.99	3740.79	3222.79	2935.79	3601.13		
CV (%)	Interaction and sub-plot CV (%) 10.71								

In 4th year (2020-21) seven wheat varieties ('BARI Gom 26', 'BARI Gom 30', 'BARI Gom 32', 'BARI Gom 33', 'WMRI 1', 'WMRI 2',
'WMRI 3'); S1, 25 Nov.; S2, 05 Dec.; S3, 15, Dec.; 25 Dec. and 04 Jan.

Annex 6: Scenario Development Workshop report

Online Conference Report

Importance and Role of Scale Appropriate Machinery in COVID-19 Response including Gender Sensitiveness and Awareness

CSISA

Cereal Systems Initiative for South Asia

The online conference report from the meeting on 'Online Conference Report. Importance and Role of Scale Appropriate Machinery in COVID-19 Response including Gender Sensitiveness and Awareness' in Kathmandu, Nepal, held in June of 2021, can be found online here. A summary of the conference is provided below:

Summary: During the COVID-19 pandemic, the CSISA project faced many challenges because of lockdown protocols. Restricted mobility, market closures, absence of market actors and a lack of market information have particularly impacted large numbers of smallholder farmers, agricultural laborers and, particularly, women and youth. With farmers' income demolished, and remittances in sharp decline, migrant workers returned to their homes without cash, only to discover there were few employment opportunities at their rural location. Without the possibility of earning a living, they were therefore facing tough challenges in meeting their food and other household needs.

The CSISA-COVID-19 Response and Resilience Activity, led by CIMMYT and funded by the USAID/Nepal mission, rapidly and effectively responded to the threats undermining the recovery and sustained resilience of farmers in the Feed the Future (FtF) Zone of Nepal. The Activity Objectives I and II implementation period is July 2020 – December 2021. The two inter-related objectives tackled by the CSISA-COVID 19 Response and Resilience Activity are:

Objective I: *Enable rapid, targeted, and effective agricultural COVID-19 crisis response through scale- appropriate farm mechanization and rural services provision;*

Objective II: *Break the smallholder irrigation bottleneck and build rural resilience to the COVID-19 crisis.*

A virtual digital conference was organized on 21 June 2021. One hundred and forty stakeholders with extensive experience in Nepal/Asia were invited. Participants included national and international experts/ researchers in agricultural mechanizations, agronomists, Gender Equality and Social Inclusion (GESI) experts, agriculture engineers, academia, practitioners, field-based staff, scientists, agriculture senior officials, policy makers, members of civil societies, project staff, and private sectors including National Agriculture Machinery Entrepreneurs Association(NAMEA.) The main purpose of the online conference was to raise awareness of the demand for machine-based land preparation, planting, and harvesting services

in COVID-19 impacted districts. Invited to present on the effects of the COVID-19 crisis on smallholder farmers and subsequent recovery activities were federal government ministries and departments from FtF districts: Prime Minister Agriculture Mechanization Project (PMAMP), International Non Government Organizations (INGOs), Community Based Organizations, (CBOs), the private sector, Nepal Agricultural Research Council,(NARC), and staff from the Agriculture Knowledge Center (AKC), in particular from FtF districts. All the presenters shared their experiences, their achievements and what they had learned during the recovery activities carried out in the FtF zone of influence. One common factor was that these activities have contributed greatly in the recovery process towards securing the income and livelihood of the affected populations.

In the closing remarks, Mr. Rewati Raman Paudel, secretary of Ministry of Land, Agriculture and Cooperatives of Lumbini province of Nepal, stated that he appreciated the conference as one which was very useful and timely. Mr. Paudel highlighted the scaling up of mechanization as very important for a country like Nepal in the context of an agricultural labor shortage.

CEREAL SYSTEM INITIATIVE FOR SOUTH ASIA - CSISA III

www.https://www.csisa.org/

The Cereal Systems Initiative for South Asia (CSISA) was established in 2009 with a goal of benefiting more than 8 million farmers by the end of 2022. The project is led by the International Maize and Wheat Improvement Center (CIMMYT) and implemented jointly with the International Food Policy Research Institute (IFPRI), the International Rice Research Institute (IRRI) and the International Water Management Institute (IWMI). Operating in rural 'innovation hubs' in Bangladesh, India and Nepal, CSISA works to increase the adoption of various resource-conserving and climate-resilient 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. CSISA works in synergy with regional and national efforts, collaborating with myriad public, civil society and private-sector partners.

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