Cereal Systems Initiative for South Asia

Agronomy and Seed Systems Scaling

Annual Report

CSISA

Funded by

USAID FROM THE AMERICAN PEOPLE

BILL & MELINDA GATES foundation

Partners

CIMMYT International Maize and Wheat Improvement Center

IFPRI

IRRI

Contents

Abbreviations

2WT	two-wheeled tractor
4WT	four wheeled tractor
ACIAR	Australian Centre for International Agricultural Research
BRACED	Building Resilience and Adaptation to Climate Extremes and Disasters (UK Aid)
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
CSRD	Climate Services for Resilient Development
DADO	district agricultural development office
DAP	diammonium phosphate
DEW	disease establishment window
DoA	Department of Agriculture
EIGP	Eastern Indo-Gangetic Plain
FtF	Feed the Future
FY	financial year
FYM	farmyard manure
GATE	Global Agritech Nepal Pvt Ltd
GoN	Government of Nepal
GP	grain producer
ha	hectare
IGP	Indo-Gangetic Plain
kg	kilogram
KISAN	Knowledge-intensive Sustainable Agriculture and Nutrition project
KSC	Kalika Seed Company
LSC	Lumbini Seed Company
MoALD	Ministry of Agricultural and Livestock Development
MoLMAC	Ministry of Land Management, Agriculture and Cooperatives (provincial ministries)
MoP	muriate of potash
MSD	mean squared deviation
Mt	metric ton
NAMEA	Nepal Agricultural Machinery Entrepreneurs Association
NGLRP	National Grain Legume Research Program (not Programme)
NPR	Nepali rupees
NSAF	Nepal Seed and Fertilizer project
NWRP	National Wheat Research Programme
PCU	polymer coated urea
PMAMP	Prime Minister Agriculture Modernization Project
P-P	plant to plant

PSC	Panchashakti Seed Company
RH	relative humidity
SP	seed producer
SQCC	Seed Quality Control Centre *(not center)*
STCL	Salt Trading Corporation Ltd.
t	ton
UDP	urea deep placement
USAID	United States Agency for International Development
USC	Unique Seed Company

Note: Throughout this document, the exchange rate of USD 1: NPR 112.6 was used to convert Nepali rupees into US dollars.

Executive Summary

Project Rationale and Objective

Nepal's national average cereal and pulse yields tend to be below regional averages. Present rates of increase are also considered to be insufficient to meet near and long-term domestic requirements. Some of the major causes of this are increasingly costly labor markets, poor knowledge of best management practices, insufficient availability of irrigation water and mechanization, and the low risk-bearing and investment capacity among asset-poor farmers.

The CSISA Nepal Agronomy and Seed Systems Scaling project (the project) has systematically addressed these issues by:

1. Strengthening seed systems so farmers have timely access to improved, stress-tolerant varieties and hybrids for pulses, wheat and maize;
2. Targeting geographic niches and identifying management practices that enable cropping system intensification through the inclusion of lentils and mung beans as new crops cultivable by resource-poor farmers;
3. Recommending best management practices for wheat, including scale-appropriate mechanization technologies that help farmers plant early and avoid terminal heat while addressing rural labor bottlenecks;
4. Facilitating market development for small-scale technologies that enable precise nutrient management; and
5. Supporting the expansion of the private sector in the Feed the Future Zone of Influence in Nepal,[1] including the availability of appropriate agricultural mechanization options, including spares parts, improved mechanic services, and expanding the number of machinery service providers to facilitate affordable access among farmers for mechanization technologies.

Project Impact:

During the reporting period, **13,827 farmers – 33% percent of whom were women and 12% of whom were youth** – made use of improved seed, agricultural machinery, irrigation, or climate-resilient cropping practices on **a total of 8,160 ha** as a result of project activities in Nepal. In terms of land area covered, a significant contribution came from farmers who hired reapers to harvest rice and wheat from service providers (23% of land area covered), or who had employed soil conserving practices such as zero tillage or mechanized seeding (also 23%). Twenty-two percent of land area was covered with associated cultural and agronomic management practices, while ten percent came from farmers' use of improved and climate-stress varieties. Importantly, the project has achieved these impacts by working through strategic partners that help achieve scale.

Two hundred and three partner organizations were reached or engaged in working with the project during the reporting period. **Forty-eight percent of these are private sector partners,** including a multitude of agricultural input dealers and machinery sellers. Another 35% were farmer cooperatives or groups. Fourteen percent of the project's collaborators included women's organizations and producer groups. In addition, the CSISA Nepal Scaling project provided direct partnership support to 254 new firms (which include agricultural machinery service providers) to

[1] Note that since 2016 Nepal has been divided into seven provinces instead of the previous five development regions (including the Mid-western and Far Western regions). These two erstwhile regions are now covered by all of the Sudarpaschim (Far Western) and Karnali provinces and the western Terai part of Province 5.

improve their business performance and support to farmers. The text below details major accomplishments in the reporting period for the project's five key objectives:

1. Strengthened Seed Systems

- The project supported an **International Seed Conference and Expert Consultation** on 3-4 September 2019 in Kathmandu to exchange ideas, share knowledge and international good practices and innovations in the seed sector. The event was organized by MoALD's Seed Quality Control Centre (SQCC), the Nepal Agricultural Research Council (NARC), the Seed Entrepreneurs' Association of Nepal (SEAN). A total of 150 participants attended the workshop including 40% private sector representatives.
- The amount of wheat seed sold by the **five seed companies the project partners with more than doubled from 1,194 Mt in 2014 to 2,450 Mt in 2019**. This has led to a 68% increase in the number and share of new improved wheat varieties (<10 years old) since 2014. As a result these interventions, **the seed replacement rate for wheat is expected to reach 25% by 2025** (based on projections estimated by CSISA scientists), an increase of 10% from a baseline measurement in 2018.
- Through interactions with private sector partners, the project supported a **400% jump in sales of domain-expanded maize variety seeds** in the last two years.
- There have been substantial increases in the production of wheat source seed, the volumes of seed sales by partner seed companies, and the varietal diversity of wheat as a result of project interventions. Much of this support has focused on the project's five primary partner seed companies, Global Agritech Nepal Pvt Ltd (GATE Nepal), Kalika Seed Company (KSC), Lumbini Seed Company (LSC), Panchashakti Seed Company (PSC) and Unique Seed Company (USC) to provide new useful varieties for farmers**. Four of these companies prepared their five-year business plans with project support**. Analyses indicate that these companies are poised to grow with **16% growth planned in overall seed sale volume across multiple crops**.
- With technical advice from CSISA staff, a seed grower lending model was piloted for wheat seed growers in Kailali district in partnership with Laxmi Bank and Panchashakti seed company. **Twenty farmers have so far received a total of $10,000 of loans under Laxmi Bank's agriculture lending scheme** for wheat seed production.
- Five partner seed companies conducted 11 varietal trials and 86 demonstrations supported by the project for the popularization and registration of new wheat varieties.
- With technical advice from the project, a new participatory market coordination mechanism was piloted between the Nepal Agricultural Research Council (NARC), mung bean grower cooperatives, food processors and local governments. From almost no mung beans at all being planted in the western Terai in 2018, in 2019 a total of **2,100 farmers in Kailali and Kanchanpur districts grew mung beans and 1,000 farmers in Banke and Bardiya produced mung beans** for the market.

2. Sustainable Lentil and Mung Bean Intensification at Scale

- *Stemphylium* blight is a potentially devastating crop disease that threatens lentil yields in Nepal's Terai. Weather conditions directly affect disease incidence and severity. In response, the project has been supporting the development of a weather forecast based predictive model. Preliminary results indicate a strong fit between model outputs and field observations, indicating substantial potential for use as a disease early warning and forecasting system in Nepal.

- Mung beans are a leguminous crop that is not widely grown in Nepal, although they can fit well into cropping patterns in Nepal's Terai. The project supported PMAMP to expand mung bean cultivation in Kailali and Kanchanpur. **Farmers produced nearly seven tons of quality mung bean seed** that will be used to scale-out mung cultivation in 2020.
- In February and March 2019, the project supported **10 hands-on training events and demonstrations of mechanized mung bean cultivation for 215 farmers** and service providers. Several additional mung bean awareness raising events were facilitated.
- In 2019, the project also evaluated the performance of mung beans under different cropping patterns. Results indicate that potato, followed by rapeseed and then lentil are most productive. Mung bean after wheat is less promising due to the weather sensitivity of the crop after the month of march.

3. Sustainable Wheat Intensification at Scale

- Surveys conducted by the project found that **wheat productivity increased from 2.8 Mt ha^{-1} in 2018 to 3.1 Mt ha^{-1} in 2019** in the FTF zone. Data indicated that 52% of 1,200 surveyed farmers had adopted the improved wheat cultivation practices promoted by CSISA. Of the farmers surveyed, 43% had also adopted longer duration wheat varieties popularized by the project. Among these farmers, use of these varieties increased productivity by almost 0.5 Mt ha^{-1} on average. **When combined with early sowing practices, farmers using long-duration varieties can avoid the significant loss of 20 kg ha^{-1} day^{-1} of yield due to terminal heat stress in the Terai.** These findings led the project to facilitate the National Wheat Research Program to register elite long duration varieties, including NL 1327 and Borlaug 100, such as in Nepal.
- Project efforts to support earlier sowing through zero-tillage service provision is resulting in increasing successes through ongoing and new collaborations with the Prime Minister Agricultural Modernization Project and provincial agriculture ministries in the Terai. **Since 2015, the area under mechanized wheat establishment has nearly tripled**, in large part due to project interventions.

4. Precision Nutrient Management

- Key precision nutrient management activities conducted during this reporting period focused on producing evidence for the revision of the government's fertilizer recommendations for increased use of balanced nutrient application, and more efficient and less wasteful use of fertilizers.
- Experimental results suggest that **polymer coated urea appears to have particular promise in reducing nitrogen application by up to 40 kg ha^{-1} without compromising wheat yield**. Farmer participatory evaluations of polymer coated urea in rice also indicated that this is a preferred source of nitrogen as it gave the highest yield among a suite of tested alternatives in Kanchanpur.
- During the reporting period, the project cooperated with the Nepal Seed and Fertilizer project and developed a partnership with one of the two government-sanctioned fertilizer suppliers, Salt Trading Corporation Ltd (STCL), to use their dealer network to increase awareness of the balanced application of fertilizers. STCL dealers were subsequently trained in improved product stewardship and how farmers can increase efficiency in fertilizer application.
- The project has proven to be successful in making technologies for efficient fertilizer use more accessible through commercial and public-sector pathways. **In March 2019 the Sudurpashchim and Province 5 governments started to subsidize the purchase of efficient fertilizer hand-crank spreaders by providing a 50% subsidy** for farmer groups,

cooperatives and private firms to buy them from dealers receiving technical and marketing advice by CSISA. By the end of this reporting period, PMAMP's Dang Maize Super Zone had subsidized the purchase of 45 spreaders by farmers groups and cooperatives.

5. Mechanization and Irrigation

- **The number of reapers in use in Nepal's Terai has increased from 22 in 2014 to almost 3,500 in 2019,** including self-propelled and commercial expansion beyond the FtF zone without CSISA support. This indicates substantial evidence of reaching scale, with strong spill-over effects beyond intervention areas.
- Studies conducted by the project in Nepal's mid-hills found that **use of mini-tillers to prepare fields for transplanting increases rice productivity by an average of 1,110 kg ha^{-1}** (27%) among adopting farmers. Very small farms (≤0.25 ha) make the most rice productivity gains through accessing mini-tiller services.
- A major project achievement was the participation of more than 40 international experts and project partners, including private sector partners, the Director General of the Department of Agriculture (DoA) and the PMAMP chief at a **'Traveling Seminar on Scale-appropriate Machinery for Cereal Crop Harvesting in South Asia'.** The 25–29 March 2019 seminar provided a platform to share across countries and the public and private sector and to learn about cereal harvesting technologies in Asia.
- In 2017/18, the project supported three Indian seed drill manufacturers to participate in CSISA's Mechanization and Irrigation Design Sprint. This activity has continued to yield benefits. Dharti Agro, a leading Indian manufacturer subsequently began selling its new 2WT seed drill (seeder-planter) in Nepal in mid-to-late 2018. The Nepal sales agent, Kuber and Sons, received a number of units of these planters (seed drills) and began to sell them in March 2019. This activity, which is no longer directly facilitated by the project, provides clear evidence of ongoing impact and the potential to scale-out the use of appropriate agronomy and crop establishment through commercial pathways and mechanization.
- The project's stall at four agricultural fairs (Butwal in Province 5, Khajura in Banke, Rajapur in Bardiya and Dhangadhi in Kailali) **raised awareness on scale-appropriate machinery technologies to the 10,000 visitors** to the stalls.
- Research conducted in the second and third phases of the wider CSISA project on irrigation showed that rice and wheat yields in Nepal's Terai can be substantially improved by applying additional irrigation. Access to groundwater, however, is still lacking in many parts of the Terai. As such, the project continued its research on the development of a **two-wheel tractor powered attachment to drill shallow tube wells**. Results have been promising; the machine could address the problem of the high cost of drilling wells and the unavailability of labor for manual drilling.

Project Overview and Theory of Change

Cereal and pulse yields in Nepal fall well below regional averages and the present rates of yield increase will not meet long-term domestic requirements. Factors that contribute to the low yields of staple crops in Nepal include scarce and costly farm labor, poor knowledge of best agricultural management practices by smallholder farmers, insufficient irrigation and mechanization to overcome soil moisture and labor deficits, and farmers' reluctance to take risks and invest in new technologies, including diversified cropping systems. Also, innovative applied research has long been under-funded and the benefits of research have often not reached farmers. Sudarpashchim Province and Province 5 in the west of Nepal are acutely affected by these constraints and suffer high rates of poverty in their Terai plains areas. These areas also receive limited attention from the private sector in terms of investment in agriculture.

The Cereal Systems Initiative for South Asia (CSISA) has been working in India, Nepal and Bangladesh since 2009 to identify and research technologies for improving the yields of staple crops. Nepal's Terai plains and Midhills are one of CSISA's working areas as there is considerable scope for improving farmers' lives by making agriculture more productive and sustainable. The Government of Nepal's 20-year Agriculture Development Strategy (ADS, 2015–2035) recognizes the need for new science-led innovations, crop diversification for income generation, strengthened input systems for seeds and fertilizer, mechanization to address out-migration and the aging agricultural workforce, and enterprise development to create jobs and extend support services to farmers.

To address these priorities, USAID's additional investment in CSISA, in the form of the 'Agronomy & Seed Systems Scaling project' (hereafter referred to as 'the project' or the 'CSISA Scaling Project'), was launched in October 2014 to scale-up and -out the research findings and technologies developed under original CSISA program investments. The project worked with government agencies, farmers' groups, service providers, agro-dealers, seed enterprises and other development partner-supported projects to scale-up previous achievements, mainly in the Terai (Figure 1).

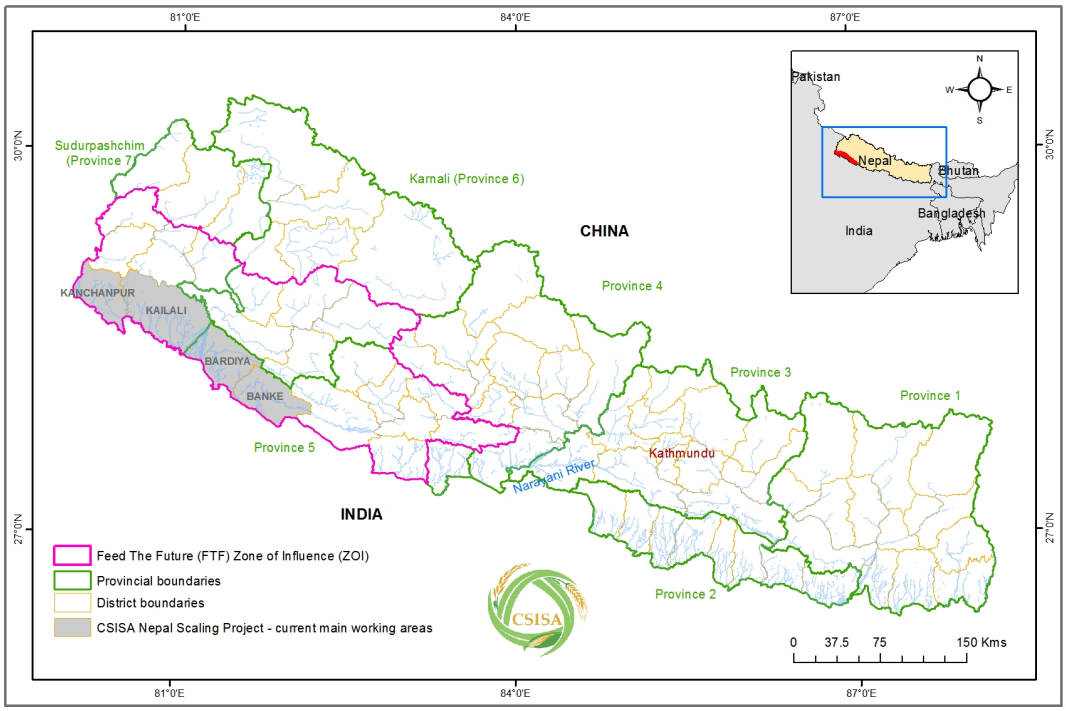


Figure 1: Main working areas of the CSISA Agronomy and Seed Systems Scaling project and key locations mentioned in this report

The project's expected outcomes align with those of the Global Food Security Act (GFSA; Appendix 3).

The project focused on the following objectives and activities to address the project's theory of change as illustrated in Figure 2:

1. Robust seed systems that ensure timely access to elite cultivars and hybrids.
2. Pulse (lentils and mung beans) intensification and diversification, adopted at scale.
3. Cropping systems approaches for sustainably intensifying wheat and minimizing climatic stress.
4. The facilitation of efficient and low-risk strategies for the precise and productive use of nutrients.
5. Scale-appropriate mechanization and irrigation (this component received co-funding from USAID India, which ended in September 2017).

The five main chapters of this report describe the achievements of these five objectives in project year 2018/19. Note that this project ended on 30 September 2019 at the end of the current reporting period.

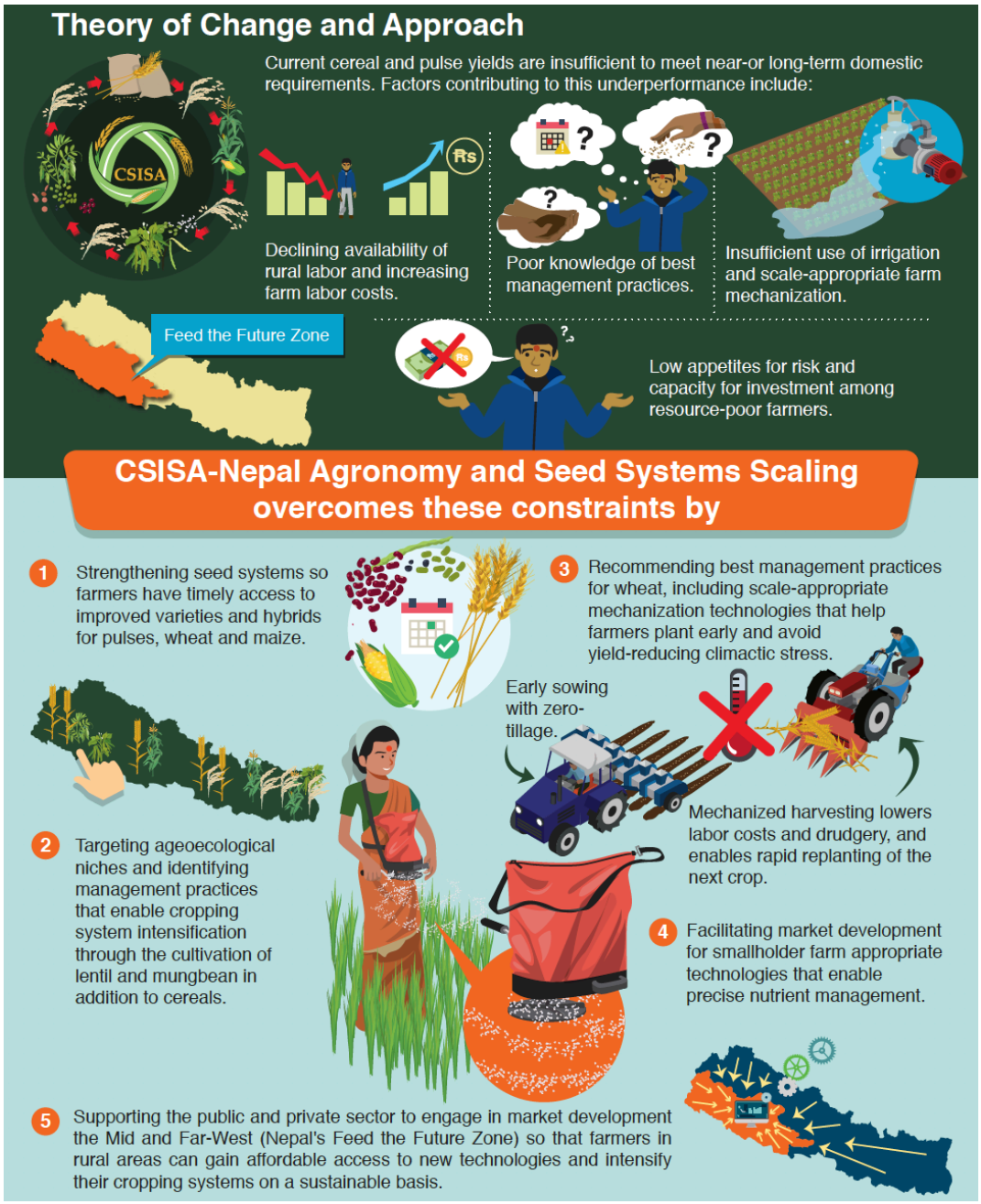


Figure 2: CSISA Nepal Agronomy and Seed Systems Scaling theory of change in simplified format.

Progress During the Reporting Period October 2018–September 2019

OBJECTIVE 1: STRENGTHENED SEED SYSTEMS

The adoption of improved crop varieties can aid Nepali farmers to increase their productivity while also assisting in efforts to build resilience to pests and diseases, in addition to drought and high temperatures. Nepal's farmers currently replace only about 16% of the seed of major cereal crops in each cropping cycle with quality-controlled seed. The remainder comes from home-saved seed and seed exchanged with neighbors and relatives. Although saving of seed is important from the standpoint of *in-situ* biodiversity conservation, this practice also has some downsides. The limited seed replacement rate increases the potential for yield losses over time, and in some cases pest and disease infestation can result. And, as the national seed industry is at a nascent stage, most crop varieties – including many of those traditionally grown by farmers – respond poorly to biotic and abiotic stresses. Many farmer also have little awareness of the benefits of adopting new varieties.

The CSISA Nepal Agronomy and Seed Systems Scaling project (the project) has worked since 2014 to develop robust seed systems for cereals and legumes in Nepal by supporting seed enterprises to become stronger, more market-oriented, and more professionally organized. The project also works to strategically link seed enterprises with other actors along the seed value chain. To achieve these aims, the project has taken a public–private partnership approach to strengthening the capacity of stakeholders in the wheat and mung bean value chains. The main stakeholders that the project has worked with include seed companies, dealers, producer groups, food processors, cooperatives, research and development organizations and other development partners.

In project year 2018/19 the project provided valuable support to:

- input dealers to stock and sell registered maize hybrids;
- private seed companies to expand their wheat and pulse seed businesses;
- develop new markets for mung beans; and
- strategic investments and enhanced coordination among seed system actors.

1.1 Input dealers stocking and selling registered maize hybrids

Expanding markets for hybrid maize – In 2018, Nepal imported 493 million metric tons (Mt) of maize grain from India at a cost of $122 million, mainly for poultry feed. The National Feed Association estimated that this amount is increasing by about 10% a year. Under its National Seed Vision document (2013–2025) and its Agriculture Development Strategy (2015–2035), the Government of Nepal is promoting hybrid maize production to boost the in-country production of maize. Over 40 imported hybrid varieties have been registered so far, but more than 80% of them are only legally recommended for use east of the Narayani river; i.e. in the central and eastern parts of the country. Traders and retailers have known it was illegal to sell this seed west of the Narayani River.[2]

To address this pressing issue, the project facilitated the Seed Quality Control Centre (SQCC)[3], the Nepal Agriculture Research Centre (NARC) and seed companies to test the performance of available hybrids in areas west of the Narayani River. The project also helped develop proposals to extend the geography of tested and proven hybrids. As a result, the officially recognized domains for four hybrid maize varieties (Rajkumar, Nutan, 9220 and TX-369) were officially expanded at the end of 2015.

[2] See Figure 1 for location of the Narayani river
[3] SQCC is the government entity responsible for seed registration and quality control.

Although it took place in the first year of the project, as described below, this achievement had important knock-on effects in subsequent years.

Promotion of new hybrids – Leading on from the extension of the domains of the four hybrids, in 2015, the Nepali feed mill company NIMBUS imported the varieties TX 369, Bioseed 9220 and Rajkumar from the multinational company Bioseed. In the following years, including throughout 2018 and 2019, the project has worked to create awareness and demand for hybrid maize by farmers. In this reporting period, the project supported the production of a jingle to raise awareness on registered hybrid maize varieties, which was broadcast on a Banke district FM radio station. The jingle publicized the hybrid varieties, their domains and levels of productivity in the Nepali and Awadhi languages focusing on spring maize. This led to local agro-dealers selling more of this hybrid seed.

Maize farmer field days – 25 maize farmer field days were held in collaboration with cooperatives, NARC, seed companies and other private companies in the reporting period to view the results and share experiences of demonstrations of improved seed and new technologies:

- 17 days with farmer cooperatives in Dang, Surkhet, Doti, Palpa and Kavre,
- 2 events with NARC at Doti regional agricultural research station, and Surkhet agricultural research station,
- 5 events with private sector in Surkhet district (Shital agrovet), Salyan district (Unnat Krishi Kendra), Kavre district (JP Beej Bhandar), Makwanpur district (Bikash Beej Bhandar), and Doti district (Kedar Biu Bijan) and
- 1 event with Nasik seed company (Dang).

Increased seed sales – Since 2015, the project has guided NIMBUS and its retailers to develop marketing plans for the new locations where these hybrids can be legally grown to meet increasing demand. The expansion of the legal geographies where these varieties can be sold has resulted in annually increasing sales of the seeds of the three imported hybrid maize varieties (plus the Nutan variety). The rate of increase accelerated dramatically in 2018 and 2019 (Figure 1.1). In the spring and summer seasons of 2019, 14 agro-dealers in 13 Terai districts sold 229 Mt of seed of these four hybrids – an increase of 420% since 2016. This is enough seed to plant nearly 11,000 hectares of maize. These dealers estimate that in 2019 about 70% of this seed will be sold in the Midhills (where rainfed farming dominates) and 30% to plant in the spring season in the Terai (for irrigated production).

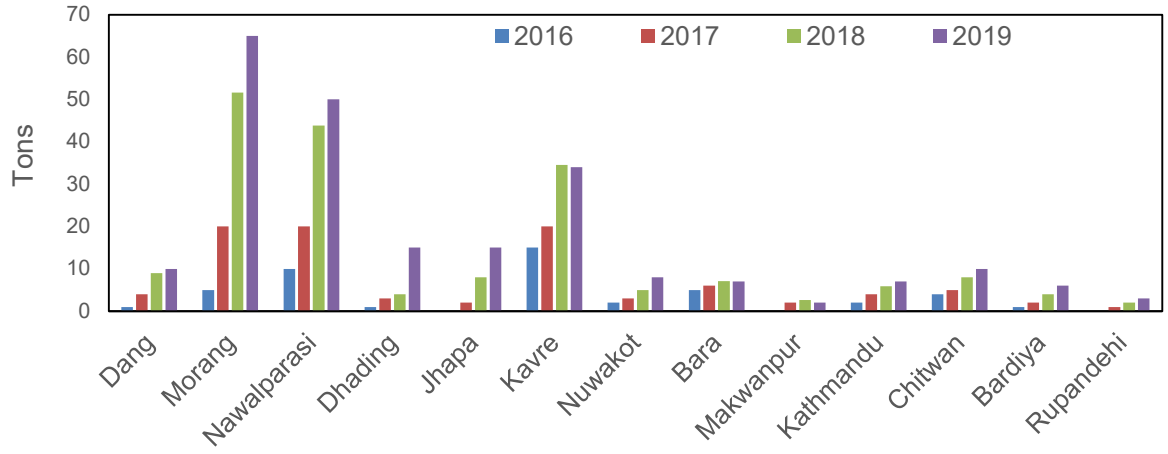


Figure 1.1: Sales of the three maize hybrids imported from Bioseed (2016–2019 actuals)

1.2 Private seed companies expand their wheat and pulse seed businesses

Millions of resource-poor farmers in South Asia derive their livelihoods from growing wheat and pulses. However, in Nepal, the seed systems of these crops have tended to be inefficiently organized and the absence of suitable business models has meant that farmers have been unable to access the elite germplasm developed by agriculture research stations. To address this, since 2014, the project has mentored Nepalese seed companies on business planning, quality seed production, and the market development of wheat and mung bean varieties. The following writeups summarize recent achievements.

Wheat

There have been substantial increases in the production of source seed, the volumes of seed sales by partner seed companies, and the varietal diversity of wheat as a result of project interventions. Much of this support has focused on the project's five primary partner seed companies, Global Agritech Nepal Pvt Ltd (GATE Nepal), Kalika Seed Company (KSC), Lumbini Seed Company (LSC), Panchashakti Seed Company (PSC) and Unique Seed Company (USC) to provide new useful varieties for farmers. See Appendix 2 for details of these companies.

Assessment of wheat value chain

In the reporting period, the project assessed the value chain of wheat in Nepal from the literature and data collected from farmers, traders and processors in the major wheat processing areas around Biratnagar, Birgunj, Bhairahawa and Kailali. The assessment found that wheat is grown on about 800,000 ha of land in Nepal with average productivity of 2.5 Mt ha^{-1} meaning that 2 million metric tons of wheat is produced in the country. The largest 40 mills consume 1.2 million tons (60% of the market), and local *chakki* mills consume 0.8 million Mt (40%) of this amount. It is assumed that Nepali production contributes only 50% of mills' demand giving a total demand of 3.2 Mt of wheat grain in the country. Figure 1.2 shows the result of the assessment's mapping of Nepal's wheat value chain. One important finding is that the seed replacement rate for wheat is only about 16%.

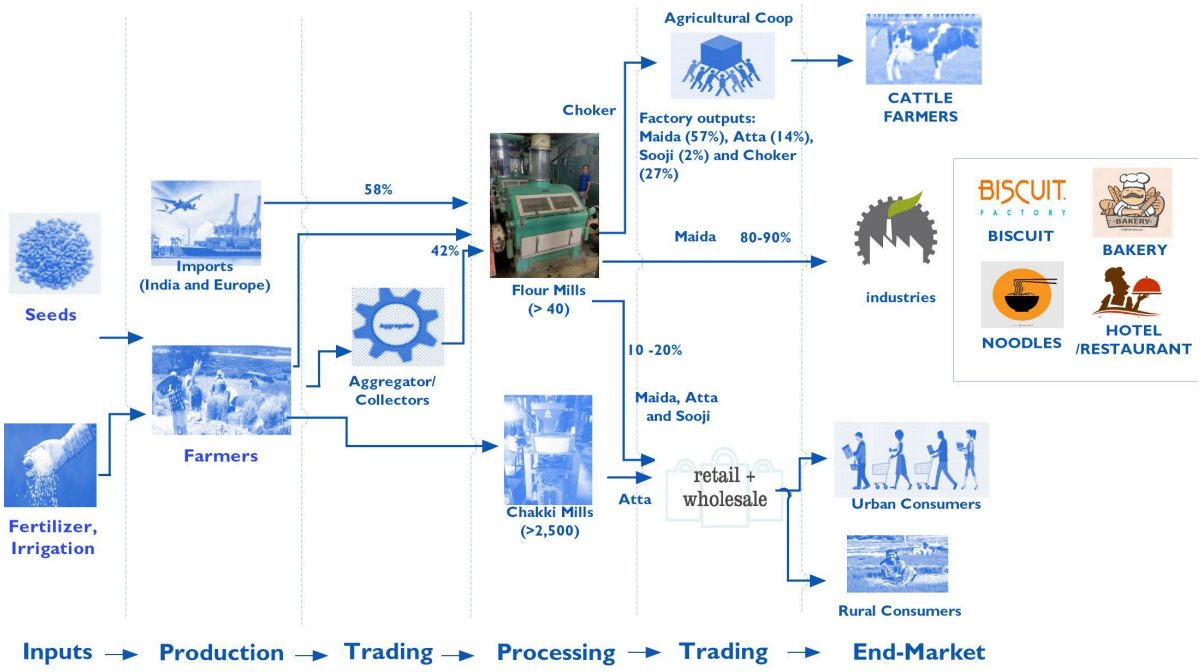


Figure 1.2: Wheat crop value chain, Nepal

The partner seed companies (GATE Nepal, KSC, LSC, PSC and USC) assimilated the assessment findings into their business plans with a major focus of their plans being to produce and popularize high yielding wheat varieties such as Borlaug 100, Banganga, Dhawalagiri, BL 4406, BL 4407 and BL 4341. The assessment confirmed that increasing productivity is the only way to increase wheat production in Nepal. Farmers are thus very likely to adopt higher yielding varieties that are introduced and made available at reasonable cost. The assessment also called for more emphasis on developing and promoting bio-fortified wheat varieties and to link agricultural interventions with improved nutrition.

The results have been shared with the SQCC and the MoALD so that the government can make provisions for better coordination of wheat input and output markets to strengthen the market systems and associated services. More details on the project's wheat seed development activities are provided in the subsequent sections.

Trials of new wheat varieties

Project support since 2014 has resulted in more than 10 new varieties with advantageous traits being introduced in the seed production chain. Borlaug 100 is a wheat blast (*Magnaporthe oryzae* pathotype *Triticum*) resistant variety that has been released in India and Bangladesh. NL 1327 is a bio-fortified variety (rich in iron). HD 2967 is a long duration later maturing and higher yielding variety that can be planted earlier to accommodate uncertain climatic conditions.

Photo 1.1: Project trials of new wheat varieties

Trial protocol – To popularize new wheat varieties, in October 2018 the project met GATE Nepal, KSC, LSC, PSC and USC seed companies and the National Wheat Research Programme (NWRP) and the Prime Minister Agriculture Modernization Project (PMAMP) to finalize the protocol for running participatory variety selection trials in small plots (50 m^2 each) in farmers' fields. CSISA staff subsequently trained company personnel to run the trials of newly released and pipeline wheat varieties, including bio-fortified varieties to popularize varieties across a wider area. The purpose of these trials is to popularize new varieties in their market segments through seed companies and their agro-dealers. In 2018/19, the five partner seed companies carried out 14 participatory variety selection trials of eight wheat genotypes (Borlaug 100, Banganga, Zincol, Miyale, Dhawalagiri, BL 4406, BL 4407 and BL 4341 across the Terai districts of Banke, Bardiya, Kailali and Kanchanpur, and the hill districts of Surkhet, Doti and Arghakhanchi. These trials were monitored by scientists from NWRP. The results were as follows:

Highest yielding varieties – Borlaug 100 yielded the most across all locations with an average yield of 4.6 Mt ha^{-1}, which was higher than all other the tested varieties (Figure 1.3). The performance of Zincol (4.29 Mt ha^{-1}) and HD 2967 (4.25 Mt ha^{-1}) was similar, followed by NL 1327 (4.13 Mt ha^{-1}). Borlaug 100 is a blast resistant variety with a high tillering capacity, large-sized (bold) grain (38.6g, 1,000 grain weight) and is free from rust diseases, and NL 1327 is also free from rust and rich in iron.

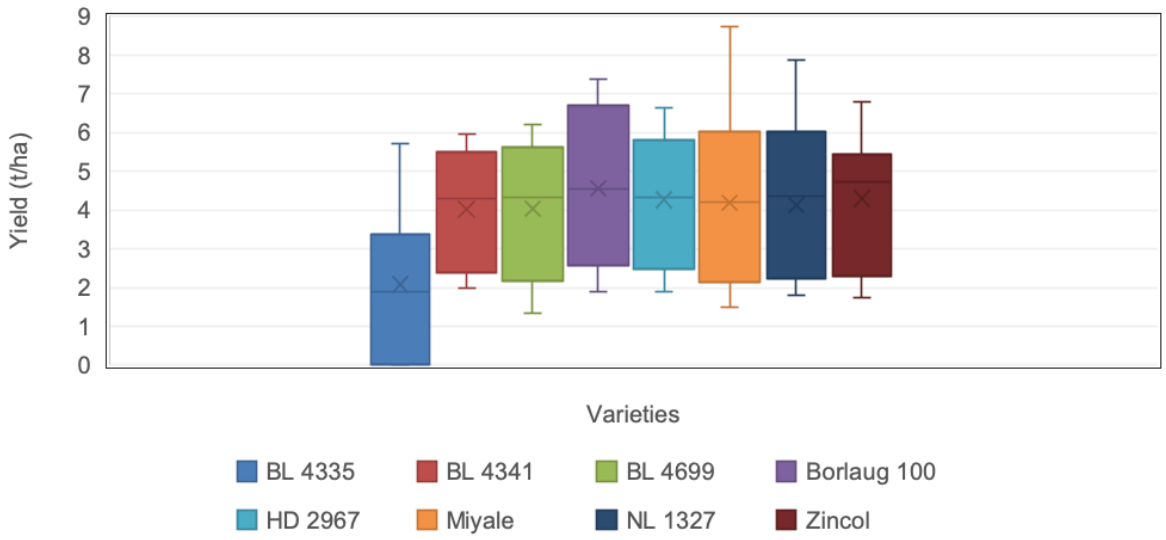


Figure 1.3: Box plots showing the comparative performance of different wheat varieties in trials (middle lines are the median, crosses represent the average, tops and bottoms of boxes show the 25th and 75th percentiles of the data, while bars show the 5th and 95th percent of the data)

NWRP scientists visited the trials, recorded disease scoring data and interacted with farmers and seed companies about the performance of these varieties. The project also shared the trial data with the NWRP team. Using the information, including those generated from on-station trials, NWRP is planning to develop a proposal for the official registration and release of Borlaug 100 and NL 1327. This will lead to faster dissemination as seed companies produced and are stocking about 21 Mt seed of these two varieties, enough for about 150 ha of seed production. In 2020 there is likely to be 500 ha of seed production of these two very promising varieties.

Demonstration plots led by private sector partners – In this season the partner companies established a much larger area of demo plots than in previous years. In the 2018/19 winter growing season, the partner seed companies also established 84 200 m^2 demonstration plots in potential growing areas in Banke, Bardiya, Kailali and Kanchanpur in the using recently released and pipeline wheat varieties, including bio-fortified varieties. The companies and their agro-dealers used these plots frequently to convince farmers to buy new varieties and to demonstrate agronomic issues.

Maintenance breeding – Additionally, in the 2018/19 wheat season the project facilitated its partner seed companies to carry out maintenance breeding of wheat varieties to clean the source seed. The maintenance breeding of eight wheat varieties (Borlaug 100, Banganga, Zincol, Miyale, Dhawalagiri, BL 4406, BL 4407 and BL 4341) was started by the five seed companies with technical facilitation from the project. This led to the companies selecting 15,000 wheat grain spikes of Borlaug 100, NL 1327 and HD 2967 for planting to build up stocks of this seed for planting-on next year.

Increased production and sales

Increased foundation seed production – There has been a substantial increase in the production of foundation seed of wheat varieties. Before 2015, the partner companies used to buy all their foundation seed from NARC stations; but from 2017, they started selling foundation seed to other agencies. This initiative is important to increase the seed replacement rate by wheat farmers. Project and other interventions mean that the replacement rate is projected to reach 25% by 2025 from the 2018 rate of only 15%.

Increased diversity – Project support has enabled the project's five primary partner seed companies to provide new useful varieties for farmers. There has been a subsequent great increase in the diversity of seed sold by these seed companies between the start of the project and the current year (Figure 1.4).

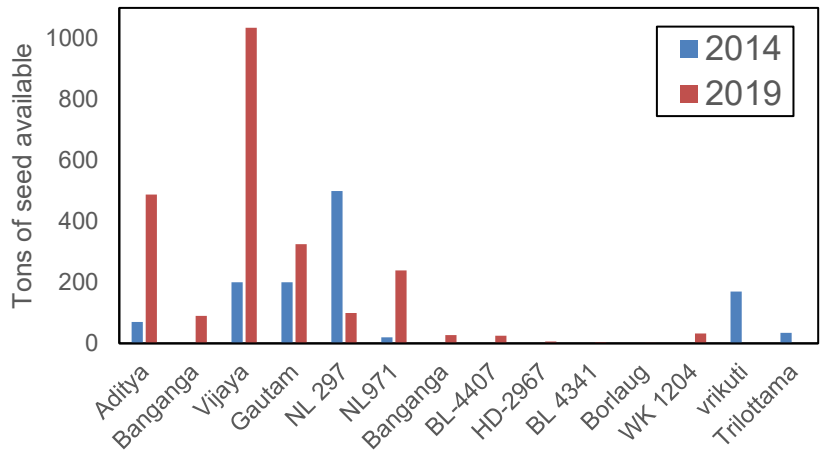


Figure 1.4: The increased diversity of the varieties of wheat seed sold by partner seed companies between 2014 and 2019

Increased sales of seed – The amount of wheat seed sold by the five seed companies more than doubled from 1,194 Mt in 2014 to 2,450 Mt in 2019 (Figure 1.5). This has been due to, i) the companies adopting good business practices such as varietal demonstrations in potential market segments, and ii) technical advances in source seed cleaning by maintaining the breeding of elite wheat germplasm in partnership with seed companies and the National Wheat Research Programme. These efforts have been supported by CSISA in Nepal.

This has led to a 68% increase in the number and share of new improved wheat varieties (<10 years old) sold by partner seed companies between 2014 and 2019 (Figure 1.5). For example, the share of NL 297 (a 35-year-old wheat variety), which accounted for 35% of partner seed company sales in 2014, is projected to account for only 12% of sales in 2019, while the sales of the new Vijaya and NL 971 varieties are projected to increase (Figure 1.4 above).

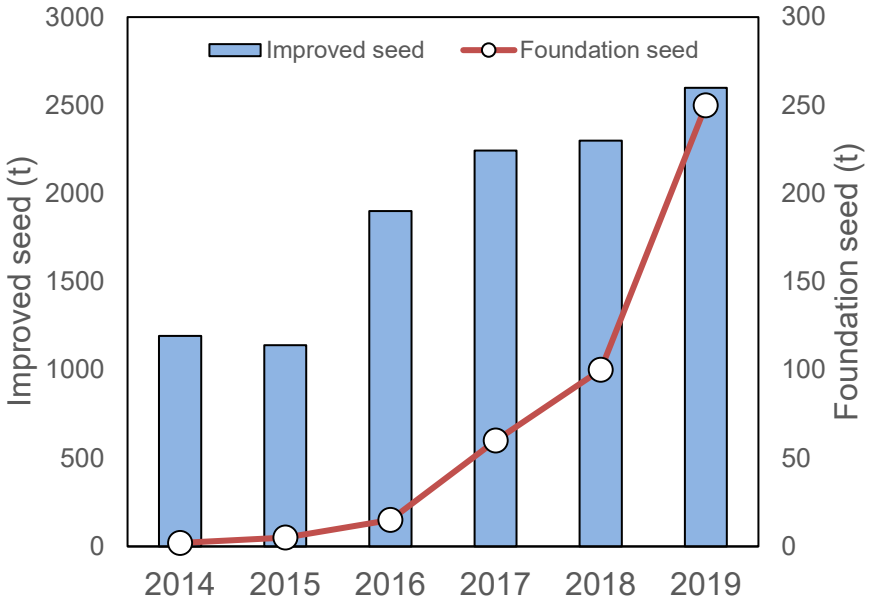


Figure 1.5: Volume of improved and foundation wheat seed sold by the project's five partner seed companies (2014–2019)

Mung beans

On-farm trials

In this reporting period, the project facilitated Panchashakti and GATE Nepal seed companies to carry out participatory variety selection trials on newly released (Pratigya) and pipeline mung bean varieties

(SML 668 and Pant Mung 5). The two companies established five trials each of five different varieties. Pant Mung 5 gave the highest yield (1.3 Mt ha^{-1}) followed by SML 668 (1.2 Mt ha^{-1}), Pratigya (1.2 Mt ha^{-1}) and Prateeksha (1.15 Mt ha^{-1}) against the average national yield of 1 Mt ha^{-1}. In spring 2019, the National Grain Legume Research Program (NGLRP) visited these trials, collected disease and insect reaction scores, and discussed the important required traits of mung beans with seed companies and farmers. The data from these on-farm trials were shared with NGLRP, which is using it to prepare a variety release proposal to submit to SQCC on Pant Mung 5. The data is also useful for to convince seed companies to popularize these varieties in new areas.

CSISA facilitated dramatic increase in mung bean cultivation

The growing of mung beans between winter wheat and the main monsoon rice crop represents an important contribution to intensifying cropping systems. Mung beans were previously only grown in the Eastern Terai; but now, due to project interventions, they are also being grown in Banke, Bardiya, Kailali and Kanchanpur in Nepal's western Terai. This has created significant income generating opportunities for farmers engaging with this new 'third' crop grown during the calendar year.

Prior to 2019, the project validated its technologies for improving mung bean yields by engaging private seed companies, millers (who dehusk and clean the beans) and NARC. The area where mung beans are grown has increased as reflected in the increased volume of mung bean seed sales by partner seed companies since 2014 (see examples of Panchashakti Seed Company Pvt. Ltd., and Global Agritech Nepal Pvt. Ltd. in Figure 1.6).

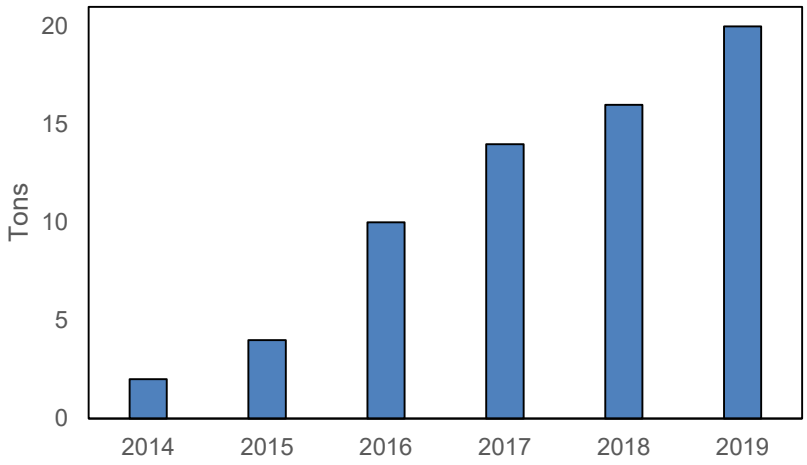


Figure 1.6: Volume of mung bean seed sales of Panchashakti Seed Company Pvt. Ltd. and Global Agritech Nepal Pvt. Ltd.

Linking mung bean farmers to profitable markets

Linking mung bean farmers to markets is challenging as most production occurs on small parcels of land, many of which are remote and poorly linked to markets, with little commercialized production. A market-based strategic framework was developed by the project in 2018 to show the links between commercial farmers in the western Terai and potential buyers (Figure 1.7). The project subsequently tried to facilitate contractual agreements between mung bean growers and millers for the assured purchase of the farmers' crops.

Steps towards contractual mung bean agreements – In the reporting period, the project developed formats for contractual agreements and facilitated five meetings between mung bean growers and millers to agree on the quality of grain to be supplied and the price to be paid. In March 2019, three meetings were held in Kailali and Kanchanpur in partnership with Sudurpashchim province, and two meetings in Banke and Bardiya. However, at the meetings the farmers and millers were unable to enter into written agreements due to the common fluctuations in the price of mung beans. But the millers said they would pay farmers at least between USD 0.53–0.62 (NPR 70–80). Subsequently, from almost no mung beans at all being planted in the western Terai in 2018, in 2019:

- 2,100 farmers in Kailali and Kanchanpur districts grew mung beans on about 300 ha, with 60% following wheat crops and 40% following potatoes or mustard crops, producing a total of 360 Mt of mung beans; and
- 1,000 Banke and Bardiya farmers grew 300 ha of mung beans producing 200 Mt of mung beans.

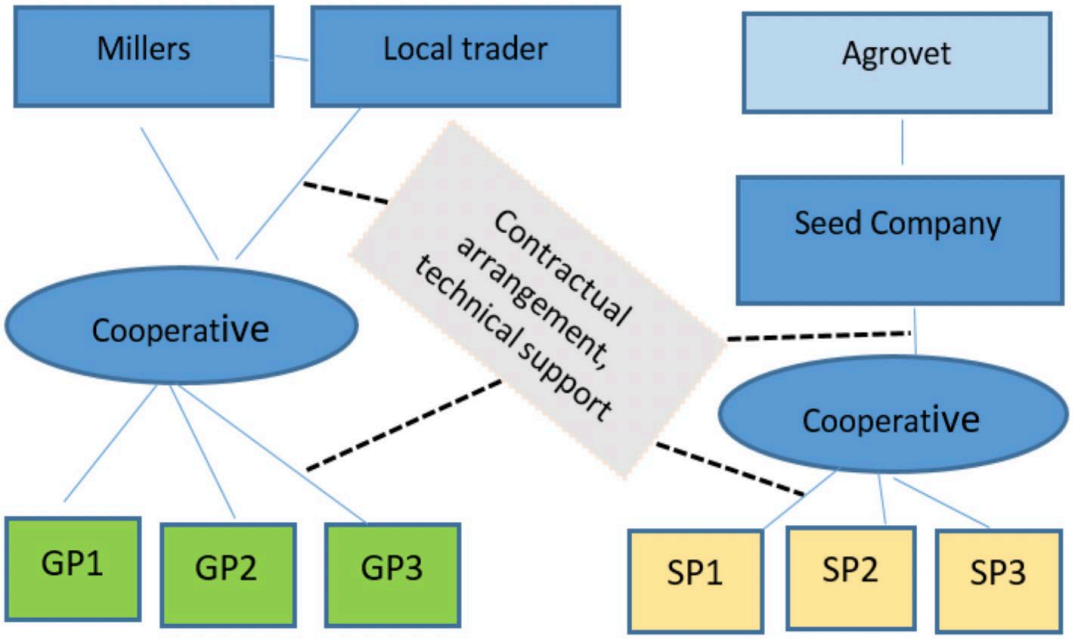


Figure 1.7: Framework for mung bean market development (GP = grain producer, SP = seed producer)

As a result of these promising new interventions that took place in 2019, the CSISA Phase III project plans to continue a focus on mung bean marketing in the 2020 season.

Increased mung bean sales – Of the total 560 Mt, it is estimated that 40% was sold in the local market, 25% sold to the regional market, 20 % consumed by farm households, 10% exchanged with relatives and 5% saved for seed. Though the millers had said they would buy the farmers crops, none of the farmers sold any of their mung beans to millers as they secured higher prices ($ 0.89–1.07, NPR 100–120) selling them directly to hotels and supermarkets. The main lessons are thus that farmers will sell to whoever pays the most, in this case being hotels and supermarkets, which were not identified in the framework as potential buyers.

Mini dal mill demonstration

In January 2019, the Indian machinery supplier Indosaw and its Nepalese dealer Jaikisan Seed visited the CSISA team to discuss potential sales in Nepal of its pulse processing machines. Indosaw demonstrated its mini mill for processing mung beans and lentils at GATE Nepal in Nepalgunj (Photo 1.2) and Panchashakti Seed Company in Dhangadhi to a total of 50 farmers, millers, seed companies and government officials. The participants remarked that the machine is useful for processing lentils and mung beans and produced good results with a recovery rate of 70% and good quality grain produced.

The agriculture officer from Sudurpashchim Province said that his ministry would include the machine in the province's agricultural machine subsidy program in 2020. Jaikisan Seed Ltd., Kathmandu is the main dealer for Indowsaw in Nepal. In late 2019, it purchased two mills for sale at Kisan Sahayog Kendra, Dhanghadi. These significant developments indicate strong market systems and change that has been initiated by the project. These opportunities will continue to be seized upon in 2020 through the broader CSISA Phase III project.

Photo 1.2: Daal mill demonstration, Banke (Milan Sapkota)

CSISA acts effectively to boost seed business market development

Although not specific to wheat and pulse seed businesses, the following achievements in this period on the overall strengthening of seed companies for the sale of all types of seed are relevant to the achievement of Objective 1:

- Four partner seed companies (GATE, LSC, PSC and USC) were supported to run their businesses more profitably by mentoring them in the production of five-year business plans (2019–2024), which plan for a 16% growth in their volumes of seed sales.
- With technical advice from CSISA staff, the seed grower lending model was piloted for wheat seed growers in Kailali district in partnership with Laxmi Bank and Panchashakti seed company. Twenty farmers have so far received a total of $10,000 of loans under Laxmi Bank's agriculture lending scheme for wheat seed production at the reduced interest rate of 8% per year. All of them paid back their loans after selling their harvested wheat. The amount per farmer ranged from $300 to $1,500 and most of the loans have been spent on labor and machines (60%) and fertilizer (30%). Lessons learned from this innovation are discussed in Box 1.1

Box 1.1: Lessons from facilitating smallholder wheat farmer's access to loans

Project experiences and studies have shown that the major constraint for farmers accessing loans is their lack of acceptable collateral. Land is their main collateral, but many farmers either do not have official land certificates or they have not been transferred into the name of the current farmer from their ancestors. It is relatively easy for farmers to access loans for buying farm machinery as the machines can serve as collateral. These insights have highlighted the need to assess and develop strong action place for how banks could be incentivized towards small agricultural loan lending under group guarantee schemes and what kinds of loan products can be introduced that are suitable for smallholder farmers.

1.3 Strategic investments and enhanced coordination among seed system actors

The project carried out a range of activities in this period to support the major seed sector stakeholders, including the central government and provincial governments, to promote and support wheat and mung bean cultivation.

Strengthening private seed companies

The project has also strengthened the capacity of seed companies on developing hybrid maize, developing business plans and advocating on seed sector policy issues. The five seed companies that the project worked with in this period are listed in Appendix 2. In this period, the project also began to work with the new provincial governments, who are now responsible for overseeing agricultural development in their areas.

Exposure to international experience

The project supported two events that exposed Nepali seed sector stakeholders to international experience of their sector with the exposure visit also facilitating networking with seed stakeholders in India.

International seed conference – The project supported the holding of an International Seed Conference and Expert Consultation on 3-4 September 2019 in Kathmandu to exchange ideas, share knowledge and international good practices and innovations. The event was organized by MoALD's Seed Quality Control Centre (SQCC), the Nepal Agricultural Research Council (NARC), the Seed Entrepreneurs' Association of Nepal (SEAN), with support from CSISA and NSAF. A total of 150 participants attended the workshop including 40% private sector representatives. The conference began with a review of progress towards achieving the National Seed Vision. Following this, the speakers from 15 countries shared experience on seed sector development from Asia, Africa and Latin America (Photo 1.3). The main overall recommendation of the workshop was to create an enabling environment for the private sector to emerge as a strong player in the seed sector. The following specific recommendations of urgent relevance to Nepal were made:

Photo 1.3: Seed experts, CSISA and NSAF project staff who shared their experiences at the seed conference

- Use smart seed subsidies and promote the market development of new seed varieties.
- The government should make available germplasm from international centers (CGIAR centers) to private sector companies and license them to produce and sell these new varieties.
- The private sector should develop the market for the seeds of domestic open pollinated varieties and hybrids, including in less favored areas, while the public sector should guarantee the availability of source seeds of the desired quality and quantity and support private sector R&D initiatives.

Participants recognized the urgency and importance of aligning the country's seed system with the new federal structure of government by building upon experiences from India and Pakistan. The national Seed Vision implementation status assessment report and the conference recommendations were handed over to SQCC, to use to bring in new ideas and approaches to achieve the goals and objectives of the National Seed Vision.

The SQCC is planning a mid-term evaluation of the National Seed Vision in 2020, and provincial governments are developing policies to address the challenges and opportunities in the seed sector in their provinces. The National Seed Vision envisions increasing the seed replacement rate from 11% in 2010 to 25% by 2025, export promotion in vegetables (750 Mt yr^{-1}), development of 20 hybrid varieties by the private sector and the development of four large seed companies. It also aims to increase average rice yields from 2.98 Mt ha^{-1} in 2010 to 3.8 Mt ha^{-1} in 2025 and the wheat yield from 2.3 to 3.1 Mt ha^{-1}, maize yield from 2.29 to 3.3 Mt ha^{-1}.

Exposure visit to India – The project organized a five-day exposure visit to India for its Nepali seed company partners from 8–12 September 2019 to explore potential germplasm, technologies and partnership modality for the growth of Nepal seed enterprises. Eleven persons from the project's five partner seed companies and three NSAF partner seed companies and a government official from each of the SQQC and NARC took part. The team observed the R&D and laboratory facilities, and interacted with the professional staff of Banaras Hindu University in Uttar Pradesh; Tiera Seed Company, Seed Works International and JK Seeds in Hyderabad; and Namdhari Seed Company in Bengaluru (Photo 1.4).

Photo 1.4: Exposure visit participants at Tiera maize R&D station, and observing seed germination techniques work in the lab of Seed Works international (both Hyderabad, India)

Participants made the following suggestions based on their experiences in the exposure visit:

- Banaras Hindu University has developed rice varieties suitable for drought, salinity and flood-prone area. HUBR-21 is a fine quality aromatic Basmati variety type, which could be suitable for growing in Nepal and could be introduced through SQCC.
- Nepal's seed companies need to have more diversified product portfolios to better meet the needs of Nepal's farmers and the diverse cropping patterns across the country.
- Seed production needs to be better organized by zoning seed production areas and by growers entering into legally binding contracts with one company for seed production and purchase through the engagement of local governments. This could address the problem of farmers selling their seeds to several buyers.
- The partner seed companies discussed producing quality hybrid maize and rice seeds for the Indian seed companies. The Indian companies discussed transferring technology and providing technical assistance to the Nepali companies.

Supporting provincial governments to strengthen the mung bean value chain

The project worked extensively with provincial level and other stakeholders in this period to scale up the mung bean value chain from the supply of suitable high yielding seed onwards.

i) Multi-stakeholder meetings – In January 2019, the project organized mung bean review and planning meetings in Dhangadhi, Kailali (Sudurpashchim Province[4]) and Nepalgunj, Banke (Province 5), which were attended by stakeholders from across the mung bean value chain and provincial agricultural ministry personnel. At the meetings:

- millers informed participants about the size of the mung bean market and quality requirements;
- farmer cooperative participants shared their experiences of the benefits of growing mung beans on soils, human nutrition and incomes;

Photo 1.5: Navaraj Joshi of Pathak Food Industries, Kanchanpur (on the left) discussing mung bean quality requirements with other millers. He explained at the Dhangadhi meeting:

"We source most of our mung beans from India. We are happy to buy Nepali mung beans, but need sufficient quantity, quality (bold and shiny grain, clean, moisture percentage below 12%) at a similar price to Indian mung beans. However, price variations from season to season makes it difficult for us to agree the price with farmers ahead of time."

- the project shared the mung bean variety performance data of the National Grain Legume Research Program (NGLRP) and CSISA;

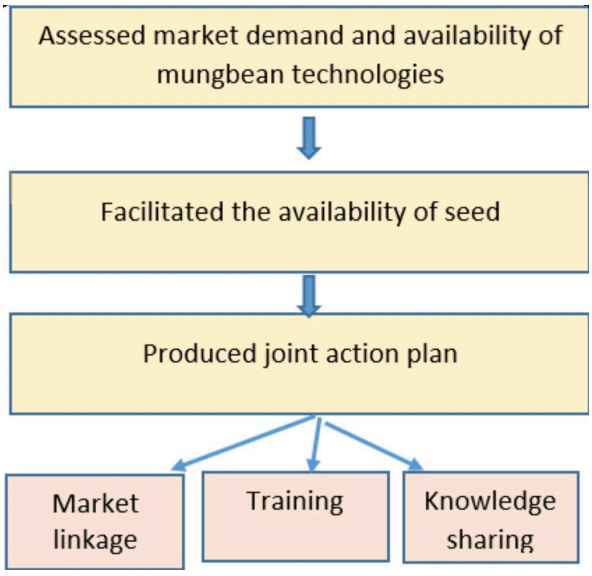


Figure 1.8: Development of Sudurpashchim Province's mung bean action plan

The meetings built the interest of both provincial ministries to support farmers to commercialize the crop. It also built the interest of buyers to encourage domestic production.

The Sudurpashchim Province meeting led to its agriculture ministry choosing to promote the Pant Mung 5 and SML 668 pipeline varieties as the highest yielding varieties in the NGLRP–CSISA trials (2 Mt ha^{-1}). Subsequently, in discussion with the project, NGLRP submitted a formal letter recommending the provincial ministry to promote these varieties, which opened the door for the ministry and private seed companies to work on these pipeline varieties. The Sudurpashchim meeting also importantly led to the provincial government and the project agreeing to collaborate to produce the following action plan for promoting the growing of mung beans in the province's two Terai districts (Kailali and Kanchanpur).

[4] Note that until recently this province was called Province 7. Its current name is Sudurpashchim Pradesh (= Far Western Province). It cover the same area as the previous Far Western Development Region.

ii) Sudurpashchim mung bean action plan – In February 2019, an action plan was developed by the project and Sudurpashchim Province's agriculture ministry in consultation with seed traders and millers on increasing mung bean production in the

province. The plan grew out of the research and development activities carried out by the project in Far Western Nepal since 2015 including participatory varietal selection, linking market actors to farmers, improved agronomic practices and scale-appropriate farm mechanization. The plan was developed through the steps shown in Figure 1.8 and was finalized and agreed upon at a meeting on 27 February 2019 in Dhangadhi. The plan assigned the following responsibilities:

- During the 2020 season, the CSISA Phase III project will provide mung bean knowledge products (a video, technology tips and informational sheets, and profiles of seed drill service providers and their
- business plans) and technical training to local government staff and farmers across the province; and facilitate contractual agreements between mung bean producers and cooperatives, and cooperatives and millers.
- The ministry plans to provide improved mung bean seed and irrigation facilities to farmers. Discussions are ongoing with the CSISA III project to advise on these development.
- The ministry and CSISA also plan to carry out monitoring visits to field sites and run a knowledge sharing workshop in Sudurpashchim Province to increase farmers' knowledge of best management practices for mung bean.

Photo 1.6: The project handing over improved agronomy production tips (fact sheets) for mung bean growers to the Secretary of Sudurpashchim provincial agricultural ministry (Suman Khanal)

At the action plan discussion meeting, the Secretary of the ministry Rabindra Pradhan (who is holding the leaflet shown in in Photo 1.6 above), expressed his appreciation for the project:

> *"We highly value the activities of the CSISA Scaling Project and CIMMYT to strengthen the mung bean value chain, especially in our province. The action plan will amplify our impacts."*

In the reporting period, the project provided the following support for implementing the action plan:

- Developed and distributed a video and 1,000 mung bean production fact sheets (Photo 1.6).
- Provided profiles of seed drill service providers and their business plans to the ministry.
- In February 2019, the project trained 5 local government staff and 200 farmers on mung bean production from the major mung bean pockets of Kailali and Kanchanpur districts.

- The project held three plant protection training events for 105 mung bean farmers in March and April 2019.

The ministry itself provided 6 Mt of improved mung bean to 200 farmers and a 50% subsidy for the digging of 10 shallow tube wells for improved irrigation. A total of $15,000 was allocated in the province's 2019 budget to invest in developing mung bean farming in the province. It is expected that the ministry will allocate at least $20,000 in its 2020 work plan to support mung bean focusing on irrigation and mechanization.

iii) Field visit – In April 2019, the project and Sudurpashchim agriculture ministry organized a visit program to mung bean farms. The participating 8 local government officials, 2 media personnel, 2 seed company personnel, 10 cooperative farmers, 2 millers and 2 agrovets observed the performance of mung bean crops in farmers' fields and gathered lessons for scaling up the production of this crop and interacted between themselves and with the farmers (Photo 1.7). They observed the following:

- How mung bean farming increases farmers' cash incomes, improves their diets (home consumption) and is used for making samosas, pakaudas, and other food products.
- How incorporating mung bean plants into the soil following harvests increases rice production by about 20% by enhancing soil nitrogen levels thus reducing the need for urea fertilizer by about 30%.
- Many mung bean farmers are women and the women farmer participants said that the planting of mung beans is very advantageous as they previously did not grow any crops between March and the June planting of monsoon rice.

Photo 1.7: Participants observing mung bean harvest (CSISA archive)

This visit encouraged collaboration. Following the interaction with farmers, the Mayor of Jhalari Municipality in Kanchanpur district (who took part in the visit) requested the project to support the calibration of seed drills for more uniform mung bean cropping, which the project subsequently provided (see writeup under Objective 2 achievements). The mayor also told farmers to visit his office to apply for irrigation (boring) and machinery support.

Yagya Raj Joshi, Senior Agriculture Development Officer of Sudurpaschim Province thanked the project and participants for their contribution in making the program field visit successful. He asid that his ministry would continue its mung bean scaling up program. He also praised the project's support for training farmers on the use of seed drills for planting mung bean, plant protection and market networking (as reported under project objective 2).

OBJECTIVE 2: SUSTAINABLE LENTIL AND MUNG BEAN INTENSIFICATION AT SCALE

The CSISA Scaling Project works to improve farmers' access to and use of resource-conserving and climate resilient technologies and management practices for growing mung beans and wheat in Nepal's FtF zone. Although mung bean seed supply and value chains feature prominently in the project's first Objective, activities in Objective 2 focus mainly on improved agronomic management of mung beans and efforts to increase yields and profitability for new mungbean farmers, in addition to crucial value-chain activities to assure output markets.

2.1 Lentils

Lentils (*Lens culinaris* ssp. *culinaris*) are the most important grain legume in Nepal. This crop's protein-rich grain and straw provide a major source of food and feed. Grain legumes play an important role in Nepalese agriculture as they contribute towards food and nutritional security. Lentils can also be used to improve nitrogen cycling in soils, and are an excellent additional crop for diversification in cereal-based farming systems. However, the productivity of Nepal's lentil farmers is less than the world average, with diseases such as *Stemphylium* blight disease being a major cause of the low productivity. In response, most of the project's work in this period focused on the development of a model to forecast the onset of this disease to inform the development of a disease early warning system. It is intended that the system will provide farmers with advanced notice of disease onset, allowing them to undertake rational disease control actions.

Refining the disease forecasting model

Stemphylium blight is a potentially devastating crop disease that threatens lentil yields in Nepal's Terai. Weather conditions directly affect disease incidence, severity and occurrence, which varies regionally and seasonally. In 2018 and 2019, this disease was addressed by the USAID supported Climate Services for Resilient Development (CSRD) in South Asia project. CSRD's efforts have permitted scientists, who are also associated with CSISA, to begin developing an early warning system based on the 'Stempedia' forecasting model. In this reporting period, the CSRD project partnered with the CSISA Scaling Project to collect the field data needed to inform the calibration, refinement and validation of the model.

Data collection – The first round of data collection took place in the 2017/18 lentil growing season. Additional data was collected between November 2018 and March 2019. It was planned to measure the status of *Stemphylium* blight and other diseases three times during the lentil growing season in 160 farmers' fields – 40 in each in Banke, Bardiya, Kailali and Kanchanpur districts (Photo 2.1). Enumerators were trained on data collection by NARC's National Grain Legume Research Program (NGLRP), which is an active partner in these efforts. The team planned to score the occurrence of the disease, record phenology and other crop management perspectives, measure yields in the 160 fields and carry out household surveys to investigate crop management practices. While the field investigations started

Photo 2.1: Lentil disease monitoring in Bardiya (Sagar Kafle)

smoothly, heavy rains in the late growing season destroyed about 10% and partially destroyed another 10% of sampling fields. Data collection was therefore completed in 120 of the planned 160 fields.

Use of the data – Using the two years of data and other data from Bangladesh, in March 2019 a model calibration exercise was carried out at several locations in Nepal and Bangladesh. The calibration considered all six model parameters of the:

- potential disease establishment window (DEW)
- maximum lower daily temperature threshold for spore release
- maximum upper daily temperature threshold for spore release
- number of days a week of susceptible window for infection (PSW)
- threshold for relative humidity above which infection takes place (RH threshold)
- threshold daily sunshine hours below which it is favorable for spore release (SSH threshold).

Results – The model was run in various combinations of the six parameters to identify the combination that most closely matched the observed data across the regions (Figure 2.1).. The mean squared deviation (MSD) and coefficient of determination (R^2) were applied to the data to assess the matches

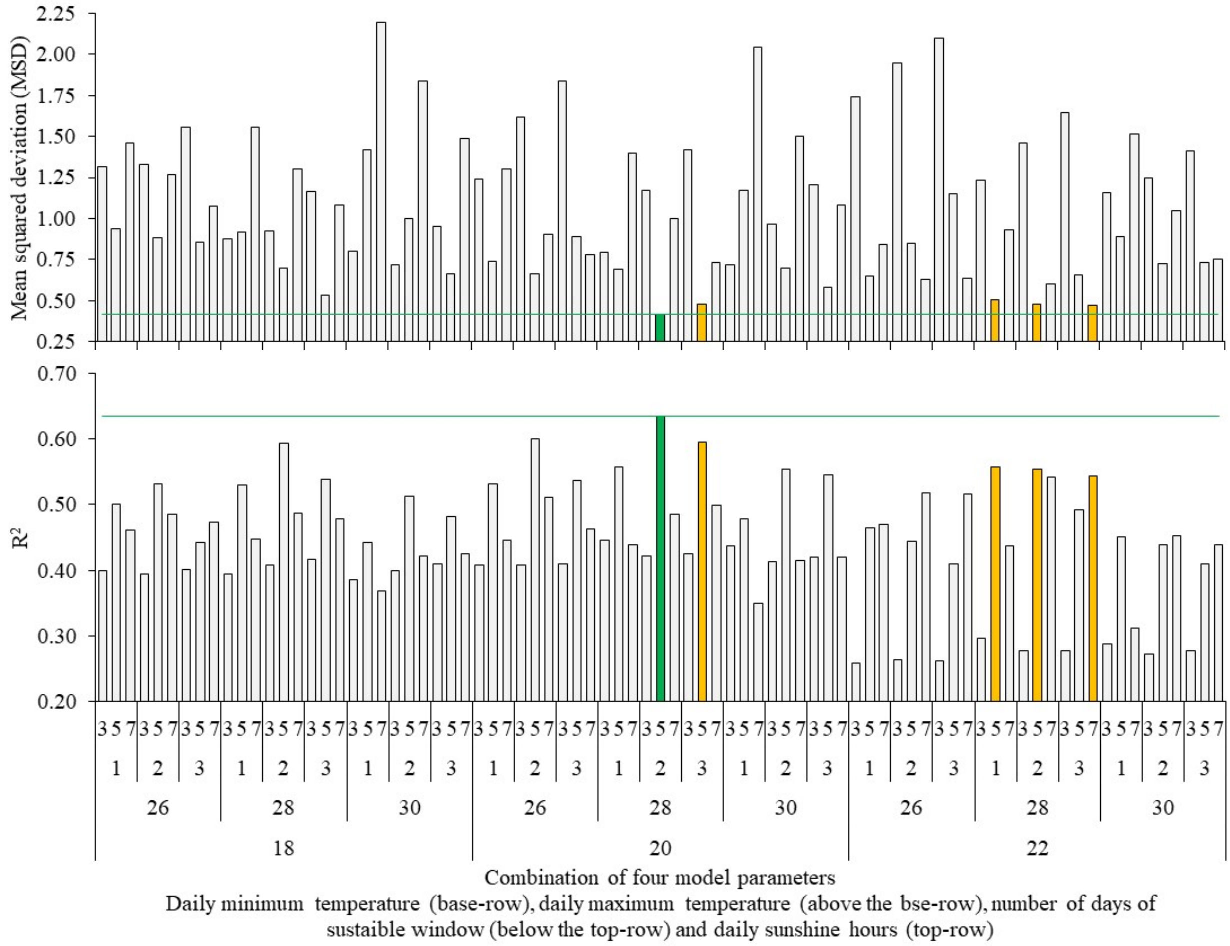


Figure 2.1: The mean squared deviation (MSD) and coefficient of determination (R^2) between observation and prediction in relation to three levels of four model parameters for three Bangladesh and two Nepal sites. The green horizontal line in the top graph indicates the lowest mean squared deviation and in the bottom graph the highest R^2 for the combination of parameters. The green bars are the best combination of parameters and the brown bars are the closer to the best of the combination of parameters.

Two parameters were insensitive or poorly sensitive to the onset of blight (DEW and RH) and were thus discarded from further analysis. As such, only four parameters were reported on. The calibrated best set of the model's parameters significantly explained (at the $P<0.0001$ level) 70% of observed variation in disease severity at the five sites (Figure 2.2). This calibrated model would likely be able to predict (based on the weather) the timing and intensity of *Stemphylium* disease in Nepal's Terai and Bangladesh. This is being validated in late 2019 under CSISA III.

Use of the model – The validated Stempedia model will ultimately be used to develop an early warning system on the occurrence of *Stemphylium* disease in lentils in Nepal's Terai and Bangladesh, which will help farmers decide whether or not and when to apply fungicide to their crops. The system will be delivered under the CSISA Phase III project in 2020.

Presentation of results – The results from the 2017/18 field data from farmers' fields were presented to the Nepal Seed and Fertilizer project-supported National Training Workshop on Seed Quality and Productivity Enhancement Technologies in Lentil on 17–18 February 2019 in Nepalgunj. It was explained how the analysis showed that financial gains from blanket applications of fungicide varied depending on field-specific yields and disease status. For example, in Kanchanpur district, gains ranged from \$955 ha^{-1} to only \$19 ha^{-1}, while in Kailali district the maximum gain was \$268 ha^{-1} (Figure 2.3), although in many situations farmers would have lost money. This creates significant financial risk for smallholder farmers. The use of the early warning system should reduce the uncertainties in the financial outcome of applying fungicides to lentil crops.

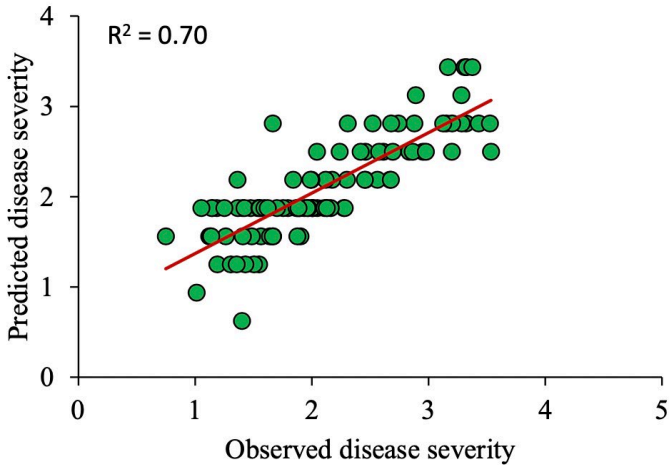


Figure 2.2: Predicted severity of Stemphylium blight disease of lentils (circles) compared with observed severity (line) based on calibrated best-set of Stempedia model parameters. The Nepal data for 2017/18 was used as part of the calibration.

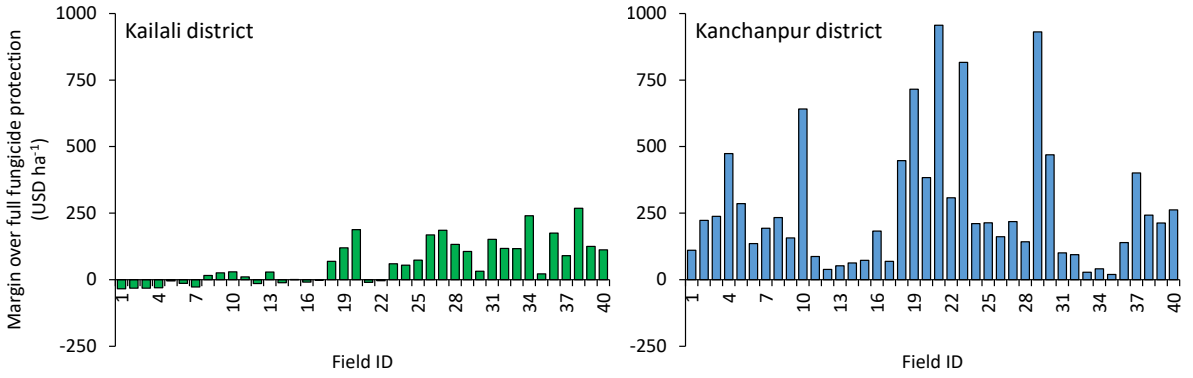


Figure 2.3: Estimated margins of full fungicide protection to control *Stemphylium* disease in lentils in 40 farmers' fields in each of Kailali and Kanchanpur districts in 2017/18. Note: Calculation is based on measured yields, estimated yield losses, farm gate price of \$0.73 kg^{-1} and \$36.36 ha^{-1} for fungicide application

Other lentil support

Joint monitoring visit – On 10–12 February 2019, the project organized a joint monitoring visit with NARC officials to observe work on *Stemphylium* disease and estimate the effect of excessive winter rainfall on lentil crops in the Terai of Sudurpashchim province and Province 5[5] (Photo 2.2). The team observed disease incidence and severity in lentil fields especially in relation to the excessive winter rainfall in the 2018/19 growing season. In coordination with NARC, the CSISA team identified the potential research issues of i) modeling the lentil root rot complex, which is widespread in lentil fields in Nepal, and ii) growing lentils in raised beds to reduce the negative impacts on productivity of excessive winter rainfall. The visit observed that the continuous rainfall in the 2018/19 growing season had affected the crop in lowland areas with heavy soils, but had less effect in drier upland areas where it had contributed to higher yields.

Photo 2.2: Monitoring team discussing *Stemphylium* disease in a lentil field in Kailali district (Ashish Chaudhary)

Other support for improved agronomy in lentil production – In this period the project also supported the calibration of seed drills, including for planting lentils (see Chapter 5), and between December 2018 and February 2019, supported the broadcasting of radio jingles on local FM radio stations that advised Mid-West and Far West lentil farmers to consider applying fungicides against *Stemphylium* disease as soon as initial symptoms appeared on their crops. The jingles also advise on how to safely handle fungicides to avoid risks to human and environmental health.

2.2 Mung beans

A valuable crop – Mung beans are a leguminous crop that can improve soil fertility and provide a source of protein and income for smallholder farmers. Mung beans are also a short duration crop (~ 90 days). In Nepal's Terai, farmers often leave their land fallow for 80–90 days after the harvesting of winter wheat and before the planting of monsoon rice, during which time mung beans can be planted and harvested. Nearly 70% of the wheat fields in the Far Western Terai could be brought under mung bean cultivation, to add an additional crop for farmers, if they are planted in February after potatoes or mustard. Mung beans can be planted in March after lentils or wheat, although such later planted mung beans are more prone to weather risks from early monsoon season rains.

A new crop in the western Terai – Mung beans are a newly introduced crop in Sudurpashchim province and Province 5 of the western Terai. Project efforts since 2014 have led to Panchashakti Seed Company and cooperatives beginning to produce and collect mung bean seeds in bulk. And since 2017, PMAMP's Kailali Wheat Super Zone, Kanchanpur Rice Zone and Kailali Oilseed Zone in the western Terai have unofficially promoted mung bean cultivation in addition to the cereals more commonly popularized by PMAMP. In addition, since 2018, the Sudurpashchim provincial government has prioritized mung bean cultivation by placing the crop in its subsidy program to make available less expensive seeds to farmers. The project had made a large contribution to the increasing number of farmers who are grow mung beans in the western Terai. In Kailali and Kanchanpur alone nearly 7 Mt of mung bean seed (enough to plant approximately 230 hectares) were sold by agrovets and seed

[5] Previously the Mid-Western and Far Western Terai.

companies to farmers prior to the 2019 planting season. Figure 2.4 illustrates the best management practices identified and developed in previous reporting periods by CSISA for growing mung beans.

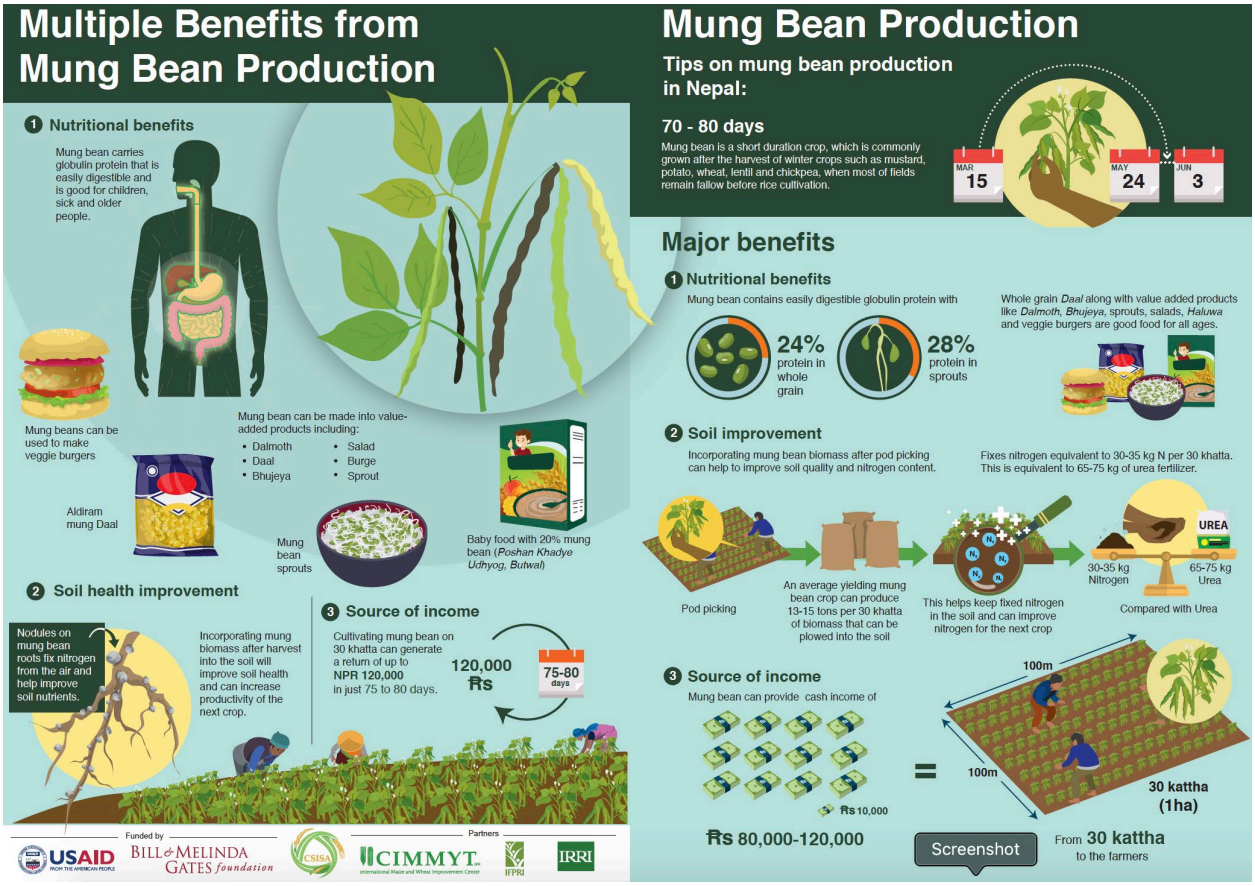


Figure 2.4: An infographics developed by CSISA that provides recommendations for mung bean cultivation in Nepal's Feed the Future Zone

In this reporting period the project carried out an assessment of this valuable high potential crop and a series of training, trials, and awareness raising to encourage the adoption of this new crop in the western Terai. Other project achievements from this period on promoting mung bean farming are described under Objective 1 achievements, including the production of a mung bean action plan, holding stakeholder meetings and supporting on-farm testing, all in coordination with the Sudurpashchim agriculture ministry.

Mung bean value chain assessment

In mid-2019, the project carried out a study to better understand the mung bean value chain. The study consulted 4 Rupandehi-based importers and 3 millers about the size of the market and market requirements, and 115 farmers and 2 seed companies in Banke, Bardiya, Kailali and Kanchanpur districts about production and seed supply issues. The main findings are presented in Box 2.1.

Box 2.1: Findings of Nepal mung bean value chain study

Demand for mung beans

- Grain legume importers estimated that about 5,000 Mt of mung beans are imported into Nepal each year (worth $4.4 million [NPR 500 million]), fulfilling about 90% of demand, with the Rupandehi market alone consuming 1,200 Mt year^{-1}.
- Mung beans are imported to make daal; dried beans for making snacks such as bhujiya and papad and as graded whole grain for sprouting.
- The 15 mills that process mung beans are mostly located in Bhairahawa, Birgunj and Biratnagar.

Growing the crop

- Mung beans are mainly planted in February and March and harvested in April and May after either wheat, potatoes or mustard in Nepal's Terai.
- The farmers got most of their mung bean seed from cooperatives, agrovets and seed companies, while some use home-saved seed.
- About 1,000 ha of mung beans are grown across the FtF zone in Nepal. Although the number of farmers growing this crop is increasing rapidly, production is still low. In 2018/19 about 5,000 households grew mung beans on an average of 0.2 ha.
- Yield is usually higher if mung beans are planted after potatoes or mustard as the longer growing period allows 2 to 3 pickings of pods. It is usually not possible to do a second picking if it is planted after wheat. Fertilizers applied to potatoes also have a residual effect and can influence mung bean crop performance.
- Farmers indicated that they incorporate the harvested plants into the soil to improve soil quality, and realize 30-40% higher rice yields from such plots.

Main challenges faced by growers

- Open grazing of livestock in Kailali, Kanchanpur and neighboring Indian districts damaged about a third of mung bean growing areas in 2019.
- The price paid to farmers is unpredictable making it difficult for millers to make pre-planting agreement with farmers. The price can vary from $0.62 (NPR 70) kg^{-1} for selling to wholesalers to $1.78 (NPR 200) kg^{-1} for selling directly to consumers.

The main conclusion from the study is that there is great potential for scaling-out mung bean production in Nepal's Terai by:

- growing mung beans in areas where spring season irrigation is available and free grazing is less common;
- focusing on planting mung beans after potatoes or vegetables to allow more than one picking compared to only one picking if planted in the smaller window following wheat;
- promoting mung beans as a source of human nutrition and soil health, as well as a cash crop; and
- branding the crop as grown-in-Nepal to promote sales.

Trials, training, and awareness raising

In this reporting period the project demonstrated and raised awareness on the great potential of growing mung beans through on-farm trials, by training farmers and other stakeholders and by disseminating messages via posters, radio messaging and other means.

On-farm trials – In 2019, the project evaluated the performance of mung beans under different cropping patterns. Trials were conducted in Kailali and Kanchanpur in farmers' fields of the SML668 variety. The highest grain yield was obtained from planting mung beans after potatoes, with a lower yield when planted after rapeseed and lentils (Figure 2.5). The lowest yield was when it was planted after wheat due to this timing only allowing a single picking of mung beans These trials showed that mung beans can be planted as a third crop instead of leaving fields fallow. This gives a more profitable and intensive cropping cycle. The growing of this third crop enhances farmers' incomes and produces a valuable source of nutrition while improving the fertility of the soil for the following rice crop by fixing nitrogen and from the incorporation of the harvested plants in the soil.

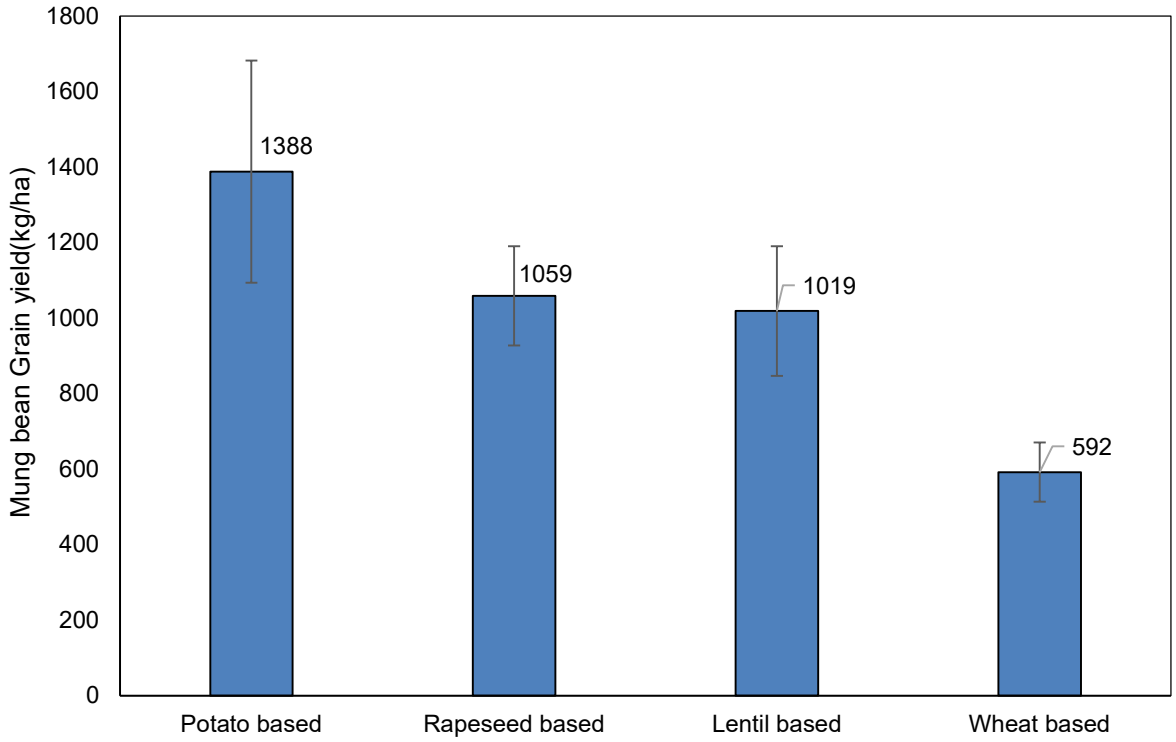


Figure 2.5: Grain yield of mung bean under different cropping patterns. Bars represent the standard deviation of the mean.

Mung bean cultivation training – In February and March 2019, the project supported 10 hands-on training events and demonstrations of mechanized mung bean cultivation for 215 farmers and service providers in Kanchanpur, Kailali, Banke and Bardiya districts in partnership with farmers' cooperative, seed companies and local governments. These events raised farmers' awareness about the importance of mung bean cultivation for human nutrition, soil fertility and intensifying cropping systems and trained seed drill service providers and farmers on how to use seed drills and troubleshoot their operation. Participants were trained on seeding rates, spacing, plant protection, irrigation and nutrient management. Mung bean production tips (informational leaflets describing how to best grow mung beans), which were developed by the project in 2017 and were recently updated, were distributed to participants. A version of these tips was also distributed for agrovets to display (Photo 2.4).

Farmer's field days – In March 2019 the project held two farmers field days to demonstrate mung bean farming.

- On 22 March 2019, a field day was held with Banke Agriculture Knowledge Centre. It was attended by 60 sixty persons from farmer cooperatives, the 'smart farming villages' (model farming villages) of Banke Agriculture Knowledge Centre, seed companies and the National Grain Legume Research Program. The participants learned about the benefits of mung beans, production methodologies and mechanized planting from observing farmers' fields and discussions with farmers and experts (Photo 2.3).

Photo 2.3: Farmers picking mung beans at a farmers field day in the Feed the Future Zone (Milan Sapkota)

- On 21 June 2019, an additional field day was organized with Sudurpashim province attended by seed company, millers, local government agriculture section and provincial government personnel. Farmers shared their experiences of mung bean cultivation and the challenges they face. The participant also discussed the planting of more diverse varieties, the need for guaranteed markets for their crops and synchronous maturity.

Awareness raising – The project raised awareness about the benefits of growing mung beans by:

- distributing 3,000 copies of improved mung bean production information leaflets to farmers, cooperatives, GATE Nepal, PSC and USC seed companies, NARC stations, millers (Pathak Food Industries of Kanchanpur and Sahu Rice Mill of Banke) and local governments;
- distributing 200 copies of a flex poster for agrovets to display to show the benefits of growing mung beans to agrovets (Photo 2.4);
- supporting GATE Nepal and Panchashakti partners seed companies to prepare a series of humorous and attention-grabbing radio jingles about seed availability and critical mung bean farming issues. These were widely broadcast on two local FM radio in the western Terai; and
- coordinating with agricultural knowledge centers to show videos ten times on mung bean growing to 200 farmers. Rural video shows such as this have proven effective to expand awareness of agronomic practices appropriate for farmers in the project's working areas

Photo 2.4: An agrovet in Kailali displaying the information on mung beans developed by the project (Lokendra Khadka)

OBJECTIVE 3: SUSTAINABLE WHEAT INTENSIFICATION AT SCALE

The yield of wheat – one of Nepal's major cereals – tends to be lower in Nepal than in other South Asian countries. Since its inception, the CSISA Scaling project, in coordination with public and private organizations, has striven to promote and scale-up climate-resilient agricultural technologies that help farmers mitigate heat stress in wheat at ripening. This activity is crucial for avoiding heat-stress induced yield loss, a problem that plagues farmers in Nepal. As the project matured over time, there has been increasing demand from provincial government partners and PMAMP for the project to provide data and evidence to improve agricultural development planning in ways that can help farmers overcome heat stress through improved agronomic practices. In this reporting period, with an increased level of engagement with provincial governments and the government's PMAMP project, the project thus continued its work to provide science-based recommendations that can be applied by farmers to improve wheat productivity.

3.1 Evidence to inform the closing of the wheat yield gap

The project is providing evidence to inform how to close the yield gap between what the highest yielding wheat farmers achieve and the yields of other farmers in the Terai. Since 2016 the project has carried out four annual wheat crop-cut and production practices diagnostic surveys (hereafter called 'the wheat production survey') to understand the technological changes from the project's interventions and identify priorities for intensifying wheat production. The farmers are selected randomly for these surveys and so may or may not have been exposed to project interventions, although many of the selected areas have been project working areas.

Results of 2018 wheat survey

2018 wheat survey – The May to August 2018 wheat production survey was carried out in six districts in the FtF Zone of Influence and other areas among 1,684 farmers (Figure 3.1).

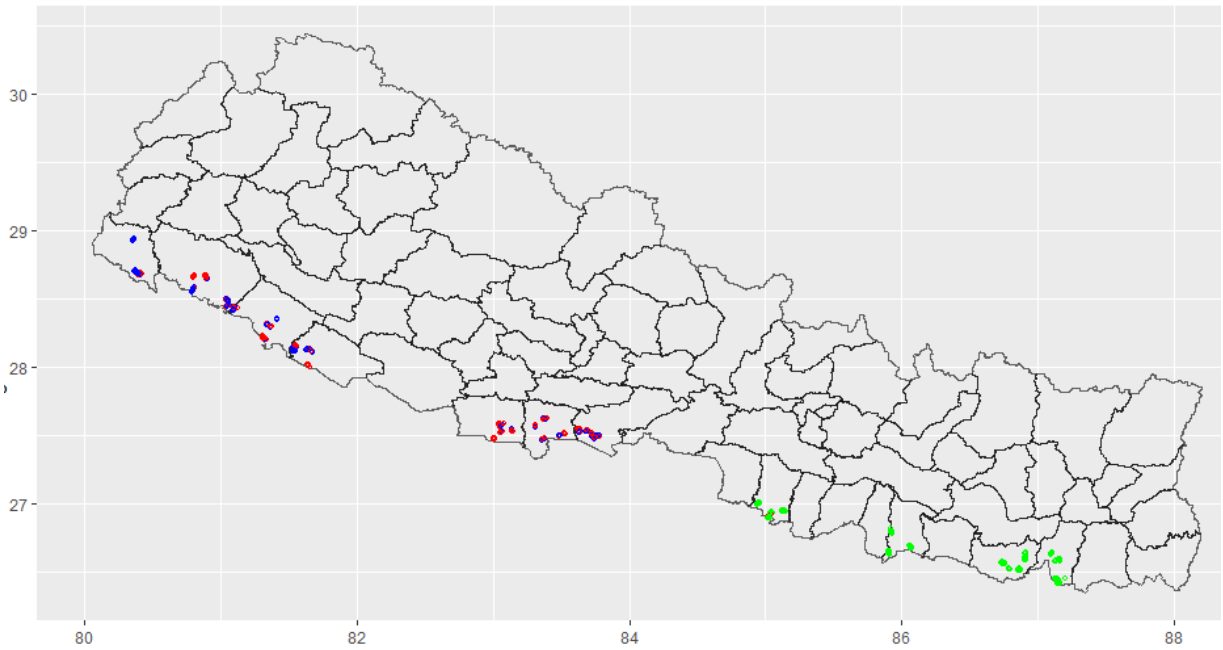


Figure 3.1: Wheat production survey locations in Nepal's Terai, 2018. The colors represent different management practice 'clusters' of farmers formed during analysis

The results on sowing time, yield gaps, and fertilizer response were shared with PMAMP's central unit and Kailali Wheat Superzone personnel at a meeting at CIMMYT Nepal's office in June 2019.

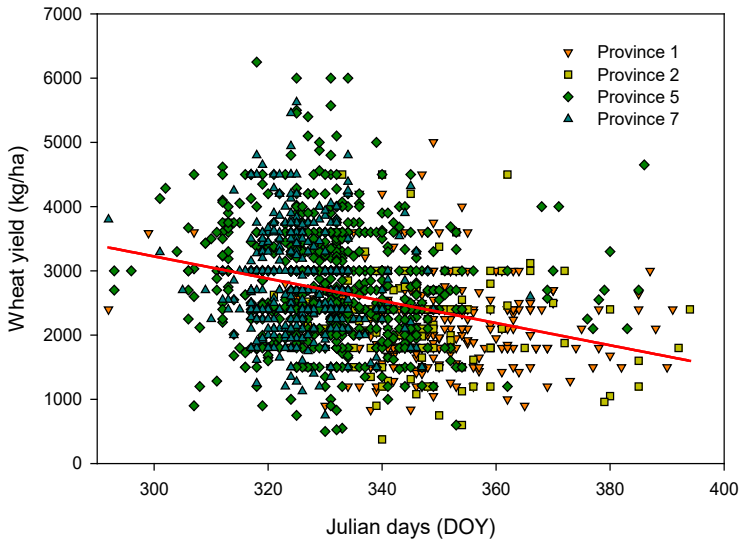


Figure 3.2: The downward sloping line shows that the late sowing decreased wheat yields in Nepal's Terai overall and province-wise (CSISA-NP wheat production survey, 2018)[6]

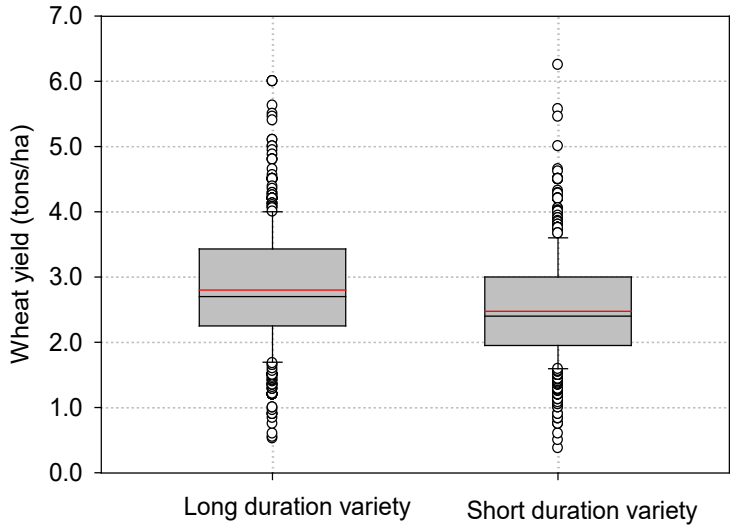


Figure 3.3: The 0.5 Mt ha^{-1} greater yield of long duration than short duration wheat (CSISA-NP wheat production survey, 2018)

Sowing time results – The findings confirm that the early sowing of long duration wheat varieties can significantly increase productivity in the Terai:

- The early sowing of wheat enhances productivity. A one-day delay in sowing after 21 November decreased yield by 20 kg ha^{-1} day^{-1} (see Figure 3.2 for trend of sowing time and yield). This is because early sowing permits the wheat crop to 'escape' the yield-reducing effects of heat stress the crop experiences if it is sown late. However, for farmers who sow early, survey results demonstrate that they should make use of longer duration wheat varieties, which help increase yield in the Indo-Gangetic Basin.

These and similar findings in previous years led the project to facilitate the NWRP to register elite long duration varieties, including NL 1327 and Borlaug 100, such as in Nepal.

Forty-three percent of the 1,684 surveyed farmers had adopted longer duration wheat varieties, and the adoption of these varieties had increased productivity by an average of almost 0.5 Mt ha^{-1} (Figure 3.3). These results provide strong evidence of the importance of varietal duration from planting to maturity, in addition to sowing date, for optimizing wheat productivity. Based on these results, the CSISA Scaling Project made further awareness raising and scaling efforts in this year, which it has passed on to the CSISA Phase III project now the scaling project has ended.

[6] Note that Province 7 is now called Sudurpashchim Province

Yield gap results – Wheat productivity in Nepal's Terai is around 2.6 Mt ha^{-1} with a current yield gap (the gap between the average and attainable yield) of around 1.5 Mt ha^{-1}. This indicates substantial remaining room for improvement. The results of the 2018 wheat production survey also showed that:

- the 10% of farmers with the highest yields (elite farmers) produced an average of 4.2 Mt ha^{-1};
- the 10% of farmers with the lowest yields (poorest farmers) harvested only 1.2 Mt ha^{-1}; and
- the 80% of farmers with middling yields (medium farmers) harvested about 2.6 Mt ha^{-1} (Figure 3.4, Nepal Terai).

This suggests that the use of improved agronomic practices has the potential to enhance wheat yields by an additional 1.6 Mt ha^{-1} if the middle 80% farmers (in terms of yield) employ similar management practices to those used by the top 10%. Similarly, the bottom 10% of farmers can enhance their yields by 3 Mt ha^{-1} if they use similar management practices to the top 10%. This highlights the potential for intensifying wheat production in Nepal.

The pattern of the yield gap between the highest yielding and lowest yielding farmers was similar in the Terai areas of all four provinces covered by the survey (Provinces 1, 2, 5 and 7[7]) (Figure 3.4). This highlights the need to improve agronomic management to enhance wheat productivity and close the yield gaps across Nepal's Terai. The means of achieving this include early sowing, using longer duration varieties, improving the efficiency of fertilizer use, and in some cases, increasing the frequency of irrigation.

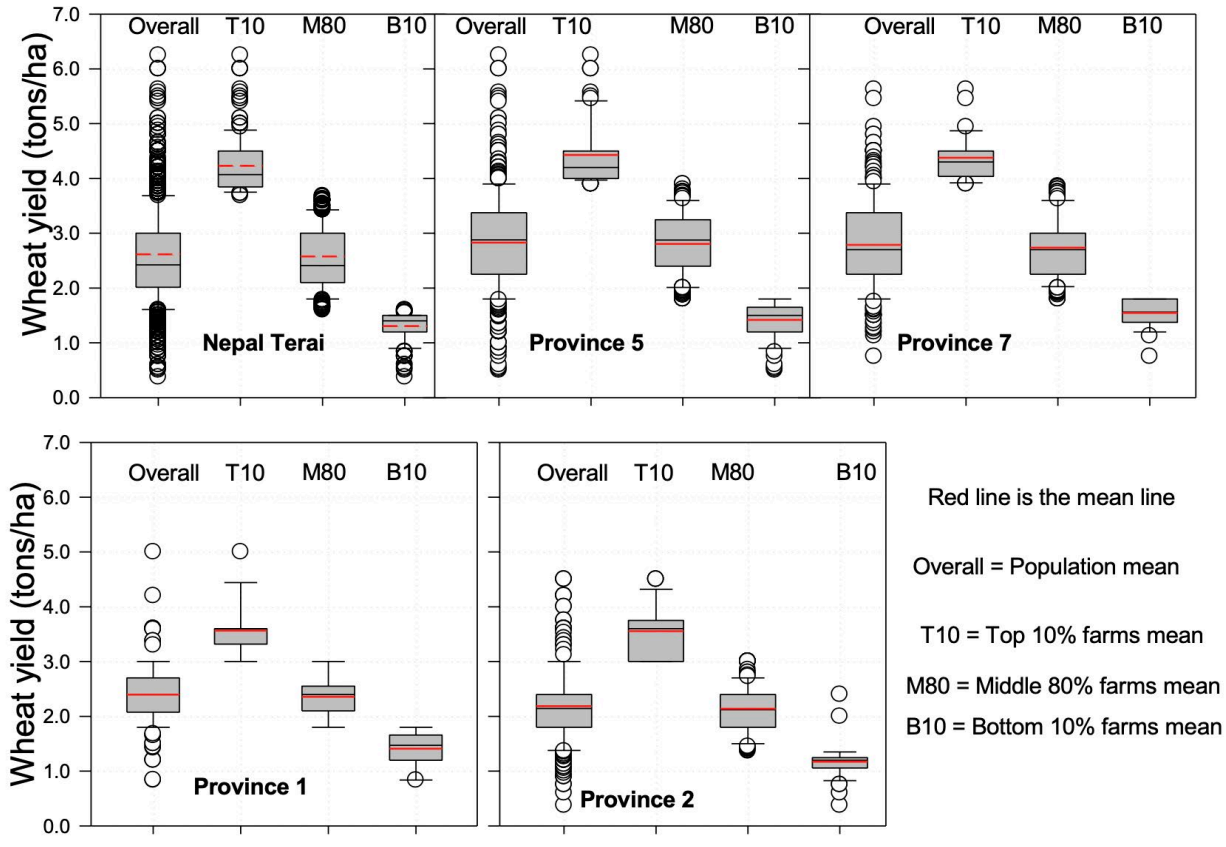


Figure 3.4: Difference in wheat yields between top 10%, middle 80% and bottom 10% yielding farmers in Nepal's Terai (CSISA-NP wheat production survey, 2018)

[7] Province 7 is now called Sudurpashchim Province

Fertilizer response results – The project collaborates strongly with the National Wheat Research Program (NWRP) and the USAID/Nepal mission funded Nepal Seed and Fertilizer (NSAF) project to review and revise the recommended doses of fertilizers for wheat in Nepal. The data from the 2018 wheat production survey shows that the current average levels of application of nitrogen and potassium (88 kg ha^{-1} N and 11 kg ha^{-1} K) are below the government's recommended rates, while the response of wheat is optimum at around 150 kg ha^{-1} nitrogen and 50 kg ha^{-1} potassium per hectare (Figure 3.5).

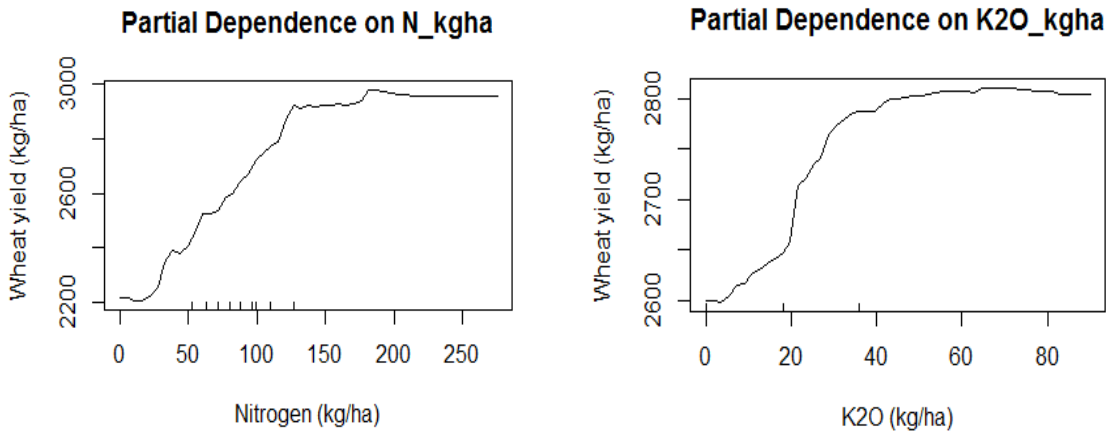


Figure 3.5: Survey results predict the effects of the application of nitrogen and potash fertilizer on wheat yields in Nepal's Terai (CSISA-NP wheat production survey, 2018)

The province-wise application rates varied for nitrogen and potassium (Figure 3.6). farmers.

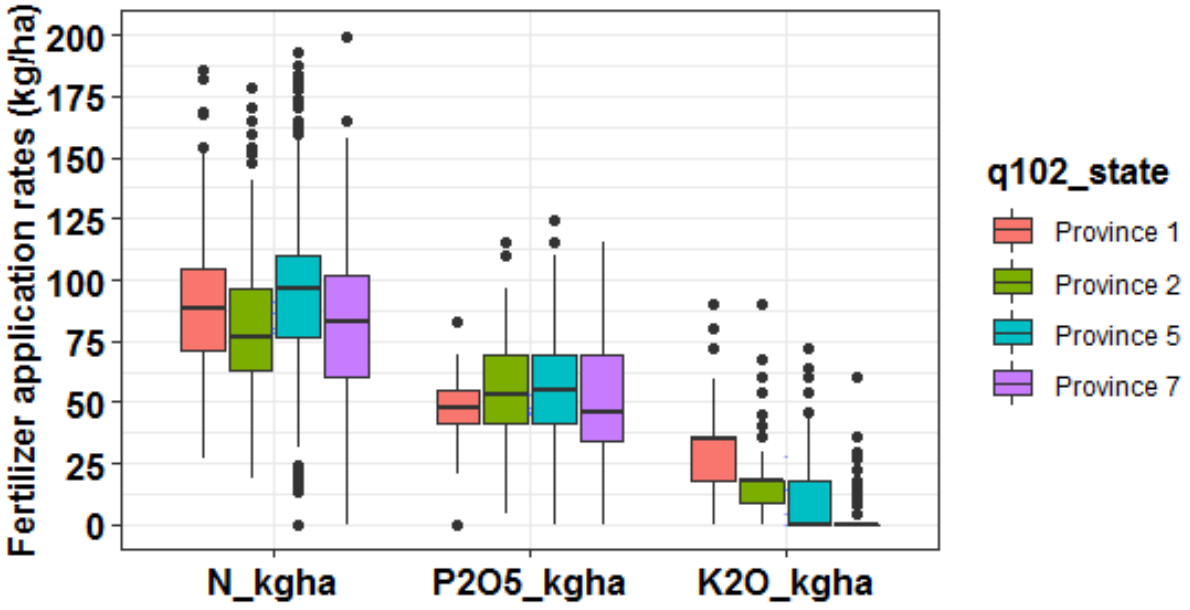


Figure 3.6: Province level fertilizer applications rates on wheat (CSISA-NP wheat production survey, 2018)

In coordination with NSAF and NARC, the project worked on developing area-appropriate recommendations to inform the forthcoming revision of the recommended doses of nitrogen and potassium on wheat in Nepal. Because the CSISA Scaling Project has ended, these activities are being

transferred to the CSISA Phase III project, with more emphasis on partnering with NSAF to assist in scaling-out these findings among Terai.

Results of 2019 wheat production survey

2019 survey – The May to August 2019 wheat production survey was carried out in 1,200 farming households in Banke, Bardiya, Kailali, Kanchanpur, Kapilbastu, Nawalparasi, and Rupendehi districts. In each district 150 samples were selected randomly from the three major wheat growing rural municipalities. As the project is ending the following writeups focus on the trends from the four surveys that show the impacts of project interventions.

Improved wheat productivity – The results of the 2019 wheat production survey show increased productivity in several districts. Average productivity increased from 2.8 Mt ha^{-1} in 2018 to 3.1 Mt ha^{-1} in 2019 in the FTF zone. Wheat yields in Banke, Kailali, and Nawalparsi districts increased by 0.5 Mt ha^{-1} with a lower rate of increase in the other districts (Figure 3.7). These increases are associated with the Scaling and CSISA III projects' provision of agronomic advice to farmers mainly channeled through PMAMP's wheat super-zones and zones. Advice was also disseminated through radio jingle messaging for the early sowing of wheat; adopting long duration wheat varieties to escape terminal wheat stress; and training farmers on better wheat management, appropriate fertilization and irrigation and weed control. These interventions have been described in previous reports.

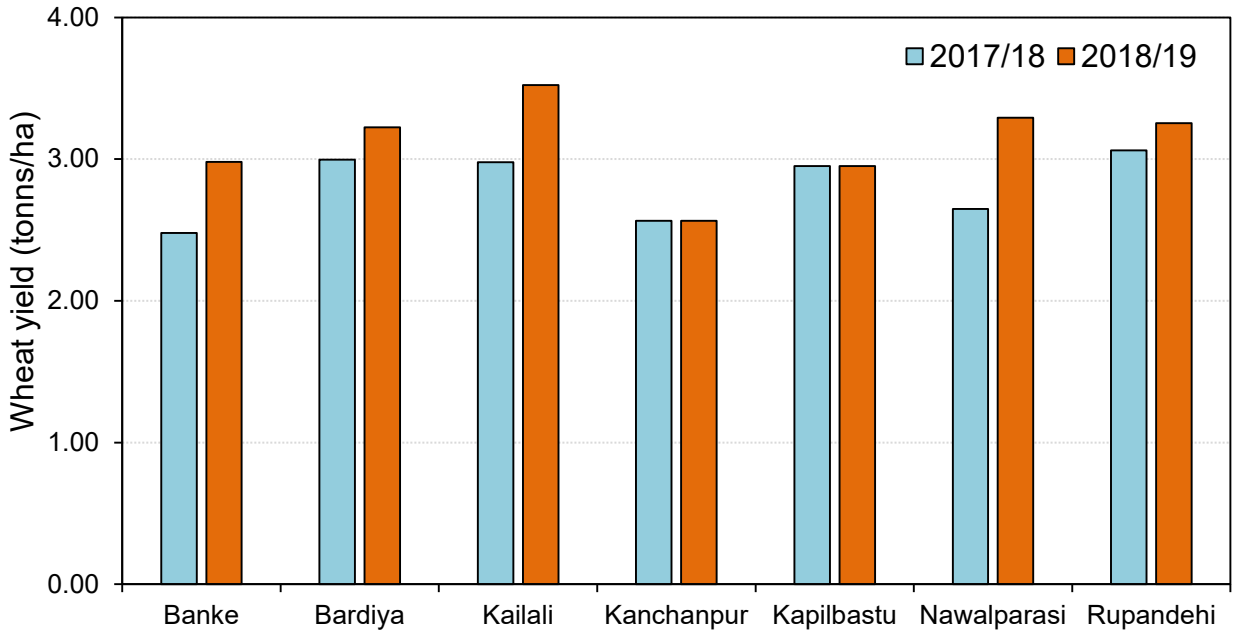


Figure 3.7: Change in wheat yields across FtF zone and CSISA working areas in 2017/18 and 2018/19 (CSISA-NP wheat production surveys)

Impact of changed wheat management practices on productivity – The increased productivity of the 2019 wheat crop is associated with changes observed in farmers' crop management practices. The 2019 survey found that 52% of the 1,200 surveyed farmers had adopted the improved wheat cultivation practices promoted by CSISA. The project's partner PMAMP mobilized its personnel to deliver the better agronomic advisories on wheat growing to farmers in 2018/19.

The project has also raised awareness on the bundles of actions that farmers can implement to improve wheat production practices in collaboration with PMAMP and other partners. These include varietal replacement, improving crop establishment (especially early sowing and zero tillage), more efficient nutrient management, increased frequency of irrigation, and appropriate weed control. The 2019 wheat

survey found that the farmers who had *not* adopted any of these practices had the lowest average yield of 2.9 Mt ha^{-1}, while the farmers who had adopted project recommendations on establishment, variety, irrigation and weed control had increased their productivity and achieved yields of up to 6.3 Mt ha^{-1} (Figure 3.8). The project believes that the increased frequency of irrigation coupled with early sowing and longer duration varieties are the key inputs that led to these farmers performing best. This information is now being extended to farmers at a larger scale through the CSISA III project. While many farmers have adopted two or three of these practices, no farmers were observed who had adopted all five improved management practices. Promotional activities and strategic research to identify mechanisms to overcome constraints are required to enhance adoption in the future.

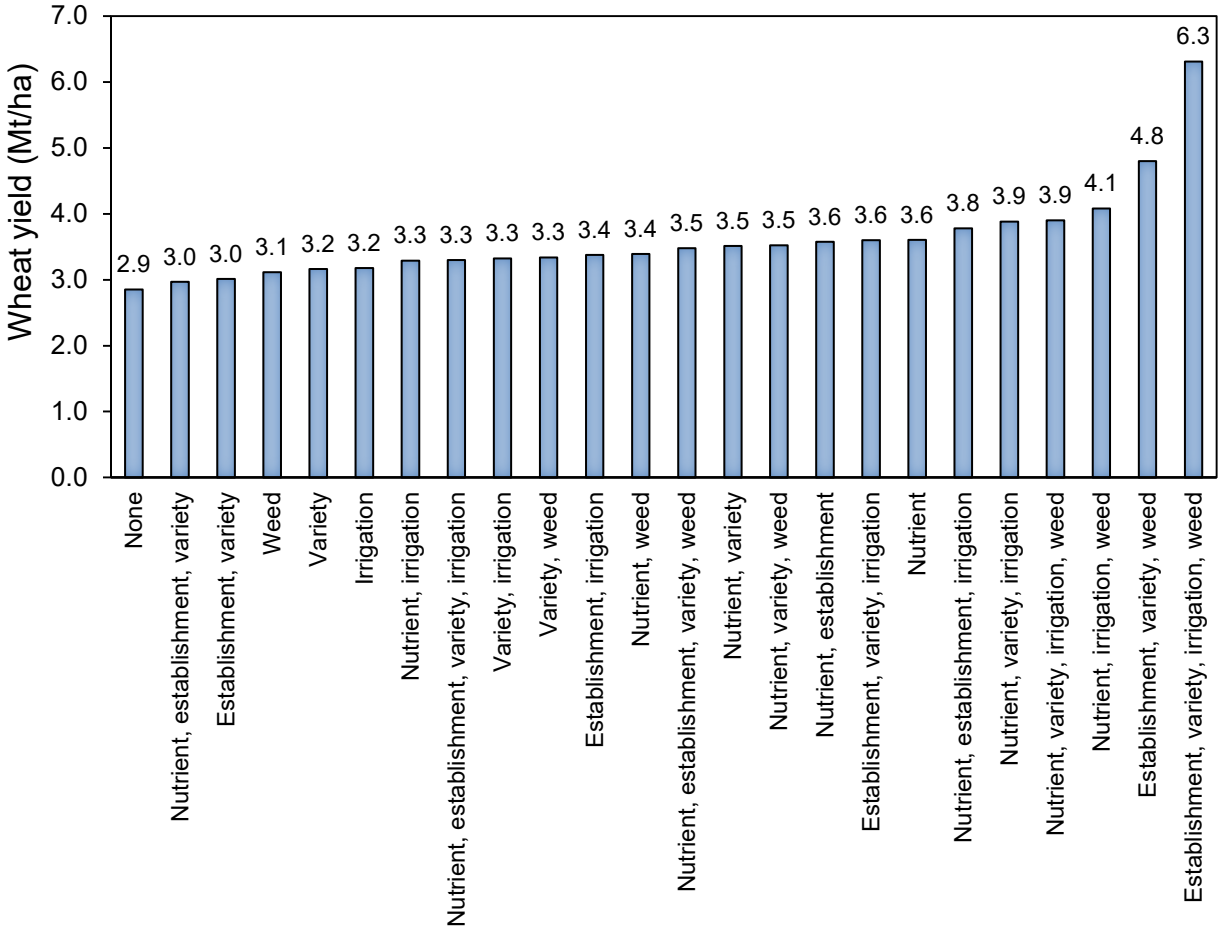


Figure 3.8: Types of crop management practices that farmers have changed in 2018/19 wheat growing season in CSISA working districts. These data show the 'step-by-step' path towards increased productivity that can be achieved by farmers employing increasingly complex management practices popularized by the project.

Zero tillage wheat demonstrations

The 2018 zero tillage demonstrations conducted by the project on wheat showed that early sowing led to higher yields in the mid and far-western Terai (Figure 3.9). Observations in 2018/19 are ongoing to provide further information about the implications of changing sowing patterns. In November 2018, the project established large demonstration plots of zero tillage wheat managed using improved agronomic practices in collaboration with MoALD's demonstration Farm in Kanchanpur, the Kailali Wheat Super Zone and a Bardiya district local government. In the lowland fields, the high soil moisture content at

sowing time meant that farmers had to sow the wheat later than the optimum time. In addition, ploughing the fields two or three times prior to sowing both increased the cost of cultivation and decreased productivity in fields adjacent to the zero tillage plots. Data collected by the project show that wheat sown using seed drills and zero tillage facilitates timely sowing, which in turn enhances wheat productivity.

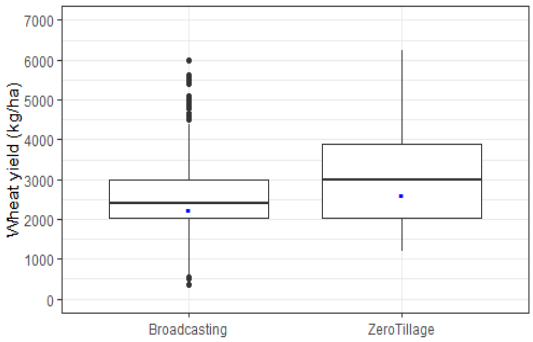


Figure 3.9: Yield advantage of zero tillage wheat over conventional tillage of 0.5 Mt ha^{-1} from even in farmer managed fields, 2018

3.2 Building a service economy for zero tillage wheat

Project campaigns through PMAMP and provincial governments on the benefits of early wheat sowing continued in the reporting period (see section 3.5 below). However, early sowing is most easily possible when farmers use zero tillage seed drills; but there is still relatively limited availability of drills in the Terai.. Between 2015 and 2019, the project and PMAMP have supported the development of 101 seed drill service providers with 185 seed drills now in operation in farmers' fields across the Terai. The impact has been a large increase in the number of seed drills (see Box 3.1).

Box 3.1: The increasing number of seed drills

Since it began, the project's regular technical backstopping and other support to government partners, machinery dealers and other stakeholders on crop establishment issues has brought about a large increase in the availability of four- and two-wheel tractor (4WTs and 2WTs) seed drills in the FtF zone. The number purchased and in operation in Sudurpashchim province and Province 5 increased from only 10 in 2015 to 135 at the start of 2019 (Figure 3.10). And the area seeded mechanically in the two province's Terai districts has increased from 250 ha in 2014 to 700 ha in 2018 (Figure 3.11). The increasing number is correlated with their commercial availability through dealers and also through entrepreneurial service providers working with farmer-clients. Around 12 local machinery dealers in the Terai areas of Sudurpashchim province and Province 5 now sell these drills.

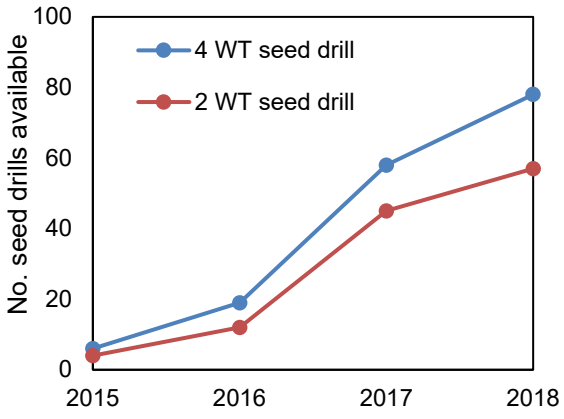


Figure 3.10: Increase in number of seed drills in Sudurpashchim province and Province 5, 2015–2018[8]

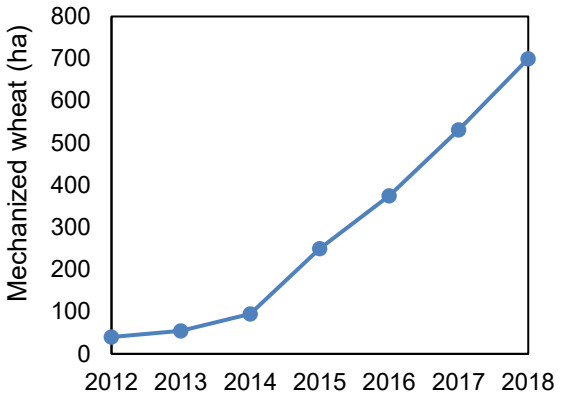


Figure 3.11: Hectares of wheat sown using seed drills in Kailali and Kanchanpur, 2011–2018[8]

[8] Note that 2018 captures FY 2019.

Demonstrations and farmer field days – In November 2018, the project, in collaboration with seed drill service providers, machinery traders and local governments established 15 zero-tillage wheat demonstration plots to raise awareness among farmers and government personnel about this technology across the Terai. In the period, two farmer field days were held at different wheat growth stages to acquaint farmers with the technology (Photo 3.1).

Photo 3.1: Farmer's field day in Udasipur, Kailali in a zero tillage wheat field (Lokendra Khadka)

Plans to diversify seed drill use – Most seed drills are owned by service providers with a few owned by cooperatives and farmers' groups. Efforts are being made by the project and PMAMP to increase the utility of the machines year-round by encouraging their use for seeding the range of cereals and pulses. This is being achieved through regular interactions between the project's engineering staff with PMAMP field staff in the Terai. The growing availability of multi-crop seeders (seed drills) is in turn facilitating the mechanized seeding of rice, maize, lentils, mung beans, black gram and other crops. The project supported service providers with technical information and advice, and by linking them to farmer-clients who are innovating to establish their crops with seed drills.

Photo 3.2: KISAN and NSAF technicians receiving hands on training on how to operate seed drills (Lokendra Khadka)

Identified machine needs to improve the quality and timeliness of wheat sowing and service provision – In January 2019, the project provided technical guidance to Sudurpashchim Province's agriculture ministry to prepare a priority list of scale-appropriate machinery for custom hiring centers in the province. The increased availability of machinery will encourage the zero-tillage establishment of wheat in the 2019/20 wheat season with support for the custom hiring centers continuing under the CSISA III project. The province is closely involved with these centers as it subsidizes their purchase of machines. Further details are given on this subject under Objective 5.

Other initiatives – Other related initiatives were the project i) linking 19 dealers with seed drill service providers in Kailali, Kanchanpur and Bardiya and ii) using the KISAN II network of agro-dealers to disseminate information about sustainable wheat growing technologies.

3.3 Wheat production training

Training – In October 2018 114 farmers and seed company, cooperative, retailer and government personnel were trained at four training events on improved wheat production technology including the importance of variety and seed replacement and the potential of bio-fortified wheat varieties.

Training of trainers – In the reporting period the project trained governmental agricultural technicians and farmer groups to enable them to train wheat farmers on improving their management practices and productivity:

- In November 2018, the project trained more than 20 potential trainers from farmer groups and cooperatives on best wheat production management practices in coordination with Kailali Wheat Super Zone (Photo 3.3).
- On 27 February 2019, the project and Sudurpashchim Province's agriculture ministry trained 20 government technicians, lead farmers, and representatives from seed companies, a seed producing farmers group and cooperatives on wheat production agronomy. The training covered suitable varieties, seeding times, best management practices, and disease and pest management. It also informed trainees about zero tillage and minimum/strip tillage practices in wheat and conservation agriculture machines such as 2WT and 4WT drawn seed drills.

Photo 3.3:Training on improved wheat production technology, Dhangadhi, Kailali, November 2018 (Pradip Chaudhary, CIMMYT)

Wheat on-farm experiment observations – In March 2019, the project supported 45 agricultural secretaries, provincial planning commission members, media and local government representatives to visit and observe demonstrations and trials of newly released and pipeline improved and bio-fortified wheat varieties in Kailali and Rupandehi districts. During the trip, provincial and local governments committed to promote the bio-fortified varieties in their forthcoming activity and extension plans for the next year. Four newspapers and three television channels covered the event and stakeholders' perception about the new project-promoted wheat varieties. The millers also committed to buying bio-fortified wheat grain at premium prices once it becomes available in sizable volumes.

3.4 Social marketing to expand awareness and use of early planting

During the reporting period, the project and PMAMP conducted a mass advertising campaign to encourage the early sowing of wheat in the FtF zone and in areas across the Terai where wheat is grown. The project provided the script and the radio stations produced short dramas to convey the main messages on the early sowing of wheat. The dramas were produced in Nepali and in Tharu languages to reach farmers with Nepali and non-Nepali mother tongues. These dramas were broadcast by eight FM stations across the four Mid-West and Far Western Terai districts in October and November 2019 just before the wheat sowing time. Field work conducted by International Food Policy Research Institute (IFPRI) indicated that these campaigns have reached farmers and increased awareness at a large scale, and that farmers are now more widely aware of the benefits of starting sowing the right varieties at the right time using long duration varieties. The media campaign also increased awareness of the importance of early planting more generally, and the use of short duration varieties for late planting to avoid yield-reducing heat stress in wheat. The project also supported FM radio stations to broadcast the names of trained service providers across the project's working areas of Kailali, Kanchanpur, Banke and Bardiya; with lists distributed to local and provincial governments for dissemination.

OBJECTIVE 4: PRECISION NUTRIENT MANAGEMENT AT SCALE

Project work on precision soil fertility and crop management in Nepal's farming systems during this period focused on testing domain and situation-specific soil fertility management options and raising awareness on the benefits of using handheld spreaders to apply fertilizers and promoting their adoption by farmers

4.1 Domain and situation-specific soil fertility management strategies developed for wheat, lentils and maize

Much of the project's work continued to focus on producing evidence for the revision of the government's fertilizer recommendations. The project carried out domain specific fertilization trials, wheat response trials and farmer assessments of different nutrient options. The project's major contributions to commercializing accessible technologies for more efficient fertilizer use are described under Objective 5 achievements. Importantly, parts of this work were done in strong alignment with the USAID supported NSAF project. The CSISA Scaling Project supported NSAF in key research and field implementation gaps that were relevant to both projects.

Producing evidence for the revision of the fertilizer recommendations

The Government of Nepal's recommended fertilizer application rates[9] for staple crops have a number of shortcomings:

- They are outdated and apply to very broad areas with few guidelines to improve the efficiency of use. This means that farmers may be advised to apply inappropriate fertilizer rates, which can fail to optimize yield and can increase their costs. Also, the over-application of nutrients can have negative environmental consequences.
- They were developed at experimental stations under conditions that don't reflect on-farm conditions and the variability in soils and climate that contribute to the efficiency of fertilizer use by crops.
- They rely heavily on urea nitrogen and in some cases miss critical nutrients such as zinc and sulphur. This over-focus on nitrogen and lack of attention to micronutrients can lead to poor crop productivity.

Whatever, the actual rates of application by farmers are well below these recommended rates. Also, the separate handling of diammonium phosphate (DAP) and muriate of potash (MoP) to provide NPK at planting results in logistical challenges and balanced crop nutrition cannot be guaranteed.

The project has supported the development of new fertilizer recommendations for Nepal that are based on the '4Rs', which include the principles of using the right fertilizer source, right rate, right time, right place to support integrated soil fertility management. The intention is that the revised recommendations can be positioned by CSISA and NSAF for awareness raising and out-scaling through private fertilizer companies, agro-dealers, cooperatives and development partners. Science-based evidence of the need to revise the recommendations can also help to encourage a rethinking of fertilizer pricing policies and the improved targeting of subsidies.

Domain specific fertilization trials[10]

Third year of response trials – The more location-specific application of plant nutrients is needed across the diverse environments of Nepal's Terai and Midhills farmland to increase efficiency, reduce costs and increase productivity. To address this, since 2016/17 the project has carried out trials to

[9] These rates are published in the Department of Agriculture's annual Agriculture Diary (Krishi Diary)
[10] Note that the fertilization findings from the wheat production survey are given in the Objective 3 writeup.

identify domain and crop-specific fertilizer blends. In collaboration with the NSAF project, in 2016/17 and 2017/18, the project conducted fertilizer response trials on wheat in Banke, Bardiya, Kailali and Kanchanpur and on maize in Dang, Kavre, Surkhet, Doti and Palpa districts. The third year of these on-farm trials (2018/19) were conducted in partnership with PMAMP and NARC and NEFEA. The trials have been harvested and data analysis is underway.

Testing new and balanced fertilizer blends – The trials included testing new fertilizer blends. In April 2019, the project held discussions with representatives from the fertilizer industry, including Adventz Export Ltd. of Gujarat, India (which is interested in expanding into Nepali markets) to stimulate demand in the western Terai for new fertilizers and blends via demonstrations with farmers. This led to the testing of three blended fertilizers NPK 20:20:10 and the two Adventz products of Sampatti (NPK 12:32:16) and Samarth (10:26:26) on maize and rice trials in the summer of 2019. These trials focused on validating the new blends under Nepalese conditions. The demonstrations in combination with NSAF-supported trainings generated demand by increasing knowledge for new fertilizer products and fertilizer management techniques

Experiments on wheat response to different fertilizer materials

Wheat trial design – Fertilizer response trials were conducted on wheat in Banke, Kanchanpur, Bardiya and Kailali districts in the winter 2018/19 growing season. Ten treatments were established at one site each in Banke, Kanchanpur, Bardiya and Kailali (Table 4.1). The treatments consisted of combinations of i) the source (including prilled urea [pellets], polymer coated urea [PCU] and sulphur coated urea) and ii) the rate of N (60 vs 100 kg ha^{-1}). Lower levels of nitrogen were applied at the Banke and Kanchanpur trials: (a) 60 or 40 kg N ha^{-1} at Banke and Kanchanpur, (b)100 or 80 kg N ha^{-1} at Bardiya and Kailali.

Table 4.1: Fertilizer trial treatments tested on 2018/19 winter wheat in 4 sites in 4 districts[11]

Treatment number	Composition
T1	0:0:0 kg NPK ha^{-1}
T2	60 or 100:50:10 kg NPK ha^{-1} – 100% of urea N from PCU applied at planting
T3	60 or 100:50:10 kg NPK ha^{-1} – 75% of urea N from PCU, 25% of urea N from 'regular' urea, all applied at planting
T4	60 or 100:50:10 kg NPK ha^{-1} – 50% of urea N from PCU, 50% of urea N from 'regular' urea, all applied at planting
T5	60 or 100:50:10 kg NPK ha^{-1} – 25% of urea N from PCU, 75% of urea N from 'regular' urea, all applied at planting
T6	60 or 100:50:10 kg NPK ha^{-1} – 100% of urea N from 'regular' urea applied at planting
T7	60 or 100:50:10 kg NPK ha^{-1} – 100% of urea N from 'regular' urea with 50% of applied after first irrigation (21 days) and 50% after second irrigation at panicle initiation
T8	40 or 80:50:10 kg NPK ha^{-1} – 100% of urea N from PCU applied at planting
T9	GoN recommended doses: 100:50:50 kg NPK ha^{-1} + 6 Mt ha^{-1} FYM
T10	60 or 100:50:10 kg NPK ha^{-1} 100% of urea N from sulphur coated urea applied at planting

Note: PCU = polymer coated urea. Regular urea was applied as prilled urea and sulphur coated urea

Wheat trial results – The grain yields observed by the project were similar across the four sites (Figure 4.1) even though in Banke and Kanchanpur only 60 kg nitrogen ha^{-1} was applied compared with

[11] Note that this trial was conducted in coordination and partnership with the USAID/Nepal Mission supported NSAF activity; as such, some of the information here may also appear in the 2018-19 NSAF Annual Report.

100 kg nitrogen ha^{-1} in Bardiya and Kailali. This suggests that the application of higher levels of nitrogen in Bardiya and Kailali may be unnecessary. Also, a reduced amount of nitrogen (40 kg ha^{-1}) applied as PCU (treatment 8) gave a similar yield as 60 kg ha^{-1} nitrogen applied as regular urea (treatment 7). This signals the potential to reduce inefficiencies in nitrogen application, although multi-year experiments are needed to confirm these results.

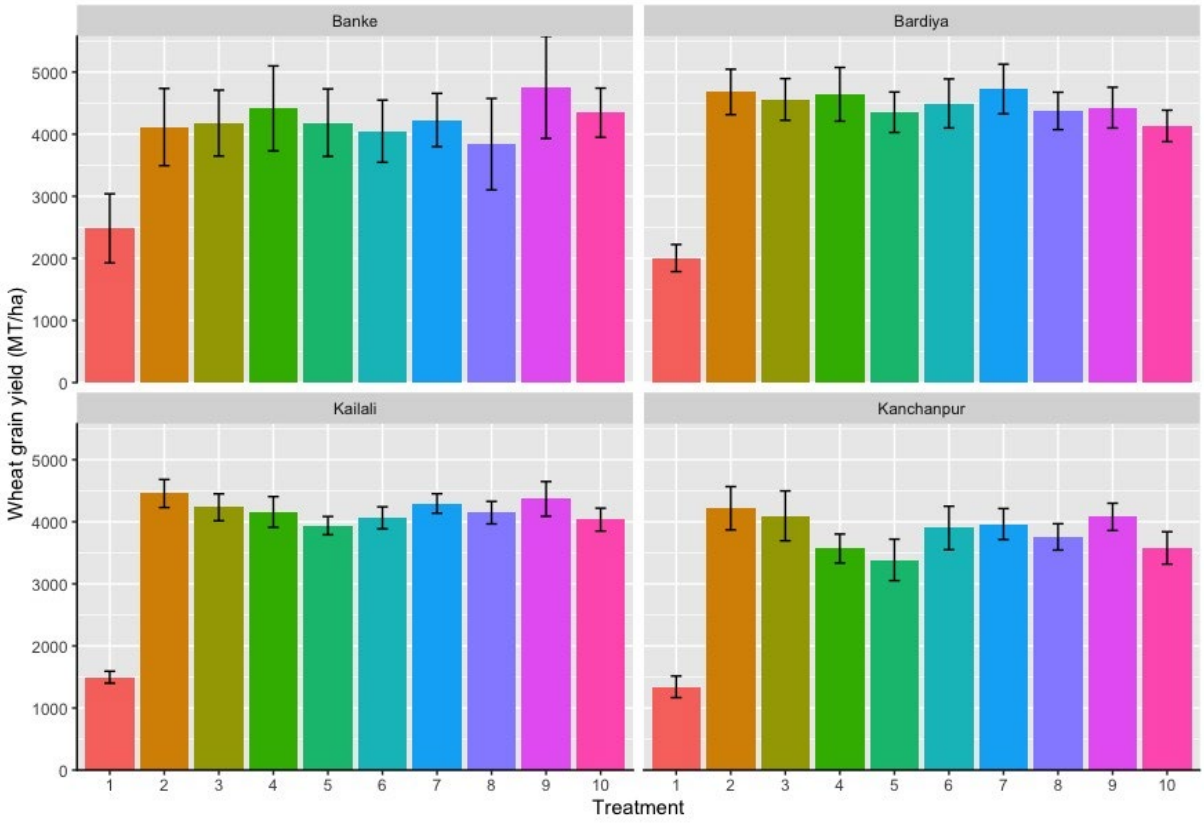


Figure 4.1: Productivity of wheat in 2018/19 season under 10 nutrient management treatment across four districts of Nepal. Notes: See treatment details in Table 4.1. Each treatment plot was replicated three times and the error bars represent the standard errors

Planning the logic for scaling-up fertilizer and agronomy packages

Since 2017, the project has collaborated with NSAF to create business logic maps that identify areas and new and existing fertilizers, seed varieties and production practices that could produce good economic returns. Examples include new fertilizer blends and region and crop-specific application rates. This work integrates advanced spatial analytics (e.g. machine learning and geospatial statistics) with causal inferences from the project's nutrient response trials. This work will be continued in the reporting period with the support of CSISA Scaling and will be taken forward by NSAF to:

- identify unsubsidized diammonium phosphate (DAP), urea, and muriate of potash (MoP) distribution and sales by the private sector as potential areas for business investments in areas in with good fertilizer responses and high farmer population densities; and
- identify high potential areas for business investments in region and crop-specific fertilizer blends.

Evaluating which nutrient management options are best-bets for rice

Rice demos – In June 2019, the project established two 450 m^2 demonstration plots in collaboration with farmer cooperatives, NARC, PMAMP and NEFEA in the western and eastern Terai to compare the

performance of hybrid (US-312) and open pollinated (Hardinath-3) varieties of rice under three different nutrition regimes. The inclusion of the eastern Terai was supported by NSAF to permit the assessment of demonstration results across different agro-climactic regions. An open pollinated variety was demonstrated in plot A and the hybrid variety in Plot B. Each of the six treatments were applied over 150 m^2 (Table 4.2). The trials were established to get farmers' perceptions of different ISFM options.

Table 4.2. Nutrient management options demonstrated to farmers for rice production and used in farmer evaluations

Treatments	Details
1. 78:50:50 kg $NP_2O_5K_2O$ kg ha^{-1}, N as PCU + 20 kg ZnSO4 + 5 kg ha^{-1} Borax	• P and K in the form of DAP and MoP • Precision broadcasting (Earthway spreaders) of PCU, spot placement of UDP • All fertilizers (NPK) applied at planting
2. 78:50:50 kg $NP_2O_5K_2O$ kg ha^{-1}, N in the form of briquetted urea (UDP) + 20 kg ZnSO4 + 5 kg ha^{-1} Borax	
3. 100:50:50 kg $NP_2O_5K_2O$ kg ha^{-1} + 20 kg ZnSO4 + Borax 5 kg ha^{-1}	• N, P and K (regular urea, DAP and MoP_ • N top dressed at tillering (21 d) and panicle initiation stages (50 d) (50%/50%) • N applied by precision broadcasting, using Earthway spreader

Assessing farmers' perceptions of nutrient management options – At crop maturity time in September and October 2019 the project held 20 farmer field days to get farmers' perspectives for possible incorporation in the design of future trials, and to identify the practices farmers are likely to prefer. Fourteen days were held with farmer cooperatives in Banke, Bardiya, Kailali, Kanchanpur; 2 days with government institutions (PMAMP Bardiya and Soil and Fertilizer Testing Laboratory, Kanchanpur); 2 days with private companies (Kisan Agroet Centre Kailali and Kisan agrovet Kanchapur); and 2 days with seed companies (Gate Nepal in Banke and Panchashakti in Kailali). Local farmers saw the demonstrations of integrated soil fertility management practices (Photo 4.1) and took part in the participatory evaluations.

Photo 4.1. Farmers' field day on rice organized in collaboration with NSAF and Sudurpashchim province's Soil and Fertilizer Testing Laboratory in Kanchanpur (Surya Bdr Thapa)

User perceptions – The highest yielding technology options were unsurprisingly scored higher by the farmers:

- The farmers preferred PCU as the source of nitrogen as it gave the highest yield and gave the lowest score to the regular urea treatment as it gave the lowest yield. This is encouraging given this product's potential for more environmentally sound and efficient fertilizer use.
- Most farmers preferred the open pollinated varieties of rice over the hybrids as the yields were similar and they didn't see a benefit in planting the hybrid.

- The farmers preferred the slow release fertilizer treatments as they cost less and can give a higher yield.
- There was no significant difference in the preferences of men and women between the three treatments and the two types of variety.

4.2 Raising awareness of the benefits of judicious fertilizer application

Handheld spreaders – Many farmers in Nepal broadcast seed and fertilizer by hand, which leads to sub-optimal and uneven application which negatively affects crop yields. The use of handheld precision spreaders for seeding and fertilization provides an inexpensive easy-to-use solution to this problem. The more uniform application of fertilizer and the seeding of rice, wheat and lentils increases yields by enabling plants to more efficiently use available nutrients. These machines are relatively affordable, costing about $35 (NPR 4,000), and are easy-to-use and women-friendly.

The project has raised awareness among farmers of the uses of these spreaders across the FtT zone in partnership with PMAMP and Nepal Agricultural Machinery Entrepreneurs Association (NAMEA) members. Most farmers like the technology, although some have pointed out the need for minor technical modifications, such as the calibration control. The project has provided feedback on these issues to the company. These spreaders enable inexperienced farmers to broadcast fertilizer efficiently. Note that other spreader-related achievements are given in the Objective 5 writeup.

Awareness raised on precision fertilizer spreaders

- **Jingles** – Radio messaging is a cheap and effective way to deliver agriculture information to farmers. The project produced short informative and entertaining radio jingles to raise awareness about the benefits of handheld spreaders. They were produced in Nepali and the local languages of Tharu and Awadhi to reach the most farmers. The project supported the broadcasting of these 'jingles' between January and March 2019, in partnership with local suppliers, on 12 FM station across the Terai of Sudurpashchim province and Province 5. The jingles were also broadcast between April and September on 7 FM stations of Banke and Bardiya districts. These and other project awareness raising activities led to many farmers buying spreaders.


मल तथा बीउ छर्ने हाते मेसिन (Seed and Fertilizer Spreader)

Figure 4.2: Precision spreader fact sheet developed by the project

- **Factsheets** – In 2018 the project produced a factsheet on how to use handheld spreaders (Figure 4.2). In this reporting period the factsheet was printed and distributed to 900 farmers through PMAMP's Kailali Wheat Super Zone, Bardiya Rice Super Zone, Banke Maize Zone, Kailali Oilseed Zone, the government's agricultural knowledge centers in Kanchanpur and Banke, and at provincial agricultural fairs in Kailali and Rupandehi. The importer SKT Traders printed this information to communicate the technology to their clients.

Training on using spreaders

Training of trainers on handheld spreader technologies

- In the first half of project year 2018/19, the project ran three training of trainers events in Bardiya on the use of fertilizer and seed spreaders for agrovets and lead farmers from the NSAF and KISAN

2 projects. Three community volunteers from NSAF, two PMAMP technicians and 20 agrovets took part. Two agrovet trainees from Bardiya subsequently conducted 45 trainings for 450 farmers on the use of spreaders in the 2018/19 wheat season. These trainings also led to the sale of 48 spreaders by four local suppliers.

- In July 2019, CSISA organized a training of trainers program on the use of spreaders for seven personnel from three local suppliers in Rajapur Municipality, Bardiya (Sikha Agrovet, Swostik Traders and Jay Laxmi Traders). On 12 August 2019, the project conducted a further training of trainers program with Kanchanpur Rice Super Zone for farmers from Bishwas Farmers' Agriculture Cooperative, Jhalari, Kanchanpur. These programs made participants familiar with operating the machines and showed them how to train their customers. In the two months following the training the suppliers briefed more than 400 farmers on the benefits of using spreaders and 60 farmers bought units to apply fertilizer to their monsoon rice crops.

Training and demonstrations on handheld spreader technologies

- **Trained agro-dealers** – In 2018, the project trained seven agricultural input dealers on operating precision spreaders. These dealers subsequently and independently ran 10 demonstrations for potential clients. Also, agro-dealer recipients of agro-entrepreneurship grants from the KISAN II project in Kailali and Bardiya demonstrated the use of spreaders to their farmer clients in this period.
- **Trained women farmers** – Handheld spreaders are a women-friendly technology. With women farmers increasingly taking a lead role in Nepalese agriculture, in January 2019, the project facilitated the NSAF project to train 10 community volunteers and demonstrate the use of urea spreaders to women at 10 sites in Kailali and Kanchanpur. Also, on 6 August 2019, during the main 2019 rice growing season, the project assisted Belauri Municipality's agriculture section and Punarbash municipality, Kanchanpur to conduct a training-cum-demonstration on precision spreaders. Twenty-five women farmers and three government technicians were trained on how to use the spreaders to spread fertilizer. RK Traders, a local spreader supplier, also participated.
- **Trained farmers 1** – In February 2019, the project facilitated Kanchanpur Agriculture Knowledge Center and PMAMP to run hands on trainings on the use of fertilizer spreaders and to demonstrate the stages of wheat growth when the application of fertilizer is most beneficial. 485 farmers participated in the five one-day trainings in Kailali and Kanchanpur and became more knowledgeable about the growth cycle of wheat and the use of spreaders. A representative from spreader supplier Manjari agro traders took part in the training.
- **Trained farmers 2** – In July and August in the 2019 rice growing season, the project carried out ten one-day training events for farmer groups and cooperatives in Dang Maize Super Zone on the operation of spreaders. The 225 participating farmers had purchased spreaders under the Super Zone's subsidy program. These machines are now being used to top dress urea on about 40 ha in the super zone.
- **Demonstrations** – In December 2018 an agrovet (SK Suppliers and Agrofirm) and four other agriculture projects (BRACED [UKAid], KISAN 2, NSAF and Suaahara [USAID]) demonstrated the use of the spreaders (Photo 4.2). This indicates an important outcome of the project – that other USAID funded activities are taking notice and coming forward to raise awareness among their beneficiaries of these simple-to-use technologies.

Photo 4.2: Fertilizer being applied with a seed and fertilizer spreader at a demonstration in December 2018 in Bardiya by SK Suppliers and Agrofirm for potential clients (Salin Acharya)

Partnership with Salt Trading Corporation to raise awareness on precision nutrient management

In this period the CSISA Scaling cooperated with NSAF to develope a partnership with one of the two government-sanctioned fertilizer supplier Salt Trading Corporation Ltd (STCL) to use their dealer network to increase awareness of the balanced application of fertilizers. STCL's dealer in the FtF zone were subsequently trained on the 4Rs of nutrient management to pass recommendations to their customers on best practices for applying fertilizer.

4.3 Public sector support for fertilizer spreaders

Nepal's new provincial governments are responsible for overseeing agricultural development in their areas. In this period, the project began to support them to identify activities to encourage farmers to make use of resource-conserving technologies and crop management practices. As a result, in March 2019 the Sudurpashchim and Province 5 governments started to subsidize the purchase of spreaders by providing a 50% subsidy for farmer groups, cooperatives and private firms to buy them. By the end of this reporting period PMAMP's Dang Maize Super Zone had subsidized the purchase of 45 spreaders by farmers groups and cooperatives.

4.4 Accessible technologies commercialized for more efficient fertilizer use

Adoption and spread of handheld spreaders

The project's activities to raise awareness about the benefits of and operation of handheld activities are reported in Section 4.2. These and previous years' activities have led to many farmers buying these spreaders including those featured in Box 4.1.

Twelve traders in the Mid-West and Far West Terai now regularly sell handheld spreaders. And PMAMP's Kailali Wheat Super Zone, Banke Maize Zone, Dang Maize Super Zone, Kanchanpur Rice Super Zone and Kailali Oilseed Zone promote them through their subsidy schemes.

Box 4.1: Two progressive farmers buy and use handheld spreaders

In 2019, Guru Prasad Chaudhary, a progressive farmer of Geruwa Municipality, Bardiya, used his new spreader to directly seed 1 hectare of rice and to urea top dress 4 ha of rice (Photo 4.3). Another farmer from the same area, Sudip Dhungana used his new spreader to directly seed rice for 14 farmers on 13 ha and to top dress 16 ha with urea. He charged $6.7 (NPR 750) per hectare, which is cheaper than the $8.9 to $13.2 (NPR 1,000–1,500) per hectare it costs to pay daily labor to hand broadcast fertilizer.

Photo 4.3: Mr. Guru Prasad Chaudhary spreading urea fertilizer in Geruwa, Bardiya (Suresh Tharu)

OBJECTIVE 5: SCALE-APPROPRIATE MECHANIZATION AND IRRIGATION

The fifth objective of the CSISA Scaling Project encourages scale-appropriate mechanization in Nepalese agriculture to enhance the timeliness of farm management operations for increased yields, and to increase profits and improve farmers' livelihoods. The project is scaling-up the technologies that CSISA has researched and developed over the past 10 years, including two-wheel tractor (2WT) power tillers and attachments like seed drills and reapers (harvesters), four-wheel tractor (4WT) seed drills and reapers, mini-tillers suitable for the cultivation of small plots and weeding, and knapsack seed and fertilizer spreaders. The project has learned from its interactions in India, including the Design Sprint, which developed seeder prototypes and multi-crop seeder attachments for two-wheel tractors, which are now available in Nepal's machinery market. CSISA has also worked to expand and develop innovative machinery businesses that offer new models of four-wheel tractor seeders and planters.

Although most of the project's work is in the FTF zone in the western Terai, the above technologies are also spreading to into central and eastern Nepal. The area under these technologies is growing as a result of the model of entrepreneurial machinery service provision, which is being supported by the project and its partners. With this approach, machinery service providers offer services to farmers on an affordable fee-per-service basis, which has enabled the impacts of CSISA to reach more farmers and area of farmland than would have been possible without this model.

In Nepal, the project has collaborated with the Prime Minister's Agriculture Modernization Project (PMAMP) and the Nepal Agricultural Machinery Entrepreneurs Association (NAMEA) to promote appropriate farm mechanization to offset labor scarcities and substitute for draft animals. PMAMP is a government project to increase the productivity of selected crops in designated production blocks – 500 ha 'zones' and 1,000 ha 'super zones'. The project sees collaboration with PMAMP as a key means of scaling-up and institutionalizing sustainable intensification technologies and improved crop management practices. It has therefore been assisting PMAMP to promote mechanized seeding, planting, weeding, and harvesting, and other crop management practices since 2016.

5.1 Evidence of CSISA's big impact among small farmers in Nepal's mid hills is increasing

The farmers in Nepal's Midhills increasingly rely on low horsepower mini-tillers to prepare their fields (see Photo 5.1). An important early project activity in 2016 and 2017 included efforts to expand the use of mini-tillers in the mid-hills. Since then, however, the project re-prioritized work in the Terrai. In an effort to learn from the project's early activities, analysis of data from the mid-hills was under taken in the reporting period to examine post-intervention potential demand for mini-tillers. The study found the following:

- Many surveyed farmers were willing to buy or hire mini-tillers to prepare terraced fields.
- Labor availability, increasing labor costs, small farm size and farmers' links with cooperatives and credit were the main factors driving demand.
- The demand for mini-tillers was inversely related to the number of draft animals farmers owned or could access.

The study on the impact of the use of mini-tillers on productivity found the following:

- Rising rural wages and the declining availability of draft animals were driving the adoption of mini-tillers.
- The use of mini-tillers was found to have increased rice productivity by an average of 1,110 kg ha^{-1} (27%) among adopting farmers.

- For farmers who have not yet adopted, ex-ante analysis indicates that they could increase their rice productivity by 1,250 kg ha^{-1} (26%) if they began using these machines.
- Very small farms (≤0.25 ha) make the most rice productivity gains through accessing mini-tiller services.

The study findings have supported the government's policy of promoting farm mechanization to offset the shortage of labor faced by Midhills farmers and informed the project's approach for supporting scale-appropriate mechanization on Nepal's farms. The main recommendations were that the government and the private sector work together to reduce the price of mini-tillers to increase adoption and that a service provider model be fostered for farmers to hire in tillers and operators.

In this reporting period, a paper on productivity impacts was published in *Land Use Policy*, while a paper on the demand study was presented to the annual meeting of the Southern Agricultural Economics Association (SAEA), USA in February 2019 and published in Technology in Society in September 2019.

Photo 5.1: A service provider preparing a small terraced field in Nepal's Midhills with a mini-tiller for planting rice. Larger machinery is unfeasible in this environment, and so the project has focused on expanding markets for such scale-appropriate machinery (Peter Lowe)

Overall, in this period the project made good progress on i) supporting policy makers and governance structures for extending access to scale-appropriate farm machinery, ii) supporting the development and availability of scale-appropriate farm machinery; iii) raising awareness on the benefits of farm mechanization; and iv) building capacity on operating and maintaining farm machinery.

5.2 Supported policy makers and governance structures to extend access to scale-appropriate farm machinery

The project supported several government initiatives to foster and support farm mechanization and helped build the knowledge of government decision makers about farm machinery innovations.

Support to government machinery testing and promotion centers

Support to promotion center – In 2017/18 the project supported the Department of Agriculture to establish its Agricultural Machinery Promotion Centre (AMPC) at Naktajhij, Dhanusha. The transition to a federal system of governance in 2017/18 saw the DoA's Agri Engineering Directorate being restructured and some powers and resources devolved to provincial governments. This delayed DoA's plans to turn AMPC into a central agriculture and mechanization training facility. The project looked at ways of supporting AMPC in the interim period, and on 20 December 2018 held a training of trainers event for AMPC staff on the use of laser levelers to prepare rice fields. The agricultural engineer placed at NAMTRC supported the training of trainers program to enable AMPC technicians to provide farm machinery training programs at a wider scale.

In this reporting period the project also supported the center to renovate its training hall and training workshop. In consultation with the center the project supported the repair and maintenance of the training and workshop halls including renovating the electrics and floors and installing a new projector and furniture and painting the walls. The work was carried out in June and July 2019. This renovation work had not been included in the center's 2018/19 budget and this support enables the center to start its new scheduled training programs. The head of AMPC appreciated the high quality of the work and consistent support provided by the project.

Traveling seminar

More than 40 international experts and project partners, including private sector partners, the Director General of the Department of Agriculture (DoA) and the PMAMP chief attended the 25–29 March 2019 Traveling Seminar on Scale-appropriate Machinery for Cereal Crop Harvesting in South Asia. The seminar provided a platform to share, discuss and learn about cereal harvesting technologies in Asia. The delegates visited project sites and partners across the Terai and informed government participants about the site-specific options for farm mechanization in Nepal.

Delegates witnessed technologies in use and discussed in detail the mechanization of Asian cereal harvesting. They saw Nepal's scale-appropriate, private sector-led mechanization in action including large combine harvesters and self-propelled reapers and the recent spread of more than 3,000 2WT reapers (Photo 5.2).

Photo 5.2: Travelling seminar delegates discuss the use of combine harvesters with farmers in Rupandehi (left) and 2WT mounted reaper-harvesters in Kailali (right) (Dakshinamurthy Vedachalam)

Delegates discussed issues with farmers who employ machinery service providers, service providers, machinery importers and sales agents. They also listened to experts from China, Bangladesh, India, Sri Lanka and Vietnam who discussed the use and potential of scale-appropriate farm machinery.

Studies on harvesting technologies

CSISA reaper study – In August and September 2019, the project collected data for a study on the value chain for reapers in Nepal to better understand the purchase and use of these machines in the FtF zone. The preliminary analysis of the data from 667 reaper service providers in Bardiya and Kailali indicates the following:

- 24% (159) of the surveyed reaper service providers had received support from government and non-governmental organizations to purchase reapers, while the other 76% had purchased the machines themselves.
- On average the providers harvested 4.7 ha of rice and 3.2 ha of wheat annually. Most harvested less than 6 ha of wheat and 6 ha of rice per year with only a few harvesting 14 ha or more of these crops, which is far below the capacity of machines (Figure 5.1). This indicates that CSISA and its partners to increase efforts to assure that service providers are fully in-demand by farmers, and that farmers are able to access services quickly as needed.
- The average annual income of a reaper service provider from providing reaper services was about $213 (NPR 24,000) (calculated at the rate of $2.66 [NPR 3,000] ha^{-1}).
- Seventeen of the reapers bought in 2018 or before were not used to harvest 2018 monsoon season rice, and 67 of these machines were not used to harvest 2019 season wheat. A major reason for this was probably the lack of repair and maintenance of these machines. This again provides a valuable learning for the project, and for the ongoing activities in CSISA III, which can benefit from these insights to refocus activities on further developing maintenance and spare parts value chains.

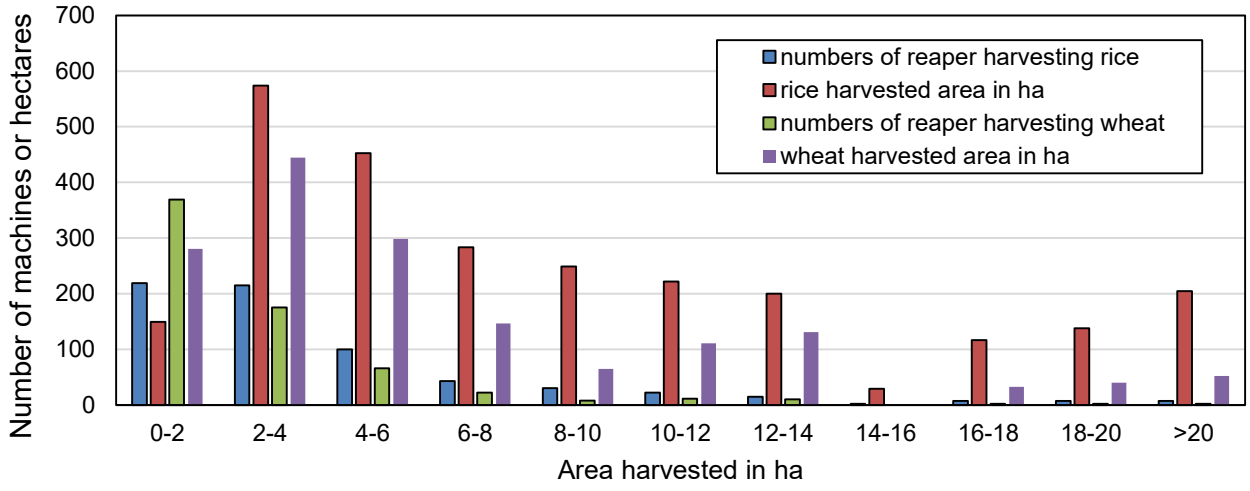


Figure 5.1: Distribution of area harvested annually by the 667 reaper service providers in Bardiya and Kailali

Sharing results – The results of the reaper study will be shared soon with the provincial agriculture ministries and other reaper value chain partners through the CSISA III project. The findings should be especially useful to guide provincial ministries' forthcoming revisions of harvesting machinery policies.

Value chain of harvesting machinery – A qualitative study on the value chain of harvesting machinery was commissioned by the project and carried out by Access Advisory in this reporting period. The preliminary report, the final version of which will be published in early 2020, provides an

overview of the value chains of rice, wheat and maize harvesting equipment available in Nepal, from manufacturers and importers to farm-level service provision. It covers a number of grain-harvesting machines and equipment and their use in the Terai, particularly in Nawalparasi, Rupandehi and Kapilvastu in Province 5 and Banke, Bardiya and Kailali in Sudarpashchim Province, plus their associated value chains in Kathmandu and abroad. The study gathered data in August and September 2019 using stakeholder questionnaires, key informant interviews, focus group discussions, market observation, and a review of secondary. The preliminary results are presented in Box 5.1.

Box 5.1: Preliminary results of value chain study of harvesting machinery in Nepal

- Aggregating the demand by small farmers for harvesting machinery services would encourage service providers to come to areas not yet serviced and thus increase the area under mechanized harvesting. This would entail groups of farmers or PMAMP working to coordinate the cropping of large areas of similar varieties of crops that mature at similar times.
- New types of support are needed to support and improve the current extensive non-formal small and medium sized agricultural machinery service entrepreneurs.
- More detailed studies are needed to understand the potential demand and willingness to pay among service providers and farmers for grain harvesting machinery and harvesting services.
- NAMEA needs further professional development and to become an institution that promotes value chain development by trainings its members:
  - to use contemporary business tools and practices to make their operations efficient and increase profits;
  - carry out internal performance reviews in relation to the industry standards.
- Private banks, the Nepal Rastra Bank and various value chain actors need to collaborate to identify and institute ways of mitigating the risks involved in agriculture mechanization:
  - Convince the banks of the large commercial potential of the farm mechanization sector so as to diminish banks' common misperception that the farm mechanization value chain is a high risk sector. Guarantee mechanisms are needed.

Access Advisory is scheduled to present the study findings to NAMEA's members and MoALD and DoA in late 2019

Photo 5.3: Project meeting with Sudurpashchim Province agricultural officials in January 2019 (CSISA archive)

Support for provincial governments

The new middle tier of government, Nepal's seven provinces, have been given considerable responsibilities for overseeing agricultural development in their areas, including on cereal-based farming systems. In the reporting period, the project provided the following support to provincial agriculture ministries on farm mechanization:

- In January 2019, the project held discussion meetings with the secretary and staff of the agriculture ministries of Sudurpashchim Province and Province 5 (Photo 5.3). The provincial governments identified activities for project support and involvement in 2019 including on identifying appropriate farm machinery for them to promote and support.

- In February 2019, the project participated in Province 5's agricultural fair at Butwal to demonstrate scale-appropriate farm machinery options and to direct agricultural fair participants towards private sector machinery suppliers.

Supporting the development and availability of scale-appropriate farm machinery in the Feed the Future Zone

During the annual reporting period, the project continued to develop and encourage the availability of scale-appropriate farm machinery for smallholders (Box 5.2 and Box 5.3)

Box 5.2: Demonstrating labor-saving advances in the weeding of maize using mini-tillers

Since 2017, the project worked with the Dang Maize Super Zone to promote the weeding of maize crops with mini-tillers. The reported savings of more than $80 ha^{-1} on weeding costs are driving demand not only for mini-tillers but also for maize planter (seeding) attachments on four-wheeled tractors, as maize must be line sown to enable mini-tiller inter-cultivation weeding. This increases the utility of mini-tillers, is replacing labor intensive manual weeding and is transforming maize production in Dang. Mahesh Regmi, the Chief of Dang Maize Super Zone, recognized the project's valuable contributions in a meeting with senior project staff in January 2019:

"The great promise of mini-tiller weeders in the Maize Super Zone is credited to CSISA's technical work. CSISA's team started it with modification of the mini-tiller to help farmers weed and earth up at the same time. The technology is being rapidly adopted with more and more demand from farmers."

Development of fertilizer applicator attachments suitable for smallholder farmers

Photo 5.4: Field testing mini-tiller side-dressing attachment for maize in Dang. Preliminary evaluations indicate that this attachment can dramatically increase the efficiency of inter-cultural operations for (Hari Prasad Acharya)

The tens of thousands of mini-tillers across the Midhills can be used to mechanically weed in-between line-sown crops. Their engines can also be used for pumping water, and with the right attachment equipment, also for planting seed. The project is working to engineer and improve the use of attachments for carrying out some of these tasks. In the reporting period, the project developed an attachment to side-dress apply urea fertilizer to maize at the same time as weeding the spaces between maize crop rows (Photo 5.4).

The prototype attachment is being tested in coordination with PMAMP in Dang Maize Super Zone. It This can dramatically increase the efficiency of inter-cultural operations for farmers growing maize. saves the labor of applying urea by hand to each plant, while the additional use of the machine can shorten the time required for service providers to break-even on their investments in mini-tillers. Research supported by CSISA III in the 2019/20 winter season will study the impact of this operation on nitrogen use efficiency and yield vis-à-vis manual weeding and fertilizer placement. These results will supply

'business intelligence' for private sector machinery dealers to drum-up sales of this machine, and to encourage manufacturers to kick-start local production of attachments.

Box 5.3: Increase in the number of reapers and the area harvested in Nepal's Terai

Since 2014, the project has worked with NAMEA and local traders to promote machine reapers for harvesting wheat and rice. The number of reapers in use in Nepal's Terai has increased from 22 in 2014 to almost 3,500 in the 2019 wheat harvest (2019 wheat survey results). The project has recorded a growing concentration of reaper-harvester service providers in the FtF zone. (Figure 5.2).

Figure 5.2: Map of Nepal showing the concentration of reaper service providers in the FtF zone in the west as a result of CSISA Scaling Project activities

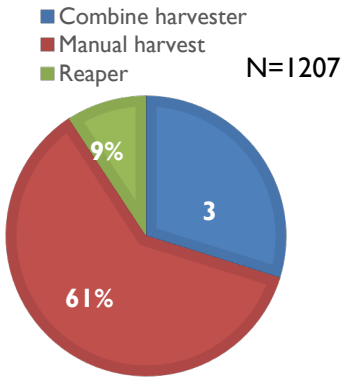


Figure 5.3: of farmers reporting using reapers to harvest wheat (2019 project wheat survey)

Maize seed drill testing

In February 2019, a performance test of maize seed drills was conducted in Dang Maize Super Zone with PMAMP and associated farmer groups. Of the four seed drills tested, most participants preferred the 4WT Chinese seed drill (Model-2BMZJ in seeding meter gear 3) because of the resulting uniform emergence of plants. There are two of these machines in Dang, and one service provider who has received technical support from the project plans to purchase another. They have been used to plant about 120 hectares in the past two maize seasons, indicating the strong potential for expanded use of seed drills by labor-constrained maize farmers.

In the test one of the seed drills (2BMZJ-3) was set to two different plant to plant spacings (with the seed drill spacing meter set to third and fourth 'gear'). Planting spacing was set at between 17 and 21 cm, whichever was possible on the machine. The results showed a wide variation in plant-to-plant spacing of emerged plants for all the seed drills and settings:

- Maize seeded by the Chinese 2BMZJ3 had 40% of emerged plants within the recommended spacing range of 20-25 cm while maize planted using the Khedut Vertical rotor had only 15% of plants in the recommended spacing range (Figure 5.4).

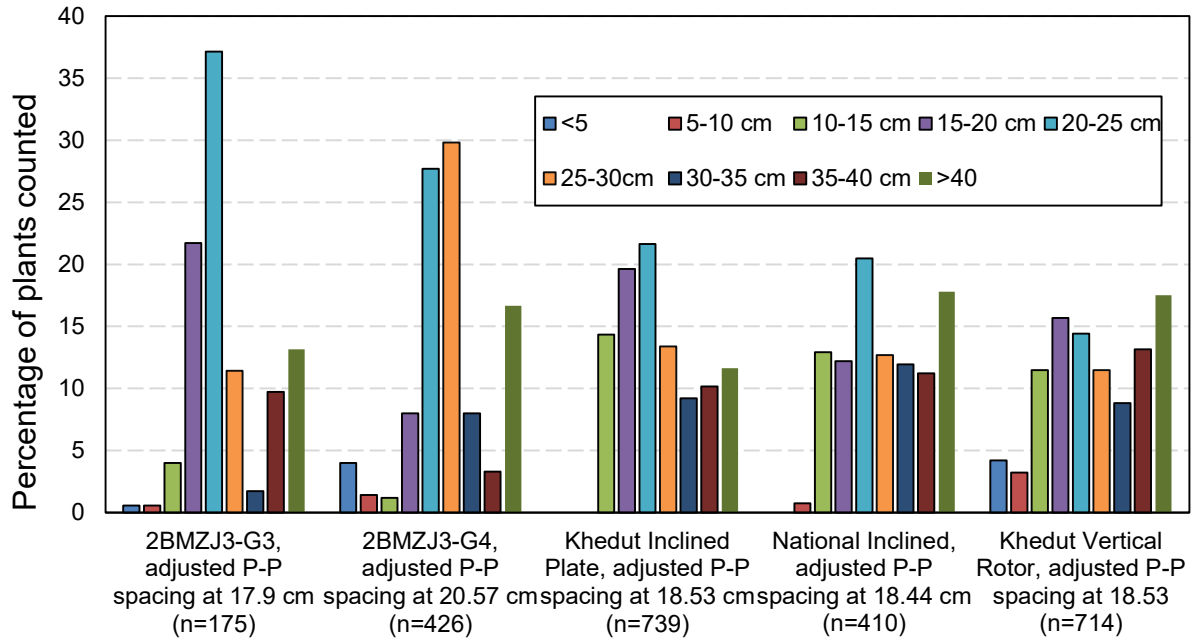


Figure 5.4: Distribution of plant spacing (P-P) of emerged maize seeded by four seed drills

- The percentage of plants having plant-to-plant spacing of more than 35 cm (double the adjusted spacing setting) was between 16% and 22% for all the drills and settings. This was mostly due to seeds not emerging as there was very little missed seed placement.
- These emergence losses can be minimized and seed requirements saved by up to 20% if proper care is taken while operating seed drill and preparing the soil to ensure that seed is sown at the correct depth in the correct moisture regime. Note that seed germination was calculated separately at 87%.

The average plant-to-plant spacing of the emerged plants was 6-10 cm more than the adjusted spacing in the different seed drills (Figure 5.5):

- The 2BMZJ-3 set in fourth gear was set to seed plants at 20.57 cm but the average spacing of emerged plants was greater at 28.65 cm.
- The Khedut vertical rotor was set to seed at 18.53 cm while the average spacing of emerged plants was 28.80 cm.

A half of this increased spacing was found to be due to i) the machine design problem of the driving wheel skidding and seed meter losses (i.e. seed missed by the seed meter and not dropped in the pipe), and ii) seeds not germinating, while the other half was due to emergence losses, which can be avoided by properly preparing land and more careful seeding (Figure 5.5). Based on these results, the CSISA Phase III project plans to react and develop work plans for the 2020 cropping season to address these concerns and to work with the private sector to train service providers on improved seed drill calibration, use and maintenance.

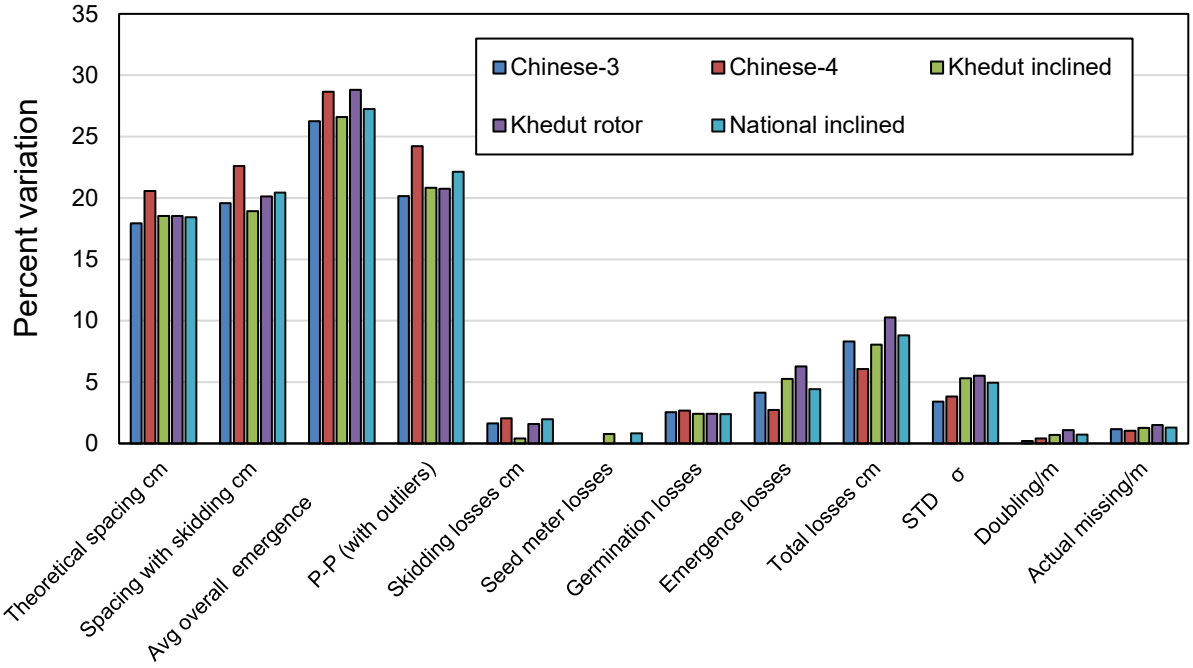


Figure 5.5: Variation in plant-to-plant spacing using different seed drills and factors that contributed to the variation (left axis = cms)

Encouraging farmers to use preferred seed drills

In 2017/18, the project supported three Indian seed drill manufacturers to participate in CSISA's Mechanization and Irrigation Desig Sprint.[12] This activity continued to yield benefits in this reporting period. One of these companies, Dharti Agro from India, subsequently began selling its new 2WT seed drill (seeder-planter) in Nepal in the second half of 2018. This seed drill is lighter weight and easier to use in the field, and has an added bracket for a rear tire and a seat to facilitate road transportation (Figure 5.6). It also has lowered seed meters attached to the row opener shanks. These engineering advances enable quick adjustments to improve seed placing. The same seeder can be adjusted to plant up to five rows of wheat or rice or two rows of maize at a time. The Nepal sales agent, Kuber and Sons, began to sell these seed drills in March 2019, providing clear evidence of project impact and the potential to scale-out the use of appropriate agronomy and crop establishment technologies through commercial pathways.

Figure 5.6: The improved Dharti 2WT seeder planter with a new easily adjustable integrated row unit is now being sold online and by machinery dealers in Nepal (Dharti)

[12] Design sprints provide the opportunity for farm machinery manufacturers to modify their machines to better suit the needs of potential buyers.

A new sulky prototype for walk behind reapers

Some service providers find walk behind reapers difficult to transport and use in fields, mainly because they lack a seat for operators. In March, 2019 a prototype 'sulky', was designed by the project for reaper operators. Sulkies are wheeled attachments for operators to stand on (Photo 5.5). The testing of this sulky in Bhairahawa on 26 March 2019 found that it enables operators to more easily travel long distance just by standing on the sulky. However, the design was found to need additional modification to enable turning in fields and operator comfort.

Photo 5.5: Sulky being tested for the first time in field in Bhairahawa. Note that a lesson from this test was that further modifications are needed for the comfort of the operator (Timothy J. Krupnik)

Post-harvest dryer network

The attendance of project and PMAMP representatives at the Feed the Future Innovation Lab for Nutrition Scientific Symposium (27–29 November 2018, Kathmandu) revealed PMAMP's interest to promote cereal grain dryers, particularly for spring rice whose harvesting coincides with the pre-monsoon rainfall that can make drying difficult. Leading on from the workshop an informal network was established by the project with members of PMAMP's zones and super zones and the Department of Agriculture's Post Harvest Section for sharing information on the subject, especially on adapting rice grain dryers to also dry maize, which should greatly reduce the incidence of aflatoxin. This network is expected to lead to the development and increased use of post-harvest crop driers and has led to PMAMP showing interest to import a grain dryer for spring rice for market testing by one of its farmer cooperatives.

To explore how to address this issue, in March 2019 the CSISA Scaling Project brought in consultants knowledgeable on the sun-drying of rice in east Asia to present to the project and PMAMP about

different types of sun driers. However, most of these driers are too expensive for smallholder farmers to acquire. The project is now working with PMAMP to raise awareness on service provision and cooperative ownership models to provide farmers with access to these driers. As the CSISA Scaling Project has now ended, the CSISA III project is actively pursuing these emerging opportunities.

5.3 Awareness raised on the benefits of farm mechanization

In this reporting period, project-supported demonstrations, awareness campaigns, farmer field days, presentations at agricultural fairs and interaction programs raised awareness about and encouraged the use of scale-appropriate farm machinery in Nepal's Feed the Future Zone.

Seed drill demonstrations – The awareness of traders and local governments was raised on the use of seed drills via project-supported demonstrations of zero tillage wheat in Banke, Bardiya, Kailali and Kanchanpur in October and November 2018 in coordination with local and provincial government agriculture sections.

Photo 5.6: A four-wheel tractor with the 2BMZJ-3 Chinese-made precision multi-crop planter sowing maize (Hari Prasad Acharya, CIMMYT)

Project support has led to the number of seed drills in Dang district increasing to more than a dozen, most of which are owned by farmer cooperatives, with the cost of buying them partially offset by PMAMP. In the past year, with technical support from the project, PMAMP has doubled the area of seed drill-planted maize under it to 2,200 ha. In the reporting period, at the request of PMAMP, the project helped extend the area of maize planted by seed drill in Dang Maize Super Zone by supporting demonstrations at new sites in November 2018 and February 2019, and by running a promotional campaign. Also, on 22 November 2018 and 24 February 2019, the project conducted demonstrations for 150 farmers and other stakeholders to promote mechanized maize seeding in Banke Maize Zone using the most popular seeding machine from PMAMP Dang (Photo 5.6). Around the same time, awareness raising rallies were held across the zone to disseminate information on seed drills. Subsequently, 19 more farmers hired in seed drills to drill 4 ha of maize in new parts of Dang in the February 2019 planting season.

Reaper awareness campaign – In November 2018, an awareness raising campaign on the benefits of reapers to farmers and service providers was carried out in Kapilvastu district in collaboration with the Kapilvastu Rice Super Zone. An additional campaign was carried out to encourage the use of reaper harvesting of cereals (rice and wheat) in Banke (Photo 5.7). Soon after, the super zone included reapers in its machinery promotion program and the number of reapers increased from 2 to 18 across the Super Zone.

Photo 5.7: Project campaigns using mobile advertising on auto-rickshaws and distributing leaflets to build awareness and encourage the use of reapers in Kapilvastu (left) and the use of seed drills in Banke (right). (Subash Adhikari)

Farmer field days – The Modern Agriculture Farm in Bardiya, which has been developed by the Guruchan Custom Hiring Centre as an agricultural machinery service center and demonstration site, held a farmer field day on 8 October 2018 to demonstrate directly seeded rice to new and potential customers. Thirty-five farmers from eight farmer groups listened to experiences of growing direct-seeded rice and had their questions answered (Photo 5.8). Three media persons reported the program on national TV and in newspapers. The program is thus motivating more farmers to use direct-seeded rice technology.

Photo 5.8: Farmers learning about i) farm machinery, ii) opportunities to hire service providers on an affordable basis, and iii) direct-seeded rice at a farmer field day at the model farm of Guruchan Hiring Centre in October 2018 (Subash Adhikari)

Agricultural fairs – In this reporting period the project had a stall at the agricultural fairs at Butwal in Province 5, Khajura in Banke, Rajapur in Bardiya and Dhangadhi in Kailali that raised awareness on scale-appropriate machinery. The stalls were visited by about 10,000 visitors (Photo 5.9).

Increasing use of spreaders – As described under Objective 4, in the reporting period three private sector partners were helped to promote fertilizer and seed spreaders, with Jay Laxmi Traders of Bardiya subsequently ordering 20 spreaders to sell after the demonstration at Rajapur fair. It also sold one 2WT seed drill at the fair.

Rice field day and interaction program Towards the end of the project, a field day and stakeholder interaction program was held in Jhapa by the project and Jhapa Rice Super Zone. The field visits demonstrated resource-conserving technologies including dry and wet direct-seeded rice, harvesting by reaper, and machine transplanted rice. The program also helped stakeholders identify cost-saving

technologies for other crops. The formal program discussed the activities of Jhapa Rice Super Zone with:

- Basanta Baniya, MP for Province 1, who praised the initiatives to introduce cost-saving technologies in the area;
- Benu Prasai, Director of Province 1 Agriculture Development Directorate, who thanked CIMMYT for facilitating PMAMP activities; and
- Chief of Rice Super Zone, Megnath Timilsena, who called for local governments to promote farm mechanization.

Photo 5.9: Project staff informing farmers about improved agronomic practices at Province 5's agriculture fair, Butwal (Subash Adhikari, CIMMYT)

An important issue raised by participating farmers was the high price of machines and the need for improved subsidies and market mechanisms to reduce costs and barriers to entry. They also voiced concerns that seed drills might not be worthwhile investments as they are only needed for a few weeks a year to establish crops. In response, project representatives drew attention to multi-crop seed drills that can sow different crops including wheat, maize, beans and lentils throughout the year, thereby expanding the business portfolio of service providers and presenting extended opportunities to generate income by assisting farmers with crop establishment.

5.4 Capacity built on operating and maintaining farm machinery

With support from the project, the number of scale-appropriate agricultural machines is growing in Nepal. This growth comes with the concomitant need to increase knowledge on where and how to access spare parts and repairs. However, the pace of mechanization is still constrained by the lack of operation and maintenance training for farmers and service providers and inadequate servicing and repair facilities. In the reporting period the project supported four types of farm machinery training:

- **Operation and maintenance** – In October 2018, the project assisted PMAMP's farm machinery-training program in the Banke Maize Zone and Kapilvastu Rice Super Zone by training 55 service providers on operating and maintaining farm machinery.
- **Calibration training** – On 26 and 27 November 2018, 77 service providers and 61 government technicians were trained on the use and maintenance of agricultural machines. The training focused on calibrating the application of seed and fertilizers in seed drills and precision spreaders and the use of spreaders. It also sought to influence local and provincial governments to include seeding machinery in their subsidy programs and annual development plans, which Madhuwan Municipality (Bardiya) subsequently did and soon after provided a subsidy to a local farmers' group to buy a seed drill.
- **Seed drill maintenance** – On 13 February 2019, the project trained the mechanics of Jay Laxmi Traders, Bardiya on maintaining power tiller operated seed drills to enable them to provide this service to service providers in Bardiya Rice Super Zone and beyond.

- **Reaper maintenance** – In March 2019, the project, in coordination with Dahit Traders in Gulariya and Swastic Traders in Rajapur (Bardiya), trained 124 service providers and trader technicians from Banke and Bardiya districts on maintaining reapers at five training events (Photo 5.7). Together with the CSISA III project, the CSISA Scaling Project printed 3,000 copies of the project's repair and maintenance manual[13] for multi-crop reapers which are being distributed to service providers.
- **Machinery booklet** – In August 2019, the project supported Dang Maize Super Zone to publish 1,000 copies of a booklet on the care and maintenance of the farm machinery used in maize and other crops in maize-based systems. The booklet was prepared by the project and handed over to Dang Maize Super Zone to publish from its funds. The booklet, which contains details on seed drills, weeders, spreaders, reapers, maize cob harvester and threshers, is being distributed to provincial and local governments, machinery dealers, farmer cooperatives, and custom hiring centers.

Figure 5.7: The reaper manual

Photo 5.10: The project-supported training of 2WT reaper service providers at Dahit Traders in Gulariya, Bardiya in March 2019 (Subash Adhikari, CIMMYT)

[13] 1,000 copies were published by the CSISA Scaling project

5.5 Irrigation

Research conducted in the second and third phases of the wider CSISA project on irrigation showed that rice and wheat yields in Nepal's Terai can be substantially improved by applying additional irrigation. However, inefficient groundwater use burdens risk-averse and resource-poor farmers because of the high price of irrigation water and the untimely delivery of water. This inhibits farmers from applying adequate irrigation, thus reducing their resilience to climate variability and increasing the uncertainty of returns on investments. In response, the project continued in the reporting period to focus on the importance of risk-reducing irrigation in the Terai.

Research to reduce irrigation bottlenecks – In this reporting period the project established a partnership to research the more efficient use of groundwater. The groundwork was laid in January 2019 when researchers from Manchester University and project personnel toured farms in Banke and Bardiya and the AMPC and NAMTRC centers in the eastern Terai to establish the research and development agenda. The aim of the research is to identify ways of sustainably increasing groundwater use to bolster farm resilience and the sustainable intensification of agricultural systems. A paper on the project's research on diesel pump irrigation systems was prepared for publication in this period. A summary of the paper is given at Appendix 4.

Preliminary development of locally appropriate solar irrigation systems – In this period the project also worked with local partners to further develop irrigation technologies previously developed in the second and third phase of the broader CSISA project. It continued to support a private manufacturer of agriculture machinery in Kanchanpur to develop a more affordable type of solar powered irrigation system.

Development and modification of 2WT-driven bore drilling machines – The project continued its research on the development of a 2WT powered attachment to drill shallow tube wells. The third modification and testing of 2WT driven bore drilling machine was done from 25–28 April 2019 at the Agricultural Machinery Testing and Research Centre in Nawalpur, Sarlahi. During the 4-day testing period, NARC engineers inspected the machine to better understand its engineering. They now better appreciate the potential of these small machines and included further testing and design in their ongoing research programs for 2019/20. In June 2019, the participants from NARC's Agriculture Implement Research Centre (Birganj), began a new NARC-funded project that will build on this research and modify the machine to make it more suitable for use in Nepal. The machine could address the problem of the high cost of drilling wells and the unavailability of labor for manual drilling.

Additional Information

CHALLENGES FACED DURING THE REPORTING PERIOD

Lack of permanent responsible personnel in local and provincial governments – A key challenge faced by the project throughout this reporting period has been the lack of permanent technical agriculture staff in provincial and local governments. Nepal's new federal constitution, ratified in 2015, began to come into full force with the election of the three new tiers of government – federal, provincial and local governments in 2017 and 2018. The devolution of responsibilities has meant that provincial and local governments are now responsible for agriculture support and development that previously came under the central ministry of agriculture and its district agriculture offices. Box 1 summarizes the changed situation.

Box 6.1: The new federal structure governing Nepal's agriculture

Until 2017/18, Nepal's 75 district agricultural development offices (DADOs) were the main avenue for the Ministry of Agricultural and Livestock Development (MoALD) and Department of Agriculture (DoA) to implement the government's agricultural development programs at the field level. These offices ceased to exist in 2017/18 because of federal restructuring.

The new middle tier of government, the seven provincial governments now have ministries of land management, agriculture and cooperatives. These ministries are responsible for setting province level policies and overseeing local governments. And as the DADOs phased out, 55 new agricultural knowledge centers (AKCs) (krishi gyan kendras) were established under provincial governments to provide advisory support to farmers and service providers. Many DADO administrators and technical staff have been shifted to these centers. This has meant that the project has had to react and build new relationships with new staff these offices.

The third tier of government, local governments, are responsible for implementing agricultural development programs and have their own budgets for this purpose. They can also appoint technicians to agricultural knowledge centers.

The new system is in transition and faces the following challenges:

- The staff of the agricultural knowledge centers, who mostly came from DADOs, are having to adjust from previously running programs to the more low-key role of providing advice.
- The lack of adequate agricultural technicians and sufficient knowledge in provincial and local governments and in the knowledge centers. This, however, offers opportunities to intervene and improve collaboration in support of government and CSISA's objectives.
- The lack of coordination, and in some cases overlapping and unclear responsibilities, between the three levels of government for agricultural development.
- The generally low priority given to agriculture development activities by local governments.

Uncertain funding – As mentioned in the FY18 annual report, FY18 funding was carried over to support FY19 activities, which has focused on project closure. The delays and uncertainty in funding during the project period meant that a number of key staff lost their positions and key activities were temporarily put on hold or modified.

ENGAGEMENT WITH THE MISSION AND FTF PARTNERS

The CSISA Scaling project (the project) had good working relations with other USAID funded agriculture projects in Nepal and South Asia. In Nepal, it continued to work closely with two projects supported by the USAID Mission in particular, including:

- KISAN II – a $20 million five-year project under USAID's global Feed the Future initiative that is working to advance food security in Nepal by increasing agricultural productivity; and
- The Nepal Seed and Fertilizer project (NSAF) – a five-year project to strengthen Nepal's seed and fertilizer systems.

The partnership between CSISA and these projects paved the way for scaling-up the cereal-system based technologies in Nepal:

- The two CSISA projects in Nepal (the base and CSISA Scaling Project) provided technical and extension materials and advice to KISAN II beneficiaries to improve the uptake of better-bet sustainable agriculture production and post-harvest practices and technologies for targeted cereals. KISAN II is reaching hundreds of thousands of farmers, who have been exposed to CSISA information, materials, and technologies through this partnership.
- The project provided technical backstopping support to KISAN II's technical staff on agriculture and marketing and to private dealers and firms who have received USAID grants through KISAN II. One specific input in November 2018 was the project holding a hands-on training on seed drill operation and maintenance in Dhangadhi for agriculture technicians, KISAN II area coordinators and community volunteers from NSAF's partner farmer cooperatives.
- CSISA's technical backstopping of KISAN II private firm grantees to promote improved agricultural practices, including the mechanized seeding of lentils and maize, has helped grantees achieve their targets. These grantees are making use of the services provided by the seed drill service providers who were developed by CSISA. This promotes both the service providers and the use of agricultural machinery.
- The project continued to provide research results that are used by the NSAF project, and to support the development of seed systems for crops not covered by the NSAF project. In this way, the CSISA Scaling Project filled gaps left by this investment and provides an opportunity for solid- and all-around emphasis on agricultural systems development to overcome productivity and resilience constraints in Nepal.

Appendix 1: Key project staffing

Name	Role	Institution	Address	Phone	Email
Timothy J. Krupnik	Project Leader	CIMMYT	Dhaka, Bangladesh	(+88) 0175 556 8938	t.krupnik@cgiar.org
Cynthia Carmona	Project Manager	CIMMYT	Kathmandu, Nepal	(+977) 9851197994	c.carmona@cgiar.org
Dyutiman Choudhary	Objective 1 Theme Leader	CIMMYT	Kathmandu, Nepal	(+977) 9851243703	d.choudhary@cgiar.org
Narayan Khanal	Objective 1 Contributor	CIMMYT	Kathmandu, Nepal	(+977) 9851183024	n.khanal@cgiar.org
Scott Justice	Objective 5 Theme Leader	CIMMYT	Kathmandu, Nepal	(+977) 9851027678	s.justice@cgiar.org
Gokul Paudel	Socio-economist	CIMMYT	Kathmandu, Nepal	(+977) 9845089438	g.paudel@cgiar.org
Subash Adhikari	Agricultural Mechanization Engineer	CIMMYT	Banke, Nepal	+977 9841893657	s.adhikari@cgiar.org
Lokendra Khadka	Area Coordinator	CIMMYT	Kailali, Nepal	+977 9845198379	l.khadka@cgiar.org
Salin Acharya	Area Coordinator	CIMMYT	Banke, Nepal	+977 9851223521	s.acharya@cgiar.org
Sagar Kafle	Assistant Research Associate	CIMMYT	Dang, Nepal	+977 9845156044	a.kafle@cgiar.org
Anton Urfels	Consultant	CIMMYT	Kathmandu, Nepal	--	anton.urfels@outlook.com
Moin Salam	Consultant	CIMMYT	Dhaka, Bangladesh	+880 1855871938	moinsalam1@gmail.com

Appendix 2: Project partners

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of Partnership
Government of Nepal				
Ministry of Agricultural and Livestock Development (MoALD)	Technical guidance for Government of Nepal investments in agricultural development	All	The current Agriculture Development Strategy (2015–2035) was approved by the government in late 2015. CSISA acts as a technical partner to shape the loan and investment programs associated with the strategy, which may exceed $100 million.	Active and sanctioned by CIMMYT's host country agreement
Nepal Agricultural Research Council (NARC)	Strategic and applied research on sustainable intensification technologies	Innovation towards impact	NARC is responsible for providing the scientific basis of all government recommendations; the endorsement of recommendations and the ownership of emerging sustainable intensification technologies.	Active and long-standing
Provincial governments	To strengthen provincial level policies and provincial government support for agricultural development activities	Achieving impact at scale	Provincial governments are the middle tier of government under the federal constitution and have a large degree of independence to exercise financial powers and formulate province level policies. They have important policy making and oversight roles on agricultural development. In this period the project engaged and supported the Province 5 and Sudurpashchim Province governments.	Active and new
Local governments	To strengthen local government support for agricultural development activities	Achieving impact at scale	Local governments are the local tier of government under the new constitution. They have significant roles for implementing agricultural development in their areas and are important stakeholders that the project seeks to engage.	Active and new
Nepali private feed companies, machinery importers and machinery companies				
NIMBUS (Nepali feed mill company), Kathmandu	Introduction and market development for new crop varieties and hybrids	Achieving impact at scale	Registration and market development of crop hybrids in the FtF Zone of Influence from a base of zero in 2015	Active since 2015

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of Partnership
Adventa Export Pvt. Ltd. (Gujarat India)	To test new fertilizers and scale up their use	Achieving impact at scale	Is a leading manufacturer of fertilizers in India	Partnership being formed
Dharti, (Gujarat India)	To test different seed drills and scale up use	Achieving impact at scale	Is a leading manufacturer of new designs of 2-wheel tractor seeders-planters in India, with local dealers in Nepal.	Active since 2015
Kuber and Sons, (Itahari, Sunsari)	To introduce and scale up the use of appropriate farm machinery	Achieving impact at scale	This company has many dealers across the country.	Active and long-standing
Nepali private seed companies				
GATE Nepal Seed Company, Banke	Demonstration and production of seed of new and nutrient-enriched wheat varieties	Achieving impact at scale	Pipeline and Zn and Fe enriched wheat varieties are being released combining seed company and NARC station data through a fast track approach	Active since 2015
Kalika Seed Company, Rupandehi	Demonstration and seed production of new and nutrient enriched wheat varieties	Achieving impact at scale	Pipeline and Zn and Fe enriched wheat varieties are being released combining seed company and NARC station data through fast track approach	Active since 2018
Lumbini Seed Company, Rupandehi	Demonstration and seed production of new and nutrient enriched wheat varieties	Achieving impact at scale	Pipeline and Zn and Fe enriched wheat varieties are being released combining seed company and NARC station data through fast track approach	Active since 2015
Panchashakti Seed Company, Kailali	Demonstration and seed production of new and nutrient enriched wheat varieties	Achieving impact at scale	Pipeline and Zn and Fe enriched wheat varieties are being released combining seed company and NARC station data through fast track approach	Active since 2015

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of Partnership
Unique Seed Company, Kailali	Demonstration and seed production of new and nutrient enriched wheat varieties	Achieving impact at scale	Pipeline and Zn and Fe enriched wheat varieties are being released combining seed company and NARC station data through fast track approach	Active since 2015
Trade associations				
Nepal Agricultural Mechanization Association (NAMEA)	Trade association formed with the help of CIMMYT to create an enabling environment and policy dialogue for scale-appropriate mechanization in Nepal	Systemic change towards impact	An important voice for the private sector as Agriculture Development Strategy support programs take shape	Active since 2014
Seed Entrepreneurs Association of Nepal (SEAN)	Trade association strengthened with the help of CSISA to create an enabling environment and policy dialogue for seed system strengthening and small and medium enterprises in Nepal	Systemic change towards impact	Important voice for private sector as Agriculture Development Strategy support programs take shape	Active and long-standing
Universities				
Wageningen University	The role of livestock and value chains in farmers' willingness to invest in maize intensification	Innovation towards impact	Collaboration with advanced research institutions increases the quality of science conducted in Nepal and national partners learn new research methods and contribute to the formulation of new research questions.	Active
Manchester University	To identify ways of sustainably increasing groundwater use to bolster farmers' resilience and the sustainable intensification of agricultural systems. The	Innovation towards impact	Collaboration with advanced research institutions increases the quality of science conducted in Nepal and national partners learn new research methods and contribute to the formulation of new research questions.	Partnership formed in January 2019

Partner	Partnership objective	Alignment with themes	Leveraging opportunity	Status of Partnership
	research will start in 2019.			
Projects				
Knowledge-based Integrated Sustainable Agriculture and Nutrition (KISAN)	Strategic partnership to co-support the large-scale deployment of extension information and technologies	Achieving impact at scale	The KISAN project, part of USAID's global Feed the Future (FtF) initiative, is a $20 million 5-year program to advance food security by increasing agricultural productivity. It 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. It reaches hundreds of thousands of farmers meaning they are exposed to CSISA information, materials, and technologies.	Active for more than 3 years
Nepal Seed and Fertilizer Project (NSAF)	Strategic partnership to co-support the large-scale deployment of extension information and technologies	Achieving impact at scale	The USAID Nepal-funded NSAF project ($15m for 2016–2021) focuses on the applied science-to-development continuum, including market facilitation to expand private sector-led fertilizer and seed sales. CSISA is disseminating the better-bet technologies at scale through NSAF networks.	Active since before 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

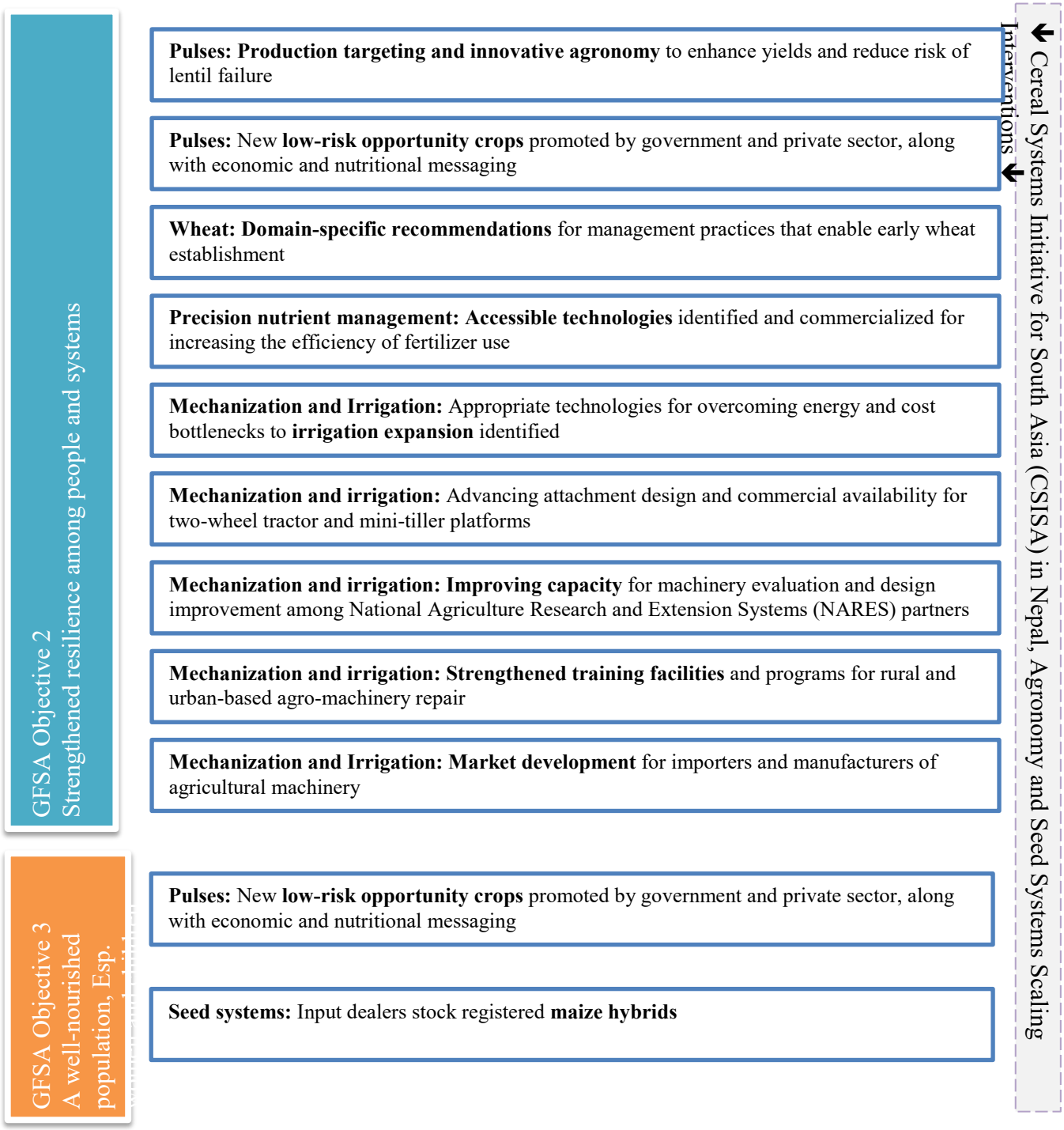
Appendix 3: Expected outcomes of CSISA-Nepal Scaling Project related to the objectives of the Global Food Security Act (GFSA)

Global Food Security Act Goal: Sustainably reduce global hunger, malnutrition, and poverty

GFSA Objective 1
Inclusive and sustainable agricultural-led economic growth

Cereal Systems Initiative for South Asia (CSISA) in Nepal, Agronomy and Seed Systems Scaling Interventions

- **Seed systems:** Input dealers stock registered **maize hybrids**
- **Seed systems:** Private seed companies expand businesses for **wheat and pulses**
- **Seed systems:** Strategic investments & **enhanced coordination** among seed system actors
- **Pulses:** New **low-risk opportunity crops** promoted by government and private sector, along with economic and nutritional messaging
- **Wheat: Domain-specific recommendations** for management practices that enable early wheat establishment
- **Wheat: Social marketing** approaches 'get the word out' on better-bet agronomy for wheat
- **Precision Nutrient Management:** Domain- and situation-specific **soil fertility management strategies** developed for wheat, lentil and maize
- **Precision nutrient management: Broad-scale awareness** of the yield and economic benefits of judicious fertilizer application
- **Mechanization and irrigation:** Appropriate technologies identified for overcoming energy and cost bottlenecks to **irrigation expansion**
- **Mechanization and irrigation:** Physical and operational models of **land aggregation** identified to permit inclusive access to innovative mechanization technologies
- **Mechanization and irrigation: New business opportunities** for laser land leveling, zero tillage, & mechanized harvesting defined with expected returns for all value chain actors
- **Mechanization and irrigation: Advancing attachment design** and commercial availability for two-wheel tractor and mini-tiller platforms
- **Mechanization and irrigation: Market development** for importers and manufacturers of agricultural machinery



CSISA-Nepal activities also map against the following intermediate results:

- **IR 1:** Strengthened inclusive agriculture systems that are productive and profitable
- **IR 2:** Strengthened and expanded access to markets and trade
- **IR 3:** Increased employment and entrepreneurship
- **IR 4:** Increased sustainable productivity, particularly through climate-smart approaches
- **IR 7:** Increased consumption of nutritious and safe diets

As well as these cross-cutting intermediate results:

- **CC IR 3:** Increased gender equality and female empowerment
- **CC IR 4:** Increased youth empowerment and livelihoods

Appendix 4: New CSISA research note on irrigation in Nepal's Terai

The project publishes scientific papers on its work, which is mostly the result of collaboration with other CSISA projects and government and non-government partner institutions. The following is a summary of a research note that will soon be published on CSISA's website alongside previously published notes to describe innovative work carried out by the project.

Costs of diesel pump irrigation systems in the Eastern Indo-Gangetic Plains: What options exist for efficiency gains?

T. Foster, R. Adhikari, A. Urfels, S. Adhikari, T.J. Krupnik | November 2019

CSISA Research Note 15

Introduction – Groundwater irrigation is critical for food security, rural livelihoods and economic development in South Asia. However, the under-exploitation of groundwater resources in the Eastern Indo-Gangetic Plain (EIGP) of Nepal and eastern India limits farmers' ability to grow crops outside the monsoon. It challenges farmers' ability to manage risks posed by rainfall variability and dry spells in the monsoon.

A major barrier to expanding groundwater irrigation in Nepal's Terai is the dependence of farmers on expensive, unsubsidized fuel. Proposals to address barriers to accessing groundwater include expanding rural electrification and renewable energy pumping technologies. However, solar irrigation faces challenges in the EIGP of high up-front capital costs, limited availability of maintenance services, and the risk of excessive groundwater withdrawal. While access to reliable electricity from the grid is increasing, policies and development initiatives that just focus on electrification and solar pumping fail to seize opportunities for near-term gains in water availability to increase farm production, income generation, and food security.

Addressing the sub-optimal performance of diesel-pump irrigation systems can offer quick improvements while supporting the future transition to alternative technologies. Many diesel-pump irrigation systems in the EIGP operate at low fuel to water delivery efficiencies, suggesting scope to improve pump performance and reduce irrigation costs. This reported research is a first-step to identify opportunities to reduce groundwater access costs in diesel-pump irrigation systems in the EIGP.

Methodology – Data were collected in two Terai districts in central Nepal where groundwater is the main source of water for most farmers, diesel-pump irrigation systems are widespread and the socio-economic status of farming communities and underlying aquifer characteristics are representative. A survey of 434 farm households who reported using groundwater was carried out to evaluate the costs of accessing groundwater and the impact of these costs on agricultural practices.

Initial results 1: Landholding and irrigation system characteristics

- The average cultivated land area of respondent households was 0.95 hectares, with 67% of households cultivating less than 1 ha.
- There was significant land fragmentation with each household on average cultivating 6 plots with a typical plot size of 0.20 hectares.
- 76% of surveyed farmers irrigated their plots using their own pumpsets while the rest rented pumpsets.
- Farmers renting pumpsets had smaller land holdings, cultivated smaller areas and received less financial support from off-farm work and remittances – indicative of constrained finances for

investing in irrigation technologies.

- The farmers accessed an average of 2.4 borewells each for irrigation with 72% of borewells rented and 81% of households renting at least one borewell for irrigation.
- 61% of pumpsets used were Indian pumpsets (which run on diesel) while the other 39% were Chinese pumpsets (which run on petrol, kerosene or diesel).
- Most Indian pumpsets typically had a higher horsepower and cost more than Chinese pumpsets; but the Chinese pumpsets were less reliable.

Initial results 2: Heterogeneity in costs of groundwater irrigation

The following results are from the 87% of sampled farmers who grew rice in the 2018 monsoon and provided supplementary irrigation to their crops with pumpsets.

- There was large farmer-to-farmer variability in the cost of groundwater irrigation ranging from \$4.4 to \$199.7 (NPR 500 to NPR 22,489[14]) to irrigate one hectare of land (average \$30.4 [NPR 3,425]).
- A major driver of these variable costs was pumpset ownership. Renters paid an average of \$1.6 (NPR 184) $hour^{-1}$ to access a pumpset the fuel costs of \$112.6 (NPR 100) per hour.
- The cost of renting varied with the highest cost of \$3.5 (NPR 400) per hour (excluding fuel) in some villages to no cost where pumpsets were shared free of charge.
- Very few of the farmers (2.7%) paid for renting a borewell.
- Differences in the fuel use efficiency of pumpsets contributed to variability in groundwater irrigation costs. The Indian pumpsets had significantly higher reported fuel consumption rates (0.95 litres $hour^{-1}$) compared with Chinese pumpsets (0.80 litres $hour^{-1}$).
- Switching from a large (> 5 HP) Indian pumpset to a smaller ($\leq$ 5 HP) Chinese pumpset equates to an average fuel consumption saving of 0.39 litres $hour^{-1}$ – equivalent to \$8.8 (NPR 991) per hectare for each irrigation (a 29% reduction).
- The time needed for a single irrigation of paddy on one hectare varied from 6 to 60 hours (average 25.4 hours). Analysis is underway to identify the main causes of irrigation event duration. It is clear that longer irrigation times can play an important role in magnifying existing differences in costs, in particular related by rental fees or fuel efficiency.

Initial results 3: – Impacts of access costs on irrigation management practices – Farmers with higher irrigation costs may choose or be forced to reduce use of irrigation inputs, resulting in greater exposure to drought risks and lower productivity. The results show farmers with the highest irrigation costs, on average irrigating paddy crops less frequently than those with lower costs. However, it is important to recognize that irrigation costs are also highly variable between farmers who irrigate at the same frequency, highlighting the importance of individual behavior in determining decisions around irrigation water use.

Research and policy implications – The preliminary findings demonstrate that opportunities exist to reduce the variable costs of groundwater irrigation in diesel-pump systems, which if implemented could support rapid, near-term improvements in agricultural productivity, intensity and livelihoods in Nepal's Terai.

- **Targeted subsidy programs** – A priority for irrigation development policy could include improving access to pumping equipment for marginalized farmers. Nepal government programs focus on subsidizing the cost of borewell drilling. Our analysis suggests this is not a key driver of the high costs of accessing groundwater for irrigation. Support should instead target increasing

[14] Exchange rate of USD 1: NPR 112.6 used to convert to dollars.

pumpset ownership by the small and marginalized farmers who rely on renting pumpsets and thus pay the most for accessing irrigation water. The overall costs of and unsustainability of subsidies are however a concern, and so programs should aim to phase out support mechanisms over time as smallholder farmers get increased access to irrigation services and the private sector develops more affordable pumpset solutions.

- **More energy-efficient pumping** – The cost of accessing irrigation could also be achieved by promoting and supporting farmers to adopt more fuel-efficient pumpsets and irrigation management practices. For example, smaller horsepower Chinese-made pumpsets consume less fuel than larger Indian pumpsets. But the Indian pumpsets are preferred as they are perceived to be more robust, along with advice given by agricultural machinery dealers who suggest larger horsepower pumpsets to maximize their profits.
- **Reduced irrigation costs** – There is a need to educate farmers about selecting fuel efficient pumpsets alongside improving quality control and the provision of maintenance services for imported Chinese pumpsets. Improving the affordability and performance of diesel-pump irrigation systems could also help support future transitions to the use of alternative energy sources (e.g. solar). However, long-term shifts to renewable pump technologies must also consider risks to groundwater sustainability posed by large reductions in the cost of pumping irrigation water. While groundwater resources appear to be underexploited in the EIGP, aggregate statistics may mask spatial heterogeneity in aquifer conditions that could locally limit sustainable extraction. These findings are consistent with broader evidence of large local variability in shallow groundwater availability and resilience to abstraction across the IGP, and warrant further attention in the Terai when assessing future potential for the intensification and extensification of groundwater irrigation.
- **Solar pumps** – The capacity to scale out renewable energy technologies, such as solar irrigation, may be affected by the characteristics of agricultural systems in the Terai and EIGP. The high levels of land fragmentation in the study area point to the need for portable high-capacity solar pumpsets. Current portable solar pumpsets are heavier, more expensive and deliver less water than existing Chinese pumpsets. Although increased demand may drive costs down, fossil fuel pumping systems are likely to remain the workhorse of irrigated cereal systems in the EIGP in coming decades, highlighting the value of efforts to reduce inefficiencies in diesel-fuel based irrigation systems alongside ongoing advances to renewable pumping technologies.