Australian Government

Australian Centre for International Agricultural Research

Final report

Project full title	**Pilot Project on Commercialization of Smallholders' CA-based Planters in Bangladesh**
project ID	LWR/2018/111
date published	
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approved by	
final report number	
ISBN	
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

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1 Acknowledgments

We are grateful to ACIAR for funding support to implement this project.

We are particularly thankful to Dr Robyn Johnston, Dr Eric Huttner, and Ms. Huilqui Noriega for their continuous support.

We acknowledge the great support from Prof Dr Monjurul Alam and Prof Dr. Abu Hadi Noor Ali Khan, Ex and present Directors of BAURES, Bangladesh Agricultural University, respectively.

We express our sincere thanks to:

- Department of Agricultural Extension (particularly UAO and SAAO of project working areas)
- Solidariadad Network Asia
- Rural Development Achademy (RDA) Bogra
- Social Islami Bank Ltd.
- Lead farmers and LSP of VMP
- All farmers who used VMP services and CASPA

2 Executive summary

The “Pilot Project on Commercialization of Small Holders’ Conservation Agriculture (CA)-based Planters in Bangladesh” was funded as a Small Research and Development Activity. The Project has three major objectives: (i) to identify gaps in policy, capacity, and roadblocks for the adoption of CA-based farm mechanization on small farms; (ii) to evaluate commercialization models for smallholders' 2-Wheel Tractor (2WT)-operated CA-based farm machinery (i.e., VMP) in Bangladesh; and (iii) to assess the opportunities and scope for 4WT planters on small farms in Bangladesh; and initiate research on and testing of appropriate 4WT-based CA (strip) planters in Bangladesh.

In this project, Hoque Corporation (HC, private company) leads the VMP manufacturing, and piloting of VMP commercialization models. For VMP commercialization, HC are working with Conservation Agriculture Service Provider Association (CASPA) to identify new and prospective local service providers (LSP) of the VMP. National Bank Ltd. (NBL) and Social Islami Bank Ltd. along with CASPA and HC work together to help new LSP to secure a loan for purchasing of the VMP alone or with a 2WT. Murdoch University led the project activities and provided technical and coordination support.

The Project was approved in August 2018 by ACIAR, but the development of contracts and signing followed by funds transfer from ACIAR to Murdoch University (MU), then to Bangladesh Agricultural University (BAU) and finally to project partners took until 10 July, 2019. During this time the Project partners (especially, HC, MU, and CASPA) carried out a limited range of project activities using funds advanced from other sources. With a variation, the Project has extended until September 2021.

This project supported a study on policy and roadblocks for small scale CA farm machinery adoption in Bangladesh. The study identified several factors hindering the adoption of CA including (i) lack of awareness outside our working hubs on CA among the major stakeholders (farmers, extensionists, etc.), (ii) concerns about the effectiveness of weed management, (iii) limited national utilization as the market demand is not created yet, (iv) lack of skilled manpower to operate machinery, (v) unavailability of functional markets for widespread supply of machinery, (vi) lack of supporting government policy, priority and programs, etc. The final report of the study was submitted in August 2020 (Annexure A).

During the last quarter of the project, a further study was conducted to evaluate outcomes from two models for commercialization of the VMP. The broad objective of this study was to test the feasible commercialization models for scale out of the CA-based planter by providing support to a private company which has demonstrated the commitment and capacity needed to scale-out the CA-based mechanization in Bangladesh. Information for this study was collected from literature review, surveys and key informant interviews (Annexure B).

The key findings of the study of 20 Local Service Providers (LSP) of the VMP are – (i) About 85% of the LSP have more than 10 years farming experience, (ii) 50% of the VMP in the survey were two years old and 10% VMP are more than 4 years years and still in good condition for operation, (iii) VMPs were more used for peanut, soybean, lentil, wheat, mustard and blackgram, less used for other crops, (iv) in many cases owners drove their own VMP, however, hiring an operator/helper was also common, (v) 95% responded that they did not face difficulties in buying spare parts, (iv) 73% of respondents confirmed that they have purchased VMP under Project Incentive Model (PIM), and PIM was more the preferred option by farmer for buying a VMP (vii) 100% of VMP owners reported that they

will replace (if needed) their VMP in future with their own financing to avoid high price, interest burden, installment pressure and so on, and (viii) 80% of the VMP owners are interested to continue the business, because it is profitable, shortens the time for crop establishment and demand has been increasing in the locality.

The project provided input to the National Agricultural Development Committee for developing the National Agricultural Policy 2018. We participated in the Rural Development and National Agricultural Machinery Fair, and we organized 10 demand creation and VMP demonstration meetings, 8 field days, and 8 VMP handover programs under Activity No. 2.1. In these events, many senior officials from Government agricultural agencies, bankers, NGOs, farmers, researchers, etc. participated. To strengthening linkage among CA and mechanization stakeholders, 31 meetings were organized under Activity No. 2.2. enabling more than 330 persons to attend from DAE, SIBL, SNA, NBL, RDA, CASPA and farmers. HC established linkages with 10 small machinery parts manufacturers. Moreover, the partners established forward linkages with Govt. organizations, banks and NGOs for the commercialization of VMP. For engagement with financial institutions, 7 meetings with high officials of banks were organized for policy and planning for loans for TIM under Activity No. 2.3.

In this project, CASPA was a catalyst to (i) identify interested LSP to purchase VMP at grassroots level, (ii) establish links between HC and LSP, (iii) provide mentorship to new LSP through old LSP, (iv) help banks and new LSP with loan document processing, (v) motivate farmers to use VMP for various crops (create demand for VMP use), (vi) help banks with loan recovery, (vii) setup VMP spare parts supply chain, (viii) host training, meetings, demonstrations and field days, (ix) data collection related to this project. This project was quite successful due to grassroot level support from CASPA.

Since the beginning of this project, a total of 147 VMPs (including 3 units exported to Tajikistan) and 30 units of 2WT have been sold under two business models: (i) 114 VMP in Planting Incentive Model (PIM) and (ii) 30 VMPs and 30 2TWs under Tri-party Investment Model (TIM). The project organized VMP operation, repair, and maintenance training programs where a total of 312 people attended. We organized LSP-led motivational meetings with farmers and local extension personnel, where 555 male and female participants attended. More than 2,000 farmers used the newly sold VMP to plant various crops on more than 956 ha of land.

The promotion and scale-out programmes of LWR/2010/080 followed by LWR/2018/111 have created awareness of the benefits of the VMP among the farmers, local service providers, extensionists, agricultural machinery manufacturers, entrepreneurs, researchers and policy officers broadly in Bangladesh, and particularly in the Project hubs. These projects also created momentum for scaled adoption of the VMP in Rajshahi, Panchaghor and Noakhali regions. More LSPs of these areas are interested to buy VMPs with incentivised-price and planting services, while farmers are eager to rent VMP planting services to sow their crops. This momentum should be maintained or enhanced to achieve sufficient scale for a self-sustaining business of the VMP commercialisation. The Aga Khan Foundation in Tajikistan funded the import of three VMP and a visit of Project Coordinator (Dr. Md. Enamul Haque) and Hoque Corporation’s Technician (Md. Mazhadul Mondol) to Tajikistan. Both of them provided hands-on training to 25 persons in Tajikistan on VMP operation, repair and maintenance in Tajikistan.

Since July 2020, the Government of Bangladesh (GoB) have been implementing a large 5-year project (A$516 million) “Farm Mechanization Through Integrated Management Project”

on agricultural mechanization and VMP is selected for promotion under this project. The activity, engagement and advocacy of LWR-2018-111 helped to position the VMP as a piece of machinery supported by the new GOB project.

In March 2020, we surveyed VMP performance including area coverage, charge for VMP sowing, earnings, profit, quality issues, etc. from 64 VMPs sold in 2019/20. Out of 64, 22 LSPs used their VMPs mostly for sowing their own crops covering an average 8 bigha (about one ha) of land; the second category of 11 VMP owners use their planter for sowing their own crops and provided on average 25 bigha planting services to neighbouring farmers. The third category of 21 VMP owners acted as individual LSP who mostly operated the VMP on their own land and provided services to an average 63 bigha of land; a few of them hired temporary operators to assist them. The fourth category of 10 VMP owners covered an average 126 bigha of land by functioning as micro-entrepreneurs as they have other agricultural input business and they have hired operators to provide service business on a wider area. The scale-out plan for the VMP needs to be tailored to the four different cohorts. Emergence of a new group of VMP who are primarlily farmers interested in timely sowing of their own crops is new discovery of thjs Project. Category 4 VMP operators are already active and experienced businesses who have adopted the VMP to expand their services. To expand the planting service business of the 4th category, they can be motivated to purchase additional VMPs and hire extra operators. These businesses could progress towards multi-service custom-hire businesses. The planting business of the 2nd and 3rd category LSPs also offer potential to expand the area planted. Developing and retaining skilled operators of VMP is a bottleneck for expanding VMP services by LSP. Training for 3 days is needed to develop a base level of skill to operate the VMP. One VMP may ensure about 1-2 months/ year job assurance for a hired VMP operator. After that, the operator tends to switch to other jobs. A high level of turnover of skilled operators was observed in this project. Year round job assurance with diverse farm implement services (e.g., transplanter, herbicide sprayers, reaper/harvester, thresher, irrigation water pump, etc.) from a one-stop machinery service center (e.g. Category 4) might retain skilled VMP operators. Alternatively, if sufficient individual farmers are willing to purchase the VMP to plant their own crops either exclusively or predominantly, this market will not suffer the problem of operator turnover.

In 2017/18, we established a demonstration trials of soybean and peanut sowing with VMPs. In those locations, demonstrations confirmed that VMP-seeding of soybean reduced planting cost by A$168 and by A$222 per ha for peanut. Additionally, 25% yield increase for soybean (600 kg/ha) yield and 100 kg/ha yield increase for peanut were gained in VMP-planted fields. Altogether, the VMP planting produced A$557 per ha of extra profit for soybean farmers and A$275/ha for peanut farmers. The demonstration trials have created demand for VMP to sow soybean and peanut in those regions.

Adoption of agricultural technologies e.g., VMP and CA depends on seasonal weather, cropping pattern, land type, crop type, demand of the commodity, etc. These factors can significantly impact on outcomes from short term project such as this one. Due to heavy rain in January, 2020, the soybean and peanut growing fields became wet and many farmers abandoned plans to grow the late-sown crops which reduced the potential services of VMP during this year. The VMP owners were able to use the planter for no more than 20-25 days since purchase. The study of Miah et al. (2017) reported that on the upland diverse-cropping area, the average area coverage per VMP was 22 ha (in about 4 months per year). In the current survey on 16% of VMP owners were able to match this planting

area coverage per VMP. The 64 monitored VMP owners were new owners (purchased in December 2019 to January 2020) operating in areas dominated by a single upland crop (soybean in south-east and peanut in north-west regions), and the natural calamities (heavy rain due to cyclones Bulbul and Amphan) and Covid-19 restricted their planting area. The average planting charges were Tk. 3,637/ha. The net average earning during about 20 to 25-day period of Tk. 2,147, 7,260, 16,077 and 32,827 was calculated for VMP owners of categories 1, 2, 3 and 4, respectively. The LSP did not report any serious quality issues with the VMP.

The small size 4WT (35-55 hp) are getting popular in Bangladesh mostly for haulage and primary full tillage for land preparation. However, 4WT-based planters are not available to farmers. The study developed a prototype 4WT-mounded seed drill with the capacity for crop establishment and CA planting. The 1st prototype of the 4WT-operated VMP has the capacity to sow various crop species in varied row spacings and seed+fertilizer rates in a single pass operation. The effective field capacity of 4WT-VMP was 2.92 ha/hr in single pass planting of wheat which was 69% higher than conventional full tillage land preparation by 4WT and manual broadcasted seed and fertilizer application. Further on-farm investigation is planned in Ponchaghor under the NUMAN Project in the Rabi season of 2021/22.

3 Background

Agriculture in Bangladesh is facing the ongoing challenge of increasing food security for its growing population (currently 160 million people and expected to reach 205 million by 2050) and improving overall land use sustainability, while decreasing costs of crop production to boost farm profitability. At present, most of the agriculture (especially rice that covers >80% of the total area) of Bangladesh is not an attractive business proposition due to high production costs mainly due to many labour-intensive manual operations. The nation-wide spread of 2-wheel tractors (2WT, 700,000 presently in use in Bangladesh) for mechanised tillage and the development over the past decade of a range of small-farm machinery for 2WT, provide a platform for implementing farm mechanization and conservation agriculture (CA) principles on small farms that will decrease costs of crop production (up to 80% less fuel and >35% irrigation water saving, more than 30% saving of labour requirements) and improve the fertility of soils in Bangladesh. Agricultural labour price has increased five-fold in Bangladesh since 2000: due to the availability of off-farm jobs, the educated young generation are less interested in farming due to physically demanding agricultural activities; and that has led to a sharply declining supply of farm labour.

Small farm sizes restrict the purchase and utility of large implements e.g., 4-wheel tractor (4WT)-based planters, combine harvester, automatic rice transplanter, etc. in most parts of Bangladesh. The 2WTs are mostly used for primary land tillage; other essential cost and labour-saving farm machinery i.e., minimum tillage planter (such as the Versatile Multi-crop Planter, VMP), small rice transplanter, rice-wheat reaper, thresher, power operated small boom sprayer, etc. are not widely used in Bangladesh. The rapid development of farm machinery in Bangladesh and China for smallholder's farm mechanization opens the window for farm mechanization in Bangladesh and simultaneously for the adoption of CA. The challenge is to accelerate the testing and adaptation of this machinery for Bangladesh conditions and then to promote scale-out through partnerships with the private sector (manufacturers, banks, farmers' organisations). Public sector barriers to commercialisation and scale out need to be identified (e.g., policies, subsidies, lending conditions) and appropriate interventions proposed to the Government of Bangladesh (GoB).

Significant progress has been made on: farm machinery manufacturing; initial testing of a commercialization mode; quality assurance for planting machinery; demonstration of CA to farmers; training of the operators, etc. under the ACIAR funded project, LWR-2010-080. Under LWR-2010-080, average benefits from the farm mechanization and CA adoption have been reported by135 studied farmers as follows: saved 34 % of labour cost, 31 % less seed applied, 6 % saving of fertilizers, 32 % lower pesticide cost leading to up to 10% lower production cost for lentil, mustard, maize, and wheat (Miah et al., 2017). From the reports of 135 farmers there were yield increases of 28 % for lentil, 19 % for mustard, 6 % for wheat by farmers who adopted CA planting using the Versatile Multi-crop Planter (VMP), and; profit increases of 47 % for lentil, 55 % for maize, 460 % for mustard and 76 % for wheat by farmers who adopted CA planting using the VMP (Miah et al., 2017).

Continuous improvement of the VMP by HC has in the last few years achieved greater reliability of seed metering, reduced planter weight, increased strength of critical parts and decreased costs of manufacturing. They have also used planting incentives, on-farm demonstration, training and mentoring for new local service providers (LSP) to develop viable custom hiring businesses through planting crops. The business model for LSP can generate about U$2,100 extra profit per year by custom hiring the VMP for planting services

for 4-6 months per year. The breakeven planting was 7.8 ha per year, while the average for 18 studied LSPs was 19 ha planted per year (Miah et al., 2017).

Together, HC and the Project Implementation Office (PIO) have arranged low interest rate loan provision for up to 80 % of the cost of a new VMP alone or with the 2WT as a package by the National Bank.

The LWR-2010-080 project also tested a commercialisation strategy which is based in part on creating demand from farmers for CA planting services. This work was focussed in 6 hubs of activity that roughly correspond to a Union administrative area. Within these areas, 6,611 farmers have hired or used the VMP/Versatile Strip Seed Drill (VSSD) to sow lentil, mustard, mungbean, sesame, jute, wheat, maize, rice, chickpea, etc. and covered more than 1,500 ha in 2017.

Hoque Corporation has begun developing the market for VMPs by setting up distribution and sales networks and developing a supply chain to manufacture component parts, maintain quality control of products and the VMP, seeks orders, deliver on time and provide after sales service. Since 2016, Hoque Corporation have worked with Project LWR/2010/080, in the working hubs, to sell the VMP where demand has been created and there is already a supply chain for spare parts, there are trained mechanics and established LSP who can mentor the new LSP. An important component of the commercialisation model developed with HC is the training of LSP in the operation of the VMP and related services such as weed control. New LSP are provided with repeated training sessions during the first 1-2 years after purchasing the VMP. Experienced operators are engaged to provide training and to mentor the new LSP. While LWR-2010-080 project ended in June 2017, Final Reviewers of the Project recommended that: As ‘Conservation Agriculture’ is very much related to ‘Climate-smart Technologies’, a linkage can be developed with ‘National and International Climate Change Network’ for wider dissemination of conservation agriculture throughout the country and other climate affected regions in Asia and others.

Since the completion of LWR-2010-080 project, HC and Murdoch University continued to out scale VMP which resulted in sales of 43 units of VMP since October 2017. Limited demand creation activities, government subsidies (up to 70%) paid for other listed machineries, heavy rainfall (that hampered planting of rabi crops in many places in late 2017), and flood were the major factors slowing the pace of out scaling of the VMP in 2017-2018.

The small 4WT (up to 55 hp) is becoming more available for haulage and primary tillage operations in limited districts of Bangladesh. The appropriate CA-based seed drill attached with such type of small 4WT could enhance the adoption of CA in Bangladesh. A few planters were imported; however, these planters did not gain popularity due to lack of versatility, and single-crop planting ability, etc. Thus, it is timely to engage in a feasibility study with farmers and LSP to determine the opportunity and scope for 4WT planting options in Bangladesh and start research to develop a 4WT-based VMP with the similar capability and versatility to the 2WT-based VMP.

Several agricultural mechanization projects have been implemented from GoB and foreign funds in selected districts of Bangladesh and sold >5,000 units of subsidised (up to 70%) 2-wheel tractor (2WT, or power tiller), power tiller operated seeder (PTOS), bed planter, thresher, combine harvester, etc. The offered subsidy packages (e.g., if a farmer would buy a PTOS or a bed planter, then s/he will get up to 70 % subsidy for a 2WT also) insists that farmers buy both the 2WT and planters. The subsidised 2WT, PTOS and bed planters are

full tillage equipment and/or planters rather minimum soil disturbance (CA) planters. However, the adoption of PTOS and bed planter for seeding was not substantial; as in most cases farmers' have been utilizing only the 2WTs for full tillage. The subsidised PTOS and bed planters remain largely unused due to lack of demand, repair and maintenance training, poor quality of the machinery, and lack continuous monitoring and mentorship of new LSP, etc.

There are clearly policy and adoption level bottlenecks to CA planter adoption. The distortion effects of the current GoB scheme that offers up to 70 % subsidy for a PTOS has not led to large scale use of the PTOS for planting, much less for CA planting. The subsidy is supporting the sales of 2WT, that clearly need no support since sales have been robust in Bangladesh for over 20 years (700,000 are currently operating having been purchased at full price by LSP).

During 2019, the Government of Bangladesh (GOB) announced a large project on agricultural mechanization which has been implemented from 2021 to 2025, where agricultural machineries are out scaled and VMP is one of the potential seed drills to out scale under the GOB project. The LWR-2018-111 project helped to position the VMP as piece of machinery supported by the new GOB project.

Through the LWR-2018-111 project, we have tested feasible commercialization models for scale out of the CA-based planter by providing support to a private company (e.g., Hoque Corporation) which has demonstrated the commitment and capacity needed to scale-out the CA-based mechanization program in Bangladesh.

4 Objectives

The Project objectives were:

1) To identify gaps in policy, capacity, and roadblocks for the adoption of CA-based farm mechanization on small farms.
2) To evaluate commercialization models for smallholders' 2WT-operated CA-based farm machinery (e.g., Versatile Multi-Crop Planter [VMP]) in Bangladesh.
3) To assess the opportunities and scope for 4WT planters on small farms in Bangladesh; and initiate research on and testing of appropriate 4-wheel tractor-based CA (strip) planters in Bangladesh.

5 Activities

To achieve the objectives, the project carried out the following activities:

Activity 1.1: Study on policies and roadblocks for small scale CA farm machinery adoption.

Activity 2.1: Demand creation and awareness raising to promote VMP in the commercialisation targetareas.

Activity 2.2: Strengthening linkage among CA and mechanisation stakeholders.

Activity 2.3: Integration of financial institutions.

Activity 2.4: Testing of VMP Commercialization Models.

Activity 2.5: Monitor adoption of VMP and evaluation of the PIM and TIM models.

Activity 2.6: Training for operators, owners, and mechanics of VMP.

Activity 2.7: Establishment of VMP value chain.

Activity 2.8: Monitoring, quality control (QC) and after sale services.

Activity 3.1: Desktop study to identify opportunities and scope for 4WT-based CA planter adoption in Bangladesh.

Activity 3.2: Develop and test the prototype of 4WT-based VMP.

6 Methodology

This pilot project worked in Rajshahi, Natore, Bogra, Rangpur, Dinajpur, Thakurgaon districts and Panchaghor and Noakhali regions of Bangladesh, because of existing networks that facilitated the commercialisation of the VMP and evidence from the cropping patterns of the farms that farmers are interested in the VMP planting service and that local service providers (LSP) were able to make a profitable business.

Activity-wise detailed methodology was as follows:

Activity 1.1: Study on policies and roadblocks for small scale CA farm machinery adoption:
An independent consultant (with expertise in agricultural economics) was hired to conduct a study with multi-level organizations/personnel involved in promotion and adoption of the CA-based machineries. Meetings/workshops/FFGD was organized with the personnel of farm machinery projects in Bangladesh (DAE, BARI, BRRI, BAU, RDA-Bogra, SRFSI and CIMMYT/CSISA-MI); machinery manufacturers and marketing companies (Hoque Corporation, Alim Industries, Janata Engineering, ACI Motors, Getco, Alam Engineering, etc.), machinery owners, LSP, and farmers to capture their learning on the farm mechanization, identify bottlenecks for further small-scale mechanisation and make recommendations to influence policy makers. The consultant prepared a report and submitted it. Policy level dialogue was not possible due to COVID-19 restriction. However, this study helped National Agricultural Mechanization Policy Guideline Development Committee that contributed to the National Agricultural Policy 2018 by providing information on the necessity and benefit of mechanization and CA.

Activity 2.1: Demand creation and awareness raising to promote VMP in the commercialisation target areas:

The project conducted various demand creation and awareness raising activities including participation at National Agricultural Machinery Fairs (6 events) on the premises of the Department of Agricultural Extension (DAE), Dhaka, Bangladesh, and at Upazila DAE offices in Boda under Ponchaghor district, sadar upazila of Thakurgaon, Durgapur upazila of Rajshahi, Subornochor and Komolnagar of Noyahali district. In the Dhaka fair, the higher agricultural officials including the Agriculture Minister, GOB visited the Project stall and showed interest on the VMP. Ten (10) demand creation meetings (focus group discussions) and VMP demonstration events were organized (4 events at Ponchaghor, 2 at Sadar, Thakurgaon; one event in each upazila of Durgapur-Rajshahi, Sadar-Natore, Sobornochor and Komolgonj of Noyakhali). In addition, this activity acted as a vehicle to develop and strengthen LSP's businesses by stimulating local demand for planting services. A total of 670 interested participants attended in these events through CASPA/DAE and were briefed on: CA, mechanization of planting, the demonstration programme, the loan arrangement with the National Bank Ltd to buy VMP and 2WT, and the benefits of mechanisation, CA and the VMP. From these events, a short-list was prepared of the probable and potential future buyers of VMP. Hoque Corporation led these activities with the involvement of CASPA, National Bank Ltd., and PIO. Hoque Corporation and National Bank Ltd. followed-up further meetings and with the short-listed potential buyers to progress towards VMP sales and LSP business establishment.

Activity 2.2: Strengthening linkage among CA and mechanisation stakeholders:

At present, CASPA is working in nine districts with more than 225 farmers groups involving about 10,000 farmers. In this project, the CASPA farmers' network was engaged to raise awareness of the benefits of CA and VMP use and to identify new and interested VMP

service providers and users (farmers). Various meetings (31 events) were organized in Rajshahi, Rangpur, Thakurgaon districts, and Panchaghor and Noakhali regions where a total of 331 key farmers (lead farmers) and concerned officials of CASPA/DAE/Solidariadad/SIBL/RDA attended. These lead farmers were trained to disseminate the VMP and CA technologies in their community. In the Project, CASPA/DAE/Solidariadad/RDA, a partnership of farmers and LSP, played a catalytic role in the on-going rollout of the farm machinery technology and also to facilitate the loan disbursement and recovery. Further, this pilot project established linkages with Rural Development Academy (RDA), Bogra; DAE; Bangladesh Agricultural Universities, NGOs (Solidariadad, etc.), projects, etc. to promote the CA and VMP.

The Project has developed the capacity of 10 small manufacturing workshops to manufacture high quality components of VMP in a short period of time. The HC basically outsourced the required components from these part manufacturing workshops and assembled components in their factory and then arranged delivery to LSP after necessary QC.

Activity 2.3: Integration of financial institutions:

The National Bank Ltd. provides limited numbers of soft loans (with low interest rate) for CASPA farmers to purchase VMP and 2WT. However, an extended loan disbursement program was developed and implemented under this project. Thus, senior level officials from the National Bank Ltd. and Social Islami Bank Ltd. were invited to participate in various field activities of CASPA and Project. A total of 14 events involving more than 300 participants including bankers, NGOs, farmers, LSPs, CASPA, DAE attended in these events. In collaboration with CASPA and the National Bank Ltd., HC led this activity to identify interested farmers/LSPs to get financial support (loan) for buying the VMP and 2WT by: linking them with the National Bank Ltd, helping LSP with processing the loan documents, introducing the LSPs to the bank, and facilitating their opening of loan accounts at the bank, etc.

Activity 2.4: Testing of VMP Commercialization Models: Under ACIAR project LWR/2010/080, two commercial models were tested for out scaling of VMP. This relative merits of the two business models were evaluated and between them there was an aim to sell at least 150 units of VMP. Sales of 147 units were achieved. The commercialization models are as follows:

(a) Planting Incentive Model (PIM): To accelerate farmer testing of planting services by VMP service providers and to attract new male and female LSPs and farmers while the technology is still unfamiliar to them; each new VMP owner was eligible for a once-only planting incentive @Tk. 500/- per bigha (0.133 ha) for up to 50 bigha (6.67 ha) of planting. This model was applicable for the purchasing of VMP alone. The Project and HC conducted audits to verify that planting was completed before the PIM was approved. The audits were also used to identify cases of poor planting performance or planter faults so that these can be corrected. However, no major fault was reported by the LSP. A few minor problems were reported related to planting in high/low moisture fields and high residue retained plots. Under PIM, the project was able to sell 114 units of VMP. Previous experience with LWR/2010/080 suggests that PIM helps the LSP to quickly build a client base for future business and reduces the risk for first time users of the VMP planting service so that they can gain confidence in its reliability and cost effectiveness. These plantings also serve as demonstrations to advertise to local farmers the availability of the services and the effectiveness of the planting.

(b) Tri-party Investment Model (TIM): In the recent past, the GoB provided up to 70% price subsidy for 2WT along with selected non-CA planting machinery. The availability of this subsidy hindered the VMP sales that are based on actual price. Through TIM, the male and female LSP/farmer was provided with 25% of the purchase price as cash, and they received 61.5% loan support (from National Bank Ltd. or Social Islami Bank Ltd.), and 13.5% from project to buy a VMP along with a 2WT. Based on National Bank policy, the male or female farmer/LSP cannot take a loan individually; so the spouse was registered as the co-receiver. The LSP/farmers had to ensure 50 bigha planting by VMP within two seasons to receive13.5% project support. The 13.5% project support to ensure 50 bigha planting helped to create demand for ongoing VMP services at farmers level. Through the TIM, the project was able to sell 30 units of VMPs and 2WTs.

Activity 2.5: Monitor adoption of VMP and evaluation of the PIM and TIM models:

The project hired an independent consultant to evaluate and report on the VMP adoption and the relative effectiveness of the two commercialisation models. The consultant completed the study and submitted the report. The broad objective of this study was to test the feasible commercialization models for scale out of the CA-based planter by providing support to a private company which has demonstrated the commitment and capacity needed to scale-out the CA-based mechanization in Bangladesh. Information for this study was collected both from primary and secondary sources using different data collection methodologies like literature review, survey and key informant interviews.

This study reported that the adoption of VMP is still at the initial stage largely confined to the project working hubs. The farmers are not yet ready to purchase the machine at the full market price. Price incentives, combined with promotional incentives, should be continued either by Projects or by the Government. VMP should also be rewarded with >50% subsidy similar to other comparable agricultural machineries (e.g., combined harvester, transplanter). Conservation Agriculture Service Providers' Association (CASPA), RDA, DAE and other stakeholders may work on advocacy issues in this connection. This study also observed from the responses of farmers and LSPs, that the PIM model had higher acceptance than the TIM model. Farmers want to avoid stringent banking formalities, documentation and time-based repayment pressure. That's why, most of them preferred equity financing through the PIM. However, TIM model must also be continued to capture the users having equity shortage. It will also help prepare the financial institutions to operate financing packages in mechanized agriculture. Successful adoption of a new technology depends on frequent monitoring and instant trouble shooting. After sales service should be done by the machinery supplier(s) with utmost sincerity. Strict clause needs to be included in the contract made with the machinery suppliers.

Activity 2.6: Training for operator, owner, mechanics of VMP:

Under this Project, we organized a total of 7 group training events in Rajshahi, Bogra, Thakurgaon and Ponchaghor where a total of 312 participants attended. In these training events, VMP operation, repair, maintenance topics were followed for the new VMP owners/operators. Profitable LSP business models including minimum area coverage/VMP/year (breakeven), advertising for mass promotion of VMP, etc. were also the part of the training program. A total of 8 hands-on training events were conducted during the project life. Hoque Corporation and CASPA led the training events with technical help from PIO and BAU. The VMP along with 2WT were handed over to each LSP after completion of the training event.

Activity 2.7: Establishment of VMP value chain:

The project worked in different districts of Bangladesh where the dealers of HC for VMP and spares sales were not established yet. In order to develop a supply chain for the purchase of the VMP and spares, CASPA's farmers group, lead LSP and local repairing workshop in each project district were engaged to arrange collection of orders and to facilitate sale of VMP and spares. Hoque Corporation and CASPA worked together to setup VMP supply chain (including spares) through the dispersed famers' groups (e.g., CASPA) and local level agricultural machineries sellers in each working locations of the project.

Activity 2.8: Monitoring, quality control (QC) and after sales services: Hoque Corporation strongly monitored VMP service after sale to identify needs for support for all VMP owners, LSP operators or local level workshops to ensure optimal performance of the VMP. They have recorded and reported the cost, time/events involvement per VMP for QC and service after sale. They also provided after sales quality assurance and quality control (QA/QC) in the manufacturing of farm machinery.

Activity 3.1: Desktop study to identify opportunities and scope for 4WT-based planter adoption in Bangladesh:

One MS Student (Mr Kamrul Islam) conducted the study under the supervision of Dr Md. Hamidul Islam, Associate Professor, Department of Farm Power and Machinery, BAU. Mr. Islam completed the study and submitted the thesis, titled "Present Status and Prospect of Tractor Mounted Planter in Bangladesh". This study confirmed that about 56,000 four-wheel tractors are available in Bangladesh. And the number of four-wheel tractors is increasing rapidly every year. However, the four-wheel tractor-mounted planter is not familiar among the farmers due to lack of four-wheel tractor operated seeders and the higher price of the four-wheel tractor itself. This study recommended the development and out scaling of a four-wheel tractor operated seeder which may gain popularity among the farmers if a community-based machinery business is developed.

Activity 3.2: Develop and test the prototype of 4WT-based VMP:

This project has developed and tested a prototype of a 4WT-based VMP for strip planting a range of crop species. The prototype was evaluated on the BAU farm with wheat up to active tillering stage. This trial had to abandoned after active tillering stage as the plot was inundated due to surrounding boro rice fields. Further investigation was not possible due to Covid-19 pandemic situation and country-wide lock down. However, further evaluation of the 4WT-based VMP is planned during the wheat season of 2021/22 by the PIO under the NUMAN Project.

7 Achievements against activities and outputs/milestones

Objective 1: To identify gaps in policy, capacity, and roadblocks for the adoption of CA-based farm mechanization on small farms.

no.	activity	outputs/ milestones	completion date	Comments
1.1	Study on policies and roadblocks for small scale CA farm machinery adoption.	- Study completed and reported. - Briefing meeting organized with policy makers to influence future CA-based and smallholders' farm mechanization policy and investment in Bangladesh.	Within 3 months of the project launching in Bangladesh.	- Study completed. - Report submitted (Annexure A). - Organizing briefing meetings with Government of Bangladesh (GoB) officials was not possible since Government offices and banks were almost closed from 26 March to 31 August, 2021 and further restrictions remain in place on travel, visits, organizing meetings due to COVID-19. - We provided CA briefing notes to National Agricultural Mechanization Policy Guideline Development Committee that contributed to the National Agricultural Policy 2018. https://moa.gov.bd/sites/default/files/files/moa.portal.gov.bd/policies/69304e3a_05f2_4e17_b369_92e2285171f0/krishi_nity_2018%20(1).pdf

CA=Conservation Agriculture; GoB=Government of Bangladesh

Objective 2: To evaluate commercialization models for smallholders' 2WT-operated CA-based farm machinery (e.g., Versatile Multi-Crop Planter [VMP]) in Bangladesh.

no.	activity	outputs/ milestones	completion date	Comments
2.1	Demand creation and awareness raising to promote VMP in the commercialisation target areas.	- 12 demo. events and 18 FFGD of VMP organized with 240 participants.	Within project period.	- Participated in 6 Rural Development and National Agricultural Machinery Fairs (DAE-Dhaka, Boda, Sadar-Thakurgaon, Durgapur, Subrnochor, Komolnagar) to demonstrate VMPs. -10 demand creation & VMP demonstration meetings organized (4=Ponchaghor, 2=Thakurgaon, 1=Rajshahi, 1=Natore, 1=Sobornochor, 1=Komolnagar) where 670 farmers attended. -8 field days organized (1=Rajshahi, 1=Natore, 2=Ponchaghor, 1=Sadar-Thakurgaon, 2=Noyakhali, 1=Sherpur) where 765 farmers attended. - 8 Handover Program organized (1=Durgapur, 1=Thakurgaon Sadar, 1=Noyakhali, 4=Ponchaghor, 1=Bogra). In these events, high officials of DAE, Banks, NGOs and local administration attended. A total of 362 paricipants attended in these event including farmers.

2.2	Strengthening linkage among CA and mechanisation stakeholders.	6 meetings with CASPA/LSP/Bank /DAE.	Within project period.	-31 strengthening linkage meetings (3 meetings =DAE Ponchoghor; 1=DAE Thakurgaon; 2=DAE Rajshahi, 2=DAE Natore, 2=DAE Dhaka; 2=CASPA Rajshahi; 4=NBL Rajshahi, Thakurgaon, Ponchaghor; 1=SIBL Noykhali; 5=Solidariadad Network Asia; 2=RDA Bogra; 7=LSP meeting at Rajshahi, Ponchaghor, Thakurgaon and Noyakhali) were organized where a total of 331 persons attending. - Established forward and backward linkage with 10 small machinery part manufacturers; - 5 forward linkgage with Govt. organizations, Banks and NGOs. - Exported 3 VMPs to Tajikistan
2.3	Integration of financial institutions.	6 meetings with Bank and selected LSP.	Within project period.	-7 meetings with (2=NBL; 4=SIBL; 1=IBBL) high officials for policy and planning meeting regarding loans for TIM model. - 7 Integration meetings with LSP and Banks were organized for TIM model (1=Rajshahi, 1=Natore, 1=Thakurgaon, 2=Ponchaghor; 1=Noyakhali, 1=Lakshimipur).
2.4	Testing of VMP Commercialization Models.	150 VMP sold. 50 2WT sold.	Within project period.	- A total of 147 VMPs sold including 3 units export to Tajikistan. - Total 30 units of 2WTs sold.
	(a) Planting Incentive Model (PIM)	- PIM tested to sell 100 VMPs.	Within project period.	- 114 VMPs sold under PIM.
	(b) Tri-party Investment Model (TIM)	- TIM tested to sell 50 VMPs and 50 units of 2WT.	Within project period.	- 30 VMPs and 2WT sold under PIM.
2.5	Monitor adoption of VMP and evaluation of the PIM and TIM models.	- 1 adoption study completed. - Report submitted and conveyed to HC, National Bank, DAE, BARC	Last months of the project.	- Study completed. - Final draft report submitted by the consultant.
2.6	Training for operators, owners, mechanics of VMP.	- 6 training events with 200 participants organized.	Last months of the project.	-7 events completed (1=Rajshahi, 2=RDA Bogra; 2=Thakurgaon; 1=Ponchoghor) where a total of 312 VMP owners, operators & field service technicians attended. - 8 Hands on training (1=Thakurgaon, 2=Ponchaghor, 3=Noyakhali, 1=Sherpur, 1=Bogra) organized where a total of 74 persons attended. - 147 LSP's individual confidence development training - A training event on VMP operation, repair and maintenance in Tajikistan during May 2019, where a total of 25 persons attended.

2.7	Establishment of VMP value chain.	150 units of VMP and 50 units of 2WT delivered to LSP Spare parts made available through CASPA. Involved Chittagong Builders for 2WT marketing.	Within project period.	-147 VMPs and 30 2WT delivered to LSPs and 3 sets of VMP exported to Tajikistan. - Involved Chittagong builders to deliver 30 units of 2WTs in project areas. - Except seed meters, most of the spare parts of VMP are made available in local market. - HC provides extra one set of seed meter with each VMP. - Developed mechanism to deliver seed meters to LSPs through courier service within 2 working days. - 8 spare parts delivery and servicing mechanisms call centers developed (3=Ponchaghor, 1=Thakurgaon, 1=Rajshahi, 1=Natore, 1=Noyakhali, 1=Bogra).
2.8	Monitoring, quality control (QC) and after sale services.	QA/QC assessment completed for 150 units of VMP after in-field planting. Owners of 150 units of VMP get after sales services.	Within project period.	-144 new and 35 old VMPs received after sales services for spare parts, repair, maintenance, planting mentorship. A new seed meter for peanut was developed to address the needs in Panchagargh. -179 LSPs provided planting services by VMP to about 956 ha of different crops in project area.

FFGD=Farmers' Focus Group Discussion; VMP=Versatile Multi-crop Planter; DAE=Department of Agricultural Extension; CASPA=Conservation Agriculture Service Providers Association; NBL=National Bank Ltd.; SIBL=Social Islami Bank Ltd.; RDA=Rural Development Achedamy; LSP=Local Service Provider; IBBL=Islami Bank Bangladesh Ltd.; PIM=Planting Incentive Model; TIM=Tri-party Investment Model; BARC=Bangladesh Agricultural Research Council; 2WT=2-wheel tractor

Objective 3: Desktop study to identify opportunities and scope for 4WT-based CA planter adoption in Bangladesh.

no.	**activity**	**outputs/ milestones**	**completion date**	**Comments**
3.1	Desktop study to identify opportunities and scope for 4WT-based CA planter adoption in Bangladesh.	Study done and report submitted. Findings of study reported to BARC and DAE.	- Within first three months.	1 MS student (Kamrul Islam,) of Farm Power and Machinery (FPM) Dept, BAU completed the study under Dr Md. Hamidul Islam, Associate Prof., Dept of FPM, BAU. The thesis "Present Status and Prospect of Tractor Mounted Planter in Bangladesh".
3.2	Develop and test the prototype of 4WT-based VMP.	One 4WT-based VMP prototype developed and tested. Report of progress and next steps submitted.	- Initial 12 months to develop. - Last 6 months to test.	Developed prototype of 4WT based VMP. Due to Covid-19 lockdown, we are unable to complete field evaluation of the developed prototype.

FFGD=Farmers' Focus Group Discussion; VMP=Versatile Multi-crop Planter; DAE=Department of Agricultural Extension; CASPA=Conservation Agriculture Service Providers Association; NBL=National Bank Ltd.; SIBL=Social Islami Bank Ltd.; RDA=Rural Development Achedamy; LSP=Local Service Provider; IBBL=Islami Bank Bangladesh Ltd.; PIM=Planting Incentive Model; TIM=Tri-party Investment Model; BARC=Bangladesh Agricultural Research Council; 2WT=2-wheel tractor

8 Key results and discussion

To promote VMP and CA, the project has participated in 6 (six) National Agricultural Machinery Fairs in Dhaka and other working districts. In these events, various people including policy planners, agricultural scientists, extension personnel, students and farmers visited the project stall and showed interest in the VMP and CA. Participation in Agricultural Machinery Fairs developed awareness in the general public, farmers, and policy planners about the benefit to use the planter e.g., VMP to establish various crops, which reduces cost, seed rate, but assured better crop yield and profitability that motivated farmers to test/use VMP in their own land. Furthermore, the project also conducted various demand creation and awareness raising activities i.e., meeting, demonstration, field days, handover events, etc. In these events a total of 1,797 persons attended. These events helped to buid trust on VMP and bridged partnership with VMP seller (e.g., HC) and 144 new LSPs (farmers).

The Project trained 312 Local Service Providers (LSP) and 43 mechanics of VMP and manufacturing factory/repairing workshops (Figure 1). More than 2,000 farmers have hired/used VMP to sow lentil, mustard, groundnut, wheat, rice, soybean, maize, rice, chickpea, etc. on more than 956 ha during the project period. During 2021, the project identified more than 225 farmers' groups working in 10 districts (with a membership of > 10,000 farm families) and continued the effort of the Conservation Agriculture Service Providers Association (CASPA) which was established during LWR-2010/080.

Figure 1: Hands on training of VMP operation, repair and maintenance

In collaboration with the CASPA, lead farmers and DAE, the project: established a total of 10 farmers' participatory demonstrations on minimum tillage, residue retention, crop rotation, weed management, non-puddled rice establishment, etc.; organized 8 Field Days, Focus Group Discussion sessions and handover program that reached many farmers most of whom are retaining some level of crop residue, practicing crop rotation; practicing strip planting systems for non-rice crops, direct seeded rice and non-puddled rice establishment.

Previously, IDE developed strategies for the commercialization of VMP through the involvement of Alim Industries Ltd., Sylhet and ACI Motors Ltd., Dhaka. However, due to low quality of materials used to manufacture the VMPs, most of them had repeated breakages during field operation. Neither of the strategies were successful in attracting additional sales; indeed the poor quality VMP hampered attempts to interest new LSP in the planters. Furthermore, due to the unproven market demand for VMP the bigger manufacturers were unwilling to invest in demand creation activities or further development and production of VMP. At the later stage of the LWR-2010-080 project, we tested two models for VMP commercialization involving a private VMP manufacturing company (e.g., Hoque Corporation, HC) as follows.

Model 1: Hoque Corporation and the PIO worked together for demand creation in targeted hubs and ensured quality production and delivery of VMP on time. That helped to identify interested new 2WT service provider groups in project working hubs, because - i) most of the service providers had 2WT which is essential to operate planters/implements and they had the financial means to buy VMP; ii) they are well known in their community for selling tillage services; iii) they are business-minded, risk takers who are open to try and adopt new technologies compared to traditional farmers; iv) they have mechanical skill and require minimal training on VMP operation and maintenance; v) they already are a trusted source of advice to farmers in their locality; vi) LSP have established linkages with extension agencies, CASPA, local administration and farmers of their community.

The live demonstration of VMP operation and on-farm demonstration of crop performances by LSP for establishing wheat, onion, garlic, lentil, chickpea, mungbean, jute, etc. were organized at Union level by PIO and HC to create demand for the VMP. The interested LSPs were asked to register with a deposit of Tk. 10,000-12,000 as a down-payment before the Rabi season. The PIO arranged VMP operation, repair and maintenance training programmes in mid-October to early-November of each year prior to handover of the VMP to LSP. During the training program, the LSP deposited 50 % of the VMP price with HC. During mid-November to early-December, HC handed over the VMP to the LSP. Service providers paid the remaining 50 % of the cost during hand over of the VMP.

During the last year of LWR-2010-080 project in 2017, the National Bank provided 80 % of the cost of VMP (and 2WT), with the LSP having to provide 20 % cash deposit. Additionally, the project provided free training to LSP on repair and maintenance of VMP, follow-up meetings with LSP, and with HC organized farmers' field days for demand creation at farmers' level. These Project activities created confidence by farmers, LSP, and involved stakeholders (e.g., DAE, BMDA, National Bank, etc.) in VMP adoption and commercialization.

Model 2: As the use of VMP could save irrigation water and reduce the cost of crop cultivation, the BMDA sought assistance from PIO and HC to promote VMP in Naogaon district in 2016 and 2017. In collaboration with BMDA and National Bank, the PIO and HC identified 62 and 15 new LSP in Naogaon district, in 2016 and 2017, respectively; where, the National Bank provide a 3-year loan package of Taka 170,000 to each LSP (after registration, Tk. 50,000 to buy a VMP and Tk. 120,000 for a 2WT) without any property mortgage. Each LSP provided a down payment of Tk. 10,000-12,000 to HC to confirm registration. The project organized the VMP training program as in Model 1. The BMDA engaged Chittagong Builders or local dealers to deliver 77 2WT units (62 and 15 units of 2WT in 2016 and 2017, respectively) in Naogaon. On behalf of the LSPs, the National Bank has settled the payment with HC and Chittagong Builders or dealers after successful handover of the VMP and 2WT.

Previous experience with LWR/2010/080 suggests that Model 1 helps the LSP to quickly build a client base for future business and reduces the risk for first time users of the VMP planting service so that they can gain confidence in its reliability and cost effectiveness. These plantings also serve as demonstrations to advertise to local farmers the availability of the planting service and effectiveness of the planting. Based on the learning about the above models, we have proposed and implemented two models (adjusted from the original models of LWR-2010-080 project) (i) Planting Incentive Model (PIM) and (ii) Tri-party Investment Model (TIM) which are described below:

(i) Planting Incentive Model (PIM):

To accelerate farmer testing of planting services by VMP service providers and to attract new male and female LSPs and farmers while the technology is still unfamiliar to them; each and every new VMP owner was eligible for a once-only planting incentive @Tk. 500/- per bigha (0.133 ha) for up to 50 bigha (6.67 ha) of planting. This model was applicable for the purchasing of the VMP alone. The Project and HC conducted audits to verify that planting was completed before the PIM was approved. The audits were also used to identify cases of poor planting performance or planter faults so that these can be corrected. However, very limited faults were noted (e.g, less germination due to lower/higher moisture level in the fields, higher amount of residue created problems for operating VMP, etc.) and these were related to operator experience. The following advice was suggested to LSPs and farmers to overcome the problems: use of sharp and straight rotary 'C' type tines/blades in front of the furrow openers for plant high residue retained plots; avoid planting with higher moisture in fields; and application of pre-emergence light irrigation in case of low moisture fields.

Under PIM, the HC were able to sell 114 units of VMP.

(b) Tri-party Investment Model (TIM): In the recent past, the GoB provided up to 70% price subsidy for 2WT along with selected non-CA planting machinery. These subsidies hinder the VMP sales based on full market price. Through TIM, the male and female LSP/farmer was provided with 25% of the purchase price as cash, received 61.5% loan support (from National Bank Ltd. or Social Islami Bank Ltd.), and 13.5% from project to buy a VMP along with a 2WT. Based on National Bank policy, the male or female farmer/LSP cannot take a loan individually; so the spouse was registered as the co-receiver. The LSP/farmers had to ensure 50 bigha planting by VMP within two seasons to receive13.5% project support. The 13.5% project support to ensure 50 bigha planting helped to create demand for ongoing VMP services at farmers level. Through the TIM, HC was able to sell a total of 30 unit of VMPs and 2WTs. However, there were reports of poor quality of the 2WTs supplied which led to may LSP to delay repayments to the banks.

Except for tillage, threshing, and irrigation, the smallholder farmers have not yet adopted farm mechanization practices in Bangladesh for many reasons, including —lack of knowledge, perceived complexity of new practices, unavailability of market-ready farm machinery, limited accessibility and availability of finance (including lack of knowledge of the process by farmers) to purchase farm machinery, and the change of mind set required before shifting to farm mechanization (e.g., minimum soil disturbance planters) and CA. The farm machinery and CA in many other countries evolved through innovation networks linking farmers, extension personnel, researchers, engineers, mechanics, input suppliers and finance organizations. Such a partnership approach tested to bring farm mechanization and CA to smallholder farmers as in Bangladesh. In addition to developing manufacturing and LSP capacity, the LWR-2018-111 and LWR-2010-080 projects have been empowering farmers and LSP to drive the development and promotion of CA and farm mechanization by the farmers' network known as the Conservation Agriculture Service Providers Association (CASPA) with currently more than 10,000 farmer members spread across >250 groups. During the initial phase, CASPA trained all members on CA, safe use of herbicides, benefits of farm mechanization, and the use of the VMP. These initiatives helped to raise awareness on VMP use in project working hubs where CASPA played the catalyst role to (i) identify interested LSP to purchase VMP at grassroots level, (ii) establish links with HC and LSP, (iii) provide mentorship to new LSP through old LSP, (iv) help banks and new LSP with loan document processing, (v) motivate farmers to use VMP for various crops (create

demand for VMP use), (vi) help banks with loan recovery, (vii) setup spare parts supply chain, (viii) host training, meetings, demonstrations and field days, (ix) data collection related to this project. This project was quite successful due to grassroot level support from CAPA.

Moreover, CASPA and PIO have begun to experiment with farmer engagement based on a collective action approach to out scale agricultural technologies within areas serviced by deep tube wells for irrigation where groups of farmers manage 50-200 ha in a block using the shared irrigation water resource. Under PIO and CASPA leadership, several of these groups have formed with the aim of collective year-round crop sequences, selection of common crop varieties, coordinated management of soil fertility and nutrients, weeds and pests, irrigation scheduling, and mechanising operations. However, country-wide lockdown and further extended periods of restricted movement due to COVID-19 has hampered the collective action approach. We have re-started collective action experimentation after COVID-19 restriction was widthdrawn under the NUMAN (LWR-2018-136) project.

During the LWR-2010-080 project period 2012 to 2015, 2016, and 2017; a total of 6, 18, 50 VMPs were monitored closely to collect performance data. The adoption of VMP by farmers to grow various crops increased over the period. On an average, each VMP covered 6.5 ha during 2012-2013; average planting area increased to 11.7, 12.5, 13.7, and 18.9 ha and served 31, 87, 93, 56, and 75 farmers during 2012-13, 2013-14, 2014-15, 2015-16, and 2016-17, respectively. In 2017, 18 LSP were purposely selected from Rajshahi, Thakurgaon, Mymensingh, and Rajbari districts for a study of their business model. The study revealed that LSPs effectively utilized VMP and 2WT for 4-6 months (Miah et al. 2017). They received Tk. 1,42,434 (with price support on VMP) and Tk. 1,36,134 (without price support) per year as net income. The average payback periods were 0.72 and 0.98 years with and without price support, respectively. The annual break-even use of VMP was 7.8 ha.

Case Studies:

The Noyakhali and Lakhipur districts are the main soybean growing area of Bangladesh where a total of 75,000 ha of soybean is grown per year. Manual cultivation of soybean is becoming challenging due to price hiking and scarcity of labour. On the other hand, manual operations delay planting and reduce soybean grain yield significantly. Late planted soybean are often damaged due to early monsoon rain that are quite frequent in southern part of the country.

Solidariadad Network Asia (SNA) is an international NGO working in south-east regions (Noyakhali and Lakhipur) of Bangladesh to promote soybean since the beginning of 2018. The SAN have been working with a total of 26,000 farmers with the involvement of 15 lead farmers and 5 producers' companies. The SNA provided technical support, market linkage for inputs and outputs including soybean cultivation training, quality seed production, linkage establishment with quality seed producers and traders, supervision and field visits during soybean cultivation to ensure good seed yield, market chain development with rhizobium inoculum producers to end-users (farmers), upward linkage establishment with feed millers. During early 2018, both SNA and the Project evaluated the VMP for soybean cultivation as a pilot project in Noyakhali and Lakhipur, where, SNA identified and assisted two lead farmers; Hoque Corporation (HC) provided commercial and services after sales; and PIO provided technical services to see the suitability of soybean cultivation by VMP and its out-scaling viability (Figure 2).

Figure 2: Meeting with SNA, Noyakhali Team

The LWR 2018/111 organized training and demonstrations program of VMP in Thakurgaon where we invited six persons from SNA Soybean Project (2 VMP owners, 2 operators and 2 Field Supervisor of SNA). Further follow-up meetings, trainings and demonstrations of VMP was conducted in Noyakhali and Lakhipur prior to handover of 2 VMPs during 2018/19. Those two VMPs owners accomplished about 100 bigha (14 ha) soybean planting during 2019. The pilot project organized follow-up field days, visits, farmers' group discussion and follow-up meetings on the performance of VMP planted soybean, time, labour and cost savings, and finally yields of soybean.

To out scale the VMP for soybean cultivation in south-eastern region of Bangladesh, the LWR/2018/111 and SNA jointly organized VMP demonstration and planning meeting with SNA Field Supervisors and Lead Farmers working for Soybean Project in Noyakhali and

Figure 3: VMP handover program was inaugurated by the Deputy Commissioner, Noyakhali District; Deputy Managing Director of Social Islami Bank Ltd, high official of SNA and LWR/2018/111 Project in Noyakhali

Lakhipur during July 2019. Each Field Supervisor was given responsibility to identify potential farmers to become Local Service Providers (LSP) of VMP. Furthermore, the SNA

and LWR/2018/111 Project dialogued with Social Islami Bank Ltd. to arrange soft loan for 6 VMP and 8 2WT buyers (e.g., LSPs). The above activities helped to sell 20 VMPs and 8 sets of 2WT in Noyakhali and Lakhipur districts during 2019/20. The LWR/2018/111 and SNA jointly organized the VMP operation, repair and training program in December, 2019 and handed over the VMPs and 2WTs to farmers in presence of the Deputy Commissioners of Noyakhali district, high officials of SNA, Bank, local leaders, LWR/2018/111 project personnel, extensionists, farmers etc. (Figure 3).

Due to heavy rain in January, 2020, the soybean growing fields became wet and many farmers abandoned plans to grow the late-sown crops which reduced the potential services of VMP during this year. The VMP owners were able to use the planter for no more than 20-25 days since purchase. In March, 2020, we have collected various informal information of VMPs' performance including (i) area coverage, charge for VMP sowing, earnings, profit, quality issues, etc. from 64 VMPs sold in 2019/20. Out of 64, 22 LSPs use their VMPs mostly for their own uses covering an average 8 bigha (about one ha) of land; the second category of 11 VMP owners use their planter for their own use and provided average 25 bigha planting services to neighbouring farmers. The third category of 21 VMP owners acted as individual LSP who mostly operated his VMP on their own land and provided services on an average 63 bigha of land; a few of them hired temporary operator to assist them. The fourth category of 10 VMP owners covered an average 126 bigha of land by functioning as micro-entrepreneurs as they have other agricultural input business locally and they have hired operators to provide service business on a wider spread area. Different marketing and support services may need to be tailored for Categories 1, 2/3 and 4. The 1st tow categories of VMP owners are a new segment in the VMP market whose goal is to use their VMP for timely sowing on their own land. Category 4 VMP operators are already active and experienced businesses who have adopted the VMP to expand their services. The planting business of the 3rd category LSPs offer addition potential to expand the area planted. To expand the planting service business of 4th category, they can be motivated to purchase additional VMPs and hire extra operators. These businesses could progress towards multi-service custom-hire businesses.

The study of Miah et al. (2017) reported on the experienced and multiple upland cropped area where the average area coverage per VMP was 22 ha (in about 4 months per year). Whereas, the monitored 64 VMP owners were new owners (purchased in December 2019 to January 2020) for single upland crops (soybean in south-east and groundnut in north-west regions), and the natural calamities (heavy rain due to cyclones Bulbul and Amphan) and Covid-19 restricted the planting areaa. The average planting charges were Tk. 3,637/ha. The net average earning during about 20-25-day period of Tk. 2147, 7260, 16077 and 32827 was calculated for VMP owners of categories 1, 2, 3 and 4, respectively. The LSP did not report any serious quality issues with the VMP.

The soybean farmers reported total A$165/ha saving from the cost of land preparation (A$48/ha), seed sowing cost (A$82/ha) and seed saving (A$35/ha), while they have obtained higher soybean grain yield by about 600 kg/ha in VMP planted plots. The total benefit of soybean farmers was A$547/ha relative to conventional planted soybean.

Peanut cultivation is getting popuar in Panchagarh district due to its demand and profit. However, manual seed sowing of peanut is labour intensive, costly and time consuming. A total of 43 VMPs were sold in 3 upazilas of Ponchaghor district where a total of 40, 146 and 264 ha of peanut was planted by VMP in 2019, 2020, and 2021, respectivey. After the harvesting season of peanut in 2019, we have studied the economic benefit of VMP use

over manual seeding of peanut. The peanut farmers reported that the total A$211/ha cost saving (A$48/ha for land preparation cost, A$136/ha for peanut seed sowing cost and A$27/ha of seed saving cost) due to use of VMP. The peanut farmers also reported 100 kg/ha of additional peanut grains due to use of VMP; these confirmed ultimate total additional benefit of A$320/ha from VMP planted peanut compared to conventionally cultivated peanut. Based on feedback from farmers, HC developed and supplied to all VMP owners an improved seed meter designed specifically for peanut.

Working with multi-stakeholders is critically important for commercialization of new agricultural technology. The LSPs and farmers are cautious to invest money for new farm implements as many of them had been cheated or had bitter experience to get proper services from private companies after purchasing implements. Involvement of universities (e.g., BAU, Murdoch University), extension agencies (e.g., DAE and BMDA) and strong coordination through PIO has built the trust among the LSPs and farmers to buy and adopt the VMP.

To assess the opportunities and scope for 4WT planters on small farmers in Bangladesh, one (1) MS student was engaged to conduct a desktop study from secondry data sources. The MS fellow has completed his degree from Bangladesh Agricultural University and submitted the thesis. This study confirmed that the limited availlabilty and higher price of agricultural labour demands agricultural machinery use in Bangladesh. The demand of PTOS (high speed rotarary tiller based planter) is increasing 7 times more than previous years but mostly it is used for land preparation and does not operate as planter (and doesn't qualify as a CA planter). The small size of 4WT (35-55 hp) are getting popularity in Bangladesh mostly for haulage and primary full tillage for land preparation. However, 4WT-based planter are not available to farmers. Therefore, the 4WT-mounded seed drill has a vast opportunity for various crop establishment and practicing CA in Bangladesh. However, there has been limited investment by the private sector to scale-up production associated with uncertain CA machinery market demand.

Under this project we have developed a prototype (Figure 4) of 4WT-based VMP with the capacity to sow various seeds in varied row spacings and seed+fertilizer rates in a single pass operation. The effective field capacity of 4WT-VMP was 2.92 ha/ha in single pass planting of wheat which was 69% higher than conventional full tillage land preparation by 4WT and manual broadcasted seed and fertilizer application. This 4WT-based planter is capable of sowing many crops from small jute seed up to maize. The prototype was evaluated in BAU farm with wheat crop up to active tillering stage. The use of 4WT-planter saved 69% of time to sow wheat seed over conventional full tillage mode. The 1st on-station trial of 4WT-planter with wheat had to be

Figure 4: Evaluation of 4WT-Planter at BAU Farm, Mymensingh

abondoned after active tillering stage as the plot was inundated by irrigation water seepage from surrounding boro rice fields. More investigation was not possible due to Covid-19 pandamic situation and country-wide lock down. However, further on-farm evaluation of the 4WT-based VMP is planned during the wheat season of 2021/22 by the PIO under NUMAN Project at Ponchaghor district.

The project contributed with the development of human resources. The project hosted 1 MS scholarship at Bangladesh Agricultural University who has completed the degree successfully. The project has organized 7 formal short-term training, 8 hands on training and 147 LSP's individual confidence development training for VMP owner/operators, extension personnel of DAE, Banks, NGOs and lead farmers where a total of 312 participants attended. Furthermore, the project scientists had given seminars in Bangladesh, Tajikistan, Australia, Switzerland (World Congress of Conservation Agriculture – on line) etc. on CA and VMP.

Several agricultural mechanization projects have been implemented from GoB and foreign funds in selected districts of Bangladesh and sold >5,000 units of subsidised (up to 70%) 2WT (power tiller), power tiller operated seeder (PTOS), bed planter, thresher, combine harvester, etc. The offered subsidy packages (e.g., if a farmer would buy a PTOS or a bed planter, then s/he will get up to 70 % subsidy for a 2WT also) insists that farmers buy both the 2WT and planters. The subsidised 2WT, PTOS and bed planters are full tillage equipment and/or planters rather minimum soil disturbance (CA) planters. However, the adoption of PTOS and bed planter for seeding was not substantial; as in most cases farmers' have been utilizing only the 2WTs for full tillage. The subsidised PTOS and bed planters remain largely unused due to lack of demand, repair and maintenance training, poor quality of the machinery, and lack continuous monitoring and mentorship of new LSP, etc.

Except for tillage, threshing, and irrigation, small holder farmers have not adopted farm mechanization practices yet for many reasons, including —lack of knowledge, perceived complexity of new practices, unavailability of market-ready farm machinery, limited accessibility and availability of finance (including lack of knowledge at farmers level) for purchase of farm machinery, and the change of mind set required before shifting to farm mechanization and CA. However, opportunities are opening up to make it easier for small holder farmers to change from labour-intensive manual farming to time and cost-saving mechanized farming. A more diverse range of small farm machinery and CA implements are being developed for small holders starting from hand tools or animal-drawn implements to planters mounted on 2WT or small 4WT (up to 55 hp). Effective farm mechanization and CA practices for small holders would also enable them to capture the economic benefits already enjoyed by the large-scale users in developed countries from mechanized farming and CA; viz. reduced fuel and labour costs and improved timeliness of operations. However, there are many biophysical and socio-economic constraints to small holder farmers in adopting farm mechanization and CA and it will be necessary to develop effective strategies to jointly improve the emerging technologies in partnership with farmers. It is noted that farm machinery and CA in many other countries evolved through innovation networks linking farmers, extension personnel, researchers, engineers, mechanics, input suppliers, and finance organization (credit providers). Such a partnership approach is also necessary to bring farm mechanization and CA to small holder farmers in Bangladesh.

Based on the typical yield gains and decreases in cost of production achieved in on-farm experiments by ACIAR Project LWR/2010/080 in the last 5 years, we estimate that 10 %

adoption of mechanized CA by Bangladesh farmers would generate a net benefit of US$36-72 million per year. However, the challenge remains to create wider demand for the farm machinery, develop nation-wide marketing channels, ensure financing for LSP, develop skilled manpower for operation and repair of machinery; and demonstrate the effectiveness, reliability, and durability of machinery at a price that allows ready adoption in the target markets.

During the Project, most of the NARS institutions, agricultural universities, extension and development agencies, and policy makers have begun to give priority to farm mechanization and CA research and many of them included CA research in their annual research programs. The Government of Bangladesh developed policy papers "Agricultural Research Vision 2030 and Beyond: Research Priorities in Bangladesh Agriculture" and National Agricultural Policy 2018 where CA research and development was given higher priority and the project contributed to developing the policy document. The GoB has approved a big agricultural mechanization project, valued at about A$516 milion, to provide subsidies to various agricultural machinery. The VMP is one of the agricultural machinery that has enlisted in the latest GoB project.

9 Impacts

9.1 Scientific impacts – now and in 5 years

Project LWR-2018-111 was successful to follow-up the outputs of LWR-2010-080 and contributed to science on effective CA practices for smallholder farms using minimum tillage implements mounted on 2-WTs. The participants continued to publish book chapters and high impact factor journal articles (19 papers and a book chapter, please see Section 11.2 List of publications produced by project) on new knowledge e.g., (i) smallholders' CA and mechanization in rainfed and irrigated systems (Haque et al., 2021, Salahin et al., 2021b, Bell et al., 2018, Araujo et al., 2020); Ammonia fluxes and emission factors (Uddin et al., 2021), nitrous oxide (N2O) fluxes from irrigated wheat (Jahangir et al., 2021); carbon and nitrogen mineralization (Salahin et al., 2021a); weed seedbank and behaviour in continuous CA (Hossain et al, 2021); soil disturbance and soil water content (Vance et al., 2020); soil nitrogen storage; carbon footprint and greenhouse gas implication under CA (Alam et al., 2020, 2019a, 2019b); performance of nonpuddled rice in CA (Haque and Bell, 2019 and Hossen et al., 2018c); effect of selected herbicides in following crops (Zahan et al., 2019); seed rate, seedling quality and growing media of rice seedling (Hossen et al., 2018a, 2018b).The outcomes of this project will lead to sustainable agriculture systems in intensive rice-based cropping systems.

9.2 Capacity impacts – now and in 5 years

The project is implementing an innovative approach by engaging one MS student to carry out research project and to build capacity for future research programs on CA in Bangladesh. Several organizations including DAE, CIMMYT, IRRI, BARI, BRRI, BAU are conducting advanced research and promotional activities on the LWR-2018/111 and LWR-2010-080-developed technologies. The Project trained 312 Local Service Providers (LSP) and 43 mechanics of VMP and manufacturing factory/repairing workshops who will provide local level support for VMP operation, repair and maintenance support. The Project has also developed the capacity of 10 small manufacturing workshops to manufacture high quality components of VMP which will sustain VMP manufacturing once the demand will increase.

9.3 Community impacts – now and in 5 years

The project was quite successful with engaging local administration, DAE officials, NGOs, local leaders, banks, service providers and farmers. The project worked in different districts based on requests by farmers and extension agents. More than 225 farmers' groups (involving >10,000 farm families) came forward to pick-up and adopt the project technologies. The project also provided support to establish linkages between the VMP commercialization partner (Hoque Corporation) and farmers' groups; and develop master trainers from the groups to train all farm families on the CA technology. These farmers' groups maintained the operation of the Conservation Agriculture Service Providers Association (CASPA) which was established during LWR-2010-080 project period.

Private companies were involved to manufacture, commercialize, and export the VMP. A total of 147 units of VMP have been manufactured and sold during the project period.

Moreover, several small manufacturers deliver parts of the current version of VMP manufactured by Hoque Corporation.

One of the great successes of the project was to pilot the VMP commercialization. In collaboration with banks (NBL, SIBL), extension (DAE, SNB and RDA), the PIO and HC identified new LSP in Noyakhali, Lakhipur, Bogra and Ponchaghar districts, where, the National Bank Ltd. and SIBL provided loan packages to LSP after registration without any property mortgage. Each LSP provided a down payment to HC to confirm registration. The project organized the VMP training program. The project also engaged Chittagong Builders to deliver 30 units of 2WT to Noyakhali and Lakhipur district. On behalf of the LSPs, the National Bank Ltd. and SIBL has settled the payment with HC and Chittagong Builders after successful handover of the VMP and 2WT. The National Bank and SIBL are interested to continue the loan program in future. The loans are unsecured, but a 20 % deposit is required by the LSP purchaser. A feature of the current promotion strategy for the VMP is to gather groups of 25-40 farmers in the neighbourhood of the new LSP who will agree to purchase planting services. The assurance of planting business is a strong incentive for the new LSP to commit to a loan.

9.3.1 Economic impacts

It is too early to calculate the overall economic impact of this intervention. Under this project, the soybean farmers reported total A$165/ha saving from the cost of land preparation (A$48/ha), seed sowing cost (A$82/ha) and seed saving (A$35/ha), while they have obtained higher soybean grain yield by about 600 kg/ha in VMP planted plots. The total benefit of soybean farmers was A$547/ha relative to conventional planted soybean. VMP using peanut farmers reported that the total A$211/ha cost-saving (A$48/ha for land preparation cost, A$136/ha for peanut seed sowing cost, and A$27/ha of seed saving cost) due to use of VMP. The peanut farmers also reported 100 kg/ha of additional peanut grains due to use of VMP; these confirmed ultimate total additional benefit of A$320/ha from VMP planted peanut compared to conventionally cultivated peanut.

Based on Miah et al. (2017) the use of VMP and CA reduces the labour cost by 10%, fuel cost by 75 to 86%, reduces irrigation water by 11 to 33%, increase crop yield by up to 28% resulting in profit gains from 48 to 560%. VMP have the capacity to sow about 1 ha of land in each day (8 hrs). The CA adopters obtained higher net return of A$ 439, A$ 112, and A$ 233 per ha for lentil, mung bean, and wheat, respectively over conventional methods. Haque et al. (2013) estimated the profit from non-puddled rice compared to conventional systems was A$ 126-152/ha. Farmers that used CA in a three-crop rotation (rice-wheat-mungbean) within a year achieved 29%, 54%, and 14% greater net profit (additional income of A$446/ year for a 1 ha farm) with aman rice, wheat, and mungbean crops, respectively, compared to farmers practicing conventional tillage. The study of Miah et al. (2017) reported on the experienced and multiple upland cropped area where the average area coverage per VMP was 22 ha (in about 4 months per year). Whereas, under the LWR-2018-111 project, the monitored 64 VMP owners were new owners (purchased in December 2019 to January 2020) operating in areas dominated by a single upland crop (soybean in south-east and peanut in north-west regions) area, and the natural calamities (heavy rain due to cyclones Bulbul and Amphan) and Covid-19 restricted their planting area. The average planting charges were Tk. 3,637/ha. The net average earning during about 20-25-day period of Tk. 2,147, 7,260, 16,077 and 32,827 was calculated for VMP owners of categories 1, 2, 3 and 4, respectively. The LSP did not report any serious quality issues with the VMP.

9.3.2 Social impacts

The project has raised awareness among more than 2,000 male and female participants who attended various dissemination activities on VMP, CA, minimum tillage, residue retention, crop rotation, safe use of herbicide: participants included local administration, extension officers, researchers, service providers, herbicide marketing company, herbicide dealers, and farmers.

This project created self-employment opportunities directly for 147 VMPs buyers plus additional assistants to help to sell planting services. Several repairing and maintenance workshop technicians were also trained and that created job opportunities in VMP operating areas. There are at least 10 parts manufacturing workshops have been developed during this project where a significant number of workers were involved and experienced to manufacture different components of VMP.

9.3.3 Environmental impacts

The traditional tillage methods have various shortcomings, such as reduced soil organic carbon and decreased soil fertility, increased water loss, and increased irrigation water use. All planting operations under minimum tillage are done using a single pass operation, which ensures <25% soil movement. Crop establishment under minimum soil disturbance by VMP could reduce by up to 85% (32 l per ha) the diesel fuel use that could reduce CO_2 emission by 83 kg per ha per crop. A life cycle analysis suggests that minimum tillage non-puddled transplanting with residue retention decreased greenhouse gas emissions by 22-29 % compared to the conventional puddling and transplanting. Most of this can be attributed to less methane emissions. With the involvement of CASPA, the project has trained more than 10,000 farmers on CA and raised awareness on the safe use of herbicides/insecticides.

9.4 Communication and dissemination activities

The project has organized farm mechanization and CA related meeting, seminars, workshops, etc. and continuously interacted with the leaders of researcher institutes, extensionists, bankers and agricultural universities. They together with policy planners were invited to the above events.

Such initiatives created awareness among the policy planners and in the policy paper “Agricultural Research Vision 2030 and Beyond: Research Priorities in Bangladesh Agriculture” and National Agricultural Policy 2018 papers published by Bangladesh Agricultural, Research Council, the GOB has given higher priority to farm mechanization and CA research and development and included these topics in the policy document.

Many NARS institutions have begun to include farm mechanization and CA research and development in their annual research plan. The Government of Bangladesh has approved A$516 million for a farm mechanization project where VMP is an enlisted machinery for promotion. Kishi Gobashona Foundation also funding various project on farm mechanization and CA.

The Aga Khan Foundation in Tajikistan funded the import of three VMP and a visit of Project Coordinator (Dr. Md. Enamul Haque) and Hoque Corporation’s Technician (Md. Mazhadul Mondol) in Tajikistan. Both of them provided hands-on training to 25 persons in Tajikistan on VMP operation, repair and maintenance in Tajikistan.

Various news article published about the benefit of the project including:

The New Age Bangladesh, 30 July 2019 https://www.newagebd.net/article/47250/matia-for-practicing-conservation-agriculture-in-bangladesh
The Daily Star on 20 July, 2018 https://www.thedailystar.net/business/conservation-farming-10pc-land-can-save-tk-1200cr-year-1613266,
Rajshahir Alo, 23 October, 2019,
Natun Provat, 10 February, 2020 etc.

10 Conclusions and recommendations

10.1 Conclusions

The application and adoption of CA-based mechanization improved soil health (Islam, 2016; Salahin et al. 2021), optimizes natural resource and input utilization, increased crop yield (Bell et al., 2017) and crop profitability (Bell et al., 2019), while reducing the crop production cost significantly (Haque et al., 2017) and greenhouse gas emissions (Alam et al. 2017). Based on these broad-based benefits there is a need to outscale CA-based mechanization throughout the country. Several factors are hindering the outscaling and adoption of CA-based mechanization including (i) lack of awareness outside our working hubs on CA among the major stakeholders (farmers, extensionists, etc.), (ii) concerns about the effectiveness of weed management, (iii) limited national utilization as widespread market demand is not created yet, (iv) lack of skilled manpower to operate machinery, (v) unavailability of functional markets for widespread supply of machinery, (vi) lack of supporting government policy, priority and programs, etc. Use of farm mechanization and CA as a feasible and profitable farm practice for small farms has been based on the performance and reliability by the VMP. Both the commercialization models implemented by the project showed signs of success, but PIM was more prefarable option to farmer for buying a VMP in future with own financing to avoid high price, interest burden, installment pressure and so on. About 80% VMP owners are interested to continue the business, because it is created self-employment opportunities, was profitable, ensured fast seeding of crops and demand has been increasing in the locality if they get similar support like PIM or TIM.

Hoque Corporation has taken the initiative to develop the market for VMPs by setting up distribution and sales networks and developing a supply chain to manufacture or import component parts, maintain quality control of component parts and the VMP, seek orders and deliver on time, continuously upgrade designs for user satisfaction and provide after sales service. However, the current sales are below the target (200/year) at which the VMP commercialisation model becomes self-sustaining, financially. Under the Government of Bangladesh (GoB) funded project “Farm Mechanization Through Integrated Management Project” on agricultural mechanization, the VMP is selected to promote under this project. The LWR-2018-111 helped Hoque Corporation to position the VMP as a piece of machinery supported by the new GOB project.

A survey of performance of 64 VMPs sold in 2019/20 identified four business models for use of the VMP. Out of 64, 34 % LSPs used their VMPs mostly for sowing their own crops covering an average 8 bigha (about one ha) of land; the second category of 17% of VMP owners use their planter for sowing their own crops and in addition provided on average 25 bigha planting services to neighbouring farmers. Hence about half of the sales were to farmers whose primary interest was in timely sowing of their own crop using less labour inputs. The third category of 33% of VMP owners acted as individual LSP who mostly operated the VMP on their own land and provided services to an average 63 bigha of land; a few of them hired temporary operators to assist them. The fourth category of 16 % of VMP owners covered an average 126 bigha of land by functioning as micro-entrepreneurs as they have other agricultural input business and they have hired operators to provide service business on a wider area. The scale-out plan for the VMP needs to be tailored to the four different cohorts. Emergence of a new group of VMP who are primarlily farmers interested

in timely sowing of their own crops is new discovery of this Project. Category 4 VMP operators are already active and experienced businesses who have adopted the VMP to expand their services. To expand the planting service business of 4th category, they can be motivated to purchase additional VMPs and hire extra operators. These businesses could progress towards multi-service custom-hire businesses. The planting business of the 2nd and 3rd category LSPs offer additional potential to expand the area planted.

On-farm demonstrations confirmed that VMP-seeding of soybean at Noakhali reduced planting cost by A$168 and by A$222 per ha for peanut at Panchagargh. Additionally, 25% yield increase for soybean (600 kg/ha) yield and 100 kg/ha yield increase for peanut were gained in VMP-planted fields. Altogether, the VMP planting produced A$557 per ha of extra profit for soybean farmers and A$275/ha for peanut farmers. The demonstration trials have created demand for VMP to sow soybean and peanut in those regions and these areas accounted for most of the sales of VMP in the last 2 years.

Adoption of agricultural technologies e.g., VMP and CA, depends on seasonal weather, cropping pattern, land type, crop type, demand of the commodity, etc. These factors can significantly impact on outcomes from short term projects such as this one. Due to heavy rain in January, 2020, the soybean and peanut growing fields became wet and many farmers abandoned plans to grow the late-sown crops which reduced the potential services of VMP during this year. The VMP owners were able to use the planter for no more than 20-25 days since purchase. The study of Miah et al. (2017) reported that on the upland diverse-cropping area the average coverage per VMP was 22 ha (in about 4 months per year). Whereas, the monitored 64 VMP owners were new owners (purchased in December 2019 to January 2020) operating in areas dominated by a single upland crop (soybean in south-east and peanut in north-west regions), and the natural calamities (heavy rain due to cyclones Bulbul and Amphan) and Covid-19 restricted their planting area. The average planting charges were Tk. 3,637/ha. The net average earning during about 20-25-day period of Tk. 2,147, 7,260, 16,077 and 32,827 was calculated for VMP owners of categories 1, 2, 3 and 4, respectively. The LSP did not report any serious quality issues with the VMP.

An important component of the commercialisation model developed with the partners of this project was the training of LSP in the operation of the VMP and related services such as weed control. New LSP are provided with repeated training sessions during the first 1-2 years after purchasing the VMP. Experienced operators are engaged to provide training and to mentor the new LSP.

In-collaboration with financial institutions, the project was successful in developing and implementing a low interest rate loan package for the CA-based planter with two banks and this needs to be continued.

Developing skilled operators of VMP is time consuming and a costly activity that needs to be adequately funded in any commercialisation model for the VMP or similar planter. If a LSP owns only a VMP that may ensure as little as 1-2 months job assurance for a hired VMP operator. After that, the operator remains unemployed for several months per year. Hence a high proportion of the skilled VMP operators switch to other jobs/business. Thus, high rates of turnover of skilled operators was observed in this project. For those VMP purchasers who were motivated to sown their own crops, not to develop a business, this is not an impediment. For small-medium sized enterprises, year-round job assurance with diverse farm implements (e.g., transplanter, herbicide sprayers, reaper/harvester, thresher, irrigation water pump, etc.) from a single stop service center might retain skilled VMP operators.

The prototype of the VMP for 4WT was developed but due to Covid travel restrictions was only tested to a limited extent. Further R&D and commercialization of 4WT-operated VMP needs to be continued as the 4WT is growing numbers in rural Bangladesh and may be a vehicle for further extension of mechanised CA planting on farms.

10.2 Recommendations

The Government of Bangladesh and the private sector should work with and strengthen CA farmers' associations (CASPA) to promote adoption and local adaptation of farm mechanization and CA.

The Government of Bangladesh and other fund providers and investors should allocate funding to conduct R, D & E on farm machinery and CA, to adapt it to the conditions and requirements of Bangladesh agriculture. A designated and funded Centre for CA may help to drive a coordinated and integrated national R, D & E programme on farm machinery and CA. Such a Centre should comprise a consortium of Government Institutes, Universities, private sector stakeholders (manufacturers, service providers) and farmers.

Laws, regulations and policies should be reviewed to identify and amend those that hamper the profitable adoption of farm mechanization and CA by farmers; and the Government of Bangladesh should remove bottlenecks for profitable engagement by the private sector in promoting farm mechanization and CA. For example, to purchase CA implements, more incentives should be provided than for conventional full tillage implements.

In-collaboration with financial institutions, the project was successful to develop and implement low interest rate loan packages for CA based planter commercialization and this needs to be continued.

To retain experienced and skilled operators, year-round job assurance with diverse farm implements (e.g., transplanter, herbicide sprayers, reaper/harvester, thresher, irrigation water pump, etc.) from a single stop service center might retain skilled VMP operators and this approach might be tested in future projects. The collective action approach involving groups of farmers working together to achieve economies of scale in the use of machinery for planting and harvesting needs to be tested also.

Human resources/scientific capacity in all aspects of farm mechanization and CA needs to be developed by providing MS and PhD scholarships, inclusion of CA in university degree curricula, and short-term training for extension officers, service providers and policy makers.

An expanded and systematic program needs to be implemented for mass promotional activities including publicity and awareness building on farm machinery and CA. The approach recommended follows that of the present project comprising demand creation, use of smart incentives and training, involvement of the manufacturer(s), banks, CASPA and the development of VMP businesses.

Price support or incentives to LSP and farm mechanization CA farmers is needed until there is evidence of adoption take-off. Another 2-3 years of support with demand creation, incentives for VMP purchase and training of new LSP would ensure this target is secured. For the commercialization and outscaling of farm machineries, future projects should provide outcomes-based incentives such as PIM or TIM models instead of subsidies on the purchase of agricultural equipment.

Initial testing results of 4WT-based VMP were encouraging, but further R&D and commercialization is required and needs to be continued to develop an effective planter for use with the 4WT that is growing in popularity in rural Bangladesh.

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11.2 List of pertinent publications produced by project participants

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12 Appendixes

12.1 Appendix 1:

During this project period, two studies were conducted by the independent consultants:

1) Study on Policies and Roadblocks for Small Scale CA Farm Machinery Adoption; and
2) Evaluation of PIM and TIM Models for the Adoption of Versatile Multi-crop Planters.

Both reports are enclosed as Appendix 1 and Appendix 2, respectively.

Appendix 1:

Appendix 2: