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Final report

Small Research and Development Activity

project	**Improving the livelihoods of marginal farmers, by outscaling irrigation and agricultural practices, through collectives, in the Eastern Gangetic Plains**
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1 Acknowledgments

This project, which investigated scaling irrigation and agricultural practices, through farmer collectives in the Eastern Gangetic Plains, brought together seven organisations. We acknowledge our colleagues across each organisation for their commitment and contribution to the research and the participating farmers and communities who worked alongside the project team.

The project was led by Erik Schmidt of the University of Southern Queensland (USQ), while the social component was led by Fraser Sugden (University of Birmingham) and the biophysical component by Michael Scobie (USQ). Stephanie Leder (Sweden Agricultural University), led the gender research component. Both Fraser Sugden and Stephanie Leder were key participants in the project “Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains” (DSI4MTF – ACIAR Project LWR/2012/79), a precursor to this small research activity. Professor Rajeshwar Mishra was a key supporter, particularly in the important area of ethical community engagement. Dipika Das a John Allwright PhD student aligned with this project is acknowledged for her contribution on gender equity in the supply chain.

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2 Executive summary

The combination of appropriate agricultural and irrigation practices, and innovative social interventions through farmer collectives, were shown to strengthen fragile agricultural livelihoods in the project "Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains" (DSI4MTF – ACIAR Project LWR/2012/79), which operated from 2014-2019. The success of the DSI4MTF model is dependent on the scalability and sustainability of the collectives, as well as the ability to manage risks associated with irrigated agriculture and climate change.

This small research activity (SRA) continued engagement with farmer collectives in six villages in Saptari (Nepal) and Bihar and West Bengal (India), with the aim to extend the use of climate-smart irrigation and water management practices and strengthen institutional structures to sustain farmer collectives to ensure their long term sustainability.

It was found that "measuring to manage" helps to improve on-farm irrigation and water management decisions, thereby mitigating climate risk. A Smart Irrigation Toolkit (SIT) approach has been outlined, which incorporates simple field level assessments using low-cost measurement equipment, supported by decision support mobile Apps. SIT provides the farmer with timely information to improve irrigation practice. It also provides managers operating at a program or scheme level, with information to support spatial and temporal benchmarking, as well as system operating, maintenance and replacement decisions.

The establishment of farmer collectives, which allow farmers to pool land, labour and capital, has been shown to be foundational for sustainable agricultural intensification by marginal farmers. The SRA period was used to identify the longer-term strategy to sustain these collectives and build their scalability. These include the need to harness existing cohesion and collective spirit within communities, the importance of expanding to form larger plots, and the critical role played by ethical community engagement in ensuring buy in from communities. Most importantly, to strengthen the collectives and ensure their sustainability after the end of the project, a Collectives Association has been proposed and piloted under this SRA. The Collectives Association brings several groups together under a single institutional framework. It helps offer broader economies of scale, strengthens linkages with other institutions, and could support training of farmers in irrigation technologies, renting of equipment, facilitating conflict resolution, and supporting blue sky ideas such as a land lease bank.

The project has had substantial success in building gender equity through the collectives, and in considering gender across the supply chain. There has also been considerable progress in strengthening links between the farmer collectives and a range of institutions and programmes. Links to the private sector, especially with regards to the marketing of agricultural produce, need to be further strengthened, and the collectives association could play a critical role.

It was suggested that the scaling of improved irrigation practices through a Smart Irrigation Toolkit (SIT) is best done through a pilot project, which integrates project learnings with organisations responsible for irrigation development. While there is good potential for scaling, business cases are required to demonstrate potential benefits to the range of beneficiaries. These business cases need to be developed in association with irrigation scheme implementation agencies, as well as with organisations supporting farmer communities. The public sector has a key role to support the initial scaling of SIT. Alignment with irrigation and agricultural department functions would establish a program for deployment, demonstration and alignment with policy. The Collectives Association would play a key mediating role for marginal farmers, and could support the deployment of SIT locally.

The COVID19 pandemic, which started in the last few months of the SRA period, is having a major impact on marginal farmers. Migrants have lost jobs due to economic collapse or lockdowns in receiving regions, while restrictions on mobility have closed the migration routes on which these livelihoods depend. In the short term, local wage labour opportunities dwindled, there has been a collapse in some vegetable markets and restriction of input supplies. On a positive note, as lockdowns were eased, there has been a reduced workload for women due to the support of returning male migrant workers. Changes in migration patterns are likely to remain in the medium term. The collective farming models proposed through DSI4MTF will be critical in the post COVID19 era, to help address the fundamental structural barriers to agricultural intensification. The collectives have helped bolster household resilience during the COVID19 lockdown, reducing individual loss from disruptions and in some cases group farming has helped enhance mental health during the crisis.

3 Introduction

The combination of appropriate agricultural and irrigation practices, and innovative social interventions through farmer collectives, were shown to strengthen marginal and tenant farmer livelihoods in the project "Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains" (DSI4MTF – ACIAR Project LWR/2012/79), which operated from 2014-2019.

While a promising integrated model, with broad development implications for food security and poverty alleviation, further research is required to improve irrigation and agricultural practices and to facilitate scaling, social inclusiveness and resilience of cooperatives to withstand future climatic, hydrological, social and economic stresses.

This small research activity (SRA) was therefore commissioned to identify opportunities to:

1. Extend the use of climate-smart irrigation and water management practices to improve agricultural productivity and profitability.
2. Strengthen institutional structures, policy frameworks and supply chains to support the sustainability of farmer collectives.

The project worked with farmer collectives previously established in six villages in Saptari (Nepal) and Bihar and West Bengal (India) (Figure 1) and supported a range of activities, at farmer demonstration sites. Further detail on these villages and the demonstration sites can be found in the DSI4MTF final report and other documentation available at https://dsi4mtf.usq.edu.au/.

The focus of the SRA was strengthening institutional structures for marginal farmers, through collectives, and developing strategies and recommendations for scaling water management and collective farming approaches for marginal farmers.

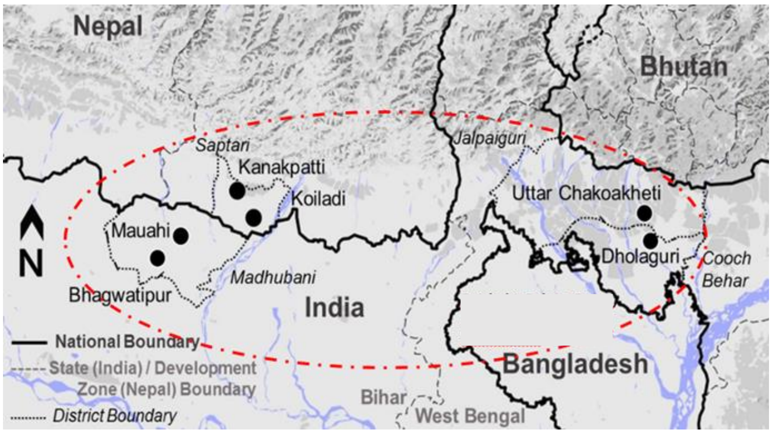

Figure 1 Locality map of study regions

4 Methodology

The project built on the emerging strength of the 20 collectives established in DSI4MTF, to support consolidation, and ultimately disengagement by the project team, so the groups could function independently and sustainably without external support. To this end the project continued to work with local farmer collectives to assess opportunities to strengthen formal and informal institutional structures, supply chain linkages, and expand economic opportunities – in the process, improving the scalability of the models. Engagement with local governments and sectoral agencies helped identify programs that align with the project and opportunities were sought to strengthen linkages with farmers and improve access to resources.

Irrigation toolkits and SmartApps, developed under DSI4MTF, were deployed by NGO's with farmer groups to maintain and improve irrigation and water management practices. Biophysical data collection focussed mainly on demonstrating the importance of monitoring and measurement to improve irrigation and agricultural production. Gender-sensitive and socially inclusive approaches for irrigation adoption, water management and collective farming was a key aspect given the background of gender inequalities and the feminization of agriculture.

The research methodology included the following elements:

1. Pilot establishment of a larger scale institution, a 'collectives association' in the West Bengal and Bihar study sites, to link the collectives together and strengthen them institutionally.
2. Regular meetings by local NGO's with DSI4MTF collectives and farmer groups to support irrigation management, crop planning, collective farming, agronomic support and capacity development including training events.
3. Focus group discussions with farmer groups and support organisations to assess opportunities to strengthen formal and informal institutional structures, supply chain linkages, and expand economic and improved irrigation and water management practices.
4. Data collection and analysis from study sites, to demonstrate improved irrigation and agricultural practices and to assess opportunities for scaling irrigation and water management tools.
5. Identification of institutions and programs, in project areas to assess opportunities for strengthening farmer linkages with agricultural development and extension programs, finance agencies, agriculture and technology suppliers and markets.
6. Discussions with key agencies to build institutional support for farmer collectives and consider opportunities to out scale water management approaches and toolkits.
7. Development of a strategy and recommendations for out scaling climate smart irrigation and community irrigation and water resource monitoring programs and for institutional strengthening of marginal farmers through collectives beyond 2020.

In field engagement with farmers was an important part of this SRA to maintain the momentum built under DSI4MTF. This engagement was impacted severely from March 2020 by travel restrictions imposed on partners under COVID. Notwithstanding, significant face to face support in crop planning and institutional strengthening was provided prior to March 2020 which subsequently continued by phone. To some extent this reinforced the projects exit strategy and the need to connect farmers with local institutions for ongoing service and support. This aspect proved quite effective; however these institutions have themselves been impacted by COVID.

A cross learning retreat in Patna in August 2019, along with two external gender and inclusion experts, proved effective in guiding the institutional strengthening and scaling aspects of the project. A full team meeting in Patna in late February allowed consolidation of progress and planning for final reporting.

5 Climate smart irrigation and water management for marginal farmers

To achieve sustainable agricultural practices there is a need to measure performance and understand how efficiencies may be gained by improving management. This "measure to manage" method has been proven to improve on-farm irrigation and water management and has potential to mitigate climate risk. A "toolkit" approach allows measurement and collection of data that can be used for system improvement.

Water use and productivity can be improved significantly by undertaking simple field level assessments using low-cost measurement equipment, supported by decision support mobile Apps. These approaches are the basis for a Climate Smart Irrigation Toolkit which when deployed across a wider irrigation district supports spatial and temporal benchmarking of a range of performance metrics.

The Smart Irrigation Toolkit (SIT) comprises three important components, namely hardware, software and training, and covers all elements of on-farm water management, including water resources, pumping and conveyance systems and in field application.

This chapter describes each component of the smart irrigation toolkit and provides Case Studies illustrating their use. Mobile phones, particularly internet connected smartphones, are efficient tools for sending and receiving information in the field and a key part of SIT was development of simple Apps to capture data, process it or instantaneously send it to cloud databases for processing and storage.

The Smart Irrigation Toolkit (SIT) approach provides useful information for decision making and practice change for i) the farmer, who obtains timely information to change a practice, ii) stakeholders operating at a program or scheme level, who require regional data to support spatial and temporal assessment as well as benchmarking and system operating, maintenance and replacement decisions.

5.1 Background

Better irrigation and agronomic practices are required to improve agricultural productivity and sustainability. During DSI4MTF irrigation system performance, efficiency and scheduling were shown to be key to increase crop production and reduce input costs. Measuring and monitoring was shown to provide a foundation for improved water management. Trials conducted across the DSI4MTF Nepal and India sites, with advisors and farmers, demonstrated how simple tests could help improve irrigation performance.

DSI4MTF demonstrated that there is generally limited knowledge within farming and extension communities on how to measure and monitor, as a precursor for good water management. The concept of a simple "toolkit" to support collection of field data, analysis using simple mobile phone apps and training for field staff evolved throughout the project.

This chapter discusses Climate Smart Irrigation (CSI), and the use of a Smart Irrigation Toolkit (SIT) for in field irrigation measurement and monitoring. Opportunities to extend and scale these approaches into government and agency implementation programs and initiatives are discussed in Chapter 7.

5.2 Climate smart irrigation toolkit (SIT)

Climate Smart Agriculture (CSA) is an integrated approach for addressing agricultural production under the realities of climate change. The approach aims to increase the adaptive capacity of famers and increase resilience and resource efficiency in farming systems (Lipper et al., 2014). The three pillars of CSA involve i) sustainably increasing productivity and incomes, ii) adapting and building resilience to climate change, iii) reducing and or improving greenhouse gas emissions (Palombi and Sessa, 2013).

The concept of Climate Smart Irrigation (CSI) is a sub development of CSA. Palombi and Sessa (2013) note that significant investment in irrigation (among other infrastructure) is necessary to build towards Climate Smart Agriculture.

To achieve sustainable practices and CSI, there is a need to “measure to manage”. Improved irrigation and water management mitigates climate risk for farmers and a “Toolkit” approach allows measurement and collection of data that can be used to guide changes to irrigation management systems and practices. Spatial data can then be used to highlight key areas of weakness in irrigation system modernisation programs.

The Smart Irrigation Toolkit (SIT) approach stemmed from a very real toolkit. Through DSI4MTF and this SRA a range of biophysical data were collected and assessed to determine irrigation performance at intervention sites. A toolkit comprising basic hand tools and measuring instruments (some shown in Figure 2) was used in the field with data recorded in notebooks for analysis in the office. As the project progressed some tools were built locally and others in Australian, using low cost materials.

The need for notebooks and office-based calculations became almost redundant when a series of simple mobile phone applets were developed to collect data and undertake routine calculations (Section 5.4).

Field staff were trained to provide understanding on measurement approaches and to ensure the safety of personnel at potentially dangerous sites, such as diesel pumps or live electrical motors. Training also improved consistency in methods for data collection to facilitate cross regional analysis.

The concept of the Climate Smart Irrigation Toolkit continues to mature. At present the Toolkit contains three separate, but equally important components; Hardware, Software and Training (**Figure 3**).

The contents of the toolkit can be tailored to suit the region. For example, regions with high proportion of diesel pumping over electric pumping will have tools specific to measure diesel flow rates. Table 1 summarises some of the tools in the toolkit.

Figure 2 Example of hand tools in the smart irrigation toolkit

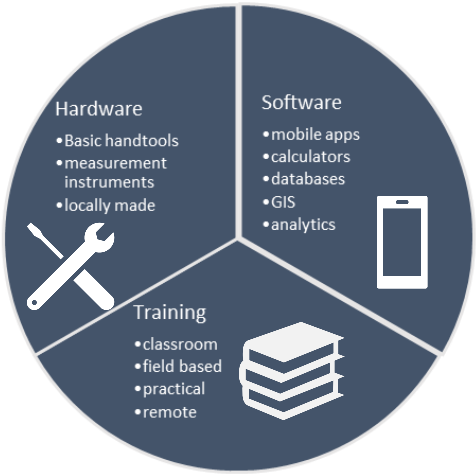

Figure 3 Smart Irrigation toolkit concept comprising Hardware, Software and training

Table 1 Example components of a Smart Irrigation Toolkit

Hardware	Basic hand tools: (spanners, screwdrivers, pliers, multimeter, etc.
	Water measurement instruments: (V-notch weir, catch cans, inline flow meter, buckets and stopwatch, groundwater depth gauge, pressure gauges)
	Water quality sensors: (pH, Electrical conductivity meters)
	Environmental monitoring equipment: (rain gauge, thermometer)
Software	Smartphone with internet access and standard GPS chip
	Backend databases for storage of benchmarking data for high level interrogation of system performance (temporally and spatially)
	GIS compatibility utilizing phone network and smart phone GPS all measurements are geolocated and stored with a timestamp.
	User analytics with ability to investigate trends in user numbers and tool usage
Training	Classroom based training including theory and concepts to show need for measurement
	Field based training on how to use the measurement devices and instruments
	Practical assessment of participants ability to collect and interpret data
	Remote training to support for participants via video conferences

The Smart Irrigation Toolkit (SIT) approach provides useful information for decision making and practice change at two levels. The first level is with the farmer and can be instantaneous. Once an assessment is completed the farmer has evidence to decide whether to change a practice or not. Some practice changes, such as changing the speed of a pump, has no capital cost and can save 30% of fuel usage. Other changes may require a capital purchase i.e. layflat polythene pipe. The second level of information for decision making and practice change is at a program, or scheme level. All field-based assessments using SIT software are logged and time stamped. This geospatial database is a powerful resource for program monitoring and will assist decision makers by providing regional and time series data on the performance of irrigation systems. For example, understanding the average performance of irrigation systems before a program of modernisation provides a benchmark for improvement. Spatial data may show that there are hotspots of poor performance that can be linked to poor input supplier or service linkages in certain districts.

The following sections introduce the elements of a farm irrigation system and components of the Smart Irrigation Toolkit (SIT) relevant to each element are introduced. Opportunities for scaling smart irrigation measurement and management practices and the Toolkit approach are discussed in Chapter 7.

5.3 Improving water use efficiency and productivity using SIT

Farm scale initiatives offer direct and immediate opportunities to improve water use efficiency and productivity for small scale farmers. For this reason, both the DSI4MTF project and the SRA focussed on farm scale intervention and demonstration.

Figure 4 shows elements in an on-farm water management system and traces the movement of water from the water source to the crop. Each element provides an opportunity to improve water use or energy efficiency. The smart irrigation toolkit addresses all these elements and includes hardware and software to monitor rainfall, groundwater and surface water resources, assess pumping system performance, identify and quantify water conveyance losses and improve infield irrigation scheduling and system application efficiency. Components of the SIT, for each element of the on-farm water management system, have been detailed in Sections 5.3.1 to 5.3.4.

Farm Water Resources

Typically farm water resources in the Eastern Gangetic Plains are in the form of ground water (shallow tube wells, deep tube wells and open or dug well). There are a number of surface water ponds of varying size, however the relatively light soil texture in the region means that many ponds do not hold water for the dry season and are not considered a reliable water resource for irrigation.

Pumping Systems

On-farm pumping systems are often categorised by the type of energy (power) used to drive them. This broadly categorised pumping systems into diesel, solar and electric (there are very few petrol pumps used for irrigation in the EGP). Each of these systems have advantages and disadvantages, but the lifetime cost of each should be considered. Solar pumping has a higher capital cost but low running costs. Diesel pumps have a lower capital or purchase costs with a higher running and maintenance cost. Regardless of the pump type careful consideration should be given to matching the pump to the duty (pressure and flow) it is required to perform

Water Transfer

From the pump, water is generally transferred across the farm using small open earth channels or using low cost polythene lay flay pipe. The advantage of an open channel is that the bund wall can easily be broken and re-built to allow basin irrigation of paddy or wheat crops. However, the channels are prone to seepage and unintentional leaks can add up to significant volumes of water loss. A low cost lay flat polythene pipe will need replacement every few seasons but can reduce losses to almost zero.

Field Application

Once the water reaches the field it is important to apply it as uniformly as possible. This ensures that each individual plant receives the same amount of water. This means that all plants should grow, mature and yield similarly. The application system should be suited and matched to the crop and farming system.

No single irrigation system is better than any other, but they all have very specific requirements for optimal performance.

Figure 4 Elements in the on-farm water management system

5.3.1 Farm water resources

Rainfall

Some local institutions consider recording daily rainfall in a monsoon environment to be unnecessary. However, rainfall dominates the soil water balance in these environments with a rainfall excess in some months and a deficit in others. During months of excess rainfall, runoff and drainage refill the ground and surface water resources. It is essential to account for the small rainfall events in the dry season for accurate irrigation scheduling, especially when using a water balance approach. It is also important for a farmer to understand the seasonal and annual rainfall trends as this will impact the ability to source water during the dry season.

Figure 5 Field assistant Janake Chaudhary collecting rainfall data

Through local village data collectors, daily rainfall data was collected to assess the timing and volume of rainfall in the intervention villages (Figure 5). This data was recorded in field sheets which then needed to be transferred and digitised (Figure 6).

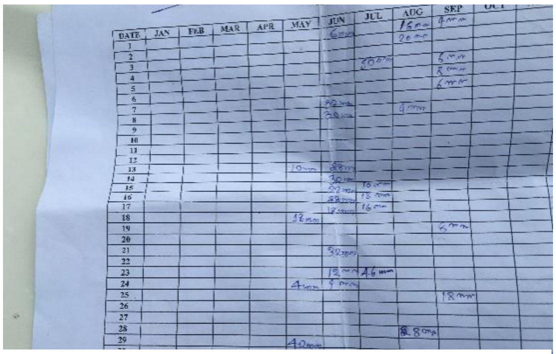

Figure 6 Record sheet for rainfall data

The data was analysed and plotted to show farmers how the current season compared to historic data. Synthetic data sets from 1950 to 2000 were used to determine the long-term average values and plot the wettest and driest years on record.

This graphic was then given to a local sign writer to produce a notice board for display in a prominent location in the village. The data was plotted and painted on to signs placed at prominent locations in the villages (Figure 7). A rainfall recorder App was subsequently developed and is discussed in Section 5.4

This information helps farmers compare rainfall in the current season with the long-term average and years of extreme rainfall and supports irrigation scheduling decisions. Real-time rainfall data can be collected at a village scale, rather than rely on meteorological stations which may be several kilometres away. Case Study 1 provides more detail on community monitoring of water resources. Table 2 summarises the smart irrigation toolkit for rainfall recording.

Figure 7 Cumulative rainfall recorded on a notice board in the village

Table 2 Smart Irrigation Toolkit (Rainfall Recording)

Hardware – a 150mm plastic rain gauge (~$6AUD) was supplied and installed at one or two locations in each village
Software – Daily rainfall data was initially recorded on a pre-printed page which was photographed and emailed back to USQ for processing. This was then digitised and entered into data bases. This process was streamlined through the introduction of the “Rainfall Recorder” App (see section 5.4 which allowed the field staff to enter and check data directly to a web database.
Training – Very basic training was required to understand the meniscus in the rain gauge and to ensure that the reading was taken at the same time (9am) each day and recorded immediately.
Once the rainfall recorder app was introduced, further training on how to enter, save and check that the record had been saved was provided.

Ground water

A large proportion of the water resource used for irrigation in the Eastern Gangetic Plains is drawn from groundwater sources, primarily from shallow tube wells. The depth to groundwater is highly seasonal with fluctuations depending on the intensity and duration of the monsoon season.

Regular data collection (nominally weekly) allowed farmers to see and understand the seasonal variability in available water (Figure 8). This depth to ground water is of key concern to farmers as it is directly related to the cost of pumping and ultimately the ability to pump water to the surface using the most common pump in the region (end-suction centrifugal pump).

Figure 8 Using a low-cost method to measure depth to ground water table

The deeper the water table the more energy (diesel or electricity) and cost is required to lift water to the surface. If the water table drops below ~8.5m from the centre of the pump, the column of water will break suction and the pump cannot operate.

Data collected from project sites showed that based on current pumping, the drawdown of water in the aquifer in the dry season, did not fall below the suction limit of surface pumps. This could change with expansion or intensification of irrigation.

Data was initially captured on field sheets which were then entered into spreadsheets for analysis. However, the Water Level tool was subsequently introduced which allowed for direct entry and data checking into a cloud database which could be accessed by project staff anywhere with an internet connection.

This information helps the farmer understand the limits on ground water resources and the impacts that over extraction will have on the cost of pumping. It also has value to regional programs, providing weekly and near real-time data on localised groundwater hydrography. Table 3 summarises the smart irrigation toolkit for groundwater monitoring.

Table 3 Smart Irrigation Toolkit (Groundwater Monitoring)

Hardware – Portable electronic depth sensing equipment (~150AUD). Alternately a device consisting of a digital multimeter, a tape measure, 2 core wire and a bicycle spoke can be crafted (~$20AUD)
Software – Groundwater depth data was initially recorded on a pre-printed page which was photographed and emailed back to USQ for processing. This was then digitised and entered into databases. This process was streamlined through the introduction of the "Water Level Recorder" App (see section 5.4) which allowed the field staff to directly enter and check data directly to a web database.
Training –Basic training was required to use the water level meter. Once the Water Level Recorder app was introduced, further training on how to enter, save and check that the record had been saved was provided.

Surface water

While surface water ponds are not used as a primary irrigation water resource in the intervention villages, they do offer emergency water supply and have the potential to be used, especially as a buffering storage in conjunction with a solar pump.

Figure 9 Measuring the depth of water in a pond usign a spirit level, stringline and a tape measure

Weekly data was collected by field assistants by measuring down to the water surface from a benchmark in the bank or at the top of the pond. Initial measurements were taken using a measuring tape attached to a bamboo pole installed in the pond. However, the bamboo was frequently removed by fishermen needing to access the entire pond or by children. This approach was replaced by measuring the vertical distance from a benchmark down to the water's edge Figure 9. A spirit level attached to a string was used to ensure the string was horizontal and a tape measure was used to determine the distance from the horizontal stringline to the water level.

The ponds were often empty at the end of the dry season due to high pond seepage and then partially or completely refilled during the monsoon season. The shape of the water depth traces can also be used to provide information on the seepage loss from the storage.

This information is valuable to farmers to help estimate the volume of water available for irrigation. It can also be used to assess water lost to evaporation and seepage and make decisions on the economics of pond rehabilitation. This also assists program managers to understand the resource available and the regional scale losses from surface water ponds which can assist in planning pond rehabilitation programs. Table 4 summarises the smart irrigation toolkit for surface water monitoring.

Table 4 Climate Smart Irrigation Toolkit (Surface Water Monitoring)

Hardware – Stringline, spirit level and a builder's tape measure (~$10AUD)
Software – Pond depth data was initially recorded on a pre-printed page which was photographed and emailed back to USQ for processing. This was then digitised and entered into databases. This process was streamlined through the introduction of the "Water Level Recorder" App (see section 5.4) which allowed the field staff to directly enter and check data directly to a web database.
Training –Training and some practice was required to accurately and precisely measure the distance from the benchmark to the water level. Once the Water Level Recorder app was introduced, further training on how to enter, save and check that the record had been saved was provided.

5.3.2 Pumping systems

Pumping represents a significant proportion of the input costs for an irrigated crop. Across the Eastern Gangetic Plains there are three common types of pumps; diesel powered end suction, electric powered end suction, and becoming more common, are submersible solar pumps. Each of these pumping systems offer advantages and disadvantages. Solar pumping is seen to be a low-cost method for pressurising and moving water, however the capital and installation costs are often prohibitive for small holder farmers without significant subsidy. Electric pumping is appealing due to the ease of starting and stopping the pump as well as the cost per unit of water moved due to subsidised electricity tariffs. However, in areas where power supply is not reliable or only available for certain periods of the day, electric pumping can be difficult to manage and can impact on the performance of the irrigation system. Diesel pumping is the most common method in the Eastern Gangetic Plains. A single pump can be moved between tube wells or ponds. Because it is such a common technology it is able to be repaired locally without the need for highly specialised technicians or parts. Another advantage of a diesel system is the ability to adjust the engine speed (RPM) easily. Additional technology is required if a user wants to regulate the speed of a solar or electric pump.

Figure 10 Working with farmers to analyse and interpret pump performance data

Diesel Pumps

Farmers have a poor understanding of the mechanics of pumping and the basics hydraulics of water transfer. Many pumps were not regularly maintained or operated at the correct engine speed. Both factors have significant impact on the efficiency of pumping and therefore the cost of pumping (Figure 10).

A simple test and apparatus were used to assess the performance of diesel pumps across the project sites. While a standard measure of pump performance is percentage overall efficiency (how well the energy stored in diesel is converted to movement of water incorporating volume and pressure), this requires the calculation of the Total Dynamic Head (TDH). This measurement is complex in groundwater pumping systems as the depth of the drawdown in the tube well is required. Therefore, a simpler method and unit of measure was used. The concept of litres of water per litre of diesel (L_{water}/ L_{diesel}) is simple to measure and an easy measurement to understand and relay to farmers.

Figure 11 A brass 3-way valve used to supply 50ml (from a syringe) of diesel to a pump

End suction centrifugal diesel pumps connected to a shallow tube well are difficult to prime and start. Therefore, a simple 3 way valve was used to divert fuel flow from the primary tank (used when starting the pump and for the first half an hour until steady state flow and static drawdown were achieved) to a 50ml pipette or syringe, which was used to measure the fuel consumption rate[1] (i.e. volume of fuel/ time to use that volume) converted to litres of diesel per hour (Figure 11). The second key measurement was the discharge rate of the pump. This was calculated my averaging five repetitions of filling a 100L bin or bucket. This value was then converted into total water pumped in an hour to maintain consistency with the pumping rate of the diesel. This value is based on a certain pump operating in a certain tube well, with a certain water level and drawdown, at a certain engine speed. If any of those factors are changed then the value of L_{water}/ L_{diesel} will also change. This is an important aspect to communicate to farmers that were trying to see whose pump was more efficient.

A very simple parameter to change in a diesel pump is the engine speed Figure 12. Both the diesel motor and the pump are machines that have a Best Efficiency Point (BEP) at which they operation is at its optimal efficiency. If the pump and motor are operated that the engine speed that most closely aligns with the BEP of both, the L_{water}/ L_{diesel} will be maximised and the cost per volume will be minimised. It is important to understand that operating the pump at higher speeds will deliver more water to the field in a given time. However, this may be at a higher cost than operating the system at the BEP.

Figure 12 Field staff using a digital tachometer to measure the pump speed (RPM) to find the Best Efficiency Point

To maximise the L_{water}/ L_{diesel} a series of pump assessments can be undertaken at various engine speeds. The engine speed (RPM) can be measured with a digital laser tachometer. These measurements can

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[1] While diesel return rate is quite low it must be considered in the calculation.

then be plotted to identify the approximate peak efficiency. Refer to Case Study 3 for examples of finding the BEP for a series of pumps

An extension activity whereby farmers stood in a rectangular shape holding a length of rope to imagine the edges of a container with the dimensions of the volume of water pumped using a litre of diesel helped visualise the importance of pump performance.

This information is valuable to farmers who can make a simple adjustment on the operating speed of a pump and potentially save 30% of operating costs. It is also of value to programs to understand the economics of diesel pumping in a region before undertaking a program of pump modernisation. Case Study 2 provides information on the importance of flow meters and calibration and Case Study 3 gives an example on finding the most efficient engine speed for a diesel pump.

Electric pumps

Electric pumps offer the key advantages of i) having relatively low operating costs, and ii) ease of operation once they are installed. Electric pumps are either single phase (for lighter duties) or three phase (for heavier duties). The disadvantages of electric pumps are most obvious when there is no existing mains connection to the site or when there is intermittent supply of electricity. Load shedding schedules from electricity supply companies also impact on the utility of electric pumps. Stopping and starting an irrigation will have impacts on the water use efficiency and therefore the cost of the irrigation. Electric pumps are clean and quiet and require less maintenance than diesel pumps. However, they are offer less flexibility. Once installed larger duty, three phase pumps are rarely moved from tube well to tube well. While a diesel pump speed is very easily adjusted, electric pumps operate at one speed (gearboxes and variable speed drives are very uncommon in the Eastern Gangetic Plains). This means that the correct pump must be selected to match the pumping duty. If the wrong size pump is selected (or an inexpensive, or readily available alternative) is selected, there may be some saving in capital cost, however the ongoing cost will accumulate over the years of operation.

Figure 13 Ensuring air tight seals is needed to collect accurate pressure readings

This information is valuable to farmers to understand that pumping is not a one-size-fits-all approach and that the capital cost of pumping represents only a small portion of the lifetime costs of the unit. This is of value to programs to understand the pumping requirement in a village, and to ensure programs approach modernisation with a good understanding of benchmark requirements.

Solar Pumps

Solar pumps are gaining significant attention as a means to sustainably reduce pumping costs. Solar pumps offer low maintenance and very low ongoing costs for irrigation pumping.

The DSI4MTF project demonstrated the use of both small (80w) and medium (3,000w) solar pumping system (Figure 14). These systems were effectively used to drip irrigate small crops (80w system) and as a diesel pump replacement (3,000w). Solar pumps are simple to operate, and while maintenance requirement is less than diesel pumps. They require highly specialised service technicians, which are generally not available at ta local level.

Figure 14 A 3,000W solar pump used as a diesel pump replacement

The discharge from solar pumps is proportional to the incident solar energy and the efficiency at which it can be converted to direct current through the photovoltaic cells. This means that unlike electric or diesel pumping the discharge and pressure generated is not fixed and will vary throughout the day and throughout the year.

Like the electric pump, there is very little adjustment or optimisation that can be done with a solar pump after the pump has been selected and installed. Therefore, understanding the duty that the pump is required to perform is critical before purchasing the pump. Solar suppliers have been categorising and selling pumps based on their input power requirements. While this is a convenient method for comparing pumps (“a 4kW is double a 2kW”) this is misinforming as the same input power can be applied to different pumps to achieve very different duties. i.e. low flow and high head for pressurised sprinklers or high flow and low head for surface irrigation. This is determined by the design of the pump not just the input power.

The performance of the pump can be assessed simply by measuring the discharged flow rate and pressure overtime. This is done with a bucket of known volume and a stopwatch (Figure 15), and pressure gauges (Figure 13). These assessments taken regularly can determine if the pump is operating at its design duty or if the water table, panel shading, or other parameters are impacting on its ability to perform as required

Assessments undertaken during the DSI4MTF project involved measuring the impact that panel orientation and cleaning the panels had on the discharge rates of solar pumping systems.

Figure 15 Bucket and Stopwatch method to collect pump discharge (flowrate) data

This information is valuable to farmers to understand the impact the maintenance has on solar pump performance and that continuous operation at a set duty is not possible. This is of value to programs to understand the field requirements of a pumping system, and that each system needs to be designed to meet user’s requirements. An out of the box solution may not suit all applications. Table 5 summarises the smart irrigation toolkit for pumping systems.

Table 5 Smart Irrigation Toolkit (Pumping systems)

Hardware – One ¼" 3-way valve and diesel hoses, a 50ml pipette or syringe, a digital tachometer, and a 100L garbage bin or bucket and a stopwatch (~$40AUD). **Software** – The Pump Assessment App (see Section 5.4) was introduced to remove some of the potential for error in calculating the L_{water}/ L_{diesel}. This tool can be augmented to include graphing of a series of assessment at different engine speeds as well as geolocating the assessments to build a back-end database to highlight problem areas. Software for assessing electric and solar pumps will need to be developed and tested to be included in the toolkit. **Training** – Training of field staff on how to collect the in-field data as well as the importance of accurate data collection was required. There is some potential for classroom-based effort to teach participants some of the basics on pumping efficiency and how to calculate the costs. Once the Pump Assessment App was introduced, further training on how to enter, save and check that the record had been saved was provided.

5.3.3 Water transfer and delivery

Water conveyance to fields of small holder farmers in South Asia is typically via small, temporary earth channels. For large fields, some farmers have constructed permanent channels that connect different plots. Typically, earthen channels have high seepage losses and reduce crop cultivation area. However, these offer the ability for farmers to simply break the bund to allow water to flood or basin irrigated a field. However, each litre of water lost to seepage along the transfer channels costs the farmer money as that water needed to be lifted and pressured with a pump.

The seepage losses can be assessed by simply measuring the discharge at the pump outlet and then measuring the flow rate into the field or bay. The difference between the flow at the pump and the flow into the field is due to the seepage loss. This is best done over a standard length of channel (longer is better providing the soil is uniform along the length).

The flow rate at the pump is measured using the bucket and stopwatch method. However, this method will not work for water flowing in a channel. To collect the flow rate along the channel or into the field, a sharp crested V-notch weir was used. The depth of water flowing through the notch of a V-notch weir can be used to calculate the flow rate (providing the exact angle of the V is known.

This assessment was undertaken in the DSI4MTF in each village that used channels for irrigation water conveyance using a home-made V-notch weir constructed from Perspex (Figure 16). The weir was made with adjustable angles (standard V-notch angles – 28º, 56º and 90º) to allow for smaller channels were greater precision may be required.

Figure 16 the depth of water flowing over a V-notch weir can be used to calculate the flow rate in a transfer channel

Figure 17 Efficiency of polythene pipes decreases with leaks and joins

Flexible polythene pipes provide an alternative to earth channels for transfer of water from the pump site to the fields. New pipes offer 100% conveyance efficiency, however after multiple uses or seasons the pipes become brittle, and leaks and joins start to reduce this efficiency (Figure 17). Attaching a polythene pipe onto a pump creates increases the total dynamic head that the pump is operating under. This is due to the friction loss that occurs along the length of the pipe. This loss is influenced by i) the roughness of the material that the pipe is made from, ii) the velocity that the water is moving, iii) the diameter of the pipe, and iv) the length of pipe.

Typically, polyethene pipe is sold based on weight. Therefore a 4” diameter pipe is more expensive than a 3” diameter pipe of the same length. However, the friction losses are higher in a 3” pipe which may result in higher ongoing costs of pumping (depending on the pump and velocity of water at the pump BEP).

Figure 18 Measuring the discharge in a channel compared to the discharge from a polythene pipe

Assessments were undertaken to assess the reduction in flow resulting from 3” and 4” polyethene pipes. This assessment can be undertaken to assess the lifetime costs of a polythene pipe and if the higher capital costs of a larger diameter pipe will in fact be more economical over the life of the pipe (Figure 18).

This information is important to farmers to understand the cost of water lost through channel transfer, and the cost of selecting a small polythene pipe to save capital costs. This information is valuable to inform irrigation programs that on the economics of installing concrete channels to reduce water loss. Case Study 5 illustrates measuring the distribution loss in an open earth cannel. Table 6 summarises the smart irrigation toolkit for water transfer.

Table 6 Smart Irrigation Toolkit (Water transfer)

Hardware – Sharp crested V-notch weir crafted from Perspex, 100L bucket and stopwatch (~$20AUD) **Software** – The V-Notch Weir App (see Section5.4) was developed to convert the depth of water flowing over the crest of a weir into a flow rate. The App can accommodate standard V-Notch angles 28º, 56º and 90º **Training** – Field-based training was provided on installation and reading of the depth over the weir.

5.3.4 Infield application

The dominant irrigation system in the Eastern Gangetic Plains is surface (bay or basin) irrigation. This method is generally not preferred especially on lighter textured soils when compared to modern irrigation systems due to the uncontrolled application of water. Through the DSI4MTF project, three improved irrigation systems were introduced i) ridge and furrow irrigation, ii) drip irrigation, and iii) sprinkler Irrigation. Each of these systems have their advantages and disadvantages and each have a variety of measurements that can be undertaken to assess the performance and benchmark the system.

Ridge and Furrow Irrigation

As the name suggests, ridge and furrow irrigation is applying water to preformed furrows with crops planted on the high ridges (Figure 19). The length of the furrow is generally dictated by the length of the field. Forming the furrows is a manual task however there are benefits to the careful construction. Poor construction will allow breakthrough of water from one furrow to the next.

Figure 19 Uncontrolled basin irrigation (right) waterlogs part of the field while leaving other parts dry. Ridge and Furrow irrigation (Left) provides a more uniform application of water

Some farmers opt to irrigate furrows in a similar way to uncontrolled basin irrigation. i.e. a single head ditch supplying all furrows at once. However, this method will give poor uniformity across the field as the water is dispersed and parts of the field have a much higher "opportunity time" than other parts. The improved method is to irrigate each channel individually ensuring that the furrows are filled as quickly as possible without overflowing. This fast filling, while is more labour intensive, provides a more uniform application of water across the field.

Through the DSI4MTF project ridge and furrow assessments were undertaken to assess the total volume of water applied and the advance and opportunity time under ridge and furrow fields (Figure 20). This assessment requires very little hardware but illustrates to famers the advantages of ridge and furrow over basin irrigation.

Figure 20 A field assistant working with a farmer to measure the advance rate of water down a furrow

This is important for farmers to understand that over irrigation can lead to water logging which will reduce yields. This information is important to programs to identify existing practice water use, which can then be used a benchmark to measure gains relating to irrigation system modernisation. Case Study 6 illustrates the use of short furrows for improved water use efficiency.

Drip Irrigation

Figure 21 Farmers involved in a drip irrigation catch can uniformity assessment

Drip irrigation is gaining favour among irrigation modernisation projects due to its ability to apply water precisely, both in terms of volume of application, and in terms of placement of water close to the plant. However, drip irrigation is one of the most complex and intensive methods of irrigation. It requires significant labour and skill to install and manage and is not suitable for all crops. Drip irrigation requires that water is filtered and that filters are cleaned and maintained to ensure that operating pressures are maintained. If a drip irrigation system is not maintained, the performance and the precision that is a key advantage of the system is lost.

Figure 22 small plastic containers are used as catch cans to measure the uniformity of Drip irrigation

A common measure of the performance of a drip irrigation system is the uniformity of which the water is applied across the field. This assessment is undertaken using small containers to catch the volume of water applied in a set time period. The small containers are called catch cans and are generally the same size (although not critical for drip irrigation). At the end of the assessment period the volume in each can is compared to the average volume through a one of a range of different equations to determine the percentage uniformity.

This activity is best done with a team of farmers so that all the cans are placed into position at the same time. The results are then discussed with the farmers demonstrating the different volumes of water in each of the rows of catch cans (Figure 21).

This information is valuable for farmers to see the actual volume being applied through each emitter in each time period (Figure 22). Based on this they may make practice changes including changing their run times or changing drip emitters. This is significant to programs as there is a need to better understand the ability and shortcomings of drip irrigation in small holder farming.

Sprinkler irrigation systems

A well-designed sprinkler irrigation system can accurately apply small volumes of irrigation to a field in a water and energy efficient manner. Sprinkler irrigation is suited to a wide range of crop types and soil types and offers a good solution to precision irrigation with less labour and management than a drip irrigation system. However, the performance of a sprinkler irrigation system is tightly linked to the ability to apply water at the correct flow rate and pressure for the sprinklers to operate correctly.

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The assessment and measurement needed to ensure optimal performance of a sprinkler irrigation system rely on measuring pressure and flow and undertaking a catch can uniformity assessment like the assessments under drip irrigation. However, for a sprinkler catch can assessment the size and shape of the catch cans needs to be uniform. The assessment requires the catch cans to be laid out in a uniform grid pattern. The irrigation system is then run for a given period after which time the volume in each can is then measured and the uniformity calculated (Figure 23).

Figure 23 Farmers and field staff involved in a sprinkler irrigation system assessment

Figure 24 Research staff training farmers in the maintenance of sprinkler irrigation systems

This information is of value to farmers to see the total depths of application that are applied under sprinkler irrigation systems. From this understanding they may choose to change their irrigation schedule to better match the crop water requirement. This is of value to programs to show the actual performance of a hardware improvement after installation and the importance of correct installation and maintenance (Figure 24). Table 7 summarises the smart irrigation toolkit for in-field application assessment.

Table 7 Climate Smart Irrigation Toolkit (In field application)

Hardware – a set of 20 – 50 small containers, pressure gauges, stopwatch (~$40AUD)
Software – there was no software developed for in field irrigation assessments during the DSI4MTF project, however a range of routine calculations could be converted to App calculators in a Toolkits pilot project.
Training Field training was required on how to collect basic data. The calculations for system uniformity were undertaken by project staff, however as noted above this could be handled by an App

5.3.5 Irrigation scheduling

Measurements of the hydraulic performance of an irrigation system are key to ensuring optimum results. However, the ongoing and continued management of the systems and how farmers schedule their irrigations with respect to the crop water demand is equally important to water use efficiency and productivity. There are a range of tools to help farmers schedule irrigations optimally. These can be hardware, and or software based, but all tools require some form of training.

Hardware Tools

There are many sensors on the market for soil moisture monitoring to guide irrigation scheduling. Many are high end and not suitable for small holder farmers. However, some offer a good insight and learning opportunities with low cost.

Wetting Front Detectors

Wetting front detectors were developed by CSIRO and have been have been successfully trialled in smallholder environments. Schmitter et al. (2016) have used this technology and have reported that yield increased were variable between different farmers, but water productivity increased by up to 17 %. Stating that in some cases the water saved could have been used to irrigate double the existing cropping area.

Chameleon Sensor

CSIRO developed the Chameleon soil water sensor system through a series of ACIAR projects. The Chameleon has three sensors placed at different depths in the soil profile. Coloured lights are used to indicate if the soil moisture is wet dry or optimum. The Chameleon sensors were installed in one site during the DSI4MTF project, however there were difficulties with the robustness of the terminal connections (Figure 25).

Figure 25 Discussing the chameleon sensor with field staff in Bhagwatipur village

Software tools

DSI Scheduler

A simple software tool was developed in the DSI4MTF project for field scale irrigation scheduling. The App used the industry standard Food and Agriculture Organisation Paper 56 method (Allen, Pereira, Raes, & Smith, 1998). The tool was used to undertake a water balance and calculate water productivity for every field and crop over the project period (Figure 26).

Unfortunately, the tool was not extended to the farmer and was not used for daily or weekly irrigation scheduling. It is anticipated that this App can be simplified and translated to local languages and used by farmers to help improve their irrigation scheduling. Case Study 4 illustrates irrigation scheduling using the mobile phone App.

Figure 26 DSI Scheduler developed for DSI4MTF

Passive data collection

Project experience suggests that passive data collection is preferred to active data collection. Active data collection involved a person taking measurements and entering data for calculation, plotting or helping to make decisions. While this data is usually reliable and highly site specific (an important concern for farmers) it required effort, and this means that it may not be seen as a priority during busy periods.

Passive data collection usually requires some form of technology to collect, analyse or interpret data. Passive systems are certainly not without fault. The cost of technology used to collect the data is usually traded off with resolution either temporally or spatially.

Accurate irrigation scheduling requires regular and accurate data in order to help the farmer make decisions on how much and when to irrigate. Water balance approaches are commonly used as a simple system for calculating the change in soil moisture based on balance between the inputs and the outputs to a soil profile. Irrigation timing and amounts required can be calculate using the deficit that is developed as a crop uses water transpiration. The water balance approach is essentially a calculation which us usually undertaken at a daily time step (however it can be more or less frequent). But the calculation is only as good as the data that informs it. If a data from rainfall or irrigation event is not captured, then the water balance and all subsequent decisions made on the information is wrong.

Exciting advances in remote sensed data being offered freely is changing some of the active and passive data collection processes that are used for irrigation scheduling.

5.4 Digital tools for measurement and assessment

Mobile phones, particularly internet connected smartphones prove to be efficient tools for sending and receiving information in the field. Simple interfaces continued to capture data, process it and/or instantaneously send it to cloud databases for processing and storage. (Schmidt et al., 2019)

Some of the tools are used for regular recording of for example groundwater and rainfall (Water Level Tool, Weather Recorder). Other tools were designed as quick calculators (e.g. Conversion Calculator, Orifice Discharge Tool, etc.) to give fast feedback to a query, without data storage. These tools form an integral part of the Smart irrigation Toolkit and are discussed in detail below.

DSI4MTF Applets

A simple data collection process of logging the location of village tube wells evolved into a cloud based spatial dataset linked to a series of integrated, mobile friendly, front end applets (Figure 27).

A range of data was collected using notebooks that were then transcribed into spreadsheets, which were then emailed to project staff to be analysed using routine analysis techniques. At each step of this data transfer there was potential for delays and lost data. A digital hub was needed to store data digitally. With the hub came a series of interfaces to enter and query the data. This system stemmed from a series of questions raised by various stakeholders. Examples of DSI4MTF Apps are given below in Figure 28 and Figure 29

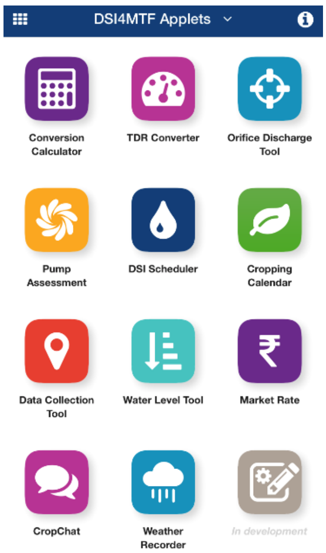
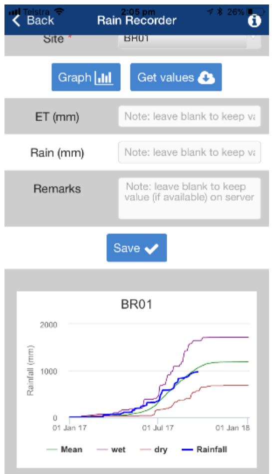


Figure 27 DSI4MTF Applets home screen showing 11 specialist apps

Rainfall Recorder App

This tool is essentially a data capture tool however it allows for some feedback of information against long term average rainfall data for the site. The tool allows the user to select a rain gauge and enter a daily total. It then plots this data as a yearly cumulative total in conjunction with the long-term average data (synthetic) to show how the season is progressing in within the bounds of the highest, lowest and average rainfall.



The tool has provision to also record an evaporation or evapotranspiration parameter, however reliable data collection of this proved difficult.

This tool could be enhanced to feed into the DSI Scheduler in future.

Water Level app

This is similar to the rainfall recorder app in that it is primarily a data collection tool. Initially the utility of weekly data collection was within the DSI data collection tool. However, with such intense data collection it was easier to create a separate tool for regular and routine data collection. This tool has a very simple user interface including date picker, site selection dropdown and digit data entry field. The user then clicks 'save' and the data is sent directly to a cloud-based server and saved. If the user does not have 3G data connection at the time they click save, the data is stored on the mobile device and automatically synchronises with the server the next time they have connection.

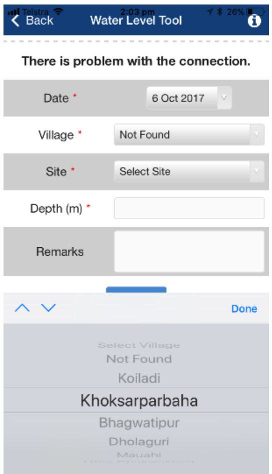


Figure 28 DSI4MTF Rainfall Recorder and Water Level App

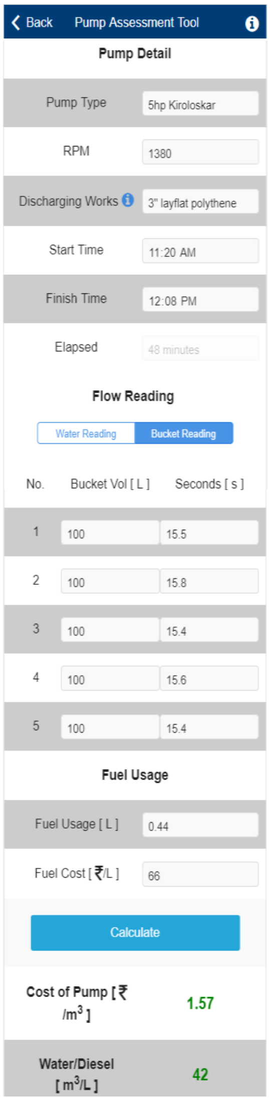
Social Media and Digital Tools

A key output from the DSI4MTF project was the development of a website to post monthly blogs and updates on the project (https://dsi4mtf.usq.edu.au). The website was useful for sharing recent project work within the team and externally. Another element bringing the project team together was the DSI4MTF WhatsApp group which had over 20 active members, including researchers, NGO's and government partners. In this group project staff shared and documented implementation, successes and challenges of the irrigation technologies and aspects of data collection using SIT. While the number of hits on the website have fallen since completion of DSI4MTF and there have been no new blog postings, there were close to 1,000 visits between June 2019 and June 2020, more than 90% of these new visitors. Fifty six percent accessed the site using Android operating system and 44% iOS, 54% were male and 46% female and 60% were 34 years of age or younger.

Digital media including videos, WhatsApp, blogposts, Facebook and the Webpage, as well as integrating SIT approaches with social media platforms provides a powerful mechanism for participants to share information and learnings.

Pump Assessment App

This calculator was built to remove some of the complication of calculating the flowrate from a series of bucket and stopwatch tests, then dividing by the diesel burn rate calculated from the time taken to deplete a known volume of diesel. The tool generates a volume per litre of diesel used and if the user enters a price per litre of diesel it will return the cost of irrigation. This tool does not record any information to database and only operates as a calculator.



V-notch Weir App

This very simple calculator has only two inputs; the angle of the V which has only three options 28º. 56º and 90º which are standard angles. The second input is the dept of water over the crest of the V. The calculator uses hydraulic formulae to return the discharge in L/s for the given depth of water.

Figure 29 DSI4MTF Pump Assessment and V-notch Weir App

Case Study 1 - Community monitoring of water resources

Good outcomes depend of regular and reliable collection of data. In the DSI4MTF project and the subsequent Short Research Activity, the project team trialled a number of different models for data collection. These models included project staff travelling weekly to the sites, downloading of specialist instruments on a 6 monthly basis and, weekly data collection by locals in the community.

While all approaches had merit, there was strength in the local community data collection. This method required careful selection of the community member and then training to ensure that they were aware of the methods to collect the data and the importance of the data to the project.

Figure 30 Recording rainfall data by local village representative Janaki

Having the community participate in data collection meant that there was a consistency in the data collection that was not apparent in the other methods trialed.

Janaki Chaudhary lives in Kanakpatti village in Saptari District of Nepal. Janaki was engaged to collect water level data from ponds and tubewells as well as record rainfall and pan evaporation rates. She would write the records down in her notebook and then call the project officer and relay the records day by day over the phone.

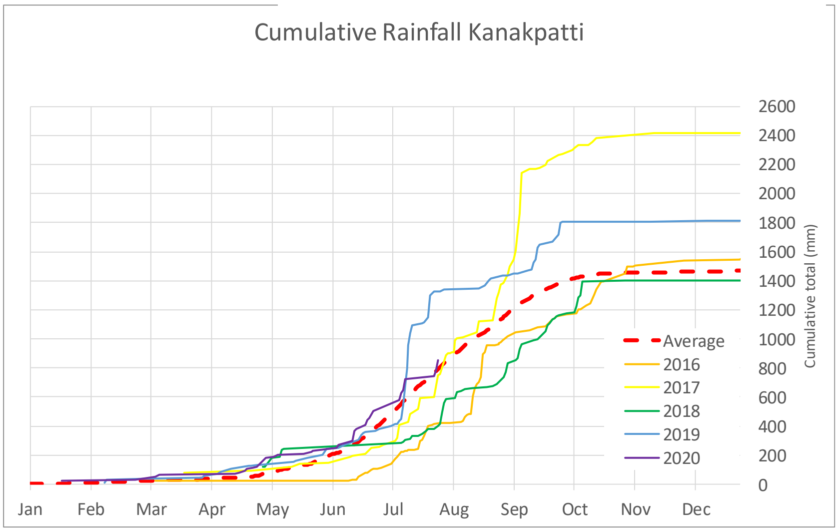


Figure 31 Rainfall data collected by Janaki shows the onset and recession of the monsoon every year and how the annual total compares to long term average

Janaki was very proficient and diligent in her record capture and keeping. The mobile phone app Water Level Recorder and Rainfall Recorder were developed for project staff, but Janaki understood English and was able to use the apps with minimal training. Janaki was given a smartphone handset and monthly credit.

Janaki took great pride in her work and this was evident in the quality of the data that she reliably returned via the mobile phone apps every week.

This model community data collection creates buy in from the community, and a talking point in the village to continue to build the momentum of the project when project staff visits are infrequent.

An article and video of Janaki's work can be found here https://dsi4mtf.usq.edu.au/biophysical-data-collection-with-janaki/

Case Study 2 – The Importance of Flow meters and Calibration

Most flow meters are designed to measure the velocity of water in the pipeline and then (assuming the velocity profile is normal) multiply that velocity by the cross-sectional area of the pipe to provide a flow rate. However, valves, bends, pipe expansions and contractions, etc. affect the velocity profile. Installing the flow meter in a position where there are straight lengths of pipe both upstream and downstream of the flow meter will reduce this error in reading.

Figure 32 Flow meter installed too close to the pump and a pipe bend

Sometimes is it not possible to install the flow meter with straight pipe on either side. In these cases, it is critical to calibrate the flow meter rather than just use the output directly. The DSI4MTF project used portable diesel pumps and rather than building a separate flow meter pipe that would need to be moved with the pump, it was decided to couple the flow meter directly to the pump (Figure 32) and then calibrate the flow meter. This ensured that every time the pump was used, the flow meter was also used.

The bucket and stopwatch method is a reasonably reliable method for measuring flow rate. This technique was used to collect the flow rate from the pump over a range of engine speeds and therefore a range of flow rates. These flow rates were then compared to flow rates taken using the poorly installed flow meter.

Figure 33 shows how the poorly installed flow meter compares to the bucket and stopwatch flowrate for three different pumps. The grey dotted line indicated that the flow meter and the bucket and stopwatch provided the same reading. The blue line shows that the flow meter at Dholaguri Site 1 slightly underestimates the flow for the bucket and stopwatch test (-5%). However, the flow meters installed on the pumps at Uttar Chakoakhetti Site I and Site II both show that the flow meters are overestimating the real flow rate by 35% and 33% respectively.

Due to the nature of the hydraulics around the flow meter, this error may not simply be linear and therefore needs to be assessed over a range of flow rates.

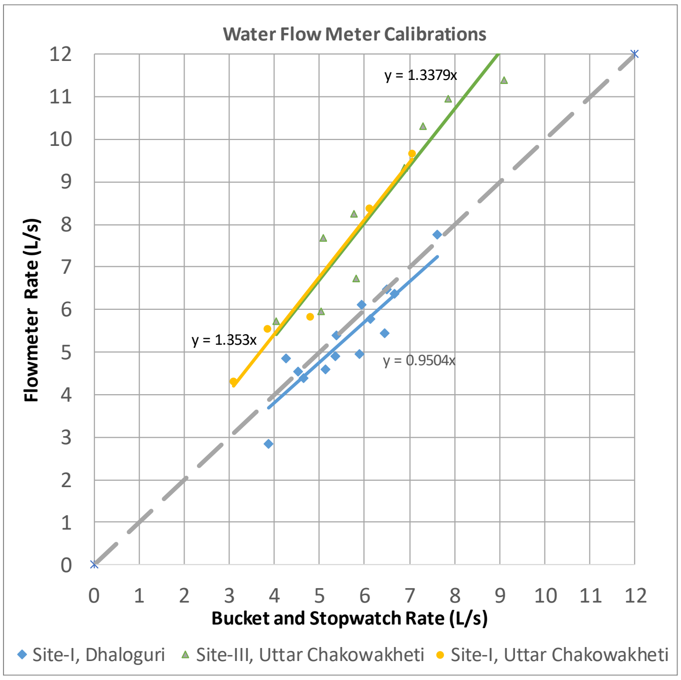


Figure 33 Comparing the bucket and stopwatch method to check flow rate recorded from flow meter.

Case Study 3 - Finding the most efficient Engine speed for a diesel pump

In many parts of the Eastern Gangetic Plains diesel pump rental is based on the hours that the engine is run. While at first glance this may seem like a simple substitute for the cost of irrigating, the volume of water needs to be considered because this really is the utility that the farmer wants. Furthermore, just measuring the hours of operation is not necessarily the best metric for assessing the true cost of pumping, because a pump running at higher speed (RPM) will often use more fuel than the same pump running at a lower speed.

Figure 34 Using a bucket and stopwatch to measure flowrate for pump assessments

Diesel used in pumping for irrigation can be a significant proportion of input costs for irrigated cropping. It is very easy to increase or decrease the engine speed on a diesel engine (much more difficult on an electric motor) and simply finding the most efficient operating speed and running the pump there can save up to 30% of diesel cost

A simple and easy to visualise proxy for efficiency is to calculate the litres of water pumped per litre of diesel used (L_{water}/L_{diesel}) this will vary depending on a range of pump and tubewell characteristics, but does give an good representation of the actual cost of irrigating.

By adjusting the engine speed (RPM) and measuring the L_{water}/L_{diesel} at each engine speed, the best efficiency point can be determined for that pump at that site.

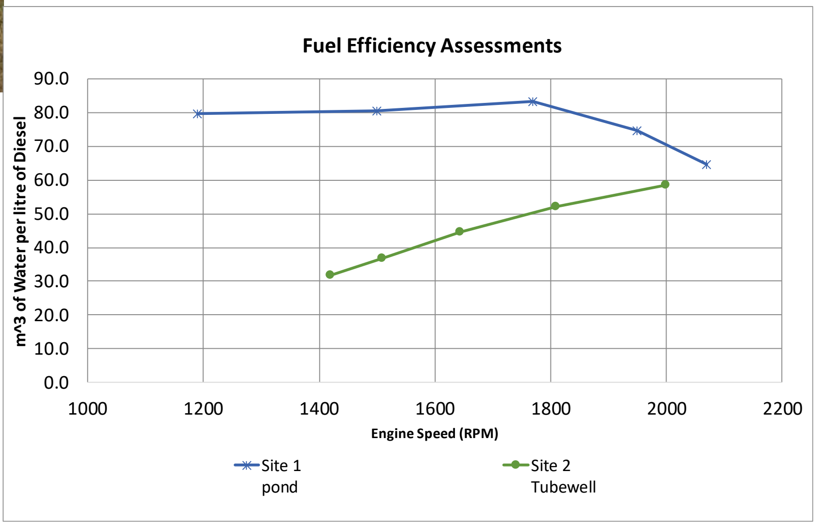


Figure 35 Plotting the Lwater/Ldiesel for different engine speeds at a pond and a tubewell

Figure 35 shows a plot of the L_{water}/L_{diesel} for varying engine speeds of two pumps in two different locations. The graph shows that for the pond installation at Site 1 (blue line) the volume of water delivered per litre of diesel is quite consistent between the engine speeds of 1200 – 1700RPM. Above 1700RPM the water per litre of diesel begins to reduce. As the pump speed gets faster, the efficiency reduces. The green line on the graph represents the L_{water}/L_{diesel} for a pump attached to a tubewell. This shows that the efficiency of pumping improves as engine speed increases. At approximately 1400RPM, just 30,000L of water is pumped per litre of diesel. However, this is doubled to 60,000L of water is delivered if the engine speed is increased to 2,000 RPM

A mobile friendly app can be used to collect data in the field and instantly calculate key information including the L_{water}/L_{diesel} and the cost of pumping. The Pump Test Tool has been designed for field officers to quickly and simple collect and report pump performance data without the need for pen and paper. The data can then be analysed at the field and results shown to the farmer, within seconds of collecting the data.

Case Study 4 – Irrigation Scheduling using a Mobile Phone App

To ensure optimum crop yields it is important to ensure that the plant has enough water (but not too much) to keep up with the atmospheric demand. Irrigation Scheduling ensures that the plant is getting not only the right amount of water but also that it is receiving it at the right time.

Either hardware or software (or a combination of both) can be used to schedule irrigations. The DSI4MTF team have develop a mobile phone software tool that calculates the crop water requirement and reports how much water to irrigate on each plot to ensure that the crop does not get water stressed.

The DSI Scheduler tool uses the FAO56 Methodology for calculating the crop water use based on the Reference Evapotranspiration (ETo) and crop specific Crop Coefficients (Kc). This crop water use can then be used in a daily soil water balance model to show how much water is left in the soil profile and when it needs to be irrigated again.

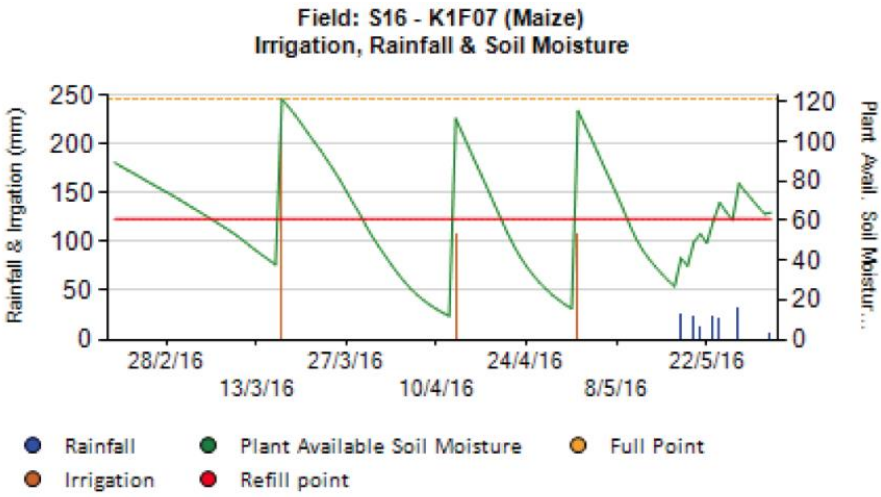


Figure 36 Output from the DSI Scheduler tool for a maize crop

Figure 36 shows output from the DSI Scheduler tool. The green line is the calculated soil moisture based on the long-term daily evapotranspiration for maize at the site, and the irrigation (orange bars) and rainfall (blue bars).

As the crop transpires the moisture is extracted from the soil and the green trace goes down. With irrigation the green trace increases again. The duration of the graph is set to the growing duration of the crop. This can be used on a daily or weekly time step to determine when to irrigate (i.e. when the green line crosses the red line refill point), or at the end of the season to assess how well the irrigation was performed. In the case of the maize crop shown in Figure 36 the timing and volume of the first irrigation was almost perfect, however the timing of the second and third irrigations were too late (green line was well below the red line then the irrigation was applied. This was compounded by the volume of the second and third irrigations being too little to refill the soil profile (green line did not reach the orange line at the top.

Figure 37 Field staff using the DSI Scheduler tool to explain irrigation timing to farmers in Madhubani, India

This visual representation in the DSI Scheduler can be used as a training aid for farmers and is part of the Smart Irrigation Toolkit.

Case Study 5 - Measuring the distribution losses in an open earthen channel

One of the simplest methods for transporting water from a water source to a field is an earthen channel. For large plots of land, farmers have constructed permanent channels that connect different plots, however these channels are not concreted or lined and continue to lose water with every irrigation.

Figure 38 Measuring pump flow rate

The significance of these losses depends on the construction of the channel and the soil parameters. To understand this loss a simple measurement can be done. The difference between the flow into the channel and the flow at a given point along the channel is the loss. Providing there are no breaks in the channel and that the measurements are taken over a short period to limit losses to evaporation, the difference is the seepage loss.

Through the DSI4MTF project, channel seepage loss assessments were undertaken at all sites that used channels for conveyance. Table 8 shows field data from a channel loss assessment in Mahbubani. The discharge rate at the pump site was measured using the bucket and stopwatch method and calculated to be 5.7l/s. the pump discharged into a channel which flowed to the field.

A V-notch weir (Figure 39) was installed 100m from the pump site. The depth of water discharging over the weir was measured and calculated to be 3.0 l/second. This meant that 2.7L/s had been lost over the 100m of earthen channel giving a conveyance efficiency of 53%

Table 8 Measurements showing reduced flow rate along an earthen channel and conveyance efficiency

	Flow rate at water source (l/s)	**Flow rate at V-notch weir(l/s)**	**Conveyance efficiency (%)**
Earthen open channel	5.7	3.0	53

Figure 39 V-notch weir made from clear perspex installed in an earthen channel

Case Study 6 – Short Furrows for improved water use efficiency

Soil texture in the DSi4MTF study sites typically ranges from sandy loam to silty loam. Surface irrigation performance is typically high on heavier soils; however, furrow irrigation is commonly practiced in potato in West Bengal. Typically, 2-3 irrigations are required to mature the crop during the winter season.

To reduce labour involved in irrigation, many field are furrowed along the length of the plot resulting in furrows of 15-20 m. assessments of the performance of surface irrigation are part of the Smart Irrigation Toolkits and project staff worked with farmer to collect data and assess the performance of their furrow irrigation

Figure 40 Field staff measuring the advance rate of water

measurement of the advance rate of water moving down a furrow were undertaken on field with short (7m) and longer (17m) furrows. This was then compared to soil moisture, profile measurements (before irrigation and 24 hours after irrigation) using a Frequency Domain Reflectometry (FDR) moisture meter.

In each case the time of advance and total irrigation time were observed, and the depth of irrigation application was calculated. Soil moisture profile samplings were done at three locations for short furrows and five locations for long furrows at regular intervals.

The estimated depths of irrigation and the measured moisture contents before irrigation and 24 hours after irrigation are shown in Table 9. It could be observed that the average depth of irrigation for shorter furrows was 2.82 cm and for long furrows it was 3.99 cm. Comparison of soil moisture profile (up to 30 cm depth) in the plot also indicates that the change in soil moisture contents at different depths were in similar range.

Therefore, it is evident that nearly similar soil wetting could be achieved for shorter furrows using lower volume of irrigation. The current study showed that by reducing furrow length, about 29% reduction in depth of irrigation could be achieved

Table 9 Field measurements and calculations of performance of short and long furrows in west Bengal

Short Furrows (7 m)						
	Advance time (s)	**Irrigation time (s)**	**Volume of water applied (m^3)**	**Area (m^2)**	**Depth of irrigation (cm)**	**Average depth of irrigation (cm)**
Furrow 1	27.03	32.03	0.08424	3.15	2.70	2.82
Furrow 2	33.21	38.21	0.10049	3.15	3.19	
Furrow 3	29.30	30.86	0.08116	3.15	2.60	
Furrow 4	32.39	33.44	0.08795	3.15	2.80	
Longer Furrows (17 m)						
	Advance time (s)	**Irrigation time (s)**	**Volume of water applied (m^3)**	**Area (m^2)**	**Depth of irrigation (cm)**	**Average depth of irrigation (cm)**

Furrow 1	140.77	127.63	0.33567	7.65	4.39	3.99
Furrow 2	131.40	128.00	0.33664	7.65	4.40	
Furrow 3	90.47	87.00	0.22881	7.65	3.00	
Furrow 4	123.14	121.00	0.31823	7.65	4.16	

6 Strengthening institutional structures, policy frameworks and supply chain linkages to support sustainability of farmer collectives

The establishment of farmer collectives which allow farmers to pool land, labour and capital was one of the primary interventions of DSI4MTF and was foundational for the success of the technical interventions of the project, and the shift towards sustainable intensification. This section reviews the successes and challenges of the collectives during the project and the implications for scaling. Compiling data from FGDs carried out during the SRA period, it documents some of the key learnings. Positive learnings include the need to harness existing cohesion and collective spirit within communities, the importance of larger plots, and the critical role played by Ethical Community Engagement in ensuring buy in from communities. Challenges posed during the project also open fields for further research. This includes for example, the best mechanisms to minimise conflict, including the optimal group size and composition. Also important are learning about the mechanisms to reduce conflict with landlords, and the interventions necessary to ensure longer term sustainability in terms of technical support. One key intervention which was piloted during the SRA period in West Bengal and Bihar was an apex body which can bind collectives together – a 'Collectives Association'. This is an instrument which can support improved linkages with stakeholders and will be critical for the success of the Climate Smart Irrigation Toolbox (SIT), whereby it can lead in training up farmers in utilisation of the tools, or can mobilise the tools on behalf of the groups to support for example, irrigation scheduling or pump efficiency tests. On an institutional level the Collectives Association can also facilitate conflict resolution and can branch into side ventures to benefit tenants and the collectives such as renting out equipment. It can also be used to support blue sky ideas such as a land lease bank.

The chapter discusses the gender engagement of the project in detail – including the successes achieved so far in building gender equity through the collectives, as well as lessons for future work in terms of how to address persisting inequalities. It also reviews a side study on gender across the supply chain and reviews the lessons for the project.

Progress in building up linkages with stakeholders in government and beyond is also discussed. While there are some challenges, considerable progress has been made in establishing enduring links with existing programmes, with some consolidated through the emerging Collectives Associations, such as in the case of the Farmer Producer Company in West Bengal. The chapter nevertheless, maps the existing networks of stakeholders and prioritises those where potential valuable links have still to be established, such as the private sector, in particular with regards to the marketing of agricultural produce, while also emphasising the need for higher level engagement.

6.1 Background

The farmer collectives piloted in DSI4MTF between 2015 and 2019 provided a model for a ground-breaking approach to address the challenges of small and fragmented holdings in the Eastern Gangetic Plains, unequal landlord-tenant relations, and the severe constraints faced by marginal and tenant farmers in accessing irrigation. Building upon a model proposed by Agarwal (2010) and building upon collective fisheries models pursued by project partner Sakhi, the collectives entailed small groups of 4-10 farmers who farm a contiguous plot of land, and engage in different types of cooperation in land preparation, production and marketing. DSI4MTF however, broke new ground firstly by piloting several flexible models of farmer collective entailing different levels of cooperation. Secondly, DSI4MTF mobilised the farmer collectives to introduce new cultivation, water management and monitoring methods, with the group approach itself directly facilitating the utilisation of new technologies.

These models evolved organically and were largely farmer led, with variations according to land ownership structure, and local experience with running groups over time. In Bihar and Nepal, some tenant farmers, who constituted a significant proportion of the farming population, were willing to engage in high levels of cooperation. Here the Project team, along with the farmers, developed a model whereby groups would lease in land collectively, farm it as a group, and share all costs and outputs. This became known as **model 1**. In North Bengal again groups were willing to take up a higher level of cooperation, but since there was little land for leasing, group members decided to consolidate their own plots to farm collectively. Most group members preferred to operate as a collective only in the dry season, although there were other forms of cooperation during the monsoon, such as labour exchange, and one of the all-women groups farmed collectively all year round. This became known as **model 2**. In both models 1 and 2, labour and output were shared, the only difference being that the land was leased in Model 1 and owned by group members in model 2.

The disinclination of farmers in some communities to pool labour paved the way for models involving medium levels of cooperation. In Bihar and Nepal, for example, some tenant farmers agreed to collectively lease a contiguous plot of land (as in model 1) and cooperate for some activities including land preparation (e.g. ploughing), crop planning, irrigation and marketing, and sometimes exchanging labour during busy spells, but decided to carry out other labour activities on their sub-plots individually, within the larger group plot. This became known as **model 3**. Among owner cultivators in Madhubani (Bihar), a fourth model evolved. Here marginal farmers owning their own fields pooled a contiguous area, and cooperated for land preparation, irrigation and input purchase, but not for sharing labour. Some of them had additional plots in other parts of the village, which they continued to cultivate individually. This became known as **model 4**.

The greatest benefits are derived from models 1 and 2 when labour, profits and outputs were shared. This helped overcome peak labour shortages and supports a pooling of knowledge, although coordinating labour can create challenges. However, an advantage which was visible in all the models, including 3 and 4, was the cultivation of a contiguous plot. Farmers therefore benefitted from associated economies of scale in machine use, input application and irrigation. Irrigation was more efficient, as farmers no longer needed to compete for pump sets and land could be irrigated at once using the new technologies and application methods tested during the project. Some of the tests and monitoring methods outlined in section 5 (which form the SIT) could be done for the whole collective, and would not need to be repeated individually for each farmer. For all models, the group approach also increased farmers' bargaining power with landlords – enabling them to obtain better rental terms and undermine the landlord's ability to extract additional 'rents' through labour contributions. The collectives have also supported better organisation for claiming state subsidies and other resources.

However, there were lingering challenges. While models 1 and 2 yielded the greatest benefits, there were also challenges of labour management, with farmers often struggling to coordinate busy schedules on the land, resulting in conflict. There were also challenges relating to gender equity within the groups, and ensuring that they were self-sustaining after the end of the project on both a social and financial level. There were also gender equity issues, particularly in relation to the distribution of work within the collectives. Addressing these challenges and improving the profitability, sustainability and cohesion of the group farms is critical if the models are to be successfully scaled both at a local or regional level. Similarly, there was still work to be done in terms of identifying and strengthening the appropriate stakeholder networks at a local level to improve the sustainability of the collectives and support the creation of new groups. There are also untapped opportunities to develop higher level stakeholder networks at a regional or national level to support dissemination and uptake of our models in policy. The purpose of the socio-economic research during the SRA period was to address these multiple scaling challenges, which are discussed below. The spread in physical sense, however, cannot sustain if change is not internalized in the culture, value system and practices of the intervention and if they are not sustainable over time. As Woltering et al (2019) notes, adoption of an innovation does not necessarily automatically translate into them being sustained over time and improving livelihoods in the long term, and it is common for the use of new technologies or innovations to fade out after funding or external project support ends.

A further priority therefore is on 'scaling deep' to strengthen our collectives institutionally and improve their sustainability. This includes addressing institutional problems, supporting continued group empowerment and cohesion, and entrenching values and beliefs within the groups. A key aim of DSI4MTF after the identification of a proposed model, was indeed to let it evolve and strengthen it institutionally over time – thus scaling deep was an important aim in the latter years of the project. However, as noted above, further improvements to the capacity of our collectives to sustain themselves over time – and thus scaling deep, is a perquisite to scaling up and out.

Under this small research activity the focus of research activities was to continue strengthening of collectives (scaling deep) while learning about how we can more effectively scale out and up by strengthening linkages with local programs, actors and agencies on the one hand, and national and state government level stakeholders on the other. Figure 41 illustrates the scaling dimensions and transitional focus of this SRA from scaling deep, towards out and up.

A key challenge for research for development innovations is to identify the most effective model through which they can be scaled, (Woltering et al. 2019). In spite of the largely successful pilot, the persisting challenges suggests that further strengthening of the collectives is required to develop a scalable model. Scaling of the collectives can be a spread in physical terms- areas, number of villages, districts – so called scaling-out. Scaling can also be considered in terms of adoption of the perspective/design or perspective within the policy of the state or non-state actors and agencies, or 'scaling up'. Both these types of scaling primarily emphasize spread and coverage in physical terms.

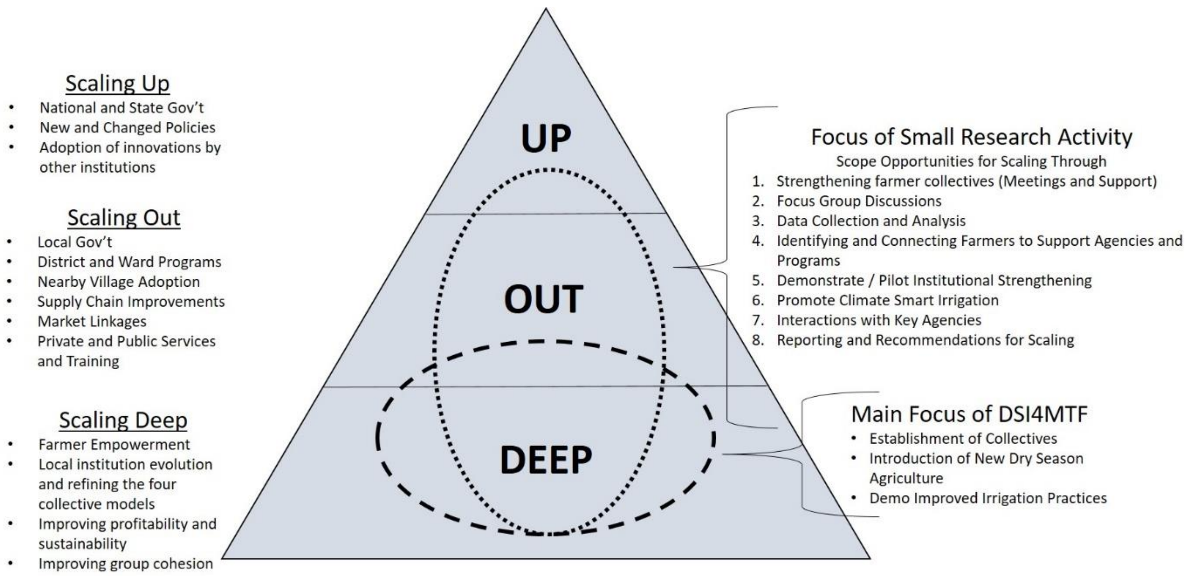


Figure 41 Scaling our collectives

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6.2 Opportunities for strengthening farmer collectives institutionally

6.2.1 Background to the collectives approach

An important aim of the SRA between 2019 and 2020 was to conduct a systematic assessment of our current models and identify how the models could be strengthened. This is critical if they are to be upscaled at a regional level, or out-scaled locally.

In August 2019 a cross-team brainstorming meeting, was held including representatives from the socio-economic team of DSI4MTF, as well as Professor Bina Agarwal, who has led the global research on farmer collectives and has played in informal advisory role on the project. The meeting also included Manohara Kadhka, a gender specialist and country representative for IWMI Nepal and Deepa Joshi who is leading the gender, youth and inclusion theme for WLE. The aim of this meeting was to consolidate social and institutional learnings and identify the next steps in the development of our farmer collectives. Thereafter, between October 2019 and February 2020 focus group discussions were held with all the groups in West Bengal, three of the groups in Bihar and three groups in Nepal. These aimed to gather perspectives of the collective members themselves on their experiences over the last 4 years, while also gathering feedback on some of the ideas proposed in Patna on how to strengthen the groups, and to further refine our ideas.

6.2.2 Positive lessons learned for out-scaling stronger collectives:

The focus groups provided an opportunity for the farmers to reflect upon their positive and negative experiences, with the hindsight of 3-4 years of farming under the collectives. In terms of positive experiences, working as a group was a highlight, even though levels of cooperation varied. Highlights, which emerged in focus groups, included the ability to work as a team and build strong social bonds and friendships. Time saving was also important for those engaged in labour pooling; whereby key tasks could be delegated within the group. Also important was the ability to learn together – through pooling knowledge. Some women in Dholaguri noted how in the past knowledge exchange took place within the family only, and they were dependent upon male household members, now they could learn collectively.

Other positive experiences were the social prestige that members of the groups had achieved by piloting new technologies – for example, in Uttar Chakoakheti it was remarked that one could not even buy spinach in the market, but now they were actually producing it, generating admiration from other community members. In Bhagwatipur and Dholaguri, some group members who had been landless labourers previously appreciated the opportunity to be in control over their land (via group or individual plots), managing their own time and decisions over cropping patterns and inputs. In the past they were working for others and working to their schedule, being paid in wages. In Uttar Chakoakheti, it was even remarked by two groups that migration has declined during the dry season, as more men choose to look for income opportunities in agriculture.

From the farmers viewpoint, there are multiple diverse benefits yielded from the collectives. If one is however to out-scale and up-scale the collectives, it is important to acknowledge the roots of success contexts, as well as the areas where the model can be modified, or where further research is required.

Starting with positive learnings, the cross-team dialogues held in Patna in August revealed a number of important points, which are discussed further in Sugden et al (2020a). Firstly, and as one would expect, the groups which demonstrate greater cohesion are more successful, particularly when it comes to pooling labour. What is particularly important though in supporting the establishment of cohesive groups, is the ability to harness existing connections between local people. Some of the most successful groups, particularly when it comes to labour sharing, were those where the members knew each other well. Cohesion was particularly high in West Bengal, where members shared strong social bonds prior to the project. There was already a farmer's club in Dholaguri which several group members were part of, and most other members were neighbours, regularly involved in religious functions or other gatherings. Most the women in Dholaguri also had experience of working together through Self Help Groups, and in both villages, informal labour exchange or *hauli* was widespread prior to the project, and this continued via the collectives during the paddy season. In this context, all the groups were to a large extent, successfully pooling labour during the dry season, with relatively minimal conflict. The ethnic homogeneity of the villages, and absence of a caste hierarchy may have helped, although these nuances require more research.

In Bihar and Nepal, social divisions were deeper due to caste hierarchies, and fewer of the members were involved in collective activities prior to the project. Group 1 of Bhagwatipur hadn't worked together before, although there was some exchange of labour, and some savings groups under the Jeevika project. In Nepal also, some members were part of a micro-credit group which existed before the collective, as well as forest user groups, but the levels of cooperation within the community, including labour exchange, prior to the project were not as evident as in West Bengal. The challenges of labour pooling were generally more acute in Nepal and Bihar.

Another important learning is with regards to the size of plots. There was a consensus amongst farmers that a larger plot of land was needed, so the collectives moved from being a supplementary livelihood activity to the primary source of food and income. This appears particularly important for landless tenants, whereby a larger plot of land under the collective will take away the need to lease in land outside the group under exploitative conditions. By individual households farming less land outside the collective in parallel, the challenge of competing schedules and conflict within groups is reduced. For example, Mahuyahi group 3, the women's collective, operates a substantial 2.6ha. This meets most of the members' food needs and they operate effectively as a team, without having to balance their farm labour responsibilities on their privately rented and collective land. In Bhagwatipur by contrast, most farmers also farmed land outside, and the competing schedules became challenging. There are other more complex benefits. For example, in Uttar Chakoakheti, as more land came under cultivation by groups, the fallow area was reduced, and the problem of free grazing cattle declined.

A final important positive learning is that the inherent flexibility in the functioning of the collectives contributed to their long-term success and sustainability. Reflecting the ethical community engagement approach (ECE) taken in this project, farmers were able to take the lead in shaping how the collectives evolved, particularly in response to challenges. For example, while labour pooling under models 1 and 2 offers significant benefits, when this became impractical, several groups such as those in Bhagwatipur and Koiladi, reverted back to individual cultivation. In Kanakpatti a hybrid model emerged, whereby part of the land was under model 1 and the remaining plots were divided amongst households under model 3. During focus groups, it emerged that membership changed over time, with new interested farmers coming on board, while those who were facing difficulties left – helping maintain social cohesion. Reasons to leave included busy schedules, childcare responsibilities, health reasons or pregnancy. The structure of groups also evolved over time, with strong leaders emerging, and continual improvements to management system, such as joint crop planning and integration of learnings from earlier seasons, as well as better record keeping.

6.2.3 Challenges identified and issues requiring further research for stronger collectives:

While there were clear benefits derived from the models, there are still challenges, which were only partially resolved during the project period, and will open up avenues for further research as the models are out-scaled.

How can we best minimise conflict?

As noted above, disagreements did take place in the groups. Sources of disagreement include decisions such as cropping choices, pest control medication options, and land preparation methods. Compromises are usually reached. For example, in Uttar Chakoakheti, some members of the group wanted to plant chilli but others disagreed. Eventually they compromised by trying a few seedlings which failed. They then decided to try palak instead. However, the most contentious source of conflict was when labour pooling takes place under models 1 and 2. This emerges as a result of the challenges managing busy schedules and emerged in the focus groups. As noted in one focus group, farmers have their own land and homes, so are busy. Members do not however get any sanctioning for failing to come on time due to strong community bonds. One male group leader noted that recently there was some transplanting work which needed to be done, but no one was available to do it. He had to till the land and transplant the seedlings himself – the crop would have died if he had not intervened. There did, however, often appear to be a gender aspect to this – for example, in mixed groups in Dholaguri it was claimed that it was often men who failed to come on time.

As noted above, collectives farming a larger area whereby there is less conflict with land outside of the collective appear to be more successful in addressing labour management challenges. However, more research is needed on solutions. A first solution relates to compensation provided by members unable to work on a particular day. These are often dealt with informally. For example, in Dholaguri and Uttar Chakoakheti, if a farmer misses one day of work, they can compensate by working for longer the next day or doing an additional day's work late. However, there are still options to explore formalising this, with more rigorous record keeping of who contributed what labour hours. Working out a more formal timetable may also be worth exploring. For example, in one of the groups in Dholaguri, there is internal arrangement before any activity and before three days every member is informed. Usually collective work would be done in the morning, so personal work can be done in the afternoon.

What is the optimum size?

Closely connected to the issue of minimising conflict, is identifying the optimal size for the collectives. At present the groups varied in size from 4 to 10 members. While some farmers felt that larger groups meant there could be a more effective division of labour, several groups during focus groups felt that more than 5 people made it difficult to coordinate activities, particularly for those engaged in labour pooling under models 1 and 2. It was noted in Dholaguri group 2 for example, that collective action dilemmas were more likely to arise the larger the group. Using the examples of free grazing cattle, it was remarked that if there were too many members, nobody would take initiative to deal with the problem, as the responsibility was spread amongst so many other people. Similarly, for labour management, it was remarked in Dholaguri group 4 that managing absences from the field informally were much easier if there were less than fewer members. On this basis, it can be suggested that around 5 may be the optimal size for a group, although this does require more systematic research on different sized groups as more collectives form in the future.

What is the right gender balance?

Another issue, which is linked to group cohesion and conflict mitigation, is the gender balance of the groups. On this there were mixed views. Some of the most successful groups were small mostly female groups, such as Mahuyahi group 1, Kanakpatti 1 and 2, and Dholaguri 4. It was remarked in focus groups with these collectives that the all women composition allowed them to talk like friends, enhancing cohesion. It was claimed that in mixed groups, men may not come regularly, yet still claim a share of the profit. If all farmers have to come at the same time, in the mixed groups it is more difficult to coordinate, as it was claimed that the men often don't listen to the women if asked to do something.

In spite of these reservations, some members preferred mixed groups, as they could capitalise on the gendered division of labour. All women groups often had to hire in men to do tasks such as ploughing, land preparation, marketing or pest control, which were considered 'male' jobs, and those in mixed groups felt that they did not have to face this challenge as they could mobilise male labour whenever it was needed. There was an inherent inequity to this however – a male group member from a mixed collective himself noted that women contribute more labour, yet men have more skills which 'compensate' for it – a perception grounded in the devaluation of perceived female tasks such as weeding, transplanting and harvesting. It is clear therefore that further research is required on group composition in different contexts, and addressing the associated challenges. There are further discussions on managing gender relations in the collectives below.

How can we address unequal relations with landlord?

While the first round of interventions had many successes in improving bargaining power with landlords in Nepal and Bihar, the focus groups suggested there were still persisting challenges, particularly in light of the success of the project. For example, there were two reports of landlords trying to increase the rent having observed the improved productivity, and another of a landlord shifted from a fixed rent to sharecropping contract (which offers lower returns to the tenant). In one case they had also been trying to take back the land to give it to another tenant. At present the NGO partners are playing a role in mediating these disputes, but in the long run, groups cannot be dependent on external partners. A collectives association, which will be discussed below, will offer one way of supporting the interests of the collectives in the longer terms for rental negotiations. There were also reports of landlords retaining subsidies for seeds, which should go to the tenants. Higher levels cooperation between groups, and the registration of groups may help address this challenge – another issue which will be discussed below.

How can we achieve long term sustainability?

A final and critical question relates to the long term sustainability of the collectives, particularly given the dependence on our NGO partners for support in accessing training, technical advice, and financial support. Members of some groups such as Dholaguri 1 showed confidence in the focus groups that they could continue independently, and they planned to even set up a new polyhouse on their own without external support. Members from others such as Uttar Chakoakheti 1 suggested that they needed a few more years of support (what kind?).

A first issue relates to technical knowledge. Most groups have access to knowledge independently from the NGO partners. These include for example, private agro-vet shops which are a primary source of knowledge on issues such as pest control in by most groups, as well as learnings from larger more experienced farmers (often male). Sometimes knowledge was transferred via their husbands. In Nepal, farmers also cited radio information on agriculture. However, while declining, the project team still plays an important role in offering agronomic advice. There is potential for continued phone contact with the project team, and most groups requested this. However, in the long run, mechanisms for more formal agricultural support systems need to be identified, and this entails much stronger link with agricultural line agencies. A second issue relates to forward and backward linkages for the collectives, particularly with regards to repairs and maintenance for equipment. In Bhagwatipur, Dholaguri and Kanakpatti, farmers complained about the challenges in getting repairs for the solar panel, which requires travel to the town – how to strengthen these linkages with service providers for technology will be a critical research issue going forward. A final issue relates to groups raising finance. While they can raise funds for day to day inputs, they are still not in a position to invest in high value equipment such as tractors – and this causes production constraints. In Kanakpatti for example, farmers complained that the tractors are all busy, and are often not available – in the past the project had supported them in arranging land preparation, but this will no longer be possible as support is phased out. Improving the investment capacity of groups is paramount in the future, and this can also entail improving access to state subsidies for agricultural equipment.

Ensuring gender empowerment as the project moves forward is also critical and will be explored more below. In Uttar Chakoakheti, there were concerns by women that when the project ends, men will stop offering them support in their groups. Men are supportive for them as long as the project is there, and the team keeps visiting the community. This has given them some respect within their household. Their confidence has increased and even the children are happy as they have some income now to purchase things for them.

6.2.4 Strengthening our models through a collectives association

The need for larger scale cooperation

A key intervention, which would address many of the challenges outlined above, would be the development of a higher level institution to bind the collectives together – this would serve in the long run to replace many of the support mechanisms which are today being provided by the project team. It would be central to the success of the proposed Climate Smart Irrigation Toolbox (SIT). At the same time, it could also potentially support access to agricultural knowledge and extension services, conflict resolution, negotiations with landlords, marketing, and equipment hire.

These proposed 'Collectives Associations' will address several of the challenges above such as unequal bargaining power with landowners, lack of support for new technologies, limited market information and limited investment capacity of groups. This institution will also be the next step in terms of out-scaling the collectives locally, and creating a base from which new groups can be formed. To some extent, the project has already facilitated some inter-group cooperation.

For examples, in Nepal and Bihar, the groups have clubbed together to support negotiations with the landlord to reduce the lease amount. In Nepal this was so two groups could manage a pond for fisheries, while in Mahuyahi of Bihar the youth group and women's group joined together to negotiate a larger leased area at a lower rent. There is some labour sharing between the groups, particularly during the busy monsoon season, in the case of Nepal. Another reason why groups cooperated was to benefit from government support for groups. For example, in Nepal farmer groups can register with the local agricultural office to access subsidies. These schemes, which take a group approach often, have a minimum number, often over 20. In Nepal, three groups teamed together so they could meet the minimum size rules. They have received vegetable and wheat seeds, and an irrigation pump was provided to Kanakpatti group 2. They need to submit meeting minutes while filing applications.

In Dholaguri, the Alor Disheri Farmers Club had existed prior to the project, yet was involved in limited activities. However, during the project, it played an informal role in supporting the collectives. For example, they had successfully had 8 new Shallow Tubewells installed with electrified pump and pump house by applying to the agri-irrigation department in Cooch Behar district as a follow-up of a stakeholder consultation conducted by DSI4MTF. Similar kinds of activities (installation of STWs, sprinkler irrigation system etc) was done in UC also through government department (Irrigation depth and agriculture dept), the groups applying as a larger entity, as was done in Nepal. The groups are also collectively accessing agriculture inputs from ADA office (Assistant Director of Agriculture, Alipurduar district), in farm machinery support including and support in apiary for the farmers by providing bee box.

The function of a collectives association would be to *formalise* existing inter-group collective action under the umbrella of a single institutional structure. The need for some kind of institutional spine to anchor the collectives was initially suggested by Professor Bina Agarwal – who has led global research on contemporary farmer collectives – during the farmer cross-learning meeting in Madhubani in early 2017. She had earlier conducted an extensive study of farmer collectives in Telangana and Kerala (Agarwal 2018), and the findings of this paper were discussed during our meeting in Patna. The success of group farms in Kerala in particular were grounded in their strong institutional base, which was independent from the government. In the case of Kerala, Kudumshree, the State Poverty Eradication Mission, established community development societies in multiple villages (Agarwal 2020). Under each would be several collectives. The groups were registered as a society or federation under the societies act, and would support training, extension, equipment hire and negotiations over leases, amongst other functions. There are three levels – the neighbourhood groups, the area development society, at a ward level, and the community development society at a Panchayat level.

It was proposed in our meeting in Patna that while we could aim for such a multi-tiered structure in the long run, in the short term we can initially start by setting up village or ward level associations, which in the future could be expanded to the Panchayat level or beyond as new groups are formed in neighbouring villages. It was decided that during the SRA period (2019-20), we would begin by formally establishing the association, then initiating modest activities such as coordination between groups, supporting the formation of new groups and supporting access to government services, and later could extend the function of the collectives. In the long run, the collectives association would be central to upscaling the collective innovations piloted under DSI4MTF. The presence of a Collectives Association which encompasses a network of smaller collectives, represents an integrated model which can be replicated elsewhere. It is believed that promoting such a model will be more sustainable than promoting a model of individual and unconnected small groups. The association will also be critical for the out-scaling of the Climate Smart Irrigation Toolbox (SIT), and it is proposed that the two models, operate in synergy.

Achievements so far

The ‘collectives associations’, a project specific term we will use to describe our cross-group institutional structures, has taken on different forms in different sites thus far. In the latter part of 2019, two collectives associations were established in West Bengal. In both villages they have been registered as Farmer Producer Organisations. These are legal entity formed by primary producers, viz. farmers, milk producers, fishermen, weavers, rural artisans, craftsmen. It can be a producer company, a cooperative society or any other legal form which provides for sharing of profits/benefits among the members. The team is also now registering the association in Uttar Chakoakheti as a Farmer Producer Company, and the association in Dholaguri is under the process of registering. Farmer Producer Companies (FPCs) are registered corporate bodies, which can support a large number of small farmers (or in our case a network of collectives) in activities such as marketing, processing, and procurement of inputs, while supporting a sharing of profits and benefits amongst its members. They are owned and governed by shareholder farmers and administered by professional managers. They adopt all the good principles of cooperatives and the efficient business practices of companies and also seek to address the inadequacies of the cooperative structure. An FPC can be formed by any 10 or more primary producers or by two or more FPO, or by a contribution of both. They can undertake activities related to production, harvesting, procurement, grading, pooling, marketing, processing, etc., of agricultural produce. The non-producers seeking to invest in these companies as shareholders are precluded under the statute concerned.

In the case of Uttar Chakoakheti, the FPC’s key role will be an association to bind the collectives together, yet it will also support women SHGs and the farmers club to increase the productivity from the land and livestock, aided by the DSI4MTF survey data. The FPC will also strengthen the internal governance and skills of these groups so that existing

DSI4MTF activities can continue under their leadership. The FPC asses what set of skill or knowledge training is required to support the farmers and will look into off-farm activity / agro based enterprise they can engage in. Examples include organic manure processing, developing a livestock unit in scientific way but supporting native species such as local hens, black Bengal goat, and cattle). Other ideas include mustard oil extraction or setting up the mini processing unit of rice bran oil, as well as a processing unit for native paddy required for the local festivals of tribal community

In case of Dhaloguri the farmers are still mobilizing the funds, but they are very much on track for the formation of the FPC. Right now, they are also in the process for the selection of board of directors and members. In the case of Dholaguri, the FPC will act as an apex body for groups in the village. While it will play the role of collectives association for our groups, its mandate will also encompass water user associations in the village (WUAs formed surrounding STWs provided by govt.) and the farmers club.

In the case of our Bihar collectives association, a community resource centre has been set up in Bhagwatipur, or a Kisan Sangatan (farmer's organisation). It is yet to be formally registered, but this will take place in due course. Following an initial two planning meetings, a management structure has been set up, with three elected members from each group for a fixed period of one year in total, making up a committee of 12. They were elected the basis of their skillset and willingness to serve the community. Monthly meetings have now been initiated in which all members from different collectives give updates on their group status, and any problems and possible solutions. A leader is yet to be appointed.

It is proposed that the resource centre for the benefits of all collectives will procure all inputs and services required by farmers collectively. They will also coordinate the hiring of services or service providers for particular agricultural tasks, and will play an intermediary role in providing solutions to crop problems. They will also support marketing and access to government schemes. They plan to appoint two active people on a wage/honorarium basis, although one of these people would be changed on a rotation basis. Their tasks will include coordinating the collection of agri-products, maintain records, collect money, negotiate with input suppliers and service providers, and identify capacity building needs and collection and distribution of inputs and services.

In Nepal, a Collectives Association has not yet been formed as a part of the project. However, recently, a Farmer Group Association was registered by farmers themselves led by a farmer in a nearby village, and this has considerable potential to fulfil a similar role, although it brings on board other farmer groups in the locality. The Shambhunath Farmer Group Association was registered in January 2020 at the Rural Municipality. The key objective of the association is to bring farmer groups together for voicing concerns and needs of farmer groups. The association brings together as many as 40 groups from the Shambhunath rural municipality in Saptari. The two DSI4MTF farmer groups from Kanakpatti are now represented in the association. The association has the potential to facilitate information flow between the groups and agricultural agencies, rural municipality and ward offices. Equipped with the collective voice of farmer groups, it can also influence policy development and implementation. For this, the linkage between the association and rural municipality is critical. The association is however in its infancy, so capacity building on effective functioning of association is required. However, there is considerable potential to work together with this association for future work with the collectives, supporting the association in strengthening linkages with private and public agricultural agencies through meetings, workshops and field visits, and using them to support the creation of new groups.

Functions for the Collectives Association moving forward

Based upon our discussions in Patna in August 2019 and the February 2020 project meeting, and the follow up focus groups with the farmers and reflections on the initial experiences of the Kisan Sangathan in Bihar and the Farmer Producer Company in West Bengal, as well as the Farmer Groups Association in Nepal, we discussed several further functions for the these three models of association in the future:

1. **Facilitating the introduction of Climate Smart Irrigation Toolbox (SIT):** The SIT, which supports evaluation of irrigation performance and local water resource monitoring will bring considerable benefits to the collectives in terms of productivity and energy/cost saving. The institutional support structure, meanwhile, which is offered by the association, would be important to facilitate the introduction of the associated technologies. Key members could for example, be trained or act as focal points, and could in turn offer support to all the farmer collectives in the community, and even farmers outside of the groups. The association could also support the collectives in accessing technical support from outside. The proposal for a fully integrated programme including the Collectives Association and SIT is outlined in section 8.
2. **Access to agricultural equipment:** There is potential for the association to also purchase irrigation and other equipment for use by all collectives, pooling their finances. During the focus group with Dholaguri group 4 for example, it was suggested that the farmers association could collectively take a loan across all groups to purchase a power tiller. This was echoed in Uttar Chakoakheti whereby it was remarked that if the association owned a tractor it could be provided for use at a much lower rent than private service providers. While at an early stage, investment in high value equipment (e.g. threshers, pump sets, zero till machinery etc) may be unfeasible through member contributions alone, the associations can support farmers in accessing subsidised equipment through government schemes. They can handle the paperwork, and can on the behalf of all farmers, apply to access state resources. This has already taken place in the case of Nepal and West Bengal, to access free tubewells.
3. **Negotiation over rents:** The association could support farmers with the negotiation over rents and other conditions with landlords. As the number of groups in the village increases, the association can increase their bargaining power, with groups acting collectively to negotiate lower rents, deal with disputes, or increase landlord contributions. As noted above, cross-group negotiation with landlords has already happened on an informal level. In Nepal, where there is a larger farmer groups association which doesn't just include the project collectives, they could negotiate for rents benefitting a wider range of tenants beyond the immediate collectives.

Case Study 7: Farmer Producer Company in Dholaguri

The District Development Manager (DDM) of National Bank for Agriculture and Rural Development (NABARD) was invited at Dhaloguri to meet the farmers from both Dholaguri and Uttar Chakoakheti in November 2019 to discuss the activities and works done under the DSI4MTF project. In this meeting more than 32 farmers were present. Farmers took DDM for a transit walk of the village and showed him the different activities (both social and bio-physical) done under the project.

The DDM discussed the prospect of establishing a Farmers Producer Company (FPC), building upon the foundations of the existing Farmers Club in Dholaguri. Under an FPC the farmers can be provided with a range of support from the Govt of India, including finance from NABARD over a span of 5-6 years if guideline of govt was followed. One FPC would receive Rs25,000,000 both in cash and kind. Accordingly, it was strictly instructed if the farmers feel the necessity of creation of FPC then they would consult Chartered Accountant for the legal procedure backed by the DDM. Following this meeting the collectives association was formed bringing together all the collectives in the village and the existing farmers club, and they held a meeting and decided to form the FPC.

Following the registration of the FPC through the DDM and a Chartered Accountant, the necessary documents were collected by the farmers. More farmers from outside the collectives were brought on board to meet the required numbers, although the leadership of the FPC still lies with the collective members. 6 board of directors and 4 general members among the farmers were selected. After this, funds were mobilised. These included processing fees of Rs15,000 for the chartered accountant. A bank account was opened with a minimum of 250 shareholders and Rs250,000 as seed money. Now the FPC is a legal entity, and the certification has been shown to the DDM of NABARD to access support.

Reflection on its success and learnings

Both the farmers and DDM are pleased that FPC in Uttar Chakoakheti received its registration in such a short period of time. Success itself is a process, supported by a number of important initiatives by the project team. In the case of the FPC formation, these include

- Met DDM, NABARD and convince him to visit Dhaloguri and meet with farmers of both project sites
- Self-reflection meeting with the farmers on the prospect of FPC to evoke courage to dream to form a company lead by the farmers. Ten members from UC were very much excited and took the initial decision that they will form a FPC.
- Selection of Charter Accountant (CA) who would be local, helpful and would charge lesser amount for the formation of the FPC. The farmers active involvement in DSI4MTF project helped DDM to support the farmers for selection of right and efficient CA.
- Accumulation of correct documents of all the 10 members required for the formation of the company.
- ADA office has approved Farmers Certificate to all the selected 10 members due to strong relationship between farming community of UC and agriculture department. Informal relationships are important.
- Accumulation of initial Fifteen thousand money required for the fees and processing charge of FPC.
- Dedicated farmers of UC like Tapan Chick Baraik, Rita Oran, Lalita Oran, Surendra Chick Baraik, Subhash Oraon who were constantly following up for all aspects required for the formation of FPC.
- Linkage building: Institutions that needed regular visit to receive various document were CA office, Bank, Court, ADA office, BLRO office.
- Selection of name of FPC and nomination of board of directors and members through participatory meeting and voting without discrepancy.
- Submission of the required documents and money (govt. fees and consultancy) to the chartered accountant on time. After 15th day from the day of submission of the document's formation of FPC was done and UC farmers received the FPC certificate
- Submission of the FPC certificate to DDM, NABARD, Coochbehar who gladly accepted the certificate and assured the necessary process would be done by him so that the name of the FPC get registered in the website of NABARD.

4. **Access to state services:** Associated with the last point, the association can offer the collectives a formal legal status through which they can access government extension, subsidies and other support. Due to a lack of land ownership or tenancy documents, many small and marginal farmers cannot easily access these schemes individually. However, the association can be registered legally as a cooperative or farmer group to avail state resources, or the association can also support eligible individual farmers with applications for support. The association can also be an entry point for training in new crops, techniques or irrigation methods, providing a link with state agricultural extension services. In Agarwal's comparison between farmer collectives in Telengana and Kerela, the latter's comparative success was rooted in their link to the state poverty alleviation mission, and their ability to secure credit through NABARD and access government support (Agarwal 2020).
5. **Marketing:** Marketing is already central to the proposed agenda of the FPCs and Kishan Sakngathan. The association could support groups in getting access to price information. The association could potentially support actual marketing of produce – for example, supporting farmers in making contact with buyers of crops and sellers of inputs. For example, Dholaguri group 4, it was remarked during Focus Groups that spinach and coriander are produced in small quantities, so it is hard to market on a large scale. Through the planned association, several groups can sell in bulk. With spinach for example, they recently faced a problem whereby they could not get a dealer to come to the village, as the amount was considered too small. Potentially they could purchase inputs in bulk for the farmers, and share these with the groups to save costs and time.
6. **Service provision:** If investments in equipment are not feasible, the association could potentially coordinate groups to access service providers for tasks such as land preparation, negotiating on behalf of the groups and coordinating work, and potentially saving costs and time. Ability to rent a tractor raised as an option in Bhagwatipur
7. **Irrigation scheduling and crop planning:** The associations could support farmers in crop planning and irrigation scheduling, according to market trends. They could develop annual plans in coordination with ward committees or municipalities/panchayats.
8. **Problem solving and knowledge pooling:** The associations can play a role in jointly identifying problems and coordinating between the groups to find solutions. These could be identified during monthly meetings, and the association can support in problem resolution. For technical or agronomical problems, they could support groups in getting the appropriate technical or agricultural support from state extension services. They can also play a role in conflict resolution, within groups, or between groups and other stakeholders (e.g. landlords). Knowledge pooling was also raised as a potential benefit during focus groups with the women run collective (group 4) n Dholaguri. They had been taking help from some male farmers from outside the group in technical issues, but the association could present an opportunity to pool knowledge from other groups. Similarly, in Uttar Chakoakheti, it was noted that as the village is large, a representative from each group being part of a larger association could ensure that all groups knew about the different opportunities or programmes they could participate in. at present this is taking place but on a more informal basis, depending on local leaders to disseminate information.
9. **Access to land:** Given the challenges posed by lack of access to land the association could support groups in accessing or increasing their plots. This could include for example coordinating with local authorities to lease in public land, it could also link up with a land bank concept, (see below). Group 2 of Dholaguri raised the prospect of using the collective association to negotiate access to a

larger area of land on lease. In Uttar Chakoakheti, there was concern that many of the vacant lands are taken by outsiders to invest in resorts or tea gardens. However, the association can help ensure land remains utilised by the local people.

The focus groups with the collective members suggested overall positive views towards the process of establishing collectives associations, and recognise significant benefits in terms of access to equipment, government services and economies of scale. There were however some notes of caution raised during focus groups. For example, collective members in all three project sites were concerned that there were many overlapping groups in the community, and many lacked a clear purpose – family members often complain about them going to too many meetings. For example, in Dholaguri, one respondent recalled bad experiences of a women's SHG federation which brought together 40-50 groups. They complained of poor communication and coordination between members and of well networked people finding it easier to get loans. Collective members called for clear roles and responsibilities and strong leadership, as well as regular meetings with good minute taking, to ensure problems are dealt with openly.

6.2.5 Farmer Associations and blue-sky thinking – a land lease bank

A recurring challenge during DSI4MTF was access to land for the collectives. Limited availability of land to lease meant groups who were keen to increase the cultivated area were constrained and new groups could not easily be formed. The role of the new collectives association in increasing access to land was raised on a number of occasions during focus groups. While this may involve negotiating with landlords directly, or with village institutions to access public land, there is a need for new ideas regarding how to maximise the utilisation of land within the community. An idea which was proposed during the Patna meeting in August 2020 by Professor Agarwal, was a land lease bank. This has never been tried before but could potentially operate as an additional role for the collectives association. The bank would not only benefit the collectives, but also individual tenant farmers, who could potentially benefit from more secure leases, larger plots of land to lease, and reduced 'resistance' from landlords.

This idea emerges from the premise that there are people who want to lease out land and people who want to lease in land, yet tenants often find it difficult to find plots in the right location and of the right type. On the land owners side, finding tenants can be challenging to ensure land is used to its maximum potential, while current land tenure laws, which allow farmer the right to claim a portion of land after a certain period of time, have resulted in most contracts being informal and word of mouth. As a result of this, the tenants experience tenure insecurity, and often can't access state support due to the fact that they have only oral contracts with landowners.

Under the land lease bank concept, landowners with surplus land (which may also include many smaller farmers without sufficient labour to cultivate all their fields), can deposit their land in the bank for lease for a fixed period of time. Meanwhile, anyone who requires extra land, can lease the land from the bank. They can put in specific requests, for example for consolidated plots. This will be easier to manage, as the bank will know what land is available. The bank would handle all the paperwork and contracts, and would retain a small percentage share of the rent. In terms of payment and incentives for landowners, they could be offered a small return for the land up front, with the remainder being paid when the land is actually leased out. Rents can be calibrated according to land quality, and would be on a fixed term. Potentially public land could also be made available for lease.

The advantage is that there would be no transaction costs on either side, saving considerable time and negotiation. It would be easier for farmers to get access to plots of land where and when they require it. A criterion would need to be set to ensure it is only for small and marginal farmers, and the person who is employed would need to be trustworthy and recognised by the Panchayat.

The opportunities posed by the land lease bank were discussed in focus groups in Bihar and West Bengal. The most optimistic perspective about the idea were in West Bengal, where there were not significant inequalities between land, yet some farmers had surplus land due to family circumstances, while others were in need of plots. Farmers noted how a lot of land lies fallow, and the land bank would offer a good opportunity to ensure that land is utilised efficiently. Land may be fallow due to shortage of labour, for example due to out-migration of a family member. At the same time, it was reported that there are many tenants looking for land to lease, yet tenants often don’t know what land is available. A centralised database where farmers could find out where land is available and didn’t need to negotiate rents, was considered a valuable opportunity. The project team for example, could use the phone app developed previously to develop a register of lands of differing qualities. Ensuring land is of the right quality is also important, and farmers saw value in using a bank to formalise the different rents for different types of land, allowing farmers to choose plots according to their willingness to pay. Focus group respondents also noted that the land lease bank would give them the chance to have land for a set, extended period. At present, the landowner sometimes offers the land for a year, but then after one season asks for it back. The bank would prevent this from happening. It was remarked that one cannot trust word of mouth contracts anymore.

There were some reservations though, particularly in Bihar where the trust between landlords and tenants is weak. There was a perception that landlords would not be in favour of the idea, given that they may see it as a way for tenants to seize the land – although the land bank concept is designed to reduce this risk. Clear sensitisation is thus needed about the benefits, and reassurance that the contract was between the property owner/tenant on the one hand and the land bank on the other (rather than being directly between the property owner and tenant).

As recommendations, it was suggested firstly that the land lease bank must build upon existing groups, such as the new collectives association, which can play a mediating role between parties. It was also raised a couple of times, that checks should be put in place such as a ceiling, to ensure that land was not seized by outsiders for commercial purposes, particularly in North Bengal due to the tea economy. For example, the farmers in Uttar Chakoakheti noted that recently 2ha of land was taken on lease for 35 years. That local person gave the land for a tea plantation. It was also noted that the original land ownership documents should not be taken by the bank to maintain the trust, although a formal contract could still be issued.

6.3 Institutional strengthening and ethical community engagement

6.3.1 Ethical community engagement in DSI4MTF

The SRA period also allowed the team an opportunity to reflect upon the community engagement process during the DSI4MTF project, and compile key learnings which can facilitate scaling. As noted above, scaling requires that change takes place at the level of values and beliefs, not just through the models growing physically. This value change depends on a spirit of collaboration and partnership. Central to the approach of DSI4MTF was Ethical Community Engagement – and approach spearheaded by CDHI in West Bengal sites, which was adopted by project teams in Saptari and Bihar. This study considers how this collaborative approach has strengthened the collectives.

As opposed to a conventional top down implementation strategy, following a ‘specialist’s’ view, DSI4MTF’s ethical community engagement approach prioritised collaboration and partnership with the community throughout the project lifecycle. Ethical engagement can be understood as collaborative interaction and partnership between the researchers and the community, each valuing others for their wisdom, insights, value system, intellectual, creative and physical endowments in evolving and analyzing concepts, methodologies, strategies, process and outcomes.

Communities were therefore not the projects' 'research subjects' but were partners and collaborators. Communities' perspectives, wisdom and priorities have been respected and given due credence to. These were cultivated in an environment of mutual trust and respect and decisions that followed in terms of how the collectives will function and how technologies will be mobilised, were based on mutually agreed objective parameters. Rather than maintaining a stiff stance the researchers and the community deliberated as equal partners demonstrating their strengths and weaknesses in the most transparent manner. This kind of engagement also applies to interaction among stakeholders who join and participate in the research endeavour under similar conditions.

During the SRA period, the project team were given the opportunity to reflect upon the last four years, and understand how ethical community engagement has contributed to the evolution of the collectives. A central conclusion was that ethical engagement has been a central element of the project's impact pathway. It has catalysed enabling conditions for researchers, the community and other stakeholders to work in tandem and collectively influence transformations in collective action, inclusion, dry season irrigation/ agriculture and intensification. Below, we outline the team's reflections on the successes of ethical community engagement during the main DSI4MTF project, as well as recent achievements during the SRA period.

6.3.2 Reflections on the cycle of ethical community engagement during DSI4MTF and SRA period

As noted above, during the early stage of the project, farmers initially saw the project as an opportunity for short term benefit via the supply of irrigation equipment or other hardware, rather than seeing it as a vision for transformative change. This stems in part from a lack of 'ownership' over previous external interventions.

For example, in Uttar Chakoakheti and Dholaguri of West Bengal, while the community is considered collective in nature and orientation, many years of isolation and marginalization have created some indifference to external interventions. State and non-state's interventions have remained notional and cosmetic, and as a result, communities have developed cynicism and distrust of external projects. When DSI4MTF proposed its pilot interventions, the community considered it as one of several such projects which were 'launched and completed' without much long-term impact. The first few visits by the team failed to attract significant interest. These visits, however, helped understand the context of the community's indifference. Causes, as identified, were several – including notional past projects, indifferent state and non-state functionaries, irrelevant policies and programs and top down mechanical planning.

The process of engagement by the project team across sites has been focused on listening, understanding, reflection and collective analysis. Establishing and continuing with frequent face to face contact with the project teams, many of whom were based near the field site, was yet another strategy that helped them open up, sharing and express their views freely. In West Bengal, the first stage of meetings was oriented around thematic reflections spread over various sessions–why the community is what it is? Why the ponds are dry and agriculture fields barren and how the menace of animal attack could be checked? The themes extended to children's education, employment and future career opportunities. Community meetings assumed a vibrancy and some of the more articulate individuals started questioning themselves. Statements included: "who can help us if we don't act ourselves," and "why can't we visit the government offices for our entitlements"? Group meetings became regular and farmers decided on the management protocols for the collectives. The outcomes extended beyond the immediate goals of the project. For instance, the community in Uttar Chakoakheti received its scheduled tribe certificates, the officials visited the village and the bio-physical systems of the project started being managed more effectively.

Local challenges combined with Ethical Community Engagement, which has conferred the groups with ownership over the interventions, has helped communities reach officials and local governance systems to claim their entitlements. Initial success resulted in the initial cynicism being replaced by determination to set and achieve their goals. Collective strength was consolidated, and opportunities started unfolding. Service providers developed trust in the ability for communities to make payments and government officials recognised the collectives as groups to be relied upon.

Case Study 8: Example of how the collectives evolved through ECE in West Bengal:

When DSI4MTF was initiated in Uttar Chakoakheti and Dholaguri, the interventions were perceived by the community to be an opportunity for physical support – often considered as ‘dole out’ and an opportunity to maximize physical benefits as much as one could do, depending upon on social position. The elements of partnership and inclusion were missing. In both locations villages were identified based on certain technical parameters and indicators. The reasons for being part of the project were external to the community.

A first stage of the ECE process was to identify these reasons and present possibilities to the community. As the process of engagement continued through an iterative process, the reasons started becoming more and more internalized, and there was a realisation that the collective can help the community develop a common perspective for livelihoods, focused around water and agriculture. As DSI4MTF continued the reasons for being part of the project became closer to the identity and aspirations of the community.

While the collectives, at first, were a short-term initiative for the farmers, gradually they brought in glimpses of opportunities which were perceived as long term gain. This brought in new members and stakeholders such as from the state, with common (and sometimes competing) interests. Soon they became collaborators, not only in the project, but also in other multiple activities which could bring future opportunity for the community.

The governance system also evolved through time. When the two villages began on the collective journey it began as a person driven activity, and the governance was based upon the group leader, who would decide the agenda of a meeting. Decisions were often pre-planned and scripted. The iterative process of engagement however led to further clarity and transparency and several of the fence sitters were able to occupy a prominent space. When the farmer’s club and Farmers’ Producers Companies (FPCs) were visualized, it mandated participation of people from different household types or gender, and multiple stakeholders.

The leadership also evolved from being individual based and authoritarian to democratic. The two villages differ in leadership. UC is homogenous and has strong tribal culture where trust and kinship is valued. The community’s leadership is respected. Considering the demand of the collective going into a more formal institutional format the tribal community shifted from informal tribal norms to formal institutional norms. The leadership in UC is democratic and maintains transparency. It, however, gives due credence and importance to traditional leadership –respecting their views and perspectives but at the same time following the norms of the formal institutions which would serve the common goal of a community collective-institution.

Later on in the project, the community has tasted the benefits of collectivization and the associated technical changes – irrigation facilities have ensured much needed timely irrigation, protected farming has enhanced opportunities for niche crops and with increased income they have been able to regain their identity. There is now a visible inclination for farmer group members to strengthen and consolidate their collective position further. Building on this enthusiasm there has been discussion around building inclusive institutions such as the various farmers associations proposed during the SRA period, such as the Farmer Producer Company in West Bengal.

ECE is critical for the long term strengthening of the collectives, as well as these new institutions. Institutions, by definition, are a collective of more than one individual joining with a clear common goal and normative structure. The collectives are institutions so long as they have a ‘common, and ‘clear goal’ and a normative structure that every member adhere to. However, there is a distinct difference between an ‘imposed institution’, when an external agency - government or otherwise - impose an institution to achieve certain goals which may not always represent the goal of the members, and an ‘evolving institution’. The latter represents institutions where a group of people are aware of and seized an issue which affects them, and which requires others with a common interest to address the challenge. To be able to achieve the given goals norms and procedures can evolve to adhere to and follow. A structure evolves, processes are decided to be followed, and accountability and responsibilities are fixed. The effectiveness of the institution(s) would depend upon the extent to which the norms are shared, and processes and procedures are followed.

ECE has helped the collectives in developing institutions with clear vision, mission and normative structure. Several iterations of the vision, mission and normative structures, which have evolved over time, have led to clarity around them. The by-laws and memorandum show concern at and for transparency and justice. This is important as national banks and local agencies who could support the collectives demand clear institutional entity with unblemished track. The community is gearing to satisfy this.

Table 10 outlines how the collectives have evolved from the beginning of the project of the SRA period, compiling the impact of the ECE approach.

Table 10 How ECE has helped influence the collectives

Before DSI4MTF project	**Now**
Aspiration level of the community was very low due to lack of confidence.	Community aspiration level is increasing – some of the farmers evolved as progressive farmers including landless women due to enhanced aspiration.
Community members were very hesitant in communicating and visiting the government departments and other agencies.	Now community members are visiting different government departments and office of the district authority. Their negotiation skill has increased,
Self-efficacy was low in adopting new technologies and communicating with outsiders.	Self-efficacy created by using ECE approaches resulted in level of happiness is increasing.
Issue based (livelihood) social bonding was lacking before the DSI4MTF.	Now community members are more organised in livelihood-based activities. Strong relationship built among the rich, poor, tenant farmers.
Women were limited to women self-help group. Capabilities of women were not identified.	Women are involved in different activities and included in collective farming, farmers club, direct marketing etc. The capabilities and skills of women are recognized by the male dominated society.
Before the DSI4MTF, community had no women groups and farmers club in the project location.	Now they have more group like water user association (WUAs), collective farming group etc.
Community based institutions and local NGOs were not aware about the ECE approaches and principles.	Now community-based institutions along with government department are aware of ECE and they are applying it in their respective fields.
The community members were not exposed to different technologies and tenants / marginalized families were not included in mainstreaming development.	The tenant and marginalized farmers are included in mainstreaming development and adopting new technologies to enhance their crops intensification and income.
Prior to DSI4MTF project, community did not emphasis on cross cutting issues of environment,	Now community members are aware of these issues and including them in their planning process for implementation.

climate change, market value chain, conjunctive use of water, nutrition sensitive agriculture etc.	
Innovative activities among the farming community were lacking though it was their wisdom to enhance the family earning.	ECE helped them in introducing new crops like spinach, coriander, broccoli, maize etc in adopting new technologies like poly house cultivation, new and improved irrigation methods etc.
Record keeping or maintenance of books was totally missing among the farming members resulted in low risk-taking capability.	Now they are maintaining their farming and marketing records. It helped them to do cost benefit analysis as well as supported them to take new challenges and risks.
Earlier farming community members were not communicating with wholesalers / trader / farmers producer organisation (FPO) directly for selling their products.	Farmers have been building relationship with different kinds of buyers for direct selling in gaining more profits from their product. Sometime buyers like FPO at distant location are directly purchasing harvested crops from farmers' field.

6.3.3 Lessons learned in Ethical Community Engagement for future work

Several lessons can be learned from the ethical community engagement process, which are critical for future work.

1. **Unlearning the values of dependency:** In the project villages, externally introduced interventions are often considered as an opportunity for personal benefits alone due to inadequate community engagement. This value needs to be unlearned and the project's first effort should be to clearly convey the meaning and purpose of the intervention. In Uttar Chakoakheti and Dholaguri for example, both had several group-based interventions like water user association already, yet there was a perception that these interventions would not benefit them but only a more powerful a person. We systematically dispelled this and communicated clearly that this was a partnership intervention.
2. **Entrenching the above values:** Just communicating is not enough, one needs to entrench the values of ECE through systematic and frequent engagement with farmers. The engagement offers opportunity for questioning and clarifying the process throughout.
3. **Evolving norms and practices:** In several interventions norms and operating systems are imposed from the above. This is not internalized neither is there the required ease and comfort of adoption. If the community participate and norms can evolve naturally, then there is a sense of ownership which makes it easy to practice.
4. **Facilitating smoother communication among farmers.** The three regions consider establishing smooth communication among the farmers and evolving common norms and procedures as a key driver for successful group formation. One can examine and analyze the issues in smooth communication. Smooth communication is hindered by power relationships across caste, class and gender. Some of these elements are implicit while others explicit. Dealing with them has been a challenge. The community engagement strategy has however been able to moderate the power asymmetry among various partners and collaborators. This is common in all the three regions. In both Madhubani and Saptari the relationship between the landlords and the farmers have been in some cases addressed and a constructive relationship created among them. This has been a win-win relationship. In West-Bengal the relationship among different farming groups, across caste and gender, have been moderated resulting into inclusive collectives which sets the stage for inclusive institutions.

5. **Building interfaces with the stakeholders including the state:** Part of the ECE process involves mediating effective and collaborative relationships between groups, the project team and state and non-state agencies, using the same processes of engagement. This is essential for later out-scaling and upscaling.

In sum, the evolving framework suggests that engagement has been able to bring the farmers together, supporting them to work as a team and create collective endowments and opportunities. The hands on in managing the collectives has led to developing institutions with long term common goals.

6.4 Gender sensitive and socially inclusive approaches in collectives and irrigation and water management

6.4.1 Gender inequalities in agriculture in the study sites

An important consideration in terms of the strengthening of the collectives in the case of any future upscaling, is to assess the success of our models in contributing to gender empowerment – and identify fields for further research. We explored the extent to which the establishment of collective farming enables women farmers to engage in smallholder agriculture earlier in the ACIAR final report (2019), chapters “Gender relations and impact of migration on agriculture” and “Gender impact assessment of collectives and new dry season irrigation technologies”, and in our key publications “Ambivalences of collective farming: Feminist political ecologies from the Eastern Gangetic Plains” in the *International Journal of the Commons* (Leder et al. 2019b), as well as in “Experiments in farmer collectives in Eastern India and Nepal: Processes, benefits and challenges” in the *Journal of Agrarian Change* (Sugden et al. 2020b).

The baseline research on of DSI4MTF found considerable barriers to women’s empowerment through agriculture. These include firstly, gendered norms which restrict access to water and land. For example, women faced challenges negotiating with men to access pumps to rent for agriculture, or getting water on time, and were often overcharged. Negotiating with landowners was also a challenge. Landownership is primarily in the name of men, and women who were landless or had small landholdings were particularly vulnerable to food insecurity. Finally, women face challenges associated with the gendered division of labour, whereby they conduct a disproportionate share of time-intense but economically and socially low valued tasks such as weeding or paddy transplantation, on top of their reproductive labour responsibilities within the household.

6.4.2 Positive lessons in gender empowerment within the collectives

The collectives were anticipated to play a critical role in addressing some of these challenges. As noted above, the collectives considerably supported households, particularly women, in managing the work burden, due to the pooling of labour. Furthermore, many of the broader benefits offered by the collectives particularly support women members – in terms of their capacity to negotiate with landlords through a group lease and their access to irrigation through the group, which negates the need to hire in pump sets.

During the project, and with follow up discussions through FGDs in the community, we reviewed several important positive lessons regarding how we have engaged with gender equity in the collectives. Firstly, it is critical to pay attention to the diversity of intra-household gender relationships when working with the collectives. This includes recognizing intra-group differences and their effects on the gendered division of labour between wife and (often out-migrated) male family or group members. A high workload of women with care tasks for children and the elderly and domestic labor such as cooking, and cleaning could significantly reduce the available time to commit to collective tasks – often a source of conflict.

Secondly, well-functioning collectives were observed in contexts of stable and close social relations among collective group members, that is building on the existing relations of trust and attachment which already exist within the community. This would suggest that women only groups are preferable, as we observed disagreements and injustices especially between landowning men and landless women members within the groups. Women-only groups could also create a more empathetic group environments allowing more partial (instead full time) contributions due to domestic workloads. However, as noted above mixed groups were preferred by some women even, and they confer advantages in terms of the division of tasks. This points to a critical need to build trust within groups and cultivate mutual understandings. Emotional attachment (to the family and neighbors) stabilizes long-term group bonding, and in some instances involving male members who have a family link to the women in a group can bring mutual benefits.

This raises an important overarching learning, which is the high value of frequent 'reflection' sessions among farmers on gender equity, such as those piloted in the participatory gender training (Leder 2016). This must also be combined with further research. A research led gender-inclusive adoption plan is necessary for future work, including further research on how to make irrigation technologies gender friendly. More research is also needed to understand how gender intersects with class, caste age and ethnicity within groups, and between groups and the larger community – and how this affect the success of the collectives, how we engage with the groups, and how we build up social relations of mutual trust.

6.4.3 Building gender equity in the supply chain: Lessons for future work

6.4.3.1 Gender in the supply chain: existing challenges

Strengthening the marketing and supply chain for our agricultural collectives emerged as an important issue to consider for the upscaling of the collectives, particularly via the proposed Collectives Association. Given the outstanding evidence of women's leadership thus far demonstrated in the collectives, it is important to consider how gender manifests itself in the agricultural supply chain. The PhD research on the challenges for bargaining by smallholder women farmers conducted by DSI4MTF team member, Dipika Das is particularly important in this context.

The study is implemented in the context of the agriculture value chain with the actors in the procurement, producers, intermediate and marketers' channel. Altogether 75 in-depth interviews and 8 Focus group discussion were conducted with women and men farmers along with value chain actors (like input supplier, mill person, tractor owner, middle-person) and key persons (like local leaders, ward chairperson, member from cooperatives, elderly villagers) and participant observation of the local markets from the four sites of the project, i.e. Kanakpatti and Koiladi village in Nepal and Bhagwatipur and Mauahi village in India of the EGP region.

The agri-supply chain flows through procurement to on farm activities to the end customers. There persists bargaining imbalances in the supply chain both upstream, where the supplies are purchased, and downstream, where the product is sold (Bijman 2012), and among the producers, women farmers are those who are at the weaker bargaining positions. In the DSI4MTF project sites, **four bargaining spheres** were identified, i.e. household, on-farm, market and intermediate spheres (Das 2020 Forthcoming). The first, **intra-household bargaining sphere** that involve bargaining issues within the household linked with farming – like sharing of household work burden, mobility access and control and farm-related decision making by women farmers. Likewise, the second **on-farm** bargaining sphere involves the bargaining issues that link with the range of activities for purchasing of input, land preparation and labour hiring and renting of farm infrastructures like tractors, harvesters and threshers by the smallholders unable to afford to buy the equipment. It also includes the bargaining associated with the purchase of irrigation. Similarly, the third sphere - **market**, involves bargaining linked with the transactions related to the purchase of the inputs and selling of the farm produce. Likewise, the fourth sphere is the bargaining issues with all the **intermediate actors** of the farm until the product is sold in the market, i.e. the landlord, middle-person, cooperatives, transport and the cold stores. It further examined if the issues in each sphere were fixed or flexible to bargain.

The women smallholder farmers faced the gendered and cultural barriers and as a result, face difficulties to make a meaningful contribution in the farming family (Das 2020 Forthcoming). Barriers to bargaining firstly include **(i) a lack of productive resources**. Smallholders in the EGP region often lack the equipment necessary for farming, like ploughing tractor, paddy thresher, irrigation machines like tube well. In such, the most economical option for the farmers is to renting equipment. However, the renting choice in a village setting reproduces bargaining imbalances. The de facto women household head often disadvantaged to face the outcome of unequal power relations. As a widow, women farmer (35 years) from Koiladi revealed that *“I must ignore when the male member has cunningly grabbed all the cauliflower seedlings that were provided by the project. It was an outcome of our collective farming. At first, I thought to fight the unfair, but later I realised what after the project’s support end, I would need his ox to plough my farm and must purchase water for irrigation from his tube well because only he has those resources that is the closest to my land. As a woman, I have no choice, but if I were a man, I would have left dealing with him, but with my conditions, I am dependent”.*

The lack of productive resources creates unequal power relations between the women farmers and the owners of productive resources that eventually positions women farmers at the weaker bargaining position that woman cannot question the unfair treatment. Similarly, some women face difficulties in hiring labours, as a widow (36) woman in Kanakpatti mentioned that, *“it is difficult to find labour in this village. I have to call labours several times to work on my farm. They do not listen. Even they are not working for free. There is no male member in my family, they fear of not getting paid. They prefer to work for rich people”*. In comparison with the families where male out-migration took place and those which lack adult male member as in a widow’s family face higher discrimination. As even the labour wage worker showed stronger bargaining position to the widowed farmer, that can be in preference to grab more workdays at the landlord’s farm in compared to work at the small farm.

A second challenge is (**ii) gendered mobility access and control.** Woman display less control over their mobility access due to power relations and gender roles which influences her participation in farming. As a woman farmer (25 years old) in Koiladi mentions that, *“if I go to the market and just take round and round to assess the price of input supplies that I want, I do not have that time. I have to come home back to take care of my family, so when my husband is not at home, I ask my neighbours to purchase for me”.* Gendered mobility influences the women’s active farm participation. It reproduces the unequal gender burden of work by decreasing their intrahousehold bargaining power. A woman farmer (31 years) in Kanakpatti mentioned, *“I can prepare tea at home but my husband and men in this village enjoy having tea at the chowk (market). Almost every day they go to the market, meet their friends, and have tea-chat. If a woman does so, she will be considered as bad because the market is males’ place. If a woman goes to market, she must return quickly to home”.* The cultural practices have now positioned men and women unequally that despite the understanding of several benefits of mobility to exposure, some women believe even if they have the exposure, they can never become equal to men.

A 45-year-old woman in EGP Madhubani, said, *“we are poor people, we cannot afford motorbike and car, we have a bicycle that my husband rides. Women with virtue do not ride a bicycle. It is not good for women to divide their legs to ride”.* This shows that the cultural practice restricts women to access the mobility needs for farming as well creating their dependency or provide them with less options, making farming expensive. However, some women farmers exercised their agency to challenge the existing gender and cultural roles. For example, riding a bicycle was one of the breakthroughs to some women farmers who experienced opportunities that cycling could bring to them. Riding bicycle not only gave them the possibility to carry a heavier load to the market for selling but also to manage their time effectively. A woman farmer (30 years) in Kanakpatti said, "*Earlier I only sold at Traffic chowk but last time I carried cauliflower to Rajbiraj market where the selling price was double than in traffic*". Riding bicycles have opened avenues towards new markets to increase profit.

A third challenges is with regards to **iii) gendered access to information***.* The traders *Feraha* come to the village to purchase from the farmers often offer the lower price and if the farmers do not have the information of the market, they may face loss. Therefore, farmers need to know the information on market price. But the access to the information is gendered that is often creating dependency on male counterpart that is caused by cultural practices and gender roles. For example, a male farmer (45 years old) from Madhubani said that *"I live with my mother, wife and children, will it sound good if my wife will call to unknown men traders to know the price? So, despite my wife having her mobile, she asks me to do it".* Alike, when came to the knowledge on the input needed for farm women were good at bargaining but were less aware of the quality and strength of the input, said an input supplier (43 years old) of Kanakpatti.

A fourth challenge is with regards to (**iv) gendered cultural practices**. The cultural practices often obstacles women bargaining for farm. There are power relations in the households – respect to parents, elders, and in-laws". A 35 years woman farmer says*, "I am married for 18 years now, but I have never talked with my FIL and I usually tell my MIL or my husband if I have to say something to my FIL. It is a display of good virtues that my parents taught".* The internalisation of such values often makes women to accept women are less valued gender. Similarly, a 40-year woman noted her husband as her master and said, *"how can I call my master by his name, I should show respect to him".* Such unequal positioning of themselves and acceptance for such belief jeopardises women's bargaining power. It hampers her household bargaining with men and elders that might be needed for farming.

Selling farm products is an essential role that a farmer must conduct to get a profit. However, cultural practices often hinder farmers from reforming the obstacles regarding the selling of produce. In Madhubani, vegetable selling is considered as a responsibility of people from a particular community called '*Kujra'*. The social values to the community are considered as lower who do not farm on their own but just collect vegetables from villages and sell to the local market called *Haatiya.* When the Madhubani farmers received support from DSI4MTF the first time did unusual vegetable farming that was overwhelming, but this could not support their economic conditions as selling was undervalued as a job of *Kujra's*. There was a 61-years men farmer in Bhagwatipur, who challenged the culture and started selling the vegetable in nearby *haatiyas.* Following him few more men started to sell vegetables. In contrast to men's stories women despite saw men selling gave their production to those men's but did not went to sell by their own. To challenge traditional values, it is more complicated for women.

6.4.3.2 Gendered bargaining experience among agriculture value chain actors

The research shows that bargaining experience in agriculture were gendered but it was interesting to find out a common perspective of men and women farmer for the question, "Who is good at bargaining?" the reply given was same by both men and women farmers that "*women are very good at bargaining*". A woman farmer (40 years) from Koiladi laughed when she recalled, "*if I send my husband to buy vegetables the quantity of vegetables, he will bring for NRs. 200, I can bring in just NRs. 150".* Men thought that haggling for price is women's feature so that many men avoid bargaining. When further explored on this, a middleman (45, years old) said, *"women are often found dealing with the items of less price but when it comes to the item that costs more like in thousands,* *women ask their husband to deal. It is difficult to bargain with men because they know the market price. If there is no men at home, it is easy for me to convince women to sell their products in cheaper rate".* Here, women who were found to escape from deciding for expensive items shows dependency on male counterpart and limits their ability to become a confident farmer.

Some women farmers shown an active participation in farming. A Dalit farmer (35 years) in Kanakpatti mentioned how her full participation have changed her life, "*I used to speak softly and was very shy to talk with people but when I started to attend trainings and meetings, I had to practice a lot that made me confident to talk with people, Now I do not hesitate to talk or ask to solve my farm problems. Earlier I never had money with me, I used to ask my mother in law for money but now, I have opened a mobile shop from my farm income. I always have money with me I am glad*". Another women in Kanakpatti said that women farmer now are not shy to bargain for the price. They stick to their position and strongly say that they do not want to sell if they do not get the adequate cost. The exposure from training and meetings have given them such insights.

Farmers working individually and in collective group have found it easier to bargain with landlords and access the market when they produce in bulk.

6.4.3.3 Lessons learned for future work

There are several important learnings for future out-scaling and upscaling of the DSI4MTF models. Firstly, womens farmer should have opportunities for bargaining training like numeracy, awareness on gender norms, practice bargaining through role-plays plays (Das 2020 Forthcoming, Leder et al. 2016, Leder, Shrestha and Das 2019a) and help to transform the restrictive gender norms to participate in agriculture. Secondly, collective bargaining power through women's farmer groups could be a potential enabler for women smallholder farmers to fully and successfully participate in the agricultural value chain. By women accessing resources they can become new role models in farming and can potentially transform unequal gender norms in markets. The collectives associations can be mobilized to support in marketing. Thirdly, access to market price information is vital and can be made accessible by introducing DSI4MTF market price app. Fourthly, women's time for productive farm and bargaining tasks is compromised by time-consuming care and nurturing tasks, so women must become more confident to bargain for her farming time at the household level (husband and in-laws). This involves extensive engagement across the household, bringing both men and women on board during the sensitization process. Finally, the concept of bargaining sisters group model (Das 2020 Forthcoming) can be introduced in the rural villages where women farmers can discuss and practice bargaining difficulties and possibilities in agriculture.

6.4.4 Gender and social relations within the project team

For future work it is important not to overlook the gender, and also broader social relations within the project team itself. The DSI4MTF team is set up of an impressive diversity of gender, age, nationalities, language, religions, family relations, job type, career stage, workspace (local, regional, national, international), job security, and economic income. The collaboration of different organisations, also brought together diverging interests, identities and roles. Roles included, among others, social mobilization, technical support, advisory roles, social inclusion, irrigation engineering, institution building, economic/agronomic research, political economy research, and gender/social justice research. At regular project meetings each representative of an organisation was encouraged to present and discuss their work. Furthermore, strong relations of mutual understanding were generated through continuous and regular communication among project staff via the team WhatsApp group as well as alternative approaches such as the Participatory Gender Training (Leder et al. 2019a). This allowed potentially unequal relations to be transformed towards more equal relations stressing commonalities rather than difference. These mutual understandings were critical for successful engagement with the community as interdisciplinary thinking and looking at issues from our different perspectives can enhance our understandings of the challenges facing the communities and in managing the groups and their access to technology. For more information, see Appendix 1 which discusses gender, disciplinary and social relations within the project team.

Figure 42 Impressions from interviews and focus group discussions conducted in Bhagwatipur and Mauahi, Madhubhani, Bihar, February 2020

6.5 External institutional arrangements that support farmer collectives and support upscaling

The discussion thus far has been on how we can strengthen the existing collectives, and make them more sustainable in the long run. This is of course critical if one is to achieve impact at scale. However, if our models can achieve **impact** at scale beyond our immediate study communities it is important to better understand how they fit within the larger institutional landscape.

While the formation of a Collectives Association discussed above goes part of the way to meeting this goal, achieving buy-in from external stakeholders is critical, as is the alignment of our collectives with existing programmes and institutions operating at a local level. This will strengthen the collectives themselves, while also supporting their out-scaling locally to neighbouring communities. Buy in from larger programmes meanwhile, also opens opportunities to upscale the models, so they can in the future become part of the larger policy landscape. The purpose of this section is to explore the larger stakeholder landscape in our study communities and identify opportunities for developing further linkages for the purpose of accessing institutional support, while strengthening forward and backward linkages for the collectives.

6.5.1 Mapping the current institutional context

The teams in West Bengal, Nepal and Bihar conducted site specific institutional mapping exercise to support this analysis. Further detail is available for Saptari, West Bengal and Madhubani in Project Reports 2, 3 and 4 and Appendix 2 outlines the approach followed.

Figure 43 Uttar Chakoakheti, West Bengal institutional map and Figure 44 Kanakapatti Nepal, Institutional mapping synthesise the institutional landscape for Uttar Chakoakheti in West Bengal, and Kanakpatti, Nepal, project sites respectively. Green signifies institutions with which strong linkages are already established, blue signifies existence of linkages but with room for strengthening and red signifies weak or non-existent linkage that needs to be strengthened for future work. Thus far progress has been made in strengthening linkages with key local government institutions such as the rural municipality in Kanakpatti, Nepal, and government bodies such as NABARD in West Bengal. This sits alongside the larger 'institutional spine' provided by the collectives association – the Farmer Group Association in Nepal and Farmer Producer Company in West Bengal. However, links with certain stakeholder require further development – including private sector players such as banks or insurance companies, as well as landlords themselves in the case of Saptari, who have yet to come on board. The latter are particularly important stakeholders, as outlined above, and bringing them on board as new linkages are developed will be important.

6.5.2 Collectives and Government Linkages

By far the most important institution is that of local government agencies. In Nepal the new Federal governance structure is taking shape, and local government institutions are evolving rapidly. This presents a unique opportunity for Nepal to integrate collective farming models in local level policy and planning which are in formulation process. For example, the newly formed rural municipalities bring together multiple line agencies, and develop their own agricultural policies using a budget allocated by the centre. There is considerable potential to advocate to include our collective farming models within their plans, offering outstanding opportunities for local level out-scaling.

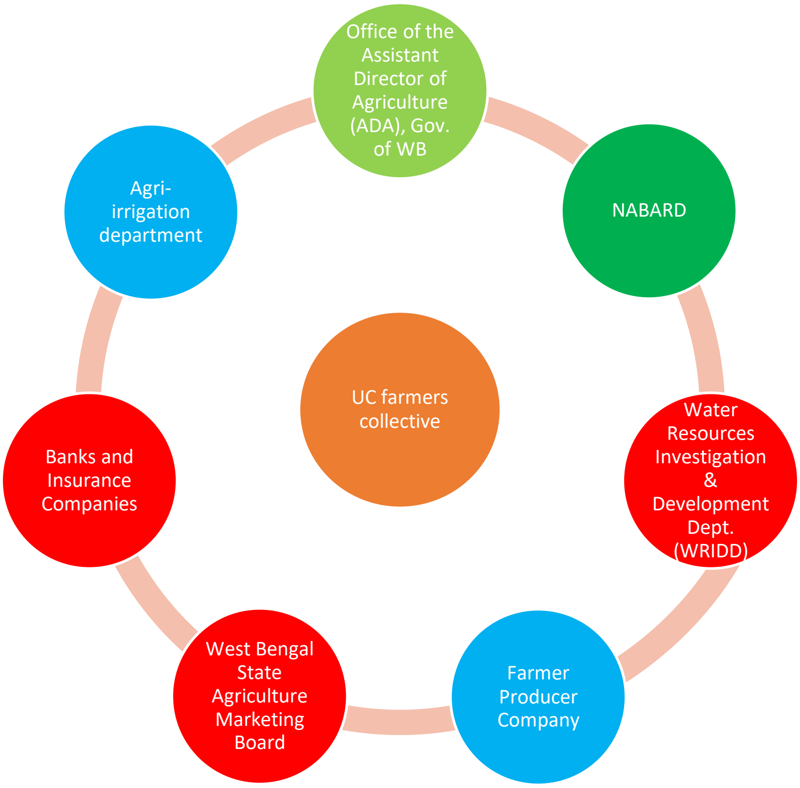

Figure 43 Uttar Chakoakheti, West Bengal institutional map

At a district level, key line agencies include the Krishi Gyan Kendra (KGK) which was the District Agriculture Office prior to restructuring. The KGK is an agricultural knowledge center established to demonstrate new agricultural technology and promote technology transfers. In the first year, focus was on supporting farmers through agri-machinery support such as thresher, rice harvester, power tiller and irrigation equipment. In the second year, the focus shifted to commercial farming and promotion of new crops. The focus of this year is on farmer groups, and is thus conducive to our project aims. Strong link with KGK can help sustain collectives after project ends with support in capacity building, agricultural extension services and subsidies. ToT (Training for Trainers) to a few farmers from collectives can help to expand KGK's skill transfer and agricultural support services more efficiently. The area covered by the KGK – namely Rajbiraj, Saptari and Siraha comprise a majority of marginal and tenant farmers. In this context, KGK has the potential to share the collective approach with other farmer groups in forming new groups thereby potentially offering opportunities for upscaling. This can be done through exposure visit of farmers to project intervention area. There are persisting challenges though, including the lack of coordination with rural municipalities, and limited staff. A priority for future work would be to organise consultation meetings bringing KGK, Rural Municipalities, wards, DSI4MTF collectives and other farmers groups together.

In Indian sites of Bihar and West Bengal, where the local governance landscape is more established, strong linkages should be developed with the Block Development Office (BDO), which fulfils a similar role to the rural municipalities. There is also considerable opportunity for institutionalizing the collectives through the wide range of state-run programs available locally.

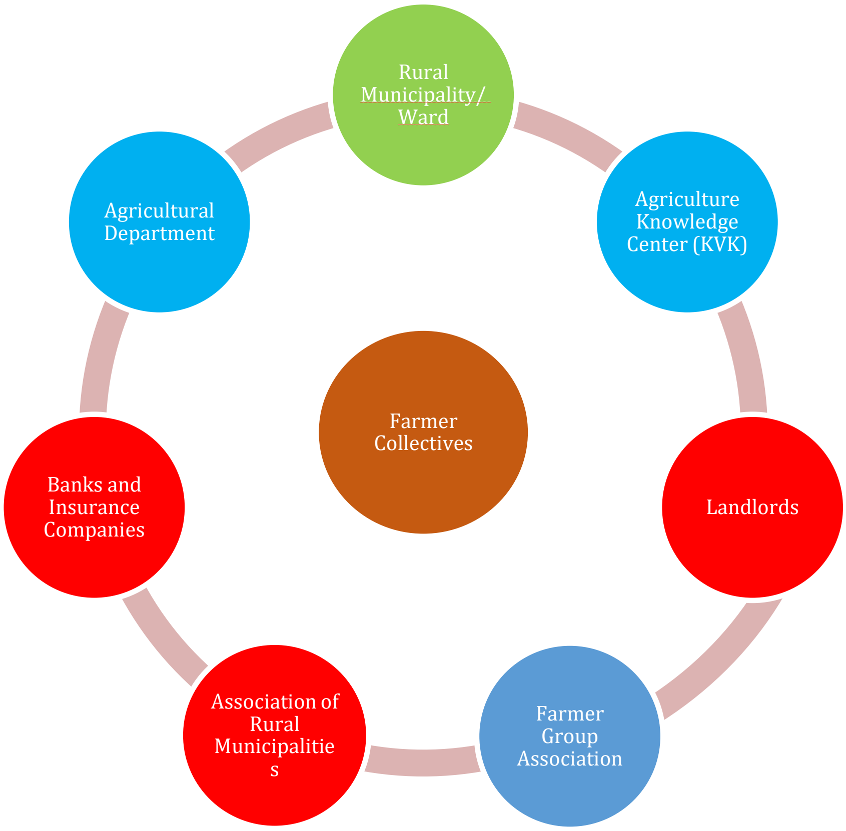

Figure 44 Kanakapatti Nepal, Institutional mapping

In Uttar Chakoakheti and Dholaguri, the Govt. Of West Bengal, Office of the Assistant Director of Agriculture (ADA), is one of the key local line agencies for agricultural support. They assist farmers with accessing seeds, fertilisers, medicines, and farm machinery while offering training on seasonal crops. A good linkage has already been cultivated with the office. Moving forward, a number of steps are required to ensure ongoing support. This includes reporting regularly on the progress and problem faced by the farmers, maintaining records of the distribution of inputs by the office and sharing records of crop output and income. Other important agencies in both Bihar and West Bengal include the Agricultural Technology Management Agency (ATMA). In West Bengal it has provided assistance through offering mini kits for boro paddy for farmers, and training on apiculture including bee box, and the Krishi Vigyan Kendra (KVK), which in West Bengal has offered skill based training on vermicompost, and support in provision of seeds.

Given that there are multiple often overlapping agencies and parallel programmes, coordination of a central institution will be important going forward – namely the collectives association, which takes the form of a Farmer Producer Companies in West Bengal, and the Kishan Sangathan's in Bihar. They play a key role in linking groups with different agencies and negotiating on their behalf, including the handling of paperwork.

Beyond the government, there are also private sector institutions which can also open up opportunities for the collectives. For example, in Madhubani, Agri-evolution (De-Haat) is a start-up company which provide services to farmers from seeds up to marketing of their produce, while offering hand holding support to rural entrepreneurs. The collectives could potentially sell their produce directly to the company, while also accessing quality planting materials. There are challenges, such as the need for a larger volume of business with more collectives for this to be profitable. Again, the collectives association is likely to play a critical role in expanding the number of collectives.

There are persisting challenges to overcome as groups seek to expand their linkages with government stakeholders. For example, there was concerns amongst our project teams in West Bengal and Nepal that successful partnerships are often mediated by strong relationships with key staff, and when they move on or are transferred, these relationships sometimes break down. For example, bureaucrat positions usually have certain rotation periods requiring them to move at certain intervals from stations to stations. Linkages can be sustained through official mechanisms such as registration of groups and collectives and signing of MOUs. Engagement with block level agricultural section through periodic site visits can also benefit farmers in accessing information about available government schemes and building enduring contacts. Such site visits will facilitate linkages at the institutional level rather than being limited to a personal level.

There are also practical challenges for farmers to link up with agricultural departments and government service centres, particularly if they are far away and not easy to reach, particularly for women farmers. Some of the farmer groups have encountered challenges in complying with often protracted government procedures and complicated forms. Lack of information can exclude farmers from available services and support. The collectives association here may play an important facilitating role. It is also hoped that accessing subsidies or services through the collectives association, as legal entity, will help overcome the challenge posed by tenants, who often lose out from support due to the lack of land ownership or other papers.

Importantly, it is critical for our collectives to harness linkages with government or non-government agencies, not only to support the scale-ability of the interventions – but also to engage actively with stakeholders, so that the models, or elements of the models can be replicated elsewhere – an important element of ‘up-scaling’. Aside from a series of stakeholder workshops and meetings throughout the SRA period to highlight the key learnings of the research, some more formal knowledge exchanges took place, such as with the World Bank funded West Bengal Accelerated Development of Minor Irrigation Project (WBADMIP), as outlined in the case study below, whereby our community engagement approach was influential in their project design.

Case Study 9: Scaling Engagement approaches for collectives: Learning from WBADMIP

Learning from the DSI4MTF has been used by an international project located in the same region. West Bengal Accelerated Development of Minor Irrigation Project (WBADMIP) is a World Bank supported Government of West Bengal managed project which aimed at effective implementation of minor irrigation using Water Users Associations. DSI4MTF’s learning were crucial and an interaction began involving DSI4MTF, another sister project under ACIAR and the local organisation CDHI on the one hand and WBADMIP on the other. A series of sharing activities followed including literature, reports, research findings and the same. What struck WBADMIP was our approach of engagement – the Ethical Community Engagement (ECE). The theme of DSI4MTF and WBADMIP were similar – bio-physical, agronomical and social sciences. This was considered an opportunity to scale the engagement approach to WBADMIP. CDHI has been facilitating the engagement approach with the WBADMIP. Although the collaboration is recent and new, we have the initial insights:

- ECE has helped the project mobilize farmers and reflect around the collective’s goals, vision and normative structure which used to be an issue pre-collaboration,
- Some of their existing groups have modified their functioning and have achieved stronger cohesion among the members with synergy,
- Water management efficiency seems to have improved as the engineers and farmers have started taking interest in each other-valuing their endowment. ECE does as has been shown earlier,
- New groups are being formed using the ECE approach and it has created impact on the existing collectives in the area,
- Encouraged by the effectiveness of ECE approach, as used under DSI4MTF, WBADMP is implementing the approach in other regions as well result of which seems promising.

6.5.3 Engagement with the private sector

Another important field for private sector engagement is crop insurance. Project sites are flood prone, and marginal farmers are disproportionately affected. Since, it is difficult for marginal and tenant farmers to obtain insurance for crops in smaller land plots, any umbrella organisation associated with collectives can facilitate group crop insurance. Therefore, linking public and private insurance company's collectives associations will insure crops collectively to minimize risks. For instance, Shikar Bank is Nepal offers agricultural insurance in Nepal for certain crops in different parts of Nepal. Linking collective farming to such schemes can protect farmers against crop damages.

One of the components for collectives to function well requires establishing and maintaining effective value chain. In future work, working with a broader range of stakeholders at different stages of the agricultural value chain is important to understand relation between farm productivity and farmer livelihoods on one hand and capture implications of collective farming on the other. Strengthening linkages with value chain actors such as banks, agronomic equipment suppliers, agrovets should be pursued.

Some approaches such as commercial pocket approach in Saptari site of Nepal have potential to bridge producer to consumer cycle and could potentially be piloted in other Indian sites. The fundamental aim of the CPA is to increase farmers' incomes, enhance food security and nutrition and improve communities' abilities to resist stresses and shocks. It also lends opportunities to enhance social cohesion though shared experiences and strengthens existing social networks. iDE began to develop and implement the CPA in Nepal in 2003 and has continued to de fine and adapt the approach since then. Key elements of the approach include the creation of a group or 'pocket' of farmers organised through a Marketing and Planning Committee that have time/resources to re-evaluate their production varieties and methods, with an external provision for technical advice and capacity building support. Collection Centres (CCs) are developed to link farmers to traders, provide pricing information, sales outlets and opportunities

An important element is the Community Business Facilitator (CBF), an entrepreneur based in rural communities who earns the commission on the sale from the agro-input suppliers and retailers. The CBF acts as a last mile supply chain actor to bridge the input supplies gap between the private sector and farmers. CBF provides appropriate and required input supplies demanded by farmers at a farm level and also provides in-situ technical guidance, some insect pest and diseases diagnosis and recommendation to improve the agriculture production and income of the farmers. CBF could be complementary volunteer or paid worker in agriculture extension services for training, capacity development, implement of better agriculture practices.

6.6 Impact of COVID19

Given the high dependence of all three of our field sites on seasonal and longer-term migrant labour to supplement fragile livelihoods, the COVID19 pandemic has unleashed an unprecedented crisis. Millions of migrants have lost their jobs due to economic collapse or lockdowns in receiving regions, while restrictions on mobility have closed down the migration routes on which these livelihoods depend. This is paralleled by significant return migration of workers who have lost their jobs, a trend which is likely to amplify in the months ahead (Dandekar and Ghai 2020).

Interviews conducted remotely with the teams pointed to new challenges as a result of the crisis. In the short term, local level wage labour opportunities have dwindled. For example, members of the Dalit group in Kanakpatti have lost their wage labour income sources due to restrictions on movement. In the long term there is likely to be significant return migration due to recession in migrant receiving countries and in Indian urban centres.

Aside from the loss of remittance and wage labour income, there were also challenges facing agricultural production. In Saptari for example, there has been a collapse in the market for vegetables, a core intervention of the project. Farmers could not sell their vegetables in local markets or Haat Bazaas due to lockdown. A few farmers sold vegetables to the local traders and consumer but at very low price. In terms of input supply, all the agro-vets and input suppliers were closed during the lockdown, so the farmers could not purchase inputs and fertilizers on time, and there is a shortage of inputs and fertilizers in the market. There were also worries about an increased culture of alcohol consumption by men during the lockdown, and concerns over the education of the children, particularly when parents are busy in the fields all day and schools are closed.

In West Bengal, the lockdown which coincided with the end of the rabi season, was a challenge for farmers. While all crops were harvested and almost 70% sold, marketing was challenging. While most potato fetched a good price, some was damaged. This was because while some could get it to the cold store, others were obliged to keep it in their house until the first ‘unlocking’ took place, resulting in some damage. It was not possible to sell crops such as chili and brinjal during the lockdown, and this was consumed by the group.

Farmers also faced problem of purchasing paddy seed and other inputs as most of the retail shops were closed. The quality and price of the seed had to compromise. But farmers could plant jute and monsoon paddy on time. The collective initiatives and irrigation systems supported a lot during this challenging situation.

Accessing labour was a challenge during the lockdown, and in West Bengal in May, there were challenges to harvest the boro paddy. Fortunately this was easier for the collectives who were pool labour than the individual farmers, as they were able to mobilise all the members of the group when needed for harvest and share the burden – and did not need to depend on workers from outside to help.

On a positive note, as lockdowns were eased there has been a reduced workload for women due to the support of male family members who may previously have been working outside. In Madhubani, labour was also more easily available to help on the farm. There has been no impact on regular farmer meetings. Farmers conducted regular group meeting and saving as usual in the village. There has been increased farm activity such are cultivation of paddy on some fallow land, as well as reports of increased social interactions, social cohesion and labour sharing between the farmers in the farm activities. The availability of labour means there has been a timely cultivation of monsoon paddy by all farmers. This benefit was also felt in West Bengal after the initial unlocking, whereby many migrant workers returned from the cities. This has created challenges though as some labour has been exploited by being paid less than the market rate. Moreover, female labours who were working from decades losing the work as few many new youth labour is now available at low cost.

Looking forward, in terms of longer-term impacts, there may be some changes in migration patterns in the months ahead. Those who were planning and processing their visa for overseas in Saptari have changed their mind due to uncertainty of job due to the COVID19. The models proposed through DSI4MTF will be critical in the post COVID19 era, whereby the ability of migrant labour to act as a ‘safety valve’ for agriculture has been called into question. In West Bengal, already migrant labour and youth farmers are also showing an interest in joining the collective groups and farmer’s producer organisation in both villages. It is thus more critical than ever before to address the fundamental structural barriers to agricultural intensification, which our project has aimed to address.

The collectives have also helped bolster household resilience during the COVID19 lockdown. In West Bengal for example, the collectives offered a valuable income source as outside employment opportunities in the forest economy dwindled following the lockdown. While there were some challenges purchasing inputs on time, collectivisation has made this process easier, while also supporting marketing. While the price for some crops had dropped, others such as potato fetched the groups a good price during the lockdown. Being in collective the amount of individual loss when this occurred, was shared among all members.

The farmers also felt that the groups enhanced their mental health during the crisis. The collective groups created awareness for safe work in maintaining social distance. They are helping each other in managing agriculture inputs, labour, finance etc resulted in monsoon paddy cultivated by all farmers and no fallow land remained in this season.

Case Study 10: Role of rural municipalities in scaling and strengthening collectives in Nepal

Rural Municipalities (RM) can play a pivotal role in the sustainability and scaling of farmer group collectives in Nepal. Following the creation of municipalities as local governing bodies through Nepal Constitution of 2015, the municipalities have the authority to formulate policies and enforce them. They will play a key role in the future in mediating access to different government programmes and support for the collectives, as outlined in the mapping below:

Figure 45 Institutional mapping for rural municipalities in Nepal

Opportunities and challenges:

There are several ways in which the rural municipalities can support farmers. Subsidies provided by the municipality can open opportunity for support for collective members. For instance, 50% wheat seed subsidy was provided to 138 farmers in this fiscal year which had a budget of 1.59 lakh. Furthermore, 80 sacks of seeds were distributed. Furthermore, there are 2 agricultural officers and 1 technical assistant in the municipality. They should be engaged with to facilitate access of rural farmers to government support and opportunities to advocate for policy change at a local level. Farmers can easily reach out to the agricultural officers due to close proximity of agricultural support. This will help farmers to access information on agricultural support offered by the section

Case Study 10: Rural municipalities in Nepal, cont…

There are however challenges, such as the lack of human resources at in the rural municipality which makes it challenging for agricultural section to get approvals for finalization of drafted agricultural programs and budget. There is one officer and accountant to manage programs drafted by all the section of RM. Consequently, there are delays. The agricultural section which is responsible to look after agricultural development of entire municipality only has 3 staffs. So, it becomes challenging for limited staff to support the needs of 12 wards. They also have not received trainings in the past 2 years. so, they lack up to date information on new agricultural technologies and approaches. Agricultural programs are also not targeted but scattered. The programs are formulated in piecemeal basis lacking integration thereby diffusing the impact, and they are often focused on infrastructural development. There is limited coordination of RM with other important agricultural agencies such as Krishi Gyan Kendra. This could result in duplication of agricultural support in some areas while no support in others.

Ways forward:

There are several immediate ways forward in terms of engagement in future work. A consultation needs to take place with the rural municipality office, on the benefits of collective farming approaches to address agricultural challenges such as land inequities and limited agricultural investment capacities of farmers in Saptari. There is a need to advocate for approach in their policies, annual plans and budget through workshop and exposure visits. This includes engaging at a ward level to ensure that the collectives are recognized in their annual programs submitted to the Rural Municipalities. It is also important to harness interest as it arises. For example, the Koiladi rural Municipality chair is interested in promoting collective farming by bringing in marginalized group to cultivate currently unutilized riverside land. This is a great opportunity to promote collective farming approach while addressing limited land availability issue for marginal and tenant farmers. They can also be approached to discuss the possibility of introducing new ideas such as a land bank, to assess whether it is practical. In terms of higher level impact or upscaling, there is potential to engage with the Association of Rural Municipalities situated in Kathmandu to promote collective approaches to agricultural production.

7 Opportunities for scaling water management and collective farming approaches for marginal farmers: A proposed integrated package

The smart irrigation toolkit (SIT) comprises a suite of tools and processes to improve on-farm irrigation performance and resource management, including hardware, software, and training (Chapter 5). Appropriate institutional arrangements to support deployment of SIT are essential and form part of the scaling challenge, and indeed the innovation (Chapter 6)

While in the previous chapter we discussed how the socio-economic learnings can be packaged via appropriate institutions serving farmers, including potentially a network of Collectives Associations (CA), this chapter discusses how our biophysical learnings can be packaged and supported as a Smart Irrigation Toolkit (SIT). Ultimately a pilot project is required to assess the important factors critical for successful scaling, including the integration of approaches with organisations responsible for irrigation development, who have mechanisms to ensure financial and social sustainability.

Deployment of the Climate Smart Irrigation Toolkit (SIT) would be by a trained project or government officer, water user association representative, irrigation system supplier or consultant, preferably as part of a broader irrigation development project. It is proposed that the Collectives Associations be scaled alongside the SIT as an integrated package. This is critical because the Collectives Association would enhance the effectiveness of the SIT roll out, given the challenges of training and technology access amongst the poorest farmers. The association could take responsibility for administering water management and technology assessments for the individual collectives or could coordinate the interactions with other institutions deploying SIT.

This section focuses on the SIT, with a view to scaling the innovation either independently or via the Collectives Association as an integrated package. The potential for scaling the innovation was assessed using two approaches, USAid's Agricultural Scalability Assessment Tool and CIMMYT's The Scaling Scan. Based on this it is recommended that a pilot project to build awareness, create a critical mass of demand, and provide training and technical support in association with key institutions is required.

7.1 Background

DSI4MTF sought to improve water use for dry season agriculture for marginal and tenant farmers in the Eastern Gangetic Plains through technical and institutional innovations. The project evaluated, at local plot scale, a range of climate smart irrigation approaches for improving irrigation practice (Chapter 5), introduced through a network of farmers, or collectives. DSI4MTF was not specifically designed for scaling improved irrigation and group farming practices, with the focus being on the piloting and assessment of these innovations. This SRA has gone on to scope the scaling opportunities and constraints while at the same time continuing to support the local farmer collectives and NGO's established under DSI4MTF. Chapter 6 focussed on the scaling challenges for the farmer collectives. It explored the possibilities of enhancing the sustainability of the models (scaling deep), while scaling them up and out, with the support of Collectives Associations, which are in turn linked up with wider stakeholder networks.

This section focuses on the scaling opportunities for the Smart Irrigation Toolkit (SIT). However, importantly, it includes the possibility of using the Collectives Association as part of the scaling model, as part of an integrated social and technical package, although the opportunity for SIT to be scaled separately is also appropriate.

While DSI4MTF relied on ACIAR project funds, scaling of the SIT will require strong partnerships with organisations prepared to invest in the roll out of the approach. A phased approach is envisaged with initial government support, followed by ongoing input from the private sector and agricultural service providers. As a proposed integrated package, the SIT will depend on strong local institutional structures such as the Collectives Association, although other grassroots organisations such as Water User Associations could also be mobilised.

Scaling the SIT, would also be supported by strategic collaborations between the project team and agencies who have an incentive to scale through their irrigation implementation programs. Scaling is complex, extending the typically technology-focused approaches to the softer elements including people, power relationships and incentives (Woltering et al 2019). DSI4MTF successfully pursued transdisciplinary approaches to introduce improved irrigation management practices to marginal farmers through collectives (Schmidt et al 2019). Lessons learnt at this local village level now need to be extended and embedded in organisations responsible for irrigation implementation programs.

Scaling will need to consider the organisational and institutional processes delivering irrigation expansion. Supply chains, markets, financing mechanisms, policies and regulations, and professional knowledge all need to scale in a sufficiently coherent and interrelated way to make scaling of a technology possible (Jacobs et al., 2018; Sartas et al., 2017).

This chapter discusses these scaling opportunities by first considering the innovation to be scaled and then considering adopters and beneficiaries, and appropriate pathways for scaling. An integrated pilot project designed for scaling is proposed in Chapter 8.

7.2 The innovation

The innovation to be scaled comprises a suite of tools and processes (the Smart Irrigation Tooklit) to improve on-farm irrigation performance and resource management through the premise of ‘measure to manage’. Appropriate institutional arrangements to support deployment of SIT is essential and forms part of the scaling challenge, and indeed the innovation.

SIT supports evaluation of the performance of an irrigation system, and monitoring of local water resources, such as groundwater and pond water. Application of SIT helps reduce water losses and improves water use efficiency, increases crop production, and improves energy use efficiency. SIT supports local monitoring of groundwater and pond water resources to assess supply constraints and plan irrigation strategies.

The Collectives Association, comprising a small network of farmer collectives, will be important to enhance the effectiveness of the SIT when deployed for marginal farmers. It would considerably increase the feasibility of technology adoption, by allowing marginal and tenant farmers to achieve economies of scale in investments and marketing which wouldn’t be possible for individual farms, while offering farmers a large contiguous plot which make irrigation investments more feasible, while also improving water use efficiency.

7.3 Adopters and beneficiaries

Deployment of the Smart Irrigation Toolkit (SIT) would be by a trained project or government officer, water user association representative, irrigation system supplier or consultant. Some elements can be implemented by the farmer (eg groundwater monitoring) independently.

As an integrated model, the SIT can be supported at a local level by the Collectives Association, with the core members of the association taking training, and implementing SIT assessment and monitoring on the contiguous plots farmed by groups, on behalf of all the members. This is significantly more practical than training farmers independently.

There are several pathways to scaling. It could be rolled out via a network of Collectives Associations as an integrated project. However, it could also be deployed as a standalone intervention, ideally as part of a broader irrigation development project. In this context, SIT could be implemented as part of the initial commissioning of a new scheme and then at regular intervals (eg annually) to inform maintenance, repairs and optimal performance. SIT could be broken into sub-elements (e.g. just groundwater monitoring or just pump set evaluation) which would segment the user market. Key adopting organisations are likely to include irrigation development agencies and funders, scheme operators and managers, government irrigation organisations responsible for agriculture and water development and water user associations (WUA's). Farmers would benefit from reduced water loss, lower energy and operating costs, better yield and higher profits. Investors and project developing agencies would benefit from better performance of infrastructure, improved system sustainability, and information to prioritise system maintenance and repairs. SIT is most applicable for dry season irrigation of higher value crops, when water is limited, volume pumped is high and the cost-benefit of improved irrigation practice is greatest.

Actors and organisations in the adoption value chain for SIT could include:

1. Funder: Donor for an irrigation project (eg World Bank, FAO, ADB, DFAT, AWP, ACIAR)
2. Implementing Agency: Government agency responsible for irrigation and agricultural development, at both State and Central Government (eg ADMIP in West Bengal).
3. Irrigation scheme designer, installer and contractors and equipment supply companies in the case of a new development.
4. Agency responsible for irrigation scheme management and service delivery. This could be a local government department, private sector representative or agent for the implementation agency. It could also include the Collective Association as part of an integrated project, or a Water User Association, with both institutions representing the end users.
5. Organisations supporting engagement with farmer communities (e.g. NGO’s for community engagement and training)
6. Private company packaging SIT technologies for commercial delivery.
7. End users, typically farmers and irrigators.

External institutions that support farmer collectives and scaling with regards to the Collectives were discussed in Section 6.5. Specific institutions that align with the scaling of SIT approaches identified by Partners have been discussed in Appendix 3 and include:

- Saptari: Farmer group associations, agricultural knowledge centre (KGK), rural municipalities, commercial pocket approach for supply chain integration and collection centres.
- West Bengal: Government of West Bengal through the assistant director of agriculture and water resource development departments and their various directorates, agricultural technology management agency (ATMA), National Bank for agricultural and rural development (NABARD) and farmer producer companies (FPC).
- Bihar: Central, block and district government agencies through their agricultural offices, service supply companies, including start-up companies like (De-Haat), agricultural knowledge centres (KVK’s), agricultural technology management centre (ATMA).

7.4 Potential for scaling

A number of tools and frameworks have been developed to assess potential for scaling (Woltering et al 2019). USAid's Agricultural Scalability Assessment Tool (Kohl and Foy, 2018 - https://www.agrilinks.org/post/guide-agricultural-scalability-assessment-tool) and CIMMYT's The Scaling Scan (Jacobs et al 2018 - https://www.cimmyt.org/news/scaling-scan-a-simple-tool-for-big-impact) provided the basis for this assessment.

7.4.1 Agricultural Scalability Assessment Tool (USAid)

The potential to scale the smart irrigation toolkit and training program is summarised in Table 11, based on the criteria presented in USAid's Agricultural Scalability Assessment Tool. Key messages are summarised below, which suggest that while there is good potential to scale the Smart Irrigation Toolkit (SIT), appropriate business cases are required. These need to be developed in association with irrigation scheme implementation agencies, as well as with organisations supporting farmer communities.

Importance of the issue SIT addresses

There is a clear alignment between on-farm irrigation monitoring using the SIT concepts and improved water and energy management, leading to increased crop production and poverty alleviation for marginal farmers. SIT, particularly when scaled alongside the Collectives Associations, align strongly with UN Sustainable Development Goals and ACIAR high level objectives. The scale of impact from introduction of SIT would be large, potentially across multiple countries and irrigated cropping systems. Impact and scaling are likely to be greatest where there is a central organisational responsibility to improve irrigation performance, with a return for both farmers implementing agencies and service delivery institutions.

Credibility and observability of SIT with key stakeholders and adopters

The need for improved water management and associated monitoring and evaluation is recognised by most government agencies and water supply authorities. This generally pertains more to the bulk water supply infrastructure and less consideration is given to the in-field infrastructure. However, the execution of monitoring programs is often poorly coordinated. Improvement in water use efficiency and productivity, and equity using SIT and Collectives Associations is easily demonstrable to farmers and advisors based on simple field measurements, assessment tools and qualitative engagement. The observability of the SIT can be significant through improved production. Converting this into an economic impact for the farmer and irrigation distributor is not as easily assessed. Better evaluation and case studies for this is required.

Ease with which SIT can be tried, purchased, adopted, and implemented effectively.

There is a reasonable level of complexity in SIT owing to the need to use measuring equipment, processes and training, which may limit adoption. Technical support, training and extension systems are often limited for small scale farmers, and thus the collectives association will be critical to address these challenges for marginal farmers. There will however need to be institutional and economic incentives for government and private sector agencies to develop capacity to deliver SIT, ideally supporting the Collectives Associations in the process, and realising the irrigation performance gains. Fortunately, the approach can be trialled at a small scale with limited investment and readily refined and repurposed for broader implementation.

Potential benefits or business case for potential adopters

Improved irrigation practice following monitoring and management will result in increased cropping intensity, yield and profitability under a wider range of new crops. Better water management results in reduced losses of water and fertilisers as well as reduced pumping costs. When combined with the group farming approach via the Collectives Association, the practicalities of implementing the new technologies would also be facilitated due to the cultivation of a contiguous plot, not to mention the role of the Association in facilitating training and access to technical support networks. The costs of implementing SIT reduces as the scale of implementation increases. Thus, employment of a project officer to provide SIT services would be most cost effective when deployment is part of a large scheme with many beneficiaries.

Business case for value chain actors and strength of the overall market system

Last mile delivery to marginal farmers is frequently a point of failure. Support in the delivery of technology via the Collectives Association as part of an integrated project therefore will be more feasible. However, the delivery of the SIT can also be facilitated if it takes place as part of a larger government programme, through government agencies, through extension support, or the private sector once the business case has been demonstrated. In the private sector, best fit is likely with an irrigation supply company who could provide SIT services as part of their supply/install/replacement program. Demand for SIT will vary depending on the irrigation district, systems deployed, cropping and organisational arrangements.

Public sector enabling environment to support commercial scaling

The public sector has a key role to support the scaling of SIT, especially in the early phases and during a pilot project. Alignment with irrigation and agricultural department functions would establish a program for deployment of SIT and demonstration of business case as well as assess alignment with policies. Again, the Collectives Association can play a key mediating role.

Table 11 Agricultural scalability assessment matrix

Group	Issues Covered	Research, Policy and Project Design Issues
A	Importance of the issue the innovation addresses	There is a clear alignment between on-farm irrigation monitoring and measurement using the SIT concepts and improved water and energy management, leading to increased crop production and poverty alleviation for marginal farmers. The approaches have been demonstrated in the project DSI4MTF working with collectives of marginal farmer's, 60% of whom were women. There is also clear evidence of the collective approach in improving the feasibility of technical interventions, in a region where around three quarters of farmers are either tenants or own less than 0.5ha with marginal scattered plots. Documentation is provided at: https://dsi4mtf.usq.edu.au/ Direct impact has been shown through increased cropping intensities (raised from 100% to >200%), increased profitability through introduction of dry season crops, better pumping efficiencies, reduced water conveyance losses, improved irrigation scheduling and better irrigation application efficiencies. The Collectives Associations, while facilitating the uptake of irrigation innovations, particularly amongst women farmers, have also supported improved bargaining power with landlords, government and market stakeholders. They have also supported a more efficient use of labour at a time of high male out-migration and agrarian stress for women. SIT, particularly if implemented alongside the Collectives Associations, aligns strongly with UN Sustainable Development Goals of zero hunger, no poverty, climate action, affordable and clean energy, and reduced inequality. It also aligns with ACIAR high level objectives of food security and poverty alleviation, natural resources and climate, human health and nutrition, empowering woman and girls, value chains and private sector engagement and building individual and institutional capacity. The scale of impact from introduction of SIT would be large, potentially across multiple countries and irrigated cropping systems, especially where there is central organisational responsibility to improve irrigation performance and return for both farmers and implementing agencies and service delivery institutions. The issue would be important to both farmers as well as local and national governments and water supply authorities.
B	Credibility and observability of the innovation with key stakeholders and adopters	The need for improved water management and associated monitoring and evaluation is recognised by most government agencies and water supply authorities. This generally pertains to the bulk water supply infrastructure and less consideration is given to the in-field infrastructure. Farmers in developing countries, as well as many developed countries, do not give consideration to irrigation system performance. Despite the impact on crop yield due to under/over irrigation and increased pumping costs with low efficiency pumps or when pumping excess water due to low application and conveyance efficiencies. This represents a barrier to adoption. Improving irrigation performance with better yields based on satisfaction of crop water requirements benefits all parties and demonstration within context of a pilot is the key opportunity. At the same time, the structural barriers to improving irrigation are widely acknowledged (Bhandari and Pandey 2006, Sugden 2014, Karn et al. 2020). Severe inequality in access to land and tenure insecurity reduce incentives for the uptake of new irrigation technologies. Meanwhile, women, who increasingly form the bulk of the agrarian workforce, face gendered barriers to accessing technologies and government support. Therefore, the benefit of SITs and the group approach, along with the larger Collectives Association, and resulting improved WUE and equity has been demonstrated for isolated system under DSI4MTF and is widely documented in the literature. There is however huge potential for wider scale piloting and demonstration of SIT as an integrated package alongside the Collectives Association, in collaboration with broader institution and irrigation implementation agencies. Improvement in WUE and equity using SIT, particularly with the support of the Collectives Associations, is easily demonstrable to farmers and advisors based on simple field measurements, assessment tools and qualitative engagement. Converting this into an economic impact for the farmer and irrigation distributor is not as easily assessed. Better evaluation and case studies for this is required.

		There is unlikely to be any opposition in the application of SIT, with or without the support of the Collectives Associations, as there are no vested interests that will be impacted.
C	Ease with which the innovation can be tried, purchased, adopted, and implemented effectively by producers (or the target adopter)	There is a reasonable level of complexity in SIT owing to the need to use measuring equipment, processes and training which may limit adoption. This is an issue in environments where adopters lack technical knowledge and where formal education levels are low. This is also a factor given SIT has a number of hardware and software components. Delivery by trained officers is therefore required. DSI4MTF effectively trained NGO staff as well as some farmers to undertake field monitoring evaluations, and the prospects of training extension and technical staff of government and other institutions should not be a problem. If implemented alongside the Collectives Association, the latter could provide a key platform for training, with representatives from each association receiving training and disseminating knowledge to the individual farmer collectives. Technical support, training and extension systems are often limited for small scale farmers, and farmers (particularly women) face practical, gendered and time constraints in accessing knowledge networks, and thus the collectives association will be critical to address these challenges. There will need however to be institutional and economic incentives for government and private sector agencies to develop capacity to deliver SIT and realise the irrigation performance gains. The cost of components in the SIT are low, however appropriate commercial models will need to be developed. This is best done initially under a funded project to pilot SIT within the arrangement of a delivery agency. This will develop and demonstrate the business case for broader adoption and institutionalisation of SIT. The training required for SIT is not intensive or extensive, it requires only basic monitoring and measuring hardware with very limited investment in equipment and infrastructure. Having measured system performance, simple changes to irrigation management can be introduced to achieve significant benefits in terms of increase in yield and profitability and improved water and energy use efficiency with reduced operating costs. The technology can be trialled at a small scale with limited investment which supports demonstration during the pilot. It can be readily refined and repurposed for local implementation. For example, just undertaking pump assessments, just assessing drip irrigation performance, just assessing channel conveyance loss.
D	Potential benefits or business case for potential adopters	Improved irrigation practice introduced following monitoring and management result in increased cropping intensity, yield and profitability under a wider range of new crops. Better water management results in reduced losses of water and fertilisers as well as reduced pumping costs. The group approach not only facilitates their uptake of improved irrigation practices, but will support them in dealing with external stakeholders to support marketing, access to land on equitable terms and access to a broader range of government entitlements. Examples of this are given in DSI4MTF project reports and Case Studies however requires a more detailed business case for adoption on a larger scale. The additional crop produced will result in a marketable surplus, and combined with improved marketing potentially via the Collectives Association, will increase farmer profitability with an ability to pay for SIT and the irrigation technologies it supports. There are also intangible benefits such as labour time savings, more efficient technologies, increased food nutrition through vegetable crops produced under better irrigation practices and environmental benefits of less deep drainage, runoff and nutrient and chemical loses. There will also be more efficient use of water when farmers operate SIT through collectives and farm a contiguous plot. The costs of implementing SIT reduce as the scale of implementation increases. Thus employment of a project officer to provide SIT services would be most cost effective when deployment is part of a large scheme with many beneficiaries. There are no equivalent technologies or approaches to compare costs against however a cost benefit could be determined. The risk to the business case is when a program of measure to manage (the essence of SIT) is implemented which does not result in practice change (eg clean the filters, adjust the pump, revise the irrigation schedule). Incentives can be provided to effect these changes when the irrigators are part of a larger managed scheme. The benefits from improved irrigation management are likely to be greatest during periods of adverse dry weather (eg climate change) and as water supplies become more limited (eg over allocation). The benefits are lower for low value crops grown

		during monsoon months or low yielding crops impacted by other agronomic factors (eg pests and disease). It is possible to implement only some components of the SIT package (eg a pump monitoring program to reduce energy costs). SIT should ideally be applied after system commissioning and on a regular basis (annual) to ensure good performance and inform maintenance and repairs.
E	Business case for value chain actors and strength of the overall market system (this applies primarily to commercial pathways)	Last mile delivery to marginal farmers is frequently a point of failure. The volume of production is small, profits are low, and service providers sparse. Support in the delivery of technology via the Collectives Association therefore will be more feasible. However, delivery of the SIT can take place as part of a larger government programme through government agencies, through extension support or the private sector or WUA's is possible once the business case has been demonstrated in a pilot. The evolution of the collectives associations to form Farmer Producer Companies and support Commercial pockets with community based facilitators also provides an opportunity. In the private sector best fit is likely with an irrigation supply company who could provide SIT services as part of their supply/install/replacement program. Further discussions with such companies are required. In many cases these companies are diversifying into supply of other agronomic inputs (eg fertiliser and chemicals) with associated advisory and testing services which could be complementary. Demand for SIT will vary depending on the irrigation district, systems deployed, cropping and organisational arrangements. Modification and refinement are therefore likely to vary to some extent depending on the target (region/area, farmer demographics, organisations serving them, supply and market systems).
F	Public sector enabling environment is in place that supports commercial scaling (this applies primarily to commercial pathways)	The public sector has a key role to support the scaling of SIT, especially in the early phases and during a pilot project. Alignment with irrigation and agricultural department functions would establish a program for deployment of SIT and demonstration of the business case as well as assess alignment with policies. Again, the Collectives Association can play a key mediating role. Public sector financial incentives could also be provided to improve the business case for farmers (or collectives), especially in early phases. Scheme wide savings would also potentially be realised through farm level system improvements, through for example rationalising bulk irrigation infrastructure and reducing system pumping costs). Commercial sustainability would be realised once a business case is demonstrated allowing entry of private sector service providers. There would be no requirement for regulatory or licensing approvals. Generally, standards for best practice irrigation system performance are available in government agencies and are reported in the literature. Running scheme wide programs would allow integration of data for regional benchmarking and performance assessment using the smart phone tools and apps used to collect data. There would be a need for training and technical support as the capability of extension and technical support services is sometimes quite poor with poor geographical coverage and accessibility and infrequency of visits. Notwithstanding the public-sector would have staff with necessary skills and technical abilities. Knowledge and budget would likely be small when considered against capital investment in irrigation schemes. Government agencies already provide a range of other related agronomic advisory services which could be seen as complementary.

7.4.2 The scaling scan (CIMMYT)

The Scaling Scan is a process developed by CIMMYT (https://www.cimmyt.org/projects/scaling/) to help identify the strengths and weaknesses in scaling an innovation. Scaling the smart irrigation toolkit (SIT) was assessed against the ten scaling ingredients listed below. The ingredients represent ten different areas that need attention for scaling to be successful (Figure 46 Areas to consider for scaling to be successful.

1. Technology/Practice - An effective and efficient solution for the issue at stake
2. Awareness and Demand - A wish and readiness for the consumer or producer to use the solution
3. Business Cases - Attractive financial/economic propositions for users and other actors to respond to the demand
4. Value Chain - Effective links between actors to pursue their business cases
5. Finance - Effective financing options for users and other value chain actors
6. Knowledge and Skills - Capacities at individual and institutional level to use, adapt and promote the innovation
7. Collaboration - Strategic collaboration within and beyond the sector to scale the innovation
8. Evidence and learning - Evidence and facts underpin and help gain support for the scaling ambition
9. Leadership and Management – Effective coordination and navigation of the scaling process
10. Public Sector Governance – Government support to reach the scaling ambition

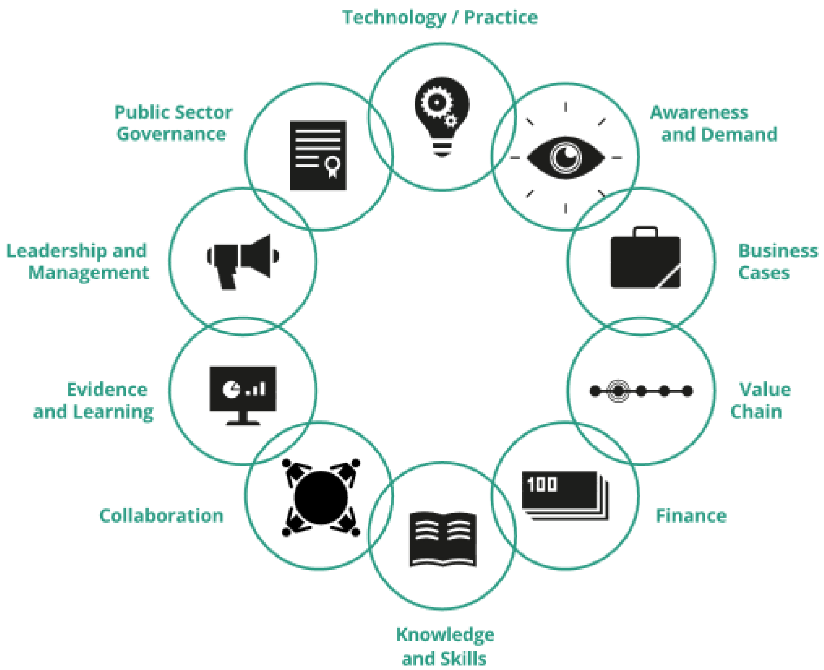

Figure 46 Areas to consider for scaling to be successful

The project team considered four questions that probe into the key drivers for reaching scale within each of the ten scaling ingredients, and scored their level of confidence in scaling capability using the ratings below.

1. No, this is very uncertain or not enough information to answer
2. Serious doubts
3. Some doubts/unsure
4. Quite confident
5. Yes definitely, this is not an issue for my scaling case OR not applicable

Results are collated in the graphics below. A more detailed assessment of each area is provided in Project Report No 5.

Table 12 Overall rating across ten scaling areas and individual questions informing each scaling area

	Overall score
1. Technology/ practice	4.1
2. Awareness and demand	3.7
3. Business cases	2.3
4. Value chain	2.6
5. Finance	3.3
6. Knowledge and skills	3.6
7. Collaboration	3.6
8. Evidence and learning	4.1
9. Leadership and management	3.8
10. Public sector governance	3.0

	Question 1	Question 2	Question 3	Question 4
1. Technology/ practice	4.7	4.2	3.8	3.7
2. Awareness and demand	3.8	3.0	3.5	4.3
3. Business cases	2.0	2.0	1.7	3.3
4. Value chain	3.5	2.0	2.8	2.0
5. Finance	3.3	3.0	4.7	2.3
6. Knowledge and skills	3.0	3.3	3.7	4.5
7. Collaboration	3.2	4.0	4.3	2.8
8. Evidence and learning	3.2	4.7	4.3	4.3
9. Leadership and management	3.7	4.0	3.3	4.0
10. Public sector governance	3.2	3.7	2.3	2.8

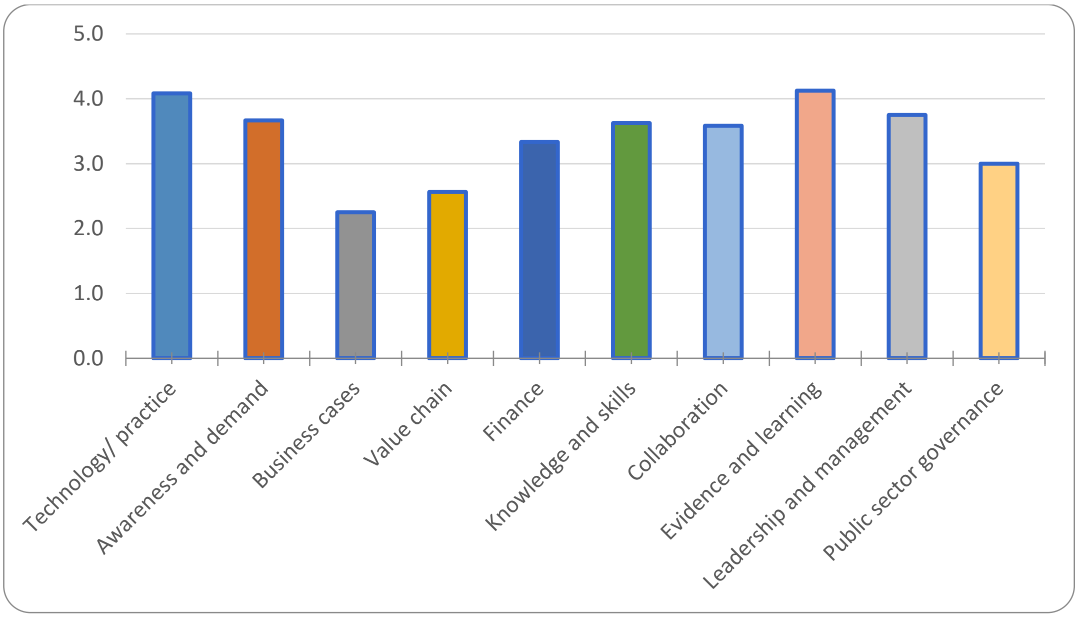

Figure 47 Graphical representation of overall scaling ratings

Interpretation of Results:

Average scores of three or below were calculated for three areas (Business Cases, Value Chain and Public Sector Governance), indicating uncertainty or doubts in the scalability of SIT, and the need for additional effort to overcome the challenges for effective scaling.

Scores of above three were calculated in the other seven areas suggesting some confidence in scaling potential in these areas. Scores above four were achieved for Technology and Practice, and Evidence and Learning, indicating high confidence in these ingredients.

There was some divergence in assessment of scores between participants across the areas of Business Cases, Value Chain, Knowledge and Skills, and Leadership and Management.

A summary of key strengths and challenges is provided below.

Key Strengths

a) Technology and practice [Score 4.1 (see Table 12)]

The smart irrigation toolkit (SIT) is highly relevant to the target group, who include government and private sector irrigation investors, agencies, advisors and managers of irrigation schemes, as well as both progressive and marginal farmers. There is generally strong recognition of the need for improved irrigation performance.

Improved irrigation performance and associated benefits, following measurement using SIT approaches, are achievable with relatively minor interventions and can usually be easily demonstrated. While the technology is relatively simple and can be modified to local environmental and social circumstances relatively easily, it requires field implementation by trained staff. Delivery could be facilitated considerably if it is institutionalized as part of an irrigation scheme development and implementation program. However, it could also be delivered as part of an integrated project utilising the piloted Collectives Associations as a delivery vehicle.

b) Evidence and learning [4.1]

There is useful and credible data available on the benefits of SIT and the potential supporting role played by the Collectives Association. However, this is at local case study scale from a few pilot sites. This needs to be documented at scheme level to demonstrate impact at scale. The innovation is a monitoring and evaluation concept which, while it provides useful immediate feedback to farmers, can equally give higher level detail on success of broader irrigation modernisation programs.

A key selling point is the integration of data collection using Apps and backend databases. This supports interrogation of data to assess regional or temporal trends and provide scheme and district benchmarking to inform maintenance and modernization programs.

Deployment of SIT by technical and extension staff of government agencies and farmer groups (WUA and Collective Associations) would support institutional learning and a more sustainable scaling process.

Strengths with some uncertainty

c) Leadership and management [3.8]

There are insufficient leaders and managers who could currently promote the innovation. SIT approaches are flexible and easily demonstrated and there are a range of models for deployment that can be explored. A broad scale pilot project is required to demonstrate to leaders and managers across various stakeholder groups of the importance of system monitoring and measurement and potential to improve irrigation system performance using SIT approaches.

d) Awareness and demand [3.7]

While stakeholders recognize the need for improved on-farm irrigation management, this is often overlooked with most focus placed on bulk water supply infrastructure. There is insufficient recognition of the importance of farm-scale, in-field irrigation management on farming profitability and overall irrigation scheme viability. Considering the poor level of irrigation and on-farm irrigation infrastructure management in many developing countries, tools and approaches such as SIT have an important role to play. Policy change may be required to support scaling and adoption especially in the government sector.

Better packaging of information is required in collaboration with other implementation agencies and as part of a pilot project to develop the path for scaling. While appropriate communication channels exist in the regions, through government, the private sector, local institutions and progressive farmers, training and exposure is required to exploit these.

While the benefits of improved irrigation through SIT, and the potential supporting role of the Collectives Association, is easily conveyed, there is lack of awareness of the business case as to how improved on-farm irrigation programs using the approach could be implemented.

There are different segments of the target group including farmers (or farmer collectives), extension officers and irrigation program managers and deployment would need to be tailored for local context. Appropriate components of the irrigation system can also be targeted depending on the local priorities (e.g. furrow irrigation or drip irrigation; pumping or irrigation scheduling).

e) Knowledge and Skills [3.6]

Central implementation agencies (e.g. government) generally have technical staff with the required knowledge and skills, however they generally do not focus on in-field irrigation monitoring and evaluation. Training should focus on officials from institutions who partner in the piloting program who could then train large number of on the ground field staff in further structured training programs. This would support further diffusion of the innovation beyond a pilot or program.

Appropriate training and skill development would support packaging into local program delivery. This could be rolled out by the Collectives Associations for an integrated model. There however also a range of other agencies, water user groups and local organisations involved in water management in most irrigation regions who could do this. Networks of NGO's, Government extension services already operate in this space.

f) Collaboration [3.6]

While there is a business case for each actor in the value chain (see section 7.3) it requires better documentation including, costs/benefits, organisational requirements and benefits. The roles and responsibilities of key actors may vary on a scheme by scheme basis and need to be clarified as part of a pilot scaling project.

Collaboration is often driven in irrigation scheme development by the contracting and implementation process, which defines the flow of funds and therefore opportunities to allocate resources for training, monitoring and evaluation during system commissioning and ongoing maintenance.

Establishing effective networks is best undertaken as part of the establishment of a new irrigation scheme. These networks then need to support ongoing system maintenance including the on-farm water element.

A pilot project will be crucial to identify the organisations, on a region-specific basis, that offer the most leverage into policy and develop effective links with parallel initiatives or policy processes that could serve to scale SIT.

Key Challenges

g) Business Case [2.3]

Climate variability, water shortage, energy costs, lower profits are all drivers for improved monitoring and measurement leading to improved practice change. A simple set of tools and processes to achieve this is timely. Regulation and governance are likely to result in increased focus on water use efficiency, driven by climate change and environmental impacts. While this creates opportunities for SIT, a strong business case still needs to be developed. This is best done as part of a broader irrigation development program with enough scale to demonstrate opportunities to all actors.

While it is expected that most value chain actors (e.g. farmers, service providers and irrigation scheme developers/managers) would benefit from improved on-farm irrigation management and adoption of SIT, and that there are both economic, social and environmental benefits, clear business cases still need to be developed. While a relatively low-cost process, consideration needs to be given to who should pay for system evaluations and how they should be funded. The role of the private sector and system installer/contractor will also be important and needs to be assessed as part of a pilot study.

While DSI4MTF provided localised evidence, this needs to be expanded in association with an agency/partner who has responsibility for broader irrigation scheme development programs. End users are unlikely to be ready to pay for these services in the short term and until the value proposition is demonstrated.

Irrigation scheme investors do not appear to have interest in on-farm performance. It is not part of their mandate. The farmers themselves lack the technical knowledge. The system designer and installer is concerned primarily about reduced cost. Ongoing performance and maintenance is generally forgotten after system installation. This is the gap that needs to be filled and a business case for this needs to be demonstrated with cost-benefit for each party. In particular the Collectives Association could play an important role in overcoming some of these barriers and ensuring financial sustainability. Appropriate models could be customised and replicated across other regions by the implementing organisation and across organisations.

h) Value Chain [2.6]

The value chain could include a number of the actors (See Section 7.3), including project investors, implementing agency (often a government department), irrigation scheme designer/contractor, agency responsible for system management, organisations supporting farmer groups (eg WUA and Collective Association), private company supplying technologies, farmer/irrigator (the end user).

Actors in the value chain would certainly have the technical ability to support and deploy SIT technology, including hardware and software systems, however further customisation and packaging would be required. Training, service and extension staff responsibilities would be the critical area and quality assurance will be key with clear roles and responsibilities.

Relations between the various actors in the chain are somewhat fragmented with an imbalance of power relationships. Strengthening of this relationship is best undertaken in the context of a specific irrigation development under the contractual obligations imposed by the development agency. The overall performance of the value chain is thus potentially very low and will be scheme specific.

The end user group (marginal farmers) need to be organised via farmer organisations, ideally the Collectives Association, for best benefits, although they could also be organised through existing cooperatives or water user associations. Through the organisation of end users input provision, marketing, access to services and bargaining power would benefit from economies of scale. There is a need for institutional change for SIT to be implemented with incentives and rewards at appropriate levels.

i) Public sector governance [3.0]

The role of government would need to be determined as part of a scaling project. Working alongside government allows determination on how the approach could be "institutionalised" as part of their standard business approach. Local and state government and extension services are integral to achieve the scaling ambition.

While national strategies and policies are in place for irrigation and water, they do not devolve down to irrigation system performance and resource monitoring. This is an operational area that has been largely ignored. Demonstration on a wider scale is essential to attract government support in scaling the innovation.

Various government financing mechanisms (such as subsidies or tariffs) could be applied to benefit scaling the innovation. The true cost and finance requirements of the innovation are still unclear and would need to be assessed as part of a larger scaling program.

j) Finance [3.0]

The investment to implement SIT would be relatively small when compared with large scheme implementation costs. However farmers may not be able to directly fund the innovation, therefore the business model would likely require costs to be built into scheme development with handover over time for ongoing support by for example the Collectives Association (which has been designed to facilitate access to costly technologies), or a WUA. Integration of this model as part of a larger modernisation and optimisation program, rather than one paid for by farmers would be preferable. Prices and subsidies and other modes of delivery can only be worked out after testing on a wider scale. There is little risk as implementation has low costs and low risk and is readily trialled and is reversible.

7.5 Scaling pathway

The smart irrigation toolkit (SIT) approach is not ready for private-sector investment since organisations in the value-chain (Section 7.3) are not well integrated and a strong business case has yet to be demonstrated at scale. A project is required to demonstrate and pilot SIT at an operational/institutional level, to further develop the business case and strengthen the value chain. External support is also necessary to support the establishment of a larger network of collectives associations, and to monitor the success and challenges the model poses, and its capacity to be used as a medium through which to roll out the technological packages provided by SIT.

Table 13 proposes appropriate scaling pathways and the role of the public and private sector.

Initial costs need to be allocated for a pilot project to build awareness, create a critical mass of demand, and provide training and technical support in association with key institutions.

The initial pilot project would work to improve the scalability of SIT and potentially Collectives Associations through appropriate packaging, simplification, and integration with other products or services.

Table 13 Scaling pathways and organisational responsibility. (Refer to Table 14 for Phases)

<table>
<tr><th>Task</th><th>Private / Commercial Sector</th><th>Public Sector</th></tr>
<tr><td>Phase 1:
Inception</td><td rowspan="3">Not appropriate for these phases
The business case is insufficiently developed for the commercial sector to drive SIT. It requires piloting and scaling and demonstration led by public sector to create scaling
The private sector is also unlikely to engage in education, awareness building, and demonstration sites, until piloting has demonstrated business case and created market for acceptance into irrigation programs.
Appropriate for these phases
NGO’s will be critical to mobilise communities using ethical community engagement processes</td><td rowspan="3">Appropriate for this phase
The public sector invests in irrigation scheme development and has the mandate, portfolio, infrastructure and bureaucratic incentives to implement. Budget could be sourced from investors in irrigation development or government programs to implement SIT as part of overall project cost. Government have an incentive to ensure performance from the irrigation infrastructure they have invested in.
Public sector could also play a role in supporting the Collectives Associations, through formal registration, and offering support. In time the Collectives Associations could play a key role in mediating between farmers and the government line agencies, raising capital, and managing the irrigation interventions at a local level.
The public sector would assist to develop the business case beyond the technical and agronomic merits of the innovation.</td></tr>
<tr><td>Phase 2:
Customisation</td></tr>
<tr><td>Phase 3:
Evaluation and Scaling (Creating demand)</td></tr>
<tr><td>Phase 4:
Commercialisation and Institutionalisation (Ongoing deployment, training and technical support)</td><td>Appropriate for this phase
Private sector could get engaged once pilot project has demonstrated the business case and market opportunity
This training would be part of normal services supporting product sales (eg irrigation, agronomic (fertiliser etc)</td><td>Appropriate for this phase
The public sector’s extension system, or its equivalent, has the financial and human resources, geographic coverage, and technical expertise to provide training and technical support. In many cases, key questions can be the number of extension officers, their training, pay, access to transportation and fuel, and accountability.</td></tr>
</table>

8 Pilot project for scaling

A cross-disciplinary integrated pilot project is required to address research questions related to scaling SIT for marginal farmers and the role of various institutions including Collective Associations and WUA's. The pilot project would ideally be funded jointly by a donor/research funder, government implementing agency and/or irrigation scheme investors. Private sector investment is not a viable option for scaling initially, until a clear business case has been demonstrated. A public-private partnership (PPP) approach could serve latter stages of a scaling project.

SIT, alongside group farming initiatives tied together through a Collectives Association, has international appeal and is applicable to both developing and developed country contexts. The focus would be on small scale farmers, who are vulnerable to poor implementation and maintenance of irrigation schemes, who are poorly served by irrigation support or extension agencies and lack economies of scale. Ideally, it would be implemented as part of a larger development scheme or irrigation development program, where there is central investment and project development responsibility.

It is recommended that scaling is done sequentially or in phases, with the explicit strategy of creating a demonstration effect, focussing initially on locations where there are reasonable market systems and public-sector infrastructure. A four-year project would support piloting, alongside appropriate implementation agencies across four phases including inception, customisation, evaluation and scaling and commercialisation and institutionalisation.

8.1 Scope of pilot project

An essential next step for scaling will be to pilot an integrated project including the smart irrigation toolkit (SIT), associated with a network for Collectives Associations. This would be either as part of large irrigation development programme and/or as part of more community focused interventions, alongside local government institutions supporting the SIT.

Regionally piloting could occur in many developing country contexts, such as South Asia (India/Nepal/Pakistan), South East Asia (Vietnam/Cambodia) and/or the Pacific (Indonesia). Priority should be given to locations where the USQ and DSI4MTF project team have existing partnerships in the EGP (e.g. India, Nepal and Bangladesh) or partnerships could be established through other ACIAR programs and partners in countries such as Pakistan, Cambodia, Vietnam and Indonesia.

Piloting would be undertaken in association with appropriate development/implementation agencies/investors. As part of piloting and demonstration, in each community, a network of farmer groups or collectives, would be strengthened to support SIT approaches, under the umbrella of a Collectives Association.

The Collectives Association, which goes alongside SIT builds upon a flexible model (Sugden et al. 2020) of farmer collectives which are suited to divergent socio-economic and land ownership contexts, and have the capacity to evolve in line with the needs of communities. It is thus adaptable to meet the needs of marginal farmers in different parts of the world facing agrarian stress alongside dwindling plot sizes and poor economies of scale. The project would not only deploy SIT through the Collectives Association, but the scope of the latter would be strengthened and expanded beyond what was achieved during DSI4MTF. This includes enhancing links with external stakeholders and markets, making joint investments. There is also scope to branch into side activities such as a land lease bank.

While potential for adoption encompasses multiple countries, it is recommended that scaling is done sequentially or in phases, with the explicit strategy of creating a demonstration effect, focussing initially on locations where there are reasonable market systems and public-sector infrastructure.

8.2 Implementation team

Under DSI4MTF, USQ and partners have successfully developed and evaluated small-scale farmer collectives and SIT in the context of India/Nepal. The USQ and the DSI4MTF team have the required experience and skills to engage in a piloting program alongside local institutions. Local institutions would include government agencies responsible for irrigation and agricultural development, agencies responsible for irrigation management and service delivery, organisations supporting farmer engagement, and private companies responsible for irrigation and agricultural services (See Section 7.3).

It is envisaged that different organisations would have interest in, and take the lead on different project phases, from inception to customisation, evaluation and ultimately commercialisation (See Section 7.5), with a transition from primarily public sector engagement in initial phases to private commercial sector in latter phases.

8.3 Timeline

A four-year project would support piloting, alongside appropriate implementation agencies (See Table 14). This would require further developing and packaging of hardware and software leading to commercialisation of the “toolkit” approach, comprising monitoring hardware, training material and software. An important part would be further development of the software to support integration and benchmarking of irrigation system performance across jurisdictions.

Table 14 Phasing of pilot project for climate smart irrigation

Phase 1: Inception	Phase 2: Customisation	Phase 3: Evaluation and scaling	Phase 4: Commercialisation and Institutionalization
Year 1	Year 1 to 2	Year 2 to 3	Year 3 to 4
Establish pilot project with key irrigation implementation agency. Broaden awareness about underlying technologies and approaches, gain better understanding of agency processes, and capabilities, and identify specific site / scheme for piloting. Establish local institutions supporting marginal farmers including establishment of new network of Collectives under the umbrella of Collectives Association or build upon existing collectives (e.g those formed in DSI4MTF) and other	Customise SIT technologies, training materials and software to be fit for purpose within the organisational constraints. Provide training and deploy at selected pilot sites via the Collectives Associations. Expand the scope of the Collectives Associations (see section 6), deepening their links with government agencies and markets at a local level, building their technical capacity and supporting group investments, new activities (e.g land lease bank). Develop sector wide vision and multi-stakeholder initiatives to deploy at other sites under separate	Evaluate and modify technologies and approaches based on piloting experience. Monitor the success of the Collectives Associations in deploying SIT, as well as their capacity to more broadly to empower marginal farmers. Develop business case and economic justification for private sector investment and delivery, possibly as part of a public private partnership (PPP).	Expand application of the integrated model through public and private sector partners into new locations and irrigation schemes.

local institutions such as WUAs.	projects under auspices of the agency. Strengthen local institutions to facilitate sustainability.		

8.4 Benefits and outcomes

By working alongside implementation agencies, the project would:

(i) Link improved irrigation practices and community monitoring of water resources into larger initiatives and delivery programs and develop training packages.
(ii) Develop platforms for delivery of climate smart irrigation practices empowering community-based monitoring and measurement using smart phone Apps to inform improved irrigation management.
(iii) Strengthen marginal farmer communities by incorporating collective farming models into larger scale institutions and policies. Build up their links with markets and other community-based organisations as well as district government departments. Develop a sustainable model through which new farmer collectives can be formed by providing them an institutional spine.
(iv) Build guidelines and programs into agency projects based on DSI4MTF approaches
(v) Further research how different models of agricultural collectives and associated technical innovations for irrigation management can be strengthened and scaled under such programs.

8.5 Social and environmental responsibility

The project would offer good gender and age equality – particularly as we plan to ground it in a network of farmer collectives, which will be led by the poorest farmers, with a focus on women's leadership. Importantly, the project team can build upon the important learnings from DSI4MTF on how the collective's function (see Section 6), and how to address equity challenges. Training in technologies and SIT can be directed equally at woman and young people from within the groups. DSI4MTF project demonstrated this opportunity for local data collection. Elements of the program could be brought into schools to raise awareness on resource management through data collection and evaluation.

Ethical Community engagement would be important to support the interface between project officers and the community, as noted in Section 6. DSI4MTF have had significant success in this regard which has been documented. Inclusion of NGO's (CDHI) to support training is proposed.

SIT benefits both small scale irrigators, large scale irrigators as well as scheme developers and implementers – while the Collectives Associations will build economies of scale which make irrigation investments more feasible. It is therefore a win-win for both ends of the spectrum.

By institutionalising deployment of integrated model through government and other irrigation implementation agencies resilience will be generated in the adoption of the innovation. There would ideally be handover from the implementation agency to the self-sustaining Collectives Associations at a local level for ongoing deployment.

Scaling of SIT would demonstrate environmental responsibility through better water and energy management and improved yields and profits, improved soil and land condition (e.g. salinity problems), better off site water resources (reduced leaching and surface loss of fertiliser and chemicals).

8.6 Financing Mechanisms

The pilot project would ideally be funded jointly by a donor/research funder, government implementing agency and irrigation scheme investors. Private sector investment is not a viable option for scaling and training initially, until a clear business case has been demonstrated. A public-private partnership (PPP) approach could serve latter stages of a scaling project

Donor/research funder

Donor/research funder support would be required to initiate a pilot project with a focus on scaling, capacity building and seeking ways to institutionalise SIT and create demand.

A four-year project will help strengthen the partners, improve mechanisms for coordination, and build the business case. The project would drive scaling until a transition or 'hand-over' can take place to the private sector or local community institutions. The project would help absorb the initial costs of creating demand and demonstrating to private sector that there is a large and profitable market to justify their investment.

Implementation Agency and Irrigation Scheme Investor

The implementation agency (most likely a government department) and scheme investor would benefit from improved performance from the irrigation systems and infrastructure. They would be best placed to finance the delivery of SIT from project investment and operating funds. Over time once the business case demonstrates improved benefits for all actors a transition model for funding could evolve where either local government extension services provide support, or farmers allocate funds for technical support and system monitoring and maintenance through irrigation suppliers, or a WUA, Farmer Producer Company or other entity with access to trained staff.

Private Sector

The private sector would initially have no incentive to create demand or provide training and technical support. The private sector is unlikely to be able to engage in going to scale until there has been piloting and demonstration of value via a government connected program. The government program would allow significant training, capacity building, and demonstration to showcase opportunity for the private sector to take further roles in scaling and delivery of the innovation once scale has been reached. Attraction of the private agricultural service sector through companies such as Netafim, Jain Irrigation and Tata, in the context of India, to support farmers and collectives' associations, would need to be explored.

The farmer

The farmer would benefit from improved water management which generally results in better yields and lower operating costs. Individual marginal farmers are unlikely to be willing to pay for SIT services. Challenges for the individual farmer include, limited financial means and access to finance, small marketable surplus to generate profit to pay for services, high risk and variability of returns. A Collectives Association or WUA would reduce the cost burden on individual farmers and allow a sharing of costs. It can also be used to help access institutional credit.

Ongoing financial sustainability

The business model for ongoing financial sustainability, after a pilot project, could include a combination of the steps below, probably with phased transition over time:

- Allocation of project development funds from the irrigation development project budget for system performance monitoring, maintenance and improvement over an agreed term (i.e. three years)
- Allocation of state or local government budget through local agricultural/irrigation departments for advisory staff responsible for agriculture and water management.
- Investment by the private sector (e.g. irrigation equipment and agricultural input suppliers) as part of their product support services.
- Funds collected from irrigators and utilised by local institutions. In particular, the Collectives Association could play a key role in raising capital from members of the collectives and facilitating access to institutional credit. Water user associations or other grassroots organisations could also support he mobilisation of funds.

9 Conclusions and recommendations

9.1 Conclusions

This project has identified opportunities to improve irrigation and water management practices, based on a smart irrigation "toolkit" approach, used for monitoring and measurement, which guides improvements in irrigation system management. Opportunities to strengthen farmer collectives and build linkages with a range of institutions have been demonstrated and shown to be critical for the sustainability of marginal farmers. Scaling these water management and collective farming approaches is key, and the potential for scaling them was assessed using two tools, USAid's "Agricultural Scalability Assessment Tool" and CIMMYT's "The Scaling Scan".

9.1.1 Climate smart irrigation and water management

Better irrigation and agricultural practices are required to improve productivity and sustainability. Measuring and monitoring provides a foundation for improved water management. Water use and productivity can be improved significantly by undertaking simple field level assessments using low-cost measurement equipment, supported by decision support mobile Apps. These approaches are the basis for a Smart Irrigation Toolkit (SIT), comprising hardware, software and training components.

The Smart Irrigation Toolkit (SIT) provides useful information for decision making and practice change at two levels. It provides evidence to farmers to guide changes to irrigation practice. It also provides irrigation program managers and operators with scheme wide information to support spatial and temporal benchmarking and highlighting key areas of weakness in irrigation system modernisation programs.

All field-based assessments using SIT software are spatially logged and time stamped. This database is a powerful resource for program monitoring and will assist decision makers by providing regional and time series data on the performance of irrigation systems. For example, understanding the average performance of irrigation systems before a program of modernisation provides a benchmark for improvement. Spatial data may show that there are hotspots of poor performance that can be linked to poor input supplier or service linkages in certain districts. SIT should be implemented as part of the initial commissioning of a new scheme and then at regular intervals (e.g. annually) to inform maintenance, repairs and optimal performance.

Fundamental to deployment of SIT at village field sites are the farmer collectives, which support group data collection training and learning. Strengthening marginal farmer collectives institutionally will be critical for continued improvement in crop production and irrigation water management. Adopting an open and ethical community engagement process also supports adoption and learning, while gender sensitive and socially inclusive approaches in irrigation and water management are important.

9.1.2 Strengthening collectives

The potential for the collectives and associated interventions to achieve impact at scale is immense. Many of the foundations are present in terms of workable and evolving models of group farming, effective engagement with the community by the project team, and the establishment of a growing network of stakeholders, and the research has identified several positive learnings. Documenting and building upon best practices (and addressing persisting challenges) is critical to scale 'deep', a perquisite for scaling up and out.

With regards to the models of group farming themselves, there are several important lessons which must be integrated into future group formation. Firstly, it has been shown how some groups are more cohesive than others due to contexts external to the project. The presence of pre-existing connections for instance, and experience of collective action, as well as socio-cultural factors are significant in explaining the higher propensity for West Bengal groups to share labour. Similarly, groups who are most depend upon the collective for their subsistence work better together. These favourable conditions for group formation and higher level collective action must be capitalised upon when the model is scaled.

Secondly, future groups would benefit from larger plots – so the collective can meet a larger share of household's subsistence needs. This would result in reduced 'conflict' in the time allocation between the collective and one's personal plot and would reduce dependence upon tenancy and landlords. This will be important to improve farmers bargaining power in the rural agrarian economy, while reducing challenges of labour management on the collectives.

Another positive learning which must be replicated during further scaling, has been the critical importance of a sensitive and iterative process of engagement with farmers throughout the project lifecycle. The Ethical Community Engagement (ECE) approach utilised in the project helps ensure ownership of the intervention. Externally introduced interventions often end up being considered an opportunity for 'personal benefit', or there is limited ownership due to top down implementation. However, the reflections of the team have shown how sustained contact, open communication and iterative engagement has supported a transformation from initial scepticism, to a full buy-in from the community. An important element of the approach has been the flexibility and the ability of farmers to drive the evolution of the models and respond to challenges on their own. This has been central to the long-term success of the models. Some groups for example have moved from higher to more limited levels of labour sharing, to minimise conflict, while others have adopted hybrid models, such as in Saptari where part of the land includes labour pooling, while other parts are farmed individually by households. The leadership and management modality for groups has been also flexible, being allowed to evolve over time. Part of the ECE process also involves mediating effective and collaborative relationships between groups, the project team and state and non-state agencies, using the same processes of engagement. This is essential for later out-scaling and upscaling, and there have been significant successes in West Bengal whereby groups are now receiving entitlements from the state which they had not previously claimed.

9.1.3 Scaling water management and collective farming approaches

A key "innovation" developed during DSI4MTF and this SRA, which needs to be scaled, is the Smart Irrigation Toolkit (SIT), for improving on-farm irrigation and water management. Appropriate institutional arrangements to support deployment of SIT are essential, and form a critical part of the scaling challenge, and indeed the innovation.

Scaling requires strong partnerships with organisations prepared to invest in the roll out of SIT approaches, and in the strengthening of marginal farmer groups to support their access to improved irrigation capability.

Many organisations would benefit from scaling improved irrigation management and collective farming approaches, including funders of irrigation infrastructure projects, project implementation agencies (often a government department), organisations supporting farmer groups (e.g. Water User Association and Collective Association), private companies supplying technologies and the end user, being the farmer and irrigator.

While there is good potential for scaling, business cases are required to demonstrate potential benefits to the range of beneficiaries. These business cases need to be developed in association with irrigation scheme implementation agencies, as well as with organisations supporting farmer communities.

The public sector has a key role to support the initial scaling of SIT. Alignment with irrigation and agricultural department functions would establish a program for deployment, demonstration and alignment with policy. The Collectives Association can play a key mediating role for marginal farmers.

The strengths of SIT are in its ease of demonstration and relevance to a range of target groups. A selling point is the integration of data collection using Apps and backend databases. This supports interrogation of data to assess regional or temporal trends and provide scheme and district benchmarking to inform maintenance and modernization programs.

There are however currently insufficient leaders and managers who would promote SIT and its role in improved water management. While stakeholders acknowledge the need for improved on-farm irrigation performance, this is often overlooked in modernisation and maintenance programs, with most focus placed on bulk water supply infrastructure. Better packaging of information is required to demonstrate potential benefits.

Key challenges include the need for a strong business case, developed as part of a broader irrigation development program with enough scale to demonstrate opportunities to all actors. Further consideration also needs to be given to who should pay for system evaluations and the roles of the government and private sector. While DSI4MTF and this small research project provided localised evidence, this needs to be expanded in association with an agency/partner who has responsibility for broader irrigation scheme development programs.

A phased approach is envisaged, with initial government support, followed by ultimately input from the private sector and agricultural service providers. An essential next step for scaling will be to pilot the smart irrigation toolkit (SIT), associated with a network for farmer collectives, either as part of large irrigation development and/or as part of more community focused interventions, alongside local government institutions supporting the SIT.

Irrigation water management is an area where Australia can play a key role in developing South and South East Asia and the Pacific region. Technologies developed under ACIAR projects, such as MARVI for groundwater monitoring (using MyWell App), now being scaled under AWP programs, and Chameleon soil water sensors (promoted through the Virtual Irrigation Academy and Agricultural Innovation Platform), provide examples of how monitoring and measurement of irrigation system performance, using data collecting tools and approaches of DSI4MTF could be scaled.

9.2 Recommendations

9.2.1 Climate smart irrigation and water management

The technical concept of Climate Smart Irrigation for improving water and energy use efficiency should be further developed, and the context and environments under which it is suitable need to be better understood. Approaches and methods for measurement and analysis, including the deployment of SmartApp’s, need to be aligned with local specifics, both in terms of local water resources and types of irrigation systems being used, as well as the socio-economic and organisational environment.

Further research should investigate the potential for collection and analysis of metadata from digital tools, to inform decision makers, and the design of databases to ensure spatial and temporal variability can be understood.

The following research questions will guide improvements to climate smart irrigation and water management approaches for small holder irrigators.

- What is the most useful suite of ‘measure to manage’ assessments in each element in a farm scale irrigation and water management system?
- What are the minimum specifications in terms of hardware, software and training to deliver quality advice for farmers, to improve water management, and for programs to generate value for assessing irrigation development projects?

- How do the SmartApp's need to be customised to meet local needs, and provide value to irrigation development program leaders?
- What is the preferred approach for delivery of irrigation and water management advice for farmers, and what is the scalability of each delivery option?
- What are the best methods to implement irrigation system management and water resource monitoring programs through government programs, the private sector and NGO's?

9.2.2 Strengthening collectives

There are several broad recommendations relating to the role of collectives in empowering marginal and tenant farmers, which were identified during the SRA period. Effective scaling includes learning from some of the unresolved challenges posed by our existing models. These generate new research avenues in their own right, while they could also be covered as part of a larger pilot project. Addressing the following research questions, will further strengthen our models of farmer collective, making them more scalable, while further strengthening fragile agrarian livelihoods, and increasing the success of the technical interventions discussed above.

- How can conflict over labour allocations be minimised within the groups? More research is needed to understand the different ways of recording labour contributions or compensating the group if one is unable to work on a particular day.
- What is the optimal group size and what is the ideal gender balance for collectives? While single gender groups appeared on the whole to have operated more effectively across the sites with reduced conflict, many women themselves felt that having some men on board allowed them to take on traditionally 'male' tasks, preventing the need for them to hire in labour. However, this again, requires further research, particularly given the concerns over equity whereby men in mixed groups often do not contribute a fair share of labour.
- How can we continue to support tenants in the context of persisting inequities in landlord-tenant relations? Unequal relationships with landlords in Bihar and Saptari have been partially undermined, but they still remain a lingering challenge depending on the site and history of the community. The need for higher level cooperation via the Collectives Association and the horizontal expansion of the models within the communities are likely to strengthen the bargaining power of tenants, but this requires more research.
- How can a Collectives Association effectively support smaller collectives to support their long-term sustainability? It has been shown that a collectives association can play a critical role in enhancing the groups access to agricultural knowledge and extension services, conflict resolution, negotiations with landlords, marketing, and equipment hire. More data is needed on the different possibilities of this 'institutional spine' in supporting a network of collectives.
- What role can a Collectives Association play in facilitating linkages with external stakeholders? What opportunities do formal registration under government programmes such as a Farmer Producer Company play in strengthening the collectives and facilitating out-scaling of the models? How can we ensure these linkages remain sustainable?
- How can a Collectives Association support the generation of more robust and resilient market linkages?
- What linkages can be generated between collectives and private sector actors such as banks or crop insurance companies? What supporting role can the Collectives Associations play in mediating these relationships?

- What further training or support is needed for women to further enhance their bargaining power in agricultural and input markets? How can this bargaining power be extended also within the household, when it comes to distribution of labour or control over income?
- How can women's bargaining power within the household be strengthened to ensure a more equitable division of labour?

9.2.3 Pilot project to scale water management and collective farming approaches for marginal farmers

It is recommended that a project linking the smart irrigation toolkit (SIT) approach, into government and private sector initiatives and delivery programs is initiated. This would be either as part of large irrigation development project and/or as part of more community focused interventions, alongside local government institutions. A four-year phased project would comprise.

- Project establishment alongside key irrigation agencies, to broaden awareness of underlying technologies and gain a clear understanding of agency processes and capabilities and to identify specific sites. Strengthen local institutions including establishment of collective associations for marginal farmers.
- Customisation of the smart irrigation toolkit to ensure a product fit for purpose within context of the implementation agency, including delivery of training. Strengthen local institutions and farmer collective associations of local institutions to facilitate sustainability. Develop sector wide vision and multi-stakeholder initiatives to deploy at other sites under separate projects under auspices of the agency.
- Evaluate and modify technologies and approaches based on piloting experience in association with the Collectives Associations, and other local institutions. Develop business case and economic justification for private sector investment and delivery.
- Expand application of the integrated model through public and private sector partners into new locations and irrigation schemes.

While piloting could occur in many developing country contexts, in South and South East Asia as well as the Pacific, priority should be given to locations building on the experiences of DSI4MTF in the Eastern Gangetic Plains.

The pilot project would ideally be initiated by ACIAR/DFAT/AWP alongside government implementing agencies and irrigation scheme investors, such as the World Bank and ADB. Private sector investment is not a viable option for scaling and training initially, until a clear business case has been demonstrated. The opportunity would be to link investments with other larger programs in the EGP. This could take the form of links to existing or future development programs run by government, such as ADMIP (West Bengal Accelerated development of Minor Irrigation project) or other similar World Bank programs. Consideration should also be given to the role of National implementation agencies (eg NABARD in India) who have carriage of international and national funding schemes such as the Green Climate Fund, USA Adaptation fund and the National Adaptation Fund.

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11 Appendices

11.1 Appendix 1: Gender and social relations in the project team

11.2 Appendix 2: Institutional Mapping Summary and Approaches

11.3 Appendix 3: Key Institutions for Scaling SIT