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Technology Transfer in the Agriculture Sector: Implementation Experiences of WeRise in Indonesia and the Philippines

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ABSTRACT

The Weather-rice-nutrient integrated decision support system (WeRise) is a web-based app aimed at improving productivity and livelihoods in rainfed rice areas. It provides advisories on optimum sowing and fertilizer application timings using suitable varieties. It was developed by the International Rice Research Institute (IRRI)-Japan collaborative research project (IJCRP) and IRRI-Philippine Rice Research Institute (PhilRice)-Japan International Research Center for Agricultural Sciences (JIRCAS) collaborative research project (IPJCRP) with funding from the Ministry of Agriculture, Forestry and Fisheries of Japan and JIRCAS. The IJCRP and IPJCRP ended in December 2020 and March 2021, respectively. Research institutions may lack the mandate to monitor research investments and assess the impact of projects after they end. However, funding agencies expect them to target and achieve development-oriented impact goals (Douthwaite et al. 2017). Technology transfer pathways (TTPs) can facilitate impact by enabling systematic transitions and gaining the commitment of transfer recipients on project sustainability. Using the cases of WeRise technology transfer in Indonesia and the Philippines, we map the processes in developing the TTPs and discuss technology transfer implementation experiences and lessons learned. Understanding the local context, early and consistent stakeholder engagement, partnership building, flexibility and responsiveness, and a communication plan were important in implementing the WeRise technology transfer.

Keywords: WeRise, technology transfer, rainfed rice, digital agriculture

INTRODUCTION

In Southeast Asia (SEA), where most rice is produced and consumed globally, rice security is inextricably linked with food security. Irrigated and rainfed lowland rice areas account for approximately 89% of the total rice area in this region. Indonesia and the Philippines are among the countries with the largest irrigated areas in SEA (Mutert and Fairhurst 2002). Unfortunately, these irrigated areas are now facing multiple challenges of water scarcity, competing demand for water from non-agricultural sectors, land conversion, and high development and operational cost of irrigation facilities (Sumaryanto 2014; Inocencio and Barker 2018). Improving productivity in rainfed rice areas has become an important strategy to achieve food security.

However, rainfed rice areas are often associated with poverty and characterized by low and unstable productivity due to variable conditions of the soil, topography, and weather (Bouman *et al.* 2000). Weather variabilities make it difficult for farmers to determine when to sow and perform other farm activities. Without access to timely and relevant information, farmers usually rely on their empirical knowledge – previous experiences, indigenous knowledge or by simply observing daily weather before or during the cropping season. Unfortunately, these have become unreliable due to the impacts of climate change including erratic rainfall and increased occurrences of drought and other weather extremes (Hayashi *et al.* 2021). The rice research and development sector responded in cognizant to these challenges.

The Weather-rice-nutrient integrated decision support system (WeRise) is a web-based application that uses a seasonal climate prediction model and crop growth simulation model. It aims to improve livelihoods and productivity in rainfed rice areas. It provides advisories on the optimum sowing and fertilizer application timings using suitable varieties three months before the cropping season. The advisories are based on the weather characteristics of the upcoming cropping season, crop growth development, soil characteristics, and farm management practices (Hayashi *et al.* 2016).

With funding from the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF Japan) and Japan International Research Center for Agriculture Sciences (JIRCAS), WeRise was developed by the International Rice Research Institute (IRRI) - Japan collaborative research project (IJCRP) and the IRRI - Philippine Rice Research Institute (PhilRice) - JIRCAS (IPJCRP) collaborative research project for the rainfed rice areas of Indonesia and the Philippines. Through WeRise, these projects hope to contribute to Sustainable Development Goal 2: Zero Hunger by transforming rainfed rice areas into a more sustainable production system through efficient water and nutrient use; and improving the climate change adaptation capacity of farmers by enabling strategic crop production decisions.

The IJCRP and IPJCRP ended in December 2020 and March 2021, respectively. WeRise was transitioned to selected agencies of the national agricultural research and extension systems (NARES) in both countries. International agricultural research for development (AR4D) institutions may lack the mandate to monitor research investments (Zuniga and Correa, 2013) and assess their impact after projects end. However, they are expected to achieve the development-oriented impact targets (Douthwaite *et al.*, 2017). Technology transfer pathways (TTPs) for WeRise in Indonesia and the Philippines were developed to facilitate impact by enabling systematic transitions and gaining the commitment of stakeholders to sustain project outputs beyond the project life cycle.

Technology transfer is proactive, intentional and necessitates an agreement among the technology transfer agents and recipients. It involves a broad set of processes that covers the transfer of know-how, experiences and equipment among different stakeholders. It is different from technology diffusion which is a passive process and an intended outcome of technology transfer (IPCC 2000; Bozeman 2000).

Using the cases of WeRise technology transfer in Indonesia and the Philippines, this paper mapped the processes used to develop TTPs and discussed the technology transfer implementation experiences and lessons learned. While documenting that technology performance is important, documenting and sharing the implementation experiences as well could result in more innovations to improve the system (Corales *et al*, 2010).

METHODOLOGY

This paper uses the case study approach, a form of qualitative descriptive research. The cases of WeRise technology transfer in Indonesia and the Philippines, where WeRise have been piloted, were purposively selected for this study. Secondary materials from project documents such as implementation plans, annual reports, and activity documentations were reviewed. Participant observation was also used as a data collection technique since the authors were complete participants of the technology transfer during the project implementation.

Process mapping and thematic analysis were the analytical tools. Drawing from Douthwaite *et al*.'s (2017) causal model (Figure 1) showing how AR4D contributes to impact, implementation experiences on the following general themes were examined: technology development and adoption, capacity development and policy influence.

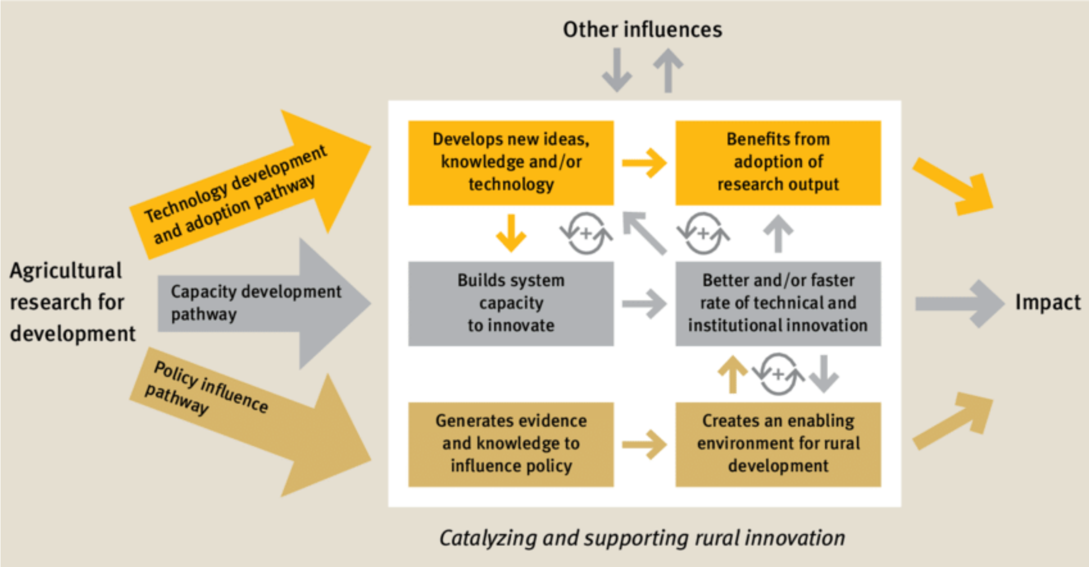


Figure 1. A causal model showing how agricultural research for development contributes to impact through three interconnected pathways.

Source: Douthwaite *et al.* 2017.

The model suggests better chances of achieving development-oriented impact targets by not focusing only on the technology development and adoption pathway. Douthwaite *et al.* (2017) posits that traditional impact pathways follow a linear model as they assume a direct relationship between project outputs and outcomes without accounting for any unintended reorganization within the system they are affecting. An example is the technology development and adoption impact pathway which can assume that technologies are adopted after they are developed. However, Douthwaite *et al.*'s model emphasized feedback loops that are dependent on the capacity development pathway. These feedback loops show that increased rates of innovation can result in increased capacity to innovate, faster adoption and adaptation rates, and an enabling environment for innovation.

RESULTS AND DISCUSSION

The results and discussion are organized in three parts. Part 1 provides the project context. Part 2 discusses the technology transfer implementation experiences and part 3 presents the key lessons learned.

1. Project context

WeRise was developed by the IJCRP on Climate Change Adaptation Rainfed Rice Areas (CCARA) with funding from the MAFF Japan and JIRCAS (Figure 2). The project was implemented from August 2010 to September 2015. Under the IJCRP on Climate Change Adaptation to develop a decision support tool for rainfed rice areas (CCADS-RR) which succeeded the IJCRP on CCARA, upgrading and upscaling of WeRise in Indonesia were undertaken from October 2015 to December 2020. For the WeRise upscaling in the Philippines, the IPJCRP kicked off in 2017 while the Joint Research Agreement among IRRI, PhilRice, and JIRCAS was signed in 2018. The project ended in March 2021.

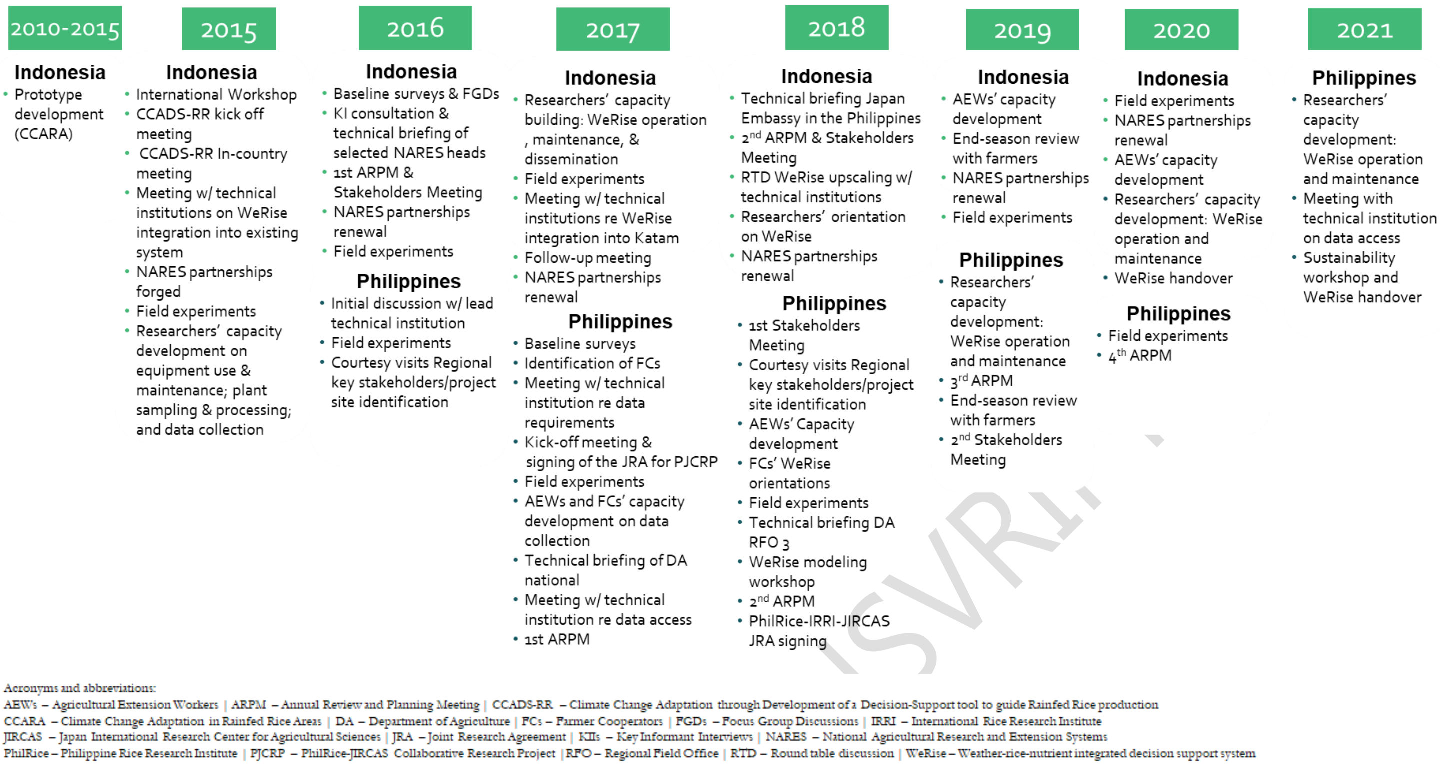
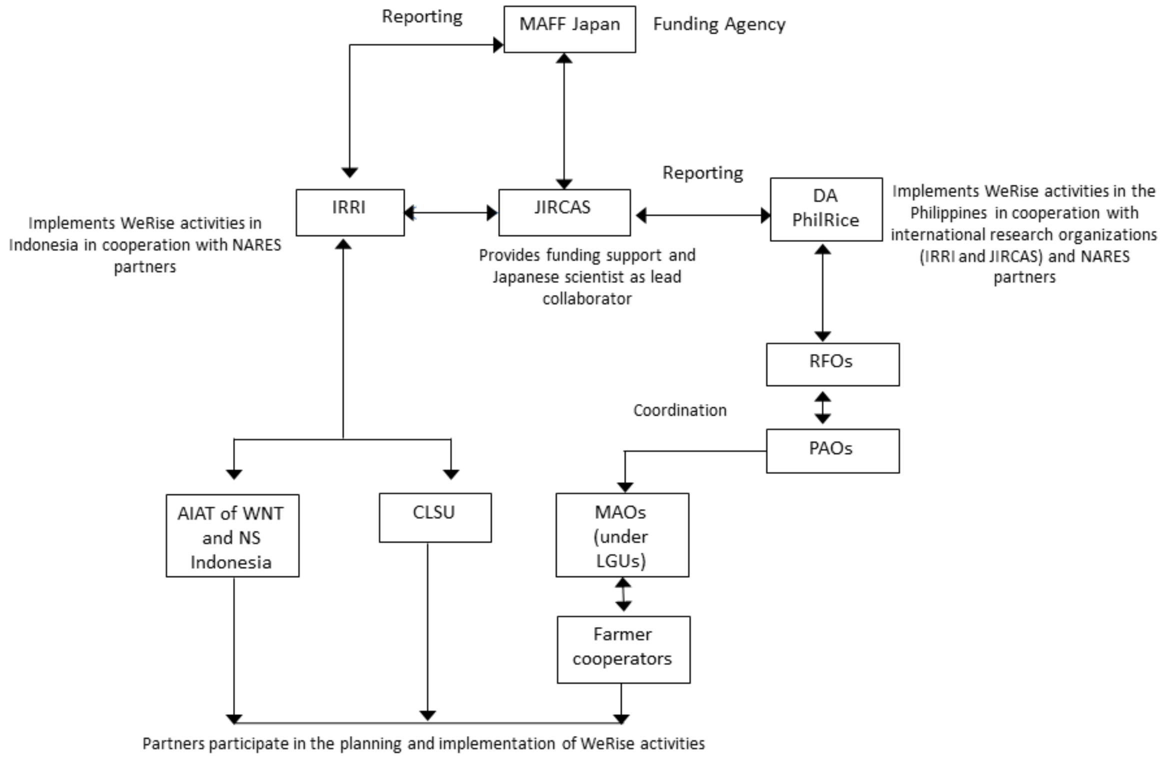


Figure 2. Timeline of key events in the history of WeRise technology transfer implementation in Indonesia and the Philippines.

Sources: Project documents.

Figure 3 presents the WeRise network, which includes a few strategic stakeholders (i.e., international research organizations, funding agencies, and NARES partners) and their respective roles. In the case of Indonesia, the network was larger at the beginning, but the number of project sites and partners was reduced as budget size decreased during project implementation.



Acronyms and abbreviations:
AIAT – Assessment Institute of Agricultural Technology | CLSU – Central Luzon State University, Philippines | DA – Department of Agriculture | IRRI – International Rice Research Institute
JIRCAS – Japan International Research Center for Agricultural Sciences | MAFF Japan – Ministry of Agriculture, Forestry and Fisheries of Japan | MAOs – Municipal Agriculture Offices
NARES - National Agricultural Research and Extension Systems | NS – North Sumatra | PAOs – Provincial Agriculture Offices | PhilRice – Philippine Rice Research Institute
RFOs – Regional Field Offices | WeRise – Weather-rice-nutrient integrated decision support system | WNT – West Nusa Tenggara

Figure 3. The WeRise network.

2. WeRise technology transfer implementation process

The general process of implementation of WeRise technology transfer activities followed three basic steps: forming institutional arrangements, conducting institutional analysis, and developing, implementing and refining the TTPs (Figure 4). Activities included key informant interviews (KIIs), stakeholder meetings, focus group discussions (FGDs), field experiments, and training-workshops.

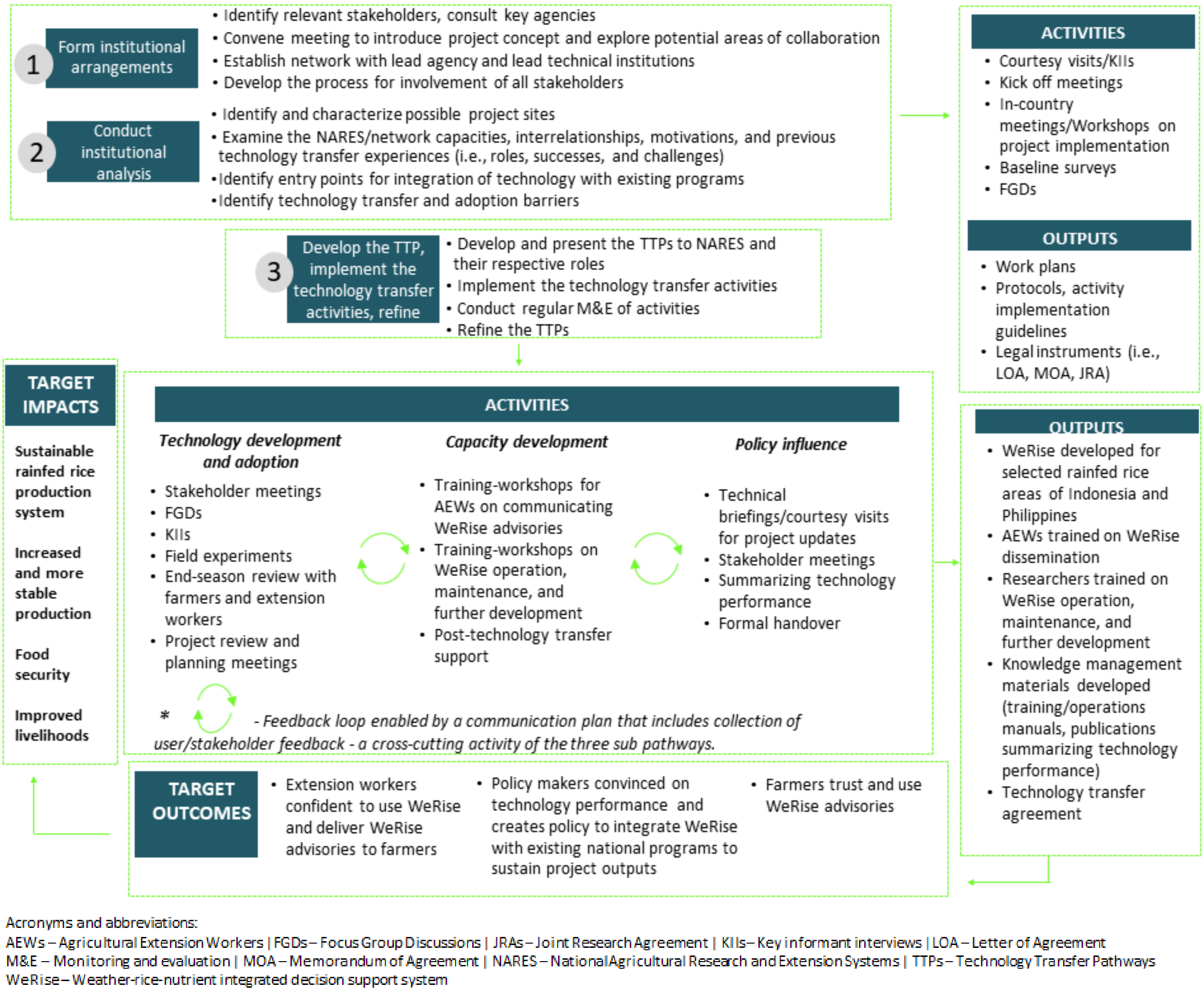


Figure 4. Technology transfer implementation process map.

3. Implementation experiences

The implementation experiences presented below first provides an overview how the TTPs were developed. The achievements and challenges encountered during the technology transfer implementation and key lessons learned follow.

3.1 The Technology Transfer Pathways

The TTPs for WeRise in Indonesia and the Philippines were developed through institutional analysis via the stakeholder approach, using tools such as FGDs, KIIs, face-to-face surveys, and desk reviews. The Contingent Effectiveness Model of Technology Transfer (CEMTT) was used as a framework to organize the information collected. The CEMTT is a qualitative technology transfer model that looks into the characteristics of the technology transfer agent (i.e., IJCRP), object (i.e., WeRise), medium (e.g., capacity building, on-site demonstration, patent and copyright), recipients, and the demand environment as determinants of an effective technology transfer. It assumes that technology transfer actors may have varying goals and criteria for technology effectiveness (i.e., number of technology adopters, economic impact, market impact, human resource development, increased research funding, etc.). It posits that successful technology transfers involve a critical mass of demand and success rates could be higher if the recipients are government agencies as this opens the possibility for co-funding among these agencies (Bozeman, 2000). The TTPs developed for Indonesia and the Philippines identified the stakeholders and their roles. They both involve stakeholders from the NARES, which are sets of government agencies. These agencies could perform roles in technology development (operation, maintenance, validation, and further development), capacity building, dissemination, and institutionalization. The ICRR and PhilRice were identified as the lead agencies for Indonesia and

Philippines, respectively (Bugayong *et al*., 2019). The TTPs served as a guiding framework in implementing the technology transfer activities.

3.2. Achievements and challenges in the sub pathways

Technology development and adoption sub pathway

WeRise integrates localized seasonal climate prediction and real-time weather data with a crop growth model. The seasonal weather predictions are based on the statistical downscaling of SINTEX-F ocean-atmosphere coupled general circulation model[1]. Yield predictions are based on recommended sowing and fertilizer application timings using the ORYZA crop growth model.[2]. The system requires data related to weather, crop, soil, and management practices. Statistical downscaling, calibration, and validation are done to improve the accuracy of the predictions (Hayashi *et al.* 2016).

WeRise was piloted in Indonesia and the Philippines. It was developed in eight provinces of Indonesia and the Philippines. A total of 15 varieties are now in these countries' WeRise databases. The predictive accuracy of WeRise was evaluated through on-farm experiments in selected provinces in both countries. Results showed that while there was no significant difference in the grain yields of farmers with and without the WeRise advisories, farmers who followed the WeRise sowing date recommendations had higher numerical yields. Predetermined sowing dates could narrow down the sowing window and avoid last-minute decisions as farmers determine the right timing based on their empirical knowledge. They can help rainfed rice farmers improve their climate change adaptation capacity through more strategic crop production decisions. Farmers can plan and coordinate farm activities and manage resources more efficiently. Further validation is recommended to determine the applicability of WeRise in more countries in SEA and other regions (Hayashi *et al.* 2021). Development of WeRise in selected countries of Sub-Saharan Africa has started.

Field experiments

On-farm and on-station field experiments are major activities and sources of primary data for WeRise technology development. A total of 43 farmer cooperators (FCs) in Indonesia and 96 FCs in the Philippines participated in the conduct of on-farm field experiments. In both countries, partners experienced difficulty in finding willing farmer cooperators. In the Philippines, FCs found the experiment protocols laborious as they had to prepare the land and repeat other production activities for all treatments (i.e., sowing timings). In both countries, FCs reported bird attacks, pests and diseases, and droughts during implementation. These stresses were consequences of the experiment design which also tested the effects of various sowing timings on yield.

There were also instances when the seeds needed for the experiments were unavailable. At the on-station experiment in PhilRice, a typhoon devastated the standing crops when it occurred near harvest time.

Monitoring of the on-farm field experiments, conducted by focal persons in the project sites, was occasionally hampered due to unavailability of transportation. The accessibility of farmers' fields was a consideration in the selection of FCs. Research instruments, particularly the automated weather stations (AWS) and their accessories malfunctioned occasionally while the experiments were ongoing. There were also delays in submission of data collected from the experiments by partners.

For the IJCRP, the annual budget followed a decreasing trend during its five-year implementation period. The number of project sites in Indonesia and frequency of travel for monitoring had to be reduced.

Weather and soil data acquisition

Forecast weather data and archive weather data were available and purchased from Forecast Ocean Plus, JAMSTEC's venture. Historical weather data is also a requirement to develop the WeRise database. It took some time to execute a Memorandum of Agreement (MOA) with the Philippine

[1] SINTEX-F was developed by Japan's Agency for Marine-Earth Science and Technology (JAMSTEC). It can predict the El Niño Southern Oscillation (ENSO) at 9-12 month lead time and provides daily weather parameters such as rainfall, wind speed, and minimum and maximum temperatures (Luo *et al*. 2008). The ENSO phenomenon is a major threat to rice production. It creates large inter-annual variability in precipitation causing severe drought and floods (Tan Yen *et al*. 2019).

[2] ORYZA was developed by IRRI and the Wageningen University and Research Center. It simulates the development, growth, and yield of different rice varieties in response to inherent soil physical and chemical properties, microclimate, and prevailing agronomic practices. It is also the foundation of other digital tools developed by IRRI.

Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) to facilitate access to weather data. In Indonesia, initial discussions with the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) took place, but a MOA did not materialize. It should be noted that PAGASA and BMKG are also government agencies like the other transfer recipients in the TTPs of Indonesia and Philippines. However, they are not under the Ministry/Department of Agriculture like the rest. Additionally, some weather data requirements were simply not available in the databases of these agencies or have not been collected due to lack of or dysfunctional weather equipment in the locations of request. Secondary soil data were also not readily available for some locations.

Capacity development sub pathway

The FGDs conducted in Indonesia indicate the insufficient number of technology facilitators and limited technology information as constraints to technology transfer. Stakeholders in both countries noted the importance of having the freedom to operate the tool implying the need for capacity development. As such, the capacity development activities aimed to train the identified transfer recipients on communicating WeRise advisories, and on operating, maintaining and further developing WeRise (Table 1). PhilRice and ICRR researchers were also trained on the installation, maintenance and troubleshooting of AWS for a more efficient data collection. The IJCRP's system developer also attended training on Geographic Information System. The IJCRP on CCADS-RR accepted three researchers from Indonesia as interns at the IRRI HQ through the on-the-job research capacity building (OJCB) for food security and environment conservation in developing countries. OJCB is a program that is also funded by MAFF Japan.

Table 1. WeRise capacity development activities.

	Venue	Period	Category	Trainees
1	IRRI HQ, Philippines	22 Jan – 26 Feb 2017	WeRise operation, maintenance, and further development	3 researchers with extension function from Indonesia
2	IRRI HQ, Philippines	24-28 Apr 2017	WeRise operation, maintenance, and further development *Basics of ORYZA	1 researcher with extension function from Indonesia
4	Iloilo, Philippines	11-13 Apr 2018	Communicating WeRise advisories to farmers	17 AEWs and Farmer Leader Technicians from Region 6 *The trainees oriented 34 Farmer cooperators on WeRise as an immediate application.
5	PhilRice, Nueva Ecija, Philippines	22-23 Oct 2018	WeRise operation, maintenance, and further development *ORYZA modeling workshop for WeRise	15 researchers/technical staff of PhilRice, PAGASA, and IRRI
6	AIAT West Nusa Tenggare (WNT), Indonesia	26-27 June 2019	Communicating WeRise advisories to farmers	19 AEWs and 5 researchers from 4 districts agriculture and extension offices of Lombok
7	PhilRice, Nueva Ecija, Philippines	22-27 July 2019	WeRise operation, maintenance, and further development	5 researchers of PhilRice CES *participants of training # 5
8	AIAT NS, Indonesia	24-25 August 2020 26-27 August 2020	Communicating WeRise advisories to farmers	30 extension workers and field agents from AIAT North Sumatra and Deli Serdang Extension Agency
9	WNT, Indonesia	2-5 November 2020	Communicating WeRise advisories to farmers	25 extension workers and field agents from Central Lombok
10	ICRR, Indonesia	16-20 November 2020	WeRise operation, maintenance, and further development	10 researchers and extension agents with research functions from ICRR, AIAT East Java, AIAT North Sumatra, AIAT South Sulawesi and AIAT Central Java
11	PhilRice, Nueva	15-19 February 2021	WeRise operation, maintenance,	13 researchers from PhilRice

Venue	Period	Category	Trainees
Ecija, Philippines		and further development	CES, Bicol, Negros and Batac *4 researchers also participated in training # 5

The activities allowed us to obtain feedback on the training, WeRise platform, and training materials; and make the necessary improvements. Results of the post-training evaluation indicate that the trainings have been successful at the first two-levels of Kirkpatrick's model (as cited in Guzman *et al.* 2018) for evaluation of training: 1) reaction of the participants on the training such as its program content, relevance, training materials, delivery, effectiveness of resource persons, and possibility of recommending to other colleagues, and 2) learnings from the training including most significant and most appreciated learnings. Another post-training evaluation may be conducted to determine any changes in the behavior/level 3 (i.e., job performance) and if there are any tangible results (level 4) after the training (i.e., application in their future research activities as indicated in the group outputs). Participants appreciated the hands-on exercises. Some thought the duration should be longer. Among the challenges encountered is force majeure as we had to postpone the AEW training in West Nusa Tenggara (WNT) due to earthquakes. During the training, the WeRise standalone version (among the instructional materials) did not work in the laptops of some participants due to system incompatibilities. In the conduct of future trainings, the participants were asked about the model/specifications of the laptops that they will use for the training. In the case of Indonesia, the training manual was prepared in English and Bahasa and local partners were present as translators and facilitators during the training.

Participants suggested increasing the number of sites and varieties in WeRise. This is indicative of the need for upscaling in more areas. Extension workers and researchers found WeRise potentially helpful for them to perform their jobs. The participants' feedback on the training manuals enabled the project team to improve the final versions in terms of format and content, among others.

Policy influence

Field evidence was summarized through journal articles and a book chapter. This evidence was also presented in conferences, seminars, and various stakeholder engagement activities. Policy makers have been invited to stakeholder meetings and annual meetings or visited personally by the project leads to provide updates on WeRise activities (technology and capacity development) and consulted on the dissemination and sustainability pathways of WeRise. In developing the TTPs, they have been among the key informants. Among their important feedback are the following: importance of integrating WeRise into existing systems or programs (e.g., Katam in Indonesia), increasing the number of sites and adding more varieties, and ensuring freedom of transfer recipients to operate the tool. Among the challenges encountered is the change in assignments of policy makers. A field day to showcase WeRise to policymakers and others was planned for North Sumatra, Indonesia. It had to be cancelled as strong winds made the crops unsuitable for showcasing.

3.3. COVID-19 pandemic

The COVID-19 pandemic has been a cross-cutting challenge for the three sub-pathways. It affected our mobility. Travel to Indonesia to hold the field day in WNT, in-person meetings with stakeholders for the WeRise handover, and face-to-face training of extension workers and researchers was cancelled. In the Philippines, the project's field technician was unable to travel to supervise the sampling activities in the on-station field experiment. The shipment of seeds needed for the wet season field experiments and conduct of such were also cancelled due to the lockdown. The prolonged lockdown and travel restrictions delayed timely budget utilization and field activities (e.g., collecting and drying samples, monitoring).

3.4. Lessons learned

We learned the importance of the following as the project faced implementation challenges:

Understanding the local context

Developing the TTP's primarily sought to understand the local context in the project sites. Using the CEMTT as a framework, it enabled examination of the demand environment; identification and characterization of the transfer recipients in terms of their capacities, motivations, inter-relationships, and other associated characteristics; identification of entry points for project implementation, and examination of barriers and prerequisites to a successful technology transfer. Understanding the local context and occasionally being immersed during activities through personal visits and close interactions with partners, facilitated implementation.

Good quality data is central to the development of digital tools such as WeRise. Understanding the capacities of potential strategic partners particularly in providing weather and soil data is critical to technology development. The availability of these data and associated costs should be considered in selecting sites for future WeRise upscaling activities.

Early and consistent stakeholder engagement, and partnership building

The TTPs enabled identification of stakeholders. Through legal instruments such as the Letter of Agreement and MOA, partnerships were forged with selected agencies of the NARES of Indonesia and the Philippines (Figure 2). Through these agencies, project activities including field experiments, capacity development activities, and stakeholder engagement activities such as meetings, FGDs, and KIIs were implemented. Farmer cooperators have also served as research partners as they implemented the on-farm field experiments and helped collect crop data. Among the earliest activities of the projects was the identification of focal persons in the partner institutions. These focal persons played a key role as project leads particularly in coordinating the activities and maintaining institutional linkages. Being local, they helped overcome the language barrier by serving as translators and facilitators in the activities when necessary. They also champion the development of sustainability plans. The project leads in ICRR and PhilRice spearheaded initiatives to conduct additional validation activities after WeRise was handed over to them. In Indonesia, ICRR - through its WeRise focal person - obtained budget support from the Indonesian Agency for Agricultural Research and Development (IAARD) for ORYZA database development and WeRise validation beginning 2017.[3] The focal person also facilitated conversations on the possible upgrading of Katam, Indonesia's homegrown cropping calendar system, using WeRise and WeRise upscaling in additional sites after the project ends. In the Philippines, the project lead facilitated the possible use of WeRise in the Smarter Rice Program Package of Technologies (PoT) for rainfed rice areas through the Agro-Specific Profiling of new varieties for PoT Development Project (ASPPD project). The ASPPD project aims to use WeRise for the strategic deployment and successful production of seeds. It aims to ensure that the new varieties released by PhilRice are competitive.

Flexibility and responsiveness

Flexibility and responsiveness have also been important. They were exhibited through adjusting the experiment protocols where possible without sacrificing the data requirements; creating information, education and communication (IEC) materials such as simplified flow charts and condensed operations, maintenance, and troubleshooting manual of research instruments, and capacity building activities for researchers/focal persons to facilitate data collection and management.

At the onset of lockdowns due to the pandemic, a Business Continuity Plan was developed. It enabled us to plan alternative methods to deliver the target milestones. For instance, due to travel restrictions, discussions on WeRise handover and sustainability plans and trainings were implemented online. In the Philippines, the protocols for the on-farm field validation experiments in Regions 3 and 6 were revised. The varieties initially planned were replaced with varieties that could be locally sourced instead of using varieties that need to be shipped from the IRRI headquarters. With some adjustments in the protocol to mimic the conditions in the FC's fields, the on-farm field experiments were conducted at the PhilRice central experiment station. PhilRice partners personally collected plant samples since hiring of contract workers was prohibited.

MAFF Japan and JIRCAS showed themselves as responsive and flexible funding agencies by approving our requests for budget realignment and reclassification, and a three-month no-cost extension until December 2020 for the case of the IJCRP on CCADS-RR that is funded by MAFF Japan.

Communication plan

The communication plan we developed helped us with stakeholder engagement activities. It enabled us to determine suitable IEC materials that need to be developed and channels and tactics for specific stakeholder groups. The IEC materials developed for WeRise include training manuals, flyers, FAQs, a micro-site, and an explainer video.

[3] ICRR is among the national research centers of IAARD.

CONCLUSIONS AND POLICY IMPLICATIONS

This paper aimed to provide a narrative documentation of the experiences and key lessons learned during the implementation of WeRise technology transfer in Indonesia and the Philippines. Project implementers may not have all the answers as they develop and transfer the technology. Thus, technology transfer should be an ongoing process throughout the project life cycle. It should involve co-development of the technology and constant feedback among the transfer agent (project implementers) and recipients (NARES in this study) from the beginning. Technology transfer implementation should involve understanding the local context, early and consistent stakeholder engagement, partnership building, flexibility and responsiveness, and a strategic communication plan.

Developing technology transfer pathways (TTPs) at the onset is imperative. TTPs can enable systematic transitions and help gain the commitment of transfer recipients on project sustainability once donor funding has ceased. The TTPs developed for WeRise identified the institutions and their roles in three sub-pathways: technology development and adoption, capacity development, and policy influence. It coincides with Douthwaite *et al*'s causal model showing how agricultural research for development contributes to impact through the three interconnected pathways.

Research projects are time-bound with an implementation period of three to five years. Development-oriented impact goals set by projects (i.e., poverty reduction, improved livelihoods) may be realized long after projects end. However, research institutions may lack the mandate and financial resources to monitor research investments after projects end.

As such, Governments can play a crucial role by providing oversight and creating an enabling environment for the development of digital tools and in putting in place mechanisms to achieve impact after funding has ceased when projects end. The following were identified policy priorities from this paper:

The Governments through the appropriate departments/ministries (e.g., Agriculture, ICT) can maximize the potential benefits of digital tools developed by various institutions (international research institutions, NGOs, micro enterprises) by conducting audits on their performance in collaboration with the lead agencies where they have been transitioned. There should also be repository or one platform where digital tools may be accessed. While integration of some tools may be ideal, standalone tools accessible in one platform would allow users menus to choose from.

Since digital tools are data-driven and rely on good quality data, governments can also create an enabling environment to facilitate access to critical data requirements (weather and soil) that local institutions can provide. Some data are collected and maintained by agencies under different Ministries/Departments and may entail tedious administrative requirements before they can be accessed by projects. Government agencies may also benefit from the data that these projects acquire throughout their project life cycle. A mechanism for data exchange or data access after the projects end may be explored. Capacity building initiatives may also be jointly implemented by government institutions and projects.

The IJCRP and IPJCRP encountered some difficulties in seeking farmer cooperators for its research experiments. Through other government programs, incentives may be given by the Government to farmers who participate in research experiments that are necessary for the development of digital agriculture tools. Validation experiments in government demonstration sites or accredited learning sites should be promoted if not institutionalized.

Governments can also help in developing business models for these tools by linking the agencies. For instance, WeRise adopts a production and exchange business model where farmers can obtain information at the pre-production and production stage (Krishnan et al., 2020). Other preferred information of farmers such as market price and buyers are not provided. Linking the project implementers with other agencies and to existing digital tools could result to a more sustainable business model.

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CONFLICTS OF INTEREST

The authors I.D.B., K.H., M.E.M.O., L.L., N.A., L.H., I.H.S., and F.L.A.P. declare no conflict of interest.