ADOPTION AND IMPACT OF ALTERNATE WETTING AND DRYING (AWD) WATER MANAGEMENT FOR IRRIGATED RICE PRODUCTION IN THE PHILIPPINES

A Final Report submitted to the Standing Panel on Impact Assessment (SPIA)

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EXECUTIVE SUMMARY

To counteract increasing water scarcity in agriculture, the International Rice Research Institute (IRRI) and its national agricultural research and extension system (NARES) partners have worked together to develop and promote the Alternate Wetting and Drying (AWD) water management approach for a number of rice-producing countries in Asia (including the Philippines). AWD is an irrigation technique in which water is only applied to the field a number of days after the disappearance of ponded water. This is in contrast to the traditional irrigation practice of continuous flooding (i.e., never letting the ponded water disappear).

The main objective of this study is to determine the multi-dimensional impacts of AWD in the Philippines. Specifically, we focus on quantitatively analyzing the micro-level economic impacts (e.g., yield, water-use, and income impact) and the environmental impacts (e.g., water saving impact at higher spatial scales and methane emission impacts) of AWD, in the context of a particular gravity-based irrigation system in the Philippines (i.e., the Rinconada Integrated Irrigation System (RIIS) in the Bicol Region). In addition, we also provide some qualitative insights on the effects of AWD adoption on non-rice-producing stakeholders (e.g., hydro-electric power companies and fishpond/fish cage operators). The four "impact dimensions" investigated in this study were purposely chosen because: (1) previous impact studies on these topics could still be improved by using more recent empirical strategies that overcome limitations in the earlier literature (e.g., previous economic studies), and/or (2) the particular impact dimension has not been thoroughly explored in the past (e.g., water saving at higher spatial scales and the impact of AWD on non-rice-producing stakeholders).

Micro-level Economic Impact. A combined randomized control trial (RCT) and difference-in-differences (DID) approach was developed to better estimate the economic impact of the AWD irrigation management technique. This empirical strategy is an improvement over previous studies because it allows one to better address selection bias from unobservable confounding factors due to the random (i.e., exogenous) nature of the AWD treatment, as well as consideration of farmer behavior before (and after) the AWD treatment. Preliminary results based only on a panel data set of 257 farmers (out of the 820 included in the study sample) suggest that AWD did not have a statistically significant impact on irrigation use and yields. We conjecture that this limited impact may be because some of the control farmers already practice some form of intermittent irrigation (i.e., a limited form of AWD) where the field is NOT actually continuously flooded throughout the season. Nonetheless, there seems to be some evidence that AWD may have improved rice incomes and increased the size of the main rice parcel farmed. However, it is important to note that these overall results should be taken with caution given the incomplete data utilized, as well as some of the limitations in the quality of the second year data and the somewhat incomplete analysis (i.e., which was borne out of time constraints, since the second year data was only collected a month before this final report was written). It should be emphasized here that results and inferences from a more comprehensive economic impact assessment (utilizing the complete data set) may be drastically different from the ones presented in this report.

Environmental Impact: Water Saving at Higher Spatial Scales. Based primarily on data from water depth readings of 168 regularly monitored farmers throughout RIIS (i.e., 84 in AWD treatment TSAGs and 84 in non-AWD control TSAGs), as well as water flow measurement from water data loggers installed at 6 turnouts (i.e., 3 in AWD TSAGs and 3 in non-AWD TSAGs), AWD seem to have been successfully implemented at the field and turnout levels, as manifested in the water level dynamics and reduction of water inputs observed for the monitored farmers in AWD treatment sites (versus the farmers in the non-AWD control sites). Although the RIIS irrigation system was hit by a strong typhoon in December, the analysis at different scales found evidence of water savings at both farmer's field and turnout levels. With AWD, water savings at farmers' field level ranged from about 11-17%, while at the turnout level, water savings ranged from 22-33%.

Environmental Impact: Methane Emissions. In the Philippines, 29% of the country's greenhouse gas (GHG) emissions stem from the agricultural sector, with almost half of it from rice production. Since GHG from rice can be mainly attributed to standing water in the soil during production, AWD is seen as a promising practice that can reduce GHG emissions from rice. Using IPCC guidelines for calculating methane and nitrous oxide emissions from rice production, together with irrigation practice information from the partial survey data collected, we find that AWD may be able to reduce GHG emissions by 10% as compared to emissions from current irrigation practice. On balance, this suggests that the GHG reduction potential of AWD in the study area may still be relatively low. This can be attributed to the observation that a substantial proportion of the surveyed farmers already utilize some form of intermittent flooding (i.e., a limited form of AWD). Therefore, the GHG reduction potential of AWD relative to comparison farmers who already use intermittent flooding will be less than the GHG reduction potential if AWD is compared to farmers that strictly use continuous flooding.

Socio-Cultural Impact: Non-Rice-Producing Stakeholders. Based on two case studies that rely on Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs), there is qualitative evidence that AWD in gravity-based irrigation systems in the Philippines may not substantially impact non-rice-producing stakeholders, unless there is full system-wide implementation of AWD that limits overall water availability. Power generation firms do not believe that they will be substantially affected by AWD adoption. These power companies think that irrigation agencies will not severely restrict overall water volume that flows through the main irrigation canal even with AWD, and since this main water flow is also typically used for power generation, they believe they will not be affected. The conjecture that 'saved' water through AWD will be used for power generation was not substantiated in our case. On the other hand, fishpond operators producing fingerlings believe that they will be negatively affected if AWD is implemented by imposing further rotational limits in the water flowing through the lateral canals where they typically operate, resulting in fish kills. Fish cage operators, who usually operate at the main water source (i.e., Lake Buhi), indicate that they may benefit (or at least not be adversely affected) if water levels at the source is maintained through AWD adoption.

Overall, based on incomplete data and initial analytical approaches, our preliminary results indicate that the impact of AWD on micro-economic outcomes (e.g., water use, yield), GHG emissions, and non-rice-producing stakeholders may be limited. Only the water saving analysis at different spatial scales provided some indication that AWD adoption in the study area statistically reduced irrigation input amounts (at least at the farmer field and turnout level). However, especially for the economic and environmental assessments, further analysis utilizing the complete two-year data set collected is still needed to produce more reliable inferences, stronger conclusions, and (hopefully) more consistent results.

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ADOPTION AND IMPACT OF ALTERNATE WETTING AND DRYING (AWD) WATER MANAGEMENT FOR IRRIGATED RICE PRODUCTION IN THE PHILIPPINES

1.0 Introduction: Research Question(s)/Objective(s)/Significance

Irrigation water in Asia is becoming increasingly scarce. Rapid population growth and multiple competing demands for water (i.e., drinking, industrial uses) have contributed to irrigation water scarcity in many developing countries in Asia, including the Philippines (Tabbal et al., 2002). This is a big challenge for major rice-producing countries given the traditional rice production practice of flooding the field for most of the rice cropping season. With continuous flooding, producing 1 kg of rice requires a large amount of water (3,000 to 5,000 liters). Tuong and Bouman (2003) estimate that, by 2025, about 2 million ha of Asia's irrigated dry-season rice and 13 million ha of its irrigated wet-season rice will experience physical water scarcity. Since rice is a major food staple in this region, there is a need for more efficient irrigation water management technologies so that rice production levels can meet the demand of a rapidly growing population even in the presence of water scarcity.

One such water management technology developed for rice cultivation in Asia is the alternate wetting and drying (AWD) irrigation approach (Bouman and Tuong 2001). AWD is an irrigation technique in which water is applied to the field a number of days after the disappearance of ponded water. This is in contrast to the traditional irrigation practice of continuous flooding (i.e., never letting the ponded water disappear). This means that the rice fields are not kept continuously submerged but are allowed to dry intermittently during the rice growing stage. The number of days in which the field is allowed to be "non-flooded" before irrigation is applied can vary from 1 day to more than 10 days. The underlying premise behind this irrigation technique is that the roots of the rice plant are still adequately supplied with water for some period (because of the initial flooding) even if there is currently no observable ponded water in the field.

In the Philippines, approximately 61% of the 4.5 million ha of rice production area is under irrigation. In light of the concerns about irrigation water scarcity in the area (Bouman et al 2007), the International Rice Research Institute (IRRI), through the Water-Savings Workgroup of the Irrigated Rice

Research Consortium (IRRC), developed a set of simple guidelines coupled with an easy-to-use and practical tool (i.e., the field water tube) to allow farmers to reduce irrigation water input while maintaining yields. This form of "safe" AWD is now a recommended practice and is widely adopted in many countries in Asia, including the Philippines (Rejesus et al 2013; Lampayan et al 2015).

"Safe" AWD consists of three key elements (Bouman et al 2007; Lampayan et al 2015): (1) shallow flooding for the first 2 weeks after transplanting to help recovery from transplanting shock and suppress weeds; (2) shallow ponding from heading to the end of flowering as this is a stage very sensitive to water-deficit stress, and a time when the crop has a high growth rate and water requirement; and (3) AWD during all other periods, with irrigation water applied whenever the perched water table falls to about 15 cm *below* the soil surface. To assist farmers in the practical implementation of "safe" AWD, a simple tool (a 25-cm-long perforated field water tube) was introduced. The field water tube can be made of plastic pipe or bamboo or any cheap material, and is embedded in the paddy field to a depth of 15 cm, with the soil removed from inside the tube, to reveal the perched water-table level (Lampayan et al 2014a). During AWD implementation, the field is irrigated to a depth of around 5 cm whenever the ponded water level has dropped to about 15 cm below the surface (Figure 1.1).

The main objective of this study is to determine the multi-dimensional impacts of AWD in the Philippines. Specifically, we focus on quantitatively analyzing the micro-level economic impacts (e.g., yield, water-use, and income impact) and the environmental impacts (e.g., water saving impact at higher spatial scales and methane emission impacts) of the AWD water management approach, for a particular gravity-based irrigation system in the Philippines. In addition, we also provide some qualitative insights on the effects of AWD adoption on *non*-rice-producing stakeholders (e.g., hydro-electric power companies and fishpond/aquaculture operators).

As it has been roughly more than 14 years since the initial introduction of AWD in the Philippines (see further discussion on this issue in the next section of this report), and given the supposed widespread dissemination of this practice (Lampayan et al., 2014b), a quantitative and/or qualitative multi-dimensional assessment of this irrigation management innovation is warranted. In a review of the

Consultative Group on International Agricultural Research's (CGIAR) impact assessment work on irrigation-related technologies, Merrey (2015, p 31 and 38) has indicated that AWD is a "good candidate for a full comprehensive ex post impact assessment" and would likely be a good research investment. The review also highlighted the "meta" impact assessment study conducted by Rejesus et al (2013) on AWD as a good foundation for conducting more comprehensive assessments of AWD. Merrey (2015, p 31) further noted that "the considerable data that have already been collected" on AWD (as used in the meta-assessment) would serve as a good base for which to conduct new surveys that would strengthen the impact evaluation of AWD.

Even with a credible meta-impact assessment already conducted on AWD, Rejesus et al (2013, 2014) and Merrey (2015) have identified areas where the impact analysis could be improved and be made more rigorous. The current study aims to address some of these "gaps." First, existing literature on the ex post micro-level economic impact assessment of AWD is improved upon by using a randomized control trial (RCT) design to better account for selection issues and confounding factors. Second, potential heterogeneity in the micro-level economic impacts is examined (i.e., upstream vs. downstream farmers, gender impacts). Note that existing studies on the impact of AWD typically do not address impact heterogeneity. Third, the environmental impact of AWD is evaluated through a methane reduction analysis and a water-saving analysis conducted at a higher spatial scale (i.e., sub-system scale). Although there have been experimental studies that examined methane emissions from AWD, only a few used data from actual farmer fields. In addition, most of the previous studies that evaluated water-savings from AWD did so at the field-level and the evidence for water-savings at higher spatial scales have been limited. Lastly, the broader socio-cultural impacts of AWD on non-farm stakeholders like power generation companies and fisher folks are qualitatively investigated in this study. There have been a number of studies that examined the socio-cultural impacts of AWD (Rejesus et al. 2013, 2014), but most of them concentrated on the effects of AWD on rice-producing households themselves (e.g., farm community well-being, social conflicts among farmers), not the effects of AWD on other non-farm stakeholders.

The remainder of this final report is organized as follows. The next section provides a background of AWD in the Philippines, the role that IRRI played in its development, and the institutional context of gravity irrigation systems in the Philippines. The third section describes the micro-level economic analysis conducted and discusses the results from data collected so far.[2] The fourth section provides discussion about the environmental impact analysis conducted, where the effects of AWD at higher spatial scales are evaluated and the methane emission effects are estimated. The fifth section discusses the impact of AWD on non-rice-farm stakeholders in the Philippines based on a qualitative analysis (i.e., focus group discussions (FGDs) and key informant interviews (KII)) in two Philippine irrigation systems. Lastly, the last section summarizes results and provides policy implications and future research directions.

[2] Note that the 2nd year data collection for this study was only collected in May/June 2017 and so, as of this writing (in June 2017), this 2nd year data is still being encoded. Therefore, full analysis of the complete data set has not been conducted and preliminary analysis of the available data so far is presented in the third section and fourth section of this final report.

2.0 Background: AWD in the Philippines

2.1 AWD Description and Role of IRRI in its Development

The AWD irrigation water management technique was developed through the research efforts of IRRI, one of the major research centers under CGIAR. In particular, the Water-Savings Workgroup under the Irrigated Rice Research Consortium (IRRC) was instrumental in the development and streamlining of this technology in the Philippines (Rejesus et al 2013, 2014).

The IRRC was established in 1997 with the aim of providing a platform to facilitate the identification, development, dissemination, and adoption of natural resource management (NRM) technologies suitable for irrigated rice-based ecosystems in several Asian countries. With funding support mainly from the Swiss Agency for Development and Cooperation (SDC) through four project phases (Phases I-IV from 1997 to 2012), the IRRC has provided a mechanism that expedited partnerships between NARES and scientists from IRRI. The IRRC structure provided an ideal situation for irrigation and water management scientists at IRRI to form a Water-Savings Workgroup and collaborate with local NARES institutions interested in water management. In particular, the IRRC's Water-Savings Workgroup worked with two National Agricultural Research and Extension System (NARES) partners in the Philippines – the Philippine Rice Research Institute (PhilRice) and the National Irrigation Administration (NIA) – to successfully disseminate this water management technique to various irrigation systems in the country (Lampayan et al 2015).[3]

In the Philippines, AWD was first evaluated in farmers' fields within a deep-well pump irrigation system (called P-38) in Tarlac Province, and by individual farmers using shallow tube wells in Nueva Ecija Province, in 2002 and 2003. AWD was then introduced to more farmers in adjoining deep-well pump irrigation systems in Tarlac Province in 2004. In 2005, piloting of AWD commenced at the lateral level of several gravity/canal irrigation systems in the Philippines, including the Upper Pampanga River

[3] Briefly, PhilRice is the Philippines' main national rice research institution mandated to undertake rice research and development. NIA, on the other hand, is the agency that helps administer various water resource systems in the Philippines (a more detailed description of NIA responsibilities and functions is discussed in the proceeding sub-sections).

Integrated Irrigation System (UPRIIS) and Bohol Irrigation System (BIS). Based on research questions raised during these demonstration and validation trials, additional field experiments were carried out at the PhilRice research station in Nueva Ecija and in farmers' fields in Tarlac between 2005 and 2011 to further explore threshold levels for the perched water table, and to evaluate the interactions between AWD and other factors such as seedling age at the time of transplanting, variety, soil texture, and fertilizer management. The field experiments at PhilRice evaluated the effects of AWD at different threshold levels (irrigation when the perched water table drops to 15, 25, or 30 cm below the soil surface) in comparison with continuous flooding. Eventually, the current "safe" AWD recommendation (i.e., applying irrigation whenever the perched water table falls to about 15 cm below the soil surface) was based on these aforementioned experiments and field trials.

Given the work of IRRI and NARES scientists in the Philippines, as well as in other countries (e.g., Bangladesh and Vietnam), AWD is now considered a mature technology with sound underpinnings that have been validated in multiple countries through extensive research and testing (Lampayan, 2015). In fact, AWD has now been integrated into national policy through Philippine Department of Agriculture (DA) Administrative Order 25, which stipulates AWD as the main water-saving technology for the Philippines.

2.2 Institutional Context: Philippine Gravity Irrigation Systems

Irrigation systems in the Philippines are usually divided into three groups: nationally- managed irrigation systems (NIS), community-managed irrigation systems (CIS), and private irrigation systems, where NIS are typically of the large gravity-based irrigation kind (rather than the pump irrigation kind). The focus of the study is on gravity-based NIS and these national systems are owned and operated by NIA – a semi-autonomous government corporation that is responsible for irrigation development in the Philippines (see also footnote 2). NIS are irrigation systems constructed and jointly operated and maintained by NIA and farmer Irrigators' Associations (IAs). A typical IA is an independent legal entity with a board of directors and officers. It is organized based on the physical layout of irrigation networks and it is typically responsible for operations and maintenance (O&M) of secondary and lateral canals. Within IAs, there are

sub-groups called "turnout service area groups" (TSAGs) that are mainly responsible for the turnouts in the secondary and lateral canals that then flows to the main farm ditches of the farmers. The IAs also collect irrigation service fees (ISFs) from their farmer-members to support the irrigation services provided by NIA, the O&M costs, and/or amortization of NIA construction costs (if applicable).[4] The IAs are then entitled to some proportion of these ISFs, of which the proportion they gain is based on how much they collect (i.e., the higher percentage collected, the higher the IA's share).

In general, IAs are responsible for managing the water allocation to their members, while NIA's responsibility is to manage the water at the main canal and make sure that water will be available in the service areas under the IA's jurisdiction (Figure 2.1). Although farmers are organized into IAs, the distribution of water among them is commonly not equitable (Sibayan et al., 2010). Traditionally (i.e., without AWD), a continuous flow of water is provided to the service areas of the IA for a certain duration (e.g., once a week, twice or three times a week, etc.), which is agreed upon by NIA and the IA to maintain the practice of being continuously flooded. Therefore, farmers in the upstream and midstream turnout IAs tend to water "excessively" by maintaining 5-7 cm of ponded water in their fields through most of the season. Farmers in the downstream service areas then receive an insufficient supply of irrigation water, usually resulting in delayed planting and crop stress/losses.

Given this context, implementation and scaling out of AWD in nationally-managed gravity irrigation systems in the Philippines can be done at several levels (and through a sequence of steps). First, AWD can be implemented at the TSAG level, where all farms covered by the turnout will be participating and collectively agreeing on how irrigation water will be shared (see Sibayan et al 2010 for a description of how this was implemented in an NIS in the Central Luzon region). Second, implementation can also be

[4] Prior to May 2016, ISF collections was clearly mandatory (under Republic Act 3601) and most members of IAs comply with payment. However, with the change of government to President Duterte's administration (in June 2016), there was some confusion among IA members (and difficulties in ISF collection) because of the President's public pronouncements of "free irrigation" (i.e., no ISFs) during the campaign period and shortly after taking office. But in a memo in NIA's website (as of Jan 2017), it indicates that ISFs are still to be collected since there is still no official implementation guidelines for the "free irrigation" policy (See the following URL: http://www.nia.gov.ph/?q=content/nia-clarifies-fee-collection).

done at the IA level such that all farmer-members within the IA agree to an AWD-based approach to allocating water. Lastly, AWD can be implemented at the overall system level. This system-level approach was the one initially used in an irrigation system in Bohol Province, where a more intermittent irrigation release schedule was implemented at the full system level based on AWD principles (i.e., water rotation every other week for upstream and downstream IAs rather than continuous flow). In this system-level approach, the AWD approach was "imposed" on all IAs within the system. Note that, before implementing any of these AWD schemes at any level, extensive training and information dissemination efforts targeted to NIA (e.g., management and local staff) and IAs (i.e., officers and members) were conducted. Moreover, there is still an element of individual decision-making by farmers on whether or not to implement/adopt AWD in their fields since they decide when/where to create cracks in the rice bunds to let water in to their paddy fields from the main farm ditch and/or lateral canals.

2.3 Adoption of AWD: Estimates for the Philippines

There is limited information about the extent of AWD adoption in the Philippines (and most other rice-producing nations in Asia). Lampayan et al. (2014b) suggest that around 93,000 ha (or ~82,000 farmers) have utilized the AWD technique in the Philippines (as of May 2011). See Table 2.1 (2nd and 3rd columns). These adoption figures roughly correspond to 2% of the 4.5 million ha of rice area in the country. However, these aforementioned adoption numbers were based on "informal" KIIs of personnel in various government agencies and NARES partners.

In the present study, we requested adoption figures directly from the NIA central office in Manila, which is primarily based on data formally reported by the regional offices (current as of Sept 2016). The adoption figures we gathered from NIA (by region) are presented in Table 2.1 (4th and 5th columns). The total adoption number (i.e., 84,784 ha or ~60,559 farmers, assuming 1.4 ha average farm size per farmer)) is lower than the earlier adoption estimates reported in Lampayan et al (2014b). The official AWD adoption estimates from NIA are also only report adoption in three regions, as compared to the more widespread adoption across regions reported in Lampayan et al (2014b).

However, note that all these aforementioned adoption figures are not based on rigorous, quantitative data collection procedures (i.e., either through analysis of widely conducted farmer surveys or more modern remote sensing technologies). This is an important "gap" in the literature since more precise adoption numbers would also lead to a more accurate indication about the level of acceptance of the technology in the Philippines. In addition, better adoption figures would improve the analysis of the "macro-scale" economic impact of AWD and would better inform policy decisions as to the level of effort (and corresponding cost) needed to further disseminate the technology. The study of Nelson et al (2015) is a step in the right direction given its use of a quantitative "climate-based" model to estimate the rice area suitable for AWD (i.e., the proper denominator for calculating adoption rates). Furthermore, SPIA's funding of research projects that investigates innovative quantitative procedures (e.g., remote sensing, use of satellite data, etc.) for estimating adoption rates of natural resource management (NRM) technologies, including AWD, is also an important step in filling the gap in knowledge about AWD adoption.

3.0 Micro-level Economic Impact of AWD: A Randomized Control Trial (RCT) Approach

3.1 Introduction

A number of surveys and microeconomic studies have been conducted to examine the "micro-level" (or farm-/field-level) impact of AWD adoption on economic outcomes of interest, such as yields, water use, input use (e.g., labor, fertilizer), and income (Lampayan, 2015, Rejesus et al., 2011, Rejesus et al., 2013). For example, Palis et al. (2004), Rejesus et al. (2011), and Valdivia et al. (2016) have all examined the impact of AWD adoption on irrigation water use, labor use, yields, and/or profits in the Philippines, particularly in regions where some of the initial AWD farm trials and dissemination efforts by IRRI were performed. Similar micro-level economic studies of AWD have also been conducted in major rice-producing countries in Asia, such as Bangladesh, China, and Vietnam (see Kurschner et al. (2010), Moya et al. (2004), Quicho (2013)).

This body of evidence generally indicate positive economic effects of AWD for rice farmers in these Asian countries (i.e., higher yields (or at least no yield penalty), lower water use, lower input costs, and higher net incomes). However, these existing economic impact studies typically relied on (1) cross-sectional survey data to provide "with and without" comparisons (see Rejesus et al., 2011), or (2) survey data for the same sample across two time periods to provide "before and after" comparisons (see Valdivia et al. 2016). Comparison of mean outcomes was the typical approach used (i.e., usually through regression analysis or related statistical techniques), where tests to determine statistical differences in outcomes are often undertaken (but not always). Key informant interviews (KIIs), focus-group discussions (FGDs), and field trial comparisons are also some of the other approaches often seen in the literature assessing the microeconomic impact of AWD (e.g., Palis et al., 2004).

The reliance on "with and without" cross-section survey data and "before and after" survey data makes it hard to account for selection bias due to unobservable confounding factors and, consequently, makes it difficult to convincingly estimate the causal impact of AWD adoption on economic variables of interest (Rejesus et al., 2013). Therefore, the main objective of this study is to more rigorously examine the economic impact of AWD adoption within a large gravity-based irrigation system in the Philippines

using a procedure that can better address unobservable confounding factors. In this regard, an RCT approach was designed to randomly assign treatment and control "turnout service area groups" (TSAGs) where farmers in treatment TSAGs were exposed (and encouraged) to adopt AWD while farmers in control TSAGs were not. This randomization allows one to better address selection bias from unobservable confounding factors due to the random (i.e., exogenous) nature of the treatment. In addition, a two-year panel data set was collected where baseline data was gathered from the treatment and control farmers prior to exposure to AWD (dry season 2016), and then follow-up data was collected after random exposure to AWD the following year (in dry season 2017). The RCT design and panel data collection allows us to conduct a difference-in-differences (DID) analysis within a randomized encouragement framework (i.e., what we call the DID-R approach) to better control for potential selection bias due to time-invariant and time-varying unobservables. Properly accounting for these time-invariant and time-varying unobservables permits us to more rigorously identify the causal impact of AWD adoption on economic outcomes. To the best of our knowledge, this is the first study that explicitly uses a panel data RCT-DID approach to better tease out the economic impact of AWD, and we contribute to the literature in this regard.

3.2 Study Area: The Rinconada Integrated Irrigation System (RIIS)

The gravity-based irrigation system considered in this study is the Rinconada Integrated Irrigation System (RIIS) in the province of Camarines Sur in the Philippines. RIIS is the largest of all the National Irrigation Systems (NIS) in the Bicol Region of the Philippines (Region V), with a service area of about 7,031 hectares (as of Dec. 2013). The system serves the municipalities of Buhi, Iriga City, Nabua, Bato, Baao and Bula, all within the fifth (5th) District of Camarines Sur. The service area is typically under monoculture cropping of rice, when the wet season normally starts in the month of June and the dry season starts in the month of November (or early December).

RIIS has an "integrated" structure with its four sub-systems: Upper Lalo, Lower Lalo, RIDA, and Barit (Figure 3.1). The main source of irrigation water for the whole system is Lake Buhi, but the Upper Lalo and Barit sub-systems are also augmented by water from the Lalo River and the Daraga/Barit rivers,

respectively. As seen in Figure 3.1, RIIS has two "arms" where water from Lake Buhi is first taken through a bifurcation structure that then allows water to flow to the lower "arm" of RIIS (i.e., which includes the Upper Lalo, Lower Lalo, and Barit sub-systems), and the upper "arm" of the system (i.e., covering the RIDA sub-system). A total of 34 Irrigators' Associations (IAs) have now been organized in the RIIS (as of Dec. 2013) with the responsibility of cleaning and maintaining the irrigation canals, collecting irrigation fees, and assisting in the operationalization of irrigation projects (See Figure 3.2). The IAs are also responsible for the management and operation of the turn-outs within their jurisdiction through the TSAGs. As of 2013, there are about 280 TSAGs and 16,391 farmers covered within the 107 km of canals in RIIS.

RIIS was selected as the focus irrigation system primarily because AWD has not yet been formally rolled-out and disseminated in this part of the county prior to the start of our study in 2016, and yet it is in a major rice producing area in the Philippines (i.e., the Bicol region ranks sixth among the 16 major rice producing regions in terms of total rice production). As such, our baseline data collection is not severely "contaminated" by promotion efforts by NIA and IRRI, and we believe there had been no AWD adoption in the system in 2016 when we started the study. [5] Moreover, since RIIS is within a major rice-producing region, the irrigated rice cropping system in the study area is representative of production in other regions of the country, such that we expect external validity of the results. Impacts inferred from this population can then be used for scaling-up and analyzing more aggregate impacts of AWD.

3.3 Empirical Strategy

3.3.1 RCT Approach: Structure and Description

The first step in our RCT approach is to select the "relevant" population from which to draw our samples from (and for which we can randomly allocate treatment and control groups). This step is necessary

[5] The majority of the initial AWD dissemination efforts were in gravity and pump irrigation systems in Central Luzon (i.e., the Upper Pampanga River Integrated Irrigation System (UPRIIS)), which is considered the number-one rice-producing region in the Philippines (3.7 million metric tons in 2014 (19% of total)). In addition, although AWD was mandated as national policy to be implemented country-wide (through the Philippine Department of Agriculture Administrative Order 25), we believe that farmers in RIIS did not utilize AWD prior to the start of our study (i.e., they may have somewhat heard about it, but not adopted it).

because not all of the 280 TSAGs in RIIS maybe "valid" TSAGs to be included in the study. For example, not all TSAGs have working turnout facilities (i.e., dilapidated turnouts and canal) and in some TSAGs there are significant amount of fish pond operators than rice farmers. In addition, we had to consider the availability of farmer lists/locations (from NIA) and historical cooperation with NIA as factors when delineating the "relevant" TSAG population. Eventually, out of the 280 total TSAGs in RIIS, only 92 "valid" TSAGs were included in the population of TSAGs that can potentially be drawn for inclusion in the study (either as treatment or control).[6]

With this valid TSAG population, we then implement a stratified "cluster" randomization design, where the clusters of choice are the TSAGs (i.e., randomization is at the TSAG level). The stratification is based on the TSAG location relative to the main water source (Lake Buhi) and are classified as follows: upstream, midstream, and downstream. To operationalize this approach, we first randomly select 42 TSAGs to be included in the study sample (i.e., 21 was treated TSAGs and 21 was control TSAGs).

It is important to note that the actual allocation of TSAGs in the valid population (of 92 TSAGs) is such that 20% are upstream, 30% are midstream, and 50% are downstream, and our random selection is consistent with this distribution. Thus, the 42 TSAGs randomly selected for the study was allocated as follows: 8 TSAGs are located upstream, 14 TSAGs are located midstream, and 20 TSAGs are located downstream. The 42 TSAGs included in the study covers around 1000 ha. These 42 TSAGs were randomly chosen proportional to "size", where the size variable is the number of farmers in the TSAG.

After the 42 TSAGs included in the study sample were randomly drawn, simple random sampling was then conducted to pick the treatment and control TSAGs within each stream location strata (i.e., 4 treated and 4 control TSAGs upstream, 7 treated and 7 control TSAGs midstream, 10 treated and 10 control TSAGs downstream). The distribution of all 42 treatment and control TSAGs are presented in Table 3.1. The list of farmers for each of the selected TSAG was then collected from NIA and we randomly selected 20 farmers in each study TSAG to participate in the study (i.e., to be surveyed).

[6] The 92 valid TSAGs are spread across 15 IAs over a service area of 1,789 ha and includes 3,828 farmers.

The decision to only choose 42 TSAGs in the study is primarily due to funding limitations (i.e., our budget really can only afford us to survey about 840 farmers (42 TSAGs x 20 farmers per TSAG)). Nevertheless, power calculations were conducted to assure that the structure of the RCT and the sample size would be able to statistically detect differences in yields and water use due to AWD. Results of power calculations based on the randomization structure above are presented in Figure 3.3.[7] We present the expected power for the yield and irrigation hours outcome variables, under varying levels of intra-cluster correlation (ICC) between 0 and 0.5 (i.e., an indication of the level of correlation of observations within each IA).

These calculations indicate that the randomization approach and the sample size for the data in the study would provide sufficient power to detect differences in water use (e.g., irrigation hours) under varying ICC levels. However, the randomization structure seem to have sufficient power for detecting yield differences only as long as the ICC is relatively low. Since the expected range of ICC is usually between 0.01 and 0.02 for human studies (Killip et al 2004), we believe our randomization structure still provides sufficient power for detecting differences between the yields of the AWD treatment group and the non-AWD control group.

Moreover, the assumed yield differential to be detected in these power calculation tests are relatively low (i.e., low yield differentials observed in previous studies, like in Rejesus et al., 2011 where there were no statistically significant difference in yields observed between AWD and non-AWD farmers), and this suggests that it would really require a very large number of observations to have large power at higher ICC levels. However, a larger sample size (beyond 820 farmers) was not attainable in our

[7] In these power calculations (using the Stata command "clustersampsi" by Hemming and Marsh (2013)), we use the estimated AWD yield and water-use impact results from Rejesus et al. (2011) as the basis for the detectable differences between treatment and control groups. The power calculation assumes that we are wanting to detect a yield difference of only 0.3 tons/ha (where AWD treatment has a yield of 5.0 tons/ha and non-AWD control has yields of 4.7 tons/ha & with standard deviations of 1.3 and 1.1, respectively). For the water use outcome, we assume that we would like to detect an irrigation hour difference of 25.3 hours (where the AWD treatment is 40.5 hours of irrigation and the non-AWD control is 65.8 hours of irrigation & with standard deviations of 22 and 85, respectively). Further, we assume a base correlation of 0.8 between the baseline outcomes and the outcomes after treatment.

case due to the aforementioned budget constraints (i.e., therefore, tradeoffs had to be made between budget and statistical power).

3.3.2 Description of Survey Data Collection and Implementation of AWD Treatment

3.3.2.1 Data collection procedures

Once the randomization structure was established and implemented (as described in the previous section), we then proceeded to conduct the survey data collection for the study. The baseline survey data collection was conducted in May/June 2016 (for dry season 2015/2016) prior to exposure of the treatment farmers to AWD. The survey questionnaire was first pre-tested (on irrigated rice farmers in Laguna province) before being used in the survey data collection in the study area. Enumerators were recruited from local agricultural state universities in the Bicol region (i.e., graduate students and faculty) and they were properly trained before being allowed to survey the study farmers. Eventually, a final baseline data set from 820 farmers were collected (414 treated farmers and 406 control farmers).[8] The spatial distribution of all 820 study respondents can be seen in Figure 3.4. Follow-up survey data collection was then conducted in May/June 2017 after the treated farmers in the study was exposed to the AWD irrigation technique in the dry season 2016-2017 (more details about this implementation is described below). Encoders were hired to transfer the data from the paper surveys and create an electronic data base that can be utilized for further statistical analysis (for both years of data collection). These encoders were supervised by our senior research assistant (Ms. Rose San Valentin) to assure quality control.

3.3.2.2 Implementation of AWD Treatment and Water Depth Monitoring

As noted above, the treatment farmers (in the randomly selected treatment TSAGs) were then exposed to AWD soon after baseline data collection was completed. Project team members (e.g., specifically, Dr. Ruben Lampayan and Dr. Evangeline Sibayan), with assistance from NIA and the Philippine Rice Research Institute (PhilRice), conducted trainings in June and August 2016 for those sample farmers in

[8] Although we intended to have 840 farmers in our sample (42 TSAGs x 20 farmers per TSAG), not all selected TSAGs had 20 total farmers and there are some cases where selected/listed farmers are no longer farming (and cannot be tracked down).

the treatment TSAGs. In these training sessions for farmers in the treated TSAGs, information about AWD was provided and implementation of AWD was strongly encouraged for the upcoming dry season (2016/2017). All farmers in the selected treatment TSAGs, even if they were not included in our study sample, were invited to attend the trainings. However, not all of the sample farmers attended these AWD trainings even with our strong encouragement (and even when offering to cover their transport cost to the training venue).[9] In addition to these AWD trainings, the field water tubes (i.e., plastic PVC pipes provided by PhilRice, in this case) were personally distributed to each selected AWD treatment farmer and its use for successfully implementing AWD was explained to them. Therefore, even for those treatment farmers not able to attend the AWD trainings, information about AWD implementation was provided and encouraged.

Prior to the start of the 2016/2017 dry season, a meeting that includes project personnel, NIA, and PhilRice, together with TSAG leaders and IA presidents, was convened to set-up a water depth monitoring system in the TSAGs included in the study. This allows us to measure weekly field water depths for at least some of the farmers included in the survey and provides a more accurate indication of whether or not some of the selected treated farmers truly implemented AWD during the season. [10] Four (4) farmers were randomly selected to be monitored in each of the study TSAGs (both treatment and control TSAGs), for a total of 168 farmers where weekly water depth was recorded (4 monitored x 42 study TSAGs).

It is important to mention here that there was no "forced" implementation of AWD at the system, sub-system, IA, or TSAG levels. That is, there were no tighter limits imposed on the water flows at these more aggregate irrigation units to "force" implementation of AWD (i.e., limit water availability) in the second year. The normal schedule of water releases (i.e., the traditionally agreed upon rotational

[9] Based on the data we have so far, only about 25% of the treated farmers attended these trainings.
[10] This water depth monitoring set-up entailed providing monetary compensation for TSAG leaders and IA presidents to perform weekly water readings and for NIA technicians to collect and electronically record these readings. Given these required monetary compensation (and our budget limitations), not all study farmers were included in this water depth reading procedure. See more discussion on this issue above.

schedule) was practiced in both the baseline and implementation years. Hence, AWD adoption is essentially at the individual level in this case, where farmers decide when/where to create cracks in the rice bunds to let water in to their paddy fields from the main farm ditch and/or lateral canals (i.e., irrigation that is consistent with AWD principles). Another important issue to note for the dry season of AWD exposure and implementation (dry season 2016/2017) is that there was a typhoon that passed through the study area in late December 2016 (Dec. 25, 2016). Thus, there were some study farmers affected and some of them decided to re-plant their fields (due to the damage). In this case, we collected survey data for the re-planted (i.e., "third" cropping) and took note of these farmers in the data set. This is one reason for the delays experienced by the project team in collecting the second-year data (i.e., some farmers were only surveyed in late June 2017). Note that most of the farmers included in the partial data set utilized in the analysis for this report are the ones who did not re-plant due to the typhoon.

3.3.2.3 Descriptive Statistics

Since the follow-up data collection was only completed in late June 2017, we only have a partial data set for 2017 that includes 257 farmers (i.e., 164 treated and 93 control). [11] But we do have a complete baseline data set for all 820 farmers (i.e., for the 2016 data collection). Mean comparison of selected 2016 baseline socio-demographic variables for the full sample (820 farmers) are presented in Table 3.2. It is clear from this table that there is balance between the AWD treated and non-AWD control farmers in terms of these baseline socio-demographic characteristics. There are no statistically significant differences in these socio-demographic variables between AWD treated ad non-AWD control groups.

In Table 3.3 and 3.4, we present AWD versus non-AWD mean comparisons for selected baseline irrigation use and economic outcome variables, respectively. For the irrigation variables (Table 3.3), only four of the nine selected baseline irrigation use variables are not statistically significant (e.g., no. of days rice parcel is without water, average depth before irrigation, average depth after irrigation, and labor used

[11] Aside from being partial, it should be noted that (at the time of writing) we have not fully double checked all the entries in the 2017 data set to make sure all of them are valid (i.e., whether most entries pass the "sniff" test such data values/entries (especially outliers) are reasonable/possible). Therefore, there may still be some errors that we have not caught (i.e., it is not "clean" and the statistics/results presented in this final report may drastically change).

for irrigation). For the remaining variables, such as irrigation frequency and no. of hours of irrigation, there already seems to be a statistically lower irrigation use (at the 5% level) for randomly selected treatment farmers (as compared to the control), even before treated farmers were exposed to AWD. For the economic outcome variables in Table 3.4 (e.g., input use, rice yield, and income variables), only a subset of them are not statistically different (at the 10% level). Most of the baseline input use, yield, and income variables (for 2016) of the randomly selected AWD farmers are statistically lower than that of non-AWD farmers (at the 10% level or less).

Therefore, there seem to be an imbalance between treatment and control farmers even before AWD exposure of the treated group (and even when we randomly chose treatment and control farmers). This suggests that it may be appropriate to use a DID approach in the impact estimation procedures to account for these initial differences observed in the baseline data. It is also heartening to see that the baseline yield differences between randomly selected treatment and control groups are observed even prior to the 2016 baseline data collection (in 2014 and 2015). As such, the parallel trends assumption that is required for the DID approach to hold would likely be satisfied in this case (more on this below).

As mentioned above, the 2017 follow-up data set (after AWD exposure of randomly treated farmers) is still not complete, and only a partial data set for 257 farmers are available. In the lower panel of Table 3.5, we present mean comparisons of selected socio-demographic (e.g., farm size, total no. of parcels), irrigation use, and yield/income variables for the 257 treated and control farmers in 2017.[12] Corresponding mean comparisons of these same 257 farmers, but for the 2016 baseline data, are presented in the top panel of Table 3.5. Notice that, even for the partial set of 257 farmers, there are some imbalances with respect to the baseline irrigation use and yield/income variables (in both 2016 and 2017 dry seasons).

[12] Given the incomplete nature of the partial data set, not all variables presented in the previous tables are easily available for the 2017 data set. These variables typically need more data calculations to obtain and as such are not included here (i.e., variables like average depth before and after irrigation, as well as the input use variables). The other socio-demographic variables, like age and no. of years of farming, are purposely not included in Table 3.5 since these only adds one more year (essentially time-invariant).

Lastly, in Table 3.6, we present some statistics about the distribution of treatment and control farmers, as well information about who eventually adopted AWD or not, in the partial sample of 257 farmers (i.e., for the full irrigation system (top panel), and for each stream location (bottom three panels).[13] For the full system, about 35% of the 257 farmers in the sample (or 54% of the 164 randomly treated farmers) said they actually practiced AWD. And majority of these AWD adopters used the field water tube (or pipe) provided (73 of the 89 farmers who said they adopted AWD). Moreover, it is important to note that most of the 257 farmers in partial sample are located upstream and less than 50% of the treated farmers in this location said they adopted AWD. This is important to highlight since farmers in the upstream location are the ones expected not to have the most incentive to apply AWD (given that they are nearest to the water source).

The discussion above primarily pertains to the descriptive statistics from the survey data collection. As mentioned in the previous section, there were 4 randomly selected farmers in each TSAG were water depths were recorded weekly. At the time of writing, the complete data for this water depth monitoring system has not been compiled and descriptive statistics for these monitored treatment and control farmers are not yet provided here. Nonetheless, an example figure that can provide some idea of how these water reading data looks like are provided in Figure 3.5. Weekly water readings for 4 farmers in a treated TSAG is presented in the top panel (A) of Figure 3.5, while the weekly water readings for another set of 4 farmers in a nearby control TSAG are presented in the bottom panel (B) of Figure 3.5. One important thing to note here are the readings in the first few weeks, where the monitored farmers in the treatment TSAG already have several "dips" in the reading where water depth went below zero (i.e., below ground level). In contrast, for the farmers in the treatment TSAG, these "dips" below ground level were only observed starting in the fourth week. These water readings data provide a good indication that the 4 monitored farmers in the treatment TSAG may have indeed practiced AWD. Therefore, these

[13] Adoption of AWD in this case is based on the answer to a direct question in the survey instrument asking "Did you practice Alternate Wetting and Drying (AWD) on your rice field last dry season? ___ Yes ___ No." If they answered "Yes" to this question, a similar question was asked about whether or not they used the field water tube.

readings may be used to really identify who among the 168 monitored farmers practiced AWD, and when combined with the survey data, can allow us to conduct a supplemental impact analysis of AWD in the future for the sub-set of 168 monitored farmers.

3.3.3 Estimation Procedures and Specification: RCT Difference-in-Differences

Given the panel nature of our data (for the partial set of 257 farmers), as well as the imbalance in some of the irrigation and economic outcome variables, we primarily rely on a DID approach as our main estimation strategy for this study. In essence, the DID approach compares the difference between the outcomes from AWD-adopting and non-AWD-adopting farmers during a pre-intervention baseline period (i.e. "before" implementation) versus the difference in the outcomes "after" AWD adoption. For a two-period panel where AWD treatment/adoption is only in the second period, the DID estimator can be naïvely estimated by first considering the following:

$$Y_{it} = \delta T_{it} + X_{it}\beta + \varepsilon_{it} \quad \text{for } (i = 1, \ldots n \text{ and } t = 1, 2), \tag{1}$$

where Y_{it} is the outcome variable of interest for farmer i in year t, T_{it} is a dummy treatment variable that is equal to one if the farmer is included in the randomly selected treatment TSAG and was encouraged to adopt AWD in $t = 2$,[14] X_{it} is a vector of control covariates, δ and β are parameters to be estimated (with δ as the measure of AWD impact), and ε_{it} is a compound error term with both time-invariant component (a_i) and time-varying component (v_{it}) such that $\varepsilon_{it} = a_i + v_{it}$.

If there were no imbalances observed in the baseline data and all the farmers in the randomly selected treatment TSAGs adopted AWD, then a straightforward Ordinary Least Squares (OLS) regression could have been used to estimate the impact parameter in (1). The random (and therefore exogenous) treatment/adoption variable assures that the estimated impact parameter from OLS is causally

[14] Note that no farmer was encouraged to adopt AWD in the first season (dry season 2016), even though we know who among these farmers will eventually be included in the "treated" group for the second season. Therefore, the dummy treatment variable is all zeroes in 2016.

identified.[15] However, with the observed imbalances in the baseline data, it may be important to account for this issue by first differencing equation (1) and following a DID framework:

$$\Delta Y_i = \delta T_i + \Delta X_i \beta + \Delta v_i \quad \text{for } i = 1, \ldots n \tag{2}$$

where the deltas (Δs) represent differencing the first time period value from the second period value. This first differencing approach works well if the main source of the imbalance can be attributed to time-invariant unobservables.

In addition, the first differencing approach in (2) may also not provide an appropriate estimate of the impact of AWD since the T_i indicator variable in this equation represents those farmers in the randomly selected treated TSAGs for which water tubes were given and AWD use were encouraged/promoted. The T_i variable does not actually indicate whether these farmers eventually adopted AWD in 2017. Nevertheless, note that the δ parameter estimate in this case is considered an Intention-to-Treat (ITT) impact estimate (i.e., it assumes that those intended to be treated with AWD was actually treated) (Duflo et al., 2006, De Janvry et al., 2011).

In light of the discussion above, we are also interested on the impact of AWD for those farmers who actually said that they utilized the practice in 2017. Therefore, we also estimate the following:

$$\Delta Y_i = \delta AWD_i + \Delta X_i \beta + \Delta v_i \quad \text{for } i = 1, \ldots n \tag{3}$$

where AWD_i is a dummy variable that is equal to one if farmer *i* reported that he/she actually adopted the AWD irrigation technique in 2017. In this case, AWD_i is not randomly assigned and likely to not be truly exogenous. Nevertheless, if the main unobservable factors that drive non-random selection into AWD adoption are time-invariant the DID first differencing approach would actually still provide consistent impact estimates. However, if the main unobservable factors are time-varying, then the impact estimate in (3) may be inconsistent and an alternative estimation approach may be required.

[15] Moreover, this OLS approach would have been appropriate even when only utilizing the 2017 data for analysis (when AWD was actually implemented), if there were no imbalances observed in the baseline data and all the farmers in the randomly selected treatment TSAGs adopted AWD.

Since we know that the T_i variable is truly random, this variable can then be used as a valid instrument in an instrumental variable (IV) (or two-stage least squares (2SLS)) estimation approach of (3).[16] The T_i variable would be a valid instrument in this case because it would likely be correlated with the decision to actually adopt AWD, but is truly uncorrelated with the time varying unobservables in the error term (if any).[17] In this case, the δ parameter estimated through the aforementioned IV technique is the Local Average Treatment Effect (LATE) (Angrist and Imbens, 1994, Duflo et al., 2006, De Janvry et al., 2011). And because there are no one in the control TSAGs that actually adopted AWD, then the impact parameter in (3) estimated through IV techniques are also considered the Treatment Effect on the Treated (TOT) (Duflo et al., 2006).

As already mentioned in the previous section, one crucial assumption for the validity of the DID approach is whether or not the outcome variables in the data follow the parallel trends assumption. Given that the mean differences in rice yields of farmers in the treated and control TSAGS seem to have been present even in 2014 and 2015, we believe the parallel trends assumption is satisfied here. This same pattern is observed for the partial data set of 257 farmers. In future analysis of this data, we will also explore the use of non-linear DID methods (Athey and Imbens, 2006) that do not rely on the validity of the parallel trends assumption to provide consistent impact estimates.

3.4 Preliminary Results and Discussion

Preliminary results from the DID regression runs estimating impacts for various outcome variables (based on the partial data set of 257 farmers) are presented in Table 3.7. Note that in these estimation runs we did not include any time-varying control covariates in the regression (i.e., since most of the time-varying covariates in the 2017 data set were not yet ready at time of writing). In addition, standard errors were not yet clustered at the TSAG level (i.e., the level of randomization in this case).

[16] For this final report, we use straightforward 2SLS for estimating equation (3). In the future, we also plan to estimate (3) using the "zero" stage approach recommended by Wooldridge (2002) and Nichols (2007). Control function approaches would also be explored as robustness checks in the future. Clustering the standard errors at the TSA level will also be implemented in future analysis of the data.

[17] Although not reported in this final report, we did test the validity of the proposed IV and found that the treatment variable T_i is indeed strongly correlated with the AWD adoption variable.

The straightforward DID estimation results for equation (2) are presented in the second column of Table 3.7 (i.e., the column with the lable "Standard DID Impact Estimate"), while the IV-DID estimation results for equation (3) are presented in the third column. In addition, an IV-DID procedure was also used to estimate something akin to equation (3), but instead of the AWD adoption variable as the main independent variable we use a dummy variable indicating whether or not the farmer in the randomly treated TSAG actually used the field water tube (PVC pipe) to practice AWD (see fourth/last column of Table 3.7). In this last case, AWD adoption is defined as the use of the field water tube and whether they reported that they practiced AWD (i.e., the field water tube question was not asked if the farmer did not indicate that they practiced AWD).

Preliminary results from Table 3.7 indicate that AWD does not have a statistically significant impact on irrigation frequency, days the main rice parcel are without water, and rice yields. However, there is some statistical evidence that AWD may have helped increase gross rice income, as well as increase the size of the main parcel farmed. The increase in parcel size may be due to AWD adoption allowing some farmers (i.e., likely those in the midstream and downstream locations) to have more access to water and consequently they were able to increase the size of the area they farm. Nonetheless, these preliminary results only suggest limited economic impact of AWD for the study area in RIIS. Taking account of the pre-existing differences in the outcomes of treated and control farmers (through the DID approach) may have played a major role in this outcome. In addition, this limited impact may also be due to the observation that some of the control farmers already practice some form of intermittent irrigation (i.e., a limited form of AWD) where the field is NOT continuously flooded throughout the season (see descriptive statistics of "Days main parcel w/o water (#)" in Table 3.3. and 3.5). Hence, with control farmers already practicing some form of intermittent flooding, the impact of AWD may not be as pronounced as when control farmers practice continuous flooding throughout the season.

Notwithstanding the discussion above, it is important to emphasize here that the results reported are still preliminary. Only data from 257 farmers out of the 820 farmers in our sample was included in the analysis. Furthermore, majority of these 257 farmers are in the upstream area. There are also important

limitations in the analysis, since additional control covariates are yet to be included and clustering of standard errors still need to be implemented. Robustness checks using several other alternative estimation procedures have also not been conducted. Given all these, the preliminary results provided in this report should be interpreted and taken with caution. These results can drastically change when the full data set is used in the analysis.

3.5 Conclusions and Plans for Further Analysis: Micro-level Economic Impact of AWD

This study aims to more rigorously estimate the impact of the AWD irrigation technique on water use, yields, and income, primarily using a combined RCT and DID approach. Preliminary results based only on panel data from 257 farmers (out of 820 included in the study sample) indicate that AWD did not have a statistically significant impact on irrigation use and yields. Although, there is some evidence that it may have improved incomes and increased the size of the main rice parcel farmed. However, as noted in the previous section, these overall results should be interpreted with caution given the incomplete data utilized, as well as some of the limitations in the quality of the data (i.e., mainly the second year follow-up data at this point) and the incomplete analysis (i.e., that was borne out of time constraints). It is important to emphasize that the results and inferences from a more comprehensive analysis in the near future (utilizing the complete data set) may be drastically different from the ones presented in this final report.

Notwithstanding the discussion above, the study proponents are planning further analysis that aims to improve on some of the preliminary work provided in this report. First, we will continue encoding and cleaning the second year follow-up data set (dry season 2016/2017). Further checking of the data will also be conducted to make sure all the data entries are reasonable and passes the "sniff" test (i.e., especially for outliers in the outcome variables and control covariates). Once this task is complete, the full two-year panel data set for all farmers included in the study can be utilized for the analysis.

Second, alternative specifications for equations (2) and (3) will be explored. Specifically, we will explore additional control covariates (X_{it}) and then decide whether or not to include these covariates in our regression runs to improve precision of our impact estimates. Weather data (e.g., precipitation and

temperature) will also be collected from local weather stations and included in the specifications. Dimension reduction procedures, like LASSO, may also be used to help determine the covariates to include in the specifications. In addition, several specifications will be constructed to explore the potential heterogeneity of AWD impacts (i.e., possibly across stream locations).

Third, several other statistical techniques that improve on the estimation procedures described above will be investigated and applied (if deemed appropriate). For example, to improve balance, we can conduct Propensity Score Matching (PSM) or Entropy Balancing to better match treatment and control farmers based on the wealth of observable variables collected in the study (See, for example, Rodriguez et al., 2007 and Hainmueller, 2012). This will likely "trim" the study sample since control farmers that are not good matches will be dropped from the sample, but the improved balance may allow us to tease out the AWD impact better. Alternative IV approaches like the "zero" stage approach and control function methods (Wooldridge, 2002) will be explored as robustness checks. The applicability of the Athey and Imbens' (2006) nonlinear DID approach will also be examined given that its validity does not rely on the parallel trends assumption holding. Clustering of standard errors will also be utilized in future regression runs using the survey data.

Lastly, as mentioned in Section 3.3.2.3 above, the water depth reading data for the 168 farmers monitored will be utilized and merged with the survey data to conduct supplemental analysis based on this partial sample. The water readings may provide better indications of the extent of AWD adoption by the study respondents and allow one to better evaluate the impact of its use. This supplemental analysis may only utilize a partial sample, but may provide other insights not observed from the complete survey data of 820 farmers.

4.0 Environmental Impact of AWD: Effects at Different Spatial Scales and Methane Emissions

4.1 Analysis of Water Use at Different Spatial Scales: Sub-System, TSAG, & Field Levels

4.1.1 Introduction/Objective/Significance

Irrigation water input applied to rice fields is much larger (i.e., by a factor of 2-10) compared to water input used for other major staple food crops in Asia, and far larger than the requirement for evapotranspiration (ET) in rice crop production. As a result, farmer field level irrigation water productivity tends to be very low (Tuong et al., 2005; Humphreys et al., 2007). However, there is large scope to increase the amount of rice grain produced per amount of irrigation water supplied by: (1) increasing yields, and/or (2) reducing irrigation inputs. There is large potential to achieve both, but in this section of the report, we only focus on the latter approach (i.e., reducing irrigation input through AWD).

The concept of water productivity becomes important when water is scarce (Bouman et al., 2007). At the field level, a number of studies have shown that total water productivity significantly increased with AWD use (Pan et al, 2017; Bueno et al., 2010). To date, AWD is widely promoted in irrigated lowland rice systems in Asia (Lampayan et al, 2015), and adopted mostly at individual farmer's field level, rather than at subsystem or irrigation system level. AWD has great potential to reduce irrigation water input to rice, with considerable benefits to farmers or society in various forms (e.g. reduced irrigation costs, increased yield, expansion of the irrigated area, more efficient use of fertilizer (i.e., reduced leaching loss), and increased water productivity).

However, whether the reduction in irrigation input to farmers' fields results in actual 'water saving' and increased water productivity at higher spatial scales is a very different question. To answer this question, it is necessary to consider each farmer's field in the context of the entire irrigation scheme (i.e., within the river basin, lake system, and/or watershed), and then how the whole system is affected by changes in farm-level management that reduce irrigation input and/or increase rice production. In this section, we attempt to compare water use and water productivities at three spatial scales: farmer's field, turnout service area group (TSAG), sub-system, and system scale; and then assess for possible water

savings at these scales. Note that the yield data for our study is not yet complete at the time of writing and, thus, water productivity calculations are not presented in this report.

4.1.2 Materials and Methods

4.1.2.1 AWD Implementation Structure

4.1.2.1.1 Treatments and turnout service area group (TSAG) selection

In dry season 2017, we set up two water management treatments: 1) AWD-TSAG, and 2) control-TSAG (See discussion in Section 3). In the randomly selected AWD-TSAGs, farmers were exposed and encouraged to adopt AWD as their water management practice. In control-TSAGs, farmers were left to use their current water management practice. A total of 42 TSAGs were randomly selected in RIIS (21 AWD-TSAGs and 21 control-TSAGs). As already shown in Table 3.1 (from the microeconomic impact section (Section 3)), these TSAGs were distributed as follows: 8 upstream TSAGs (4 AWD-TSAGs and 4 control TSAG), 14 midstream TSAGs (7 AWD-TSAGs and 7 control TSAG), 20 downstream TSAGs (10 AWD-TSAGs and 10 control TSAGs).

Before the start of the AWD treatment in the 2017 dry season, a half-day training on AWD was conducted in the 2016 wet season. This training was only given to the TSAGs selected to be exposed to AWD in the 2017 dry season. Farmers in the control-TSAGs were not trained so that these farmers solely adopt their own water management practices. Lectures on sound field water management, together with principles and practices of AWD, were given to AWD-TSAG farmers. A demonstration of how the field water tube is to be installed was also included in the training. In addition, field water tubes were made available in the 2016 wet season so that interested farmers can have experience with the field water tubes even prior to the 2017 dry season (i.e., about 3-4 farmers in a few TSAGs took up this offer and tested out the tubes in the wet season). Although AWD was not implemented in the wet season, farmers gained experience in proper installation of the field water tubes, and better appreciation of AWD**.**

4.1.2.1.2 Field level water management

To facilitate AWD adoption (in the AWD-TSAGs), all study farmers in each randomly selected AWD-TSAG site were given a field water tube by NIA and/or PhilRice personnel, and these same personnel

helped in installing the field water tubes (if requested). For each study farmer's field in the AWD-TSAG, one representative plot was typically selected for field water tube installation.

The following AWD guidelines were explained to the selected study farmers in the AWD-TSAGs: 1) during vegetative crop stage (from 10 cm plant height), irrigate up to about 5 cm water depth above the soil surface when water in the field water tubes falls below 15 cm from the soil surface; 2) during flowering stage, maintain flooded condition in the rice field (from start to end of the flowering stage); 3) after the flowering stage, go back to safe AWD which is re-irrigating the field when water is about 15 cm below the ground surface as can be seen in the tubes.

Among all the study farmers that were given field water tubes in the AWD treatment sites, field water tubes of four farmers were purposely selected for regular monitoring and recording of field water depths throughout the season (3 times a week).[18] In control-TSAGs (non-AWD TSAGs), field water tubes were also installed in farmers' fields, but only in 4 selected farmer's plots. Moreover, these field water tubes in the control sites (total of 84) were only used to monitor field water depths and were not used to practice AWD.

Other cultural management practices such as fertilizer-N application, pest and weed management practices, varieties, and others are not part of the treatment. Farmers had a free hand to manage their rice crop according to their own practice, except that AWD was encouraged in randomly selected treatment TSAGs.

4.1.2.1.3 TSAG and subsystem water management

Irrigation deliveries from secondary or tertiary canals into the turnout service areas vary depending on the agreed upon water delivery schedule of the specific turnout (i.e., agreement between the TSAGs/IAs and NIA). Some TSAGs receive water 4-5 days a week in a rotational basis, and some may be lower depending on their proximity to the water source (i.e., upstream TSAGs may receive irrigation water

[18] In selecting the four farmer tubes to be monitored (both in the treatment and control TSAGs), one was selected "upstream" of the turnout, 2 was selected "midstream" of the turnout, and 1 was selected "downstream" of the turnout. Furthermore, these four farmers should have been selected as part of the farmers to be surveyed, as discussed in the economic impact section (See Section 3).

continuously throughout the week, while downstream TSAGs may receive less often than the midstream and upstream farmers), and occurrence of rainfall. In order to further facilitate AWD implementation at the selected treatment TSAGs, IA presidents and TSAG leaders were asked to make sure that agreed irrigation delivery schedules of the TSAGs will still be followed, and to properly close turnout gates if there really is no scheduled delivery (i.e., this is to avoid continuous flowing of water in the turnouts in no-scheduled times).

At the subsystem level, irrigation diversion was based on the existing water delivery operation and schedule of the subsystem. The general description of the irrigation diversions from the source to the different subsystems are described in Section 4.1.3.2 below.

4.1.2.2 Data Collection and Analysis

4.1.2.2.1 Sub-system and Turnout Irrigation water inflows estimation and dynamics

Water inflow data were collected at the sub-system, turnout, and farmer's field levels, respectively. At the sub-system level, daily discharge data were regularly monitored and recorded by NIA personnel at the main supply canals at each of the RIIS sub-systems (Barit, RIDA, Upper Lalo, and Lower Lalo).

At the TSAG level, due to limited water level measuring devices, only six turnouts (out of a total of 42 turnouts in the study sample) were selected for turnout irrigation water inflow measurements. Two turnouts (1 AWD TSAG and 1 control TSAG) in Barit, RIDA, Upper Lalo subsystems were chosen to be measured, as shown in Table 4.1. Water level loggers (specifically, the Onset HOBO™ U20 Water Level Series Data Loggers) were used to automatically monitor the water level (or head) of irrigation near the outlet of the turnouts at 15 minutes recording interval.

Water level data were then converted into discharge data (L/s) using the head-discharge equation established for the TSA canal. The derivation of the head-discharge equation was done by measuring the discharge of the canal at different canal heads or water levels using current meters. Linear regression analysis was carried out with canal head (or water level) as independent variable and discharge as dependent variable to establish the equation. These calculated water discharge is used to compare the water use for AWD treated TSAGs versus the non-AWD treated TSAGs (in dry season 2017).

4.1.2.2.2 Farmer's field level water depths measurement and estimation of irrigation inflows

Monitoring and recording of the field water status using the field water tubes in 4 selected farmers' fields in each AWD-TSAG and each control-TSAG were done three times a week, from 20 days after transplanting up to terminal drainage (See Section 4.1.2.1.2 above). Note that a TSAG leader (also called a water tender) was assigned in each TSAG (and compensated) to regularly monitor and measure the four farmers' field water depths using a meter stick. The depth of the water inside the tube was measured from the top of the tube to the level of the water inside the tube, and is designated as water level reading R in cm. Then the actual water depth D with respect to the soil surface is computed using the following formula: D = R – 15, where D is the depth of water from the soil surface in cm.

To determine the irrigation input in each plot, instead of measuring water inflow using water flow measuring devices (as was used at the turnout level), we used the installed field water tubes to estimate the applied irrigation water at the field level. This was done by recording the field water level before starting irrigation and after irrigation was completed (Stuart et al., 2017). For each irrigation event when water did not fall below the soil surface, the amount of water applied (in mm) was calculated as the difference of the field water depths before and after irrigation. However, when field water level falls below the soil surface before irrigation application, irrigation input was computed as:

$$I = d_f + (\theta_s - \theta_f) \times D,$$

where I = irrigation (mm); d_f = final depth of standing water from the soil surface, θ_s = soil water content at saturation (cc/cc); θ_f= soil water content when the field water falls below the ground surface (cc/cc), in most cases, this soil moisture was assumed as the field capacity especially when the perched water depth is 15 cm or more from the soil surface; D= depth of perched water table depth (mm). Total water input was then calculated as the sum of water applied from irrigation and rainfall amount received.

4.1.2.2.3 Farming activities, agronomic and climatic data

The dates of land soaking, land preparation, sowing, transplanting, and harvesting were recorded by NIA at the subsystem level. This information is vital in assessing the progress of farming activities at the sub-

system level, and comparing the actual progress of farming activities with the designed cropping calendar of the subsystem.

Yield data were collected through the farmer surveys conducted in the 2016 dry season (i.e., the baseline survey) and in the 2017 dry season (the second year follow-up survey) for the study farmers in both the AWD-TSAGs and the control TSAGs (see economic impact section above). Note, however, that the second year data collection is not yet complete at the time of writing. Therefore, we do not provide any analysis in this section that involves using the yield data (such as water productivity measures). But this analysis will be conducted in the future when the survey data is complete.

Long term rainfall data (2006-2017) were also collected from the Central Bicol State University for Agriculture (CBSUA) Agromet Station, in Pili, Camarines Sur. This station is within the vicinity of the RIDA subsystem. The rainfall data is included in the calculation of total water applied in the field.

4.1.2.2.4 Water productivity and "water savings" calculations

As noted above, water productivity calculations is not yet possible at the time of writing given the incomplete survey data set. Nevertheless, in this sub-section, we discuss how we envision the water productivity calculation to proceed (at various spatial scales) and how it will be compared. Water productivity is usually expressed as irrigation water productivity (WP_I, kg grain m^{-3} total irrigation input) and/or total water productivity (WP_T, kg grain m^{-3} total irrigation plus rainfall).

At the farmer's field level, water productivity values for "AWD" and "control" will be determined by dividing the yield from each farmer's field (kg) by its total irrigation input (m^3) in the case of WP_I, or dividing by its total water input (m^3) in the case of WP_T. Then a "with and without AWD" comparison will be done to determine the difference in water productivity values at the field level. "Water savings", on the other hand, is computed in this study as the difference of the total water input between "control" and "AWD" fields divided by the total water input in "control" field. Note that field level water input difference (i.e., water savings) is provided in this report (see Table 4.5 below).

At the TSAG level, water productivities of the 6 TSAGs in Table 4.1 will be computed as the total grain produced (kg) in the TSAG divided by the total water diverted for irrigation at the turnout (m^3)

in the case of WP_I; or total grain produced (kg) in the TSAG divided by the total water diverted for irrigation at the turnout (m^3) plus rainfall in the case of WP_T. Total grain yield at the TSA is to be estimated from the average yield of farmers (kg/ha) taken in the follow-up survey (20 farmers in most TSAG) for 2017 dry season multiplied by the total area of the TSAG. Then a "with and without AWD" comparison will be done to determine if there is difference in water productivity values between the treatment and the control TSAGs. A similar approach as above will be followed for the water saving calculations (i.e., comparing water inputs of treatment and control TSAGs and calculating the difference).

At the sub-system level, irrigation water productivity will be computed as the total grain yield at the sub-system level (kg) divided by the total water diverted at the subsystem (m^3). Total yield will be estimated from the average yield of surveyed farmers within each subsystem multiplied by the total area of the sub-system. Then a "before and after AWD introduction" comparison will be conducted to determine if there is a difference in water productivity values at the subsystem level before the AWD was introduced (using data from dry season 2016) and after AWD was introduced (dry season 2017). A similar "before and after" comparison will be used to assess water input use differentials (and calculate water savings) at the sub-system level.

4.1.3 Preliminary Results and Discussion

4.1.3.1 Rainfall

In general, Camarines Sur province (where RIIS is located) experience a tropical climate: dry from March to May and wet the rest of the year (http://en.wikipedia.org/wiki/Camarines_Sur). Annual average rainfall of the province is 2,565 mm. In the study area, the 10-year average annual rainfall is about 2,225 mm, with more than 80% of this falls from May-December. The months of July, September, October, November, and December are the 5 top wettest months of the year, with monthly total rainfall over 200 mm (Figure 4.1). In the 2017 dry season (October 2016-May 2017), high rainfall occurred in the second week of October (Figure 4.2) which triggered the decision of most farmers to start their land preparation and crop establishments in some areas. In December 26, 2016, Bicol region (including our study site) was hit by typhoon "Nina" (with international code name Nock-ten) that brought strong winds and rains in the

province. This typhoon was considered as the strongest typhoon to hit Bicol in 10 years. In our study site, the typhoon dumped about 211 mm of rain that flooded some low-lying parts of study area, particularly those near Lake Baao (a shallow fresh water lake near RIDA and Barit subsystems). After the typhoon, a number of moderate rains also occurred in January, accumulating more than 150 mm of total rainfall for this month. February to May were relatively dry months, with few small rains occurring at night. Total rainfall used by rice crops during the dry season depends on when the crop was planted and the timing of terminal drainage of the field before crops were harvested. Water input to rice crops based one rainfall is presented in the succeeding sections.

4.1.3.2 General description of irrigation flows from source to subsystems

Sources of water for the whole system are Lake Buhi, Barit River, Waras River and Lalo River. Water from the control structure at Lake Buhi, flows through the Tabao River going to the Forebay, which is about 3 km away. From the intake structure, there is a 210-m canal connector going to the bifurcation structure where water flows separately for the Lower Lalo and RIDA subsystems. The main water source of Upper Lalo is from Lalo River (Figure 4.3).

Upper Lalo and Lower Lalo Subsystems. The combined Upper Lalo subsystem and Lower Lalo subsystem is usually called the Buhi-Lalo irrigation area. The Upper Lalo subsystem is also known as Division A of the Buhi-Lalo area. The main source of irrigation for Upper Lalo is from the diversion dam at the Lalo River, irrigating about 988.0 ha and serving 7 Irrigators Associations (IAs) in each cropping season. Irrigation water schedule delivery for Upper Lalo is from Monday to Sunday.

On the other hand, the Division B and Division C of the Buhi-Lalo area are collectively known as the Lower Lalo subsystem. Irrigation water for Lower Lalo is from Lake Buhi which diverts water into the irrigation intake structure to serve RIIS. Water from intake structure flows through a bifurcation structure (Figure 4.3), and this structure allows the water to flow to the Barit River and to the Main Canal. As water enters the Main Canal, it travels to the two divisions (Division B and C) whose length is about 15.9 km. Division B covers five IAs in which SAJUFIA is the upstream IA followed by MAGPALAANG FIA. Division C has 7 IAs, among them are the three IAs included in our SPIA-AWD project. These are

the SASFIA, MASAFIA and LOPALFIA. Division A has a service area of 719.4 ha while Division B has a service area of 878.4 ha.

The first release of irrigation was for land soaking, and in all subsystems (see Appendix Figure 4.1-4.3), upstream TSAGs receive irrigation water first before it moves to the lower sections. As the crop grows, the schedule of water delivery varies across subsystems, and for the case of Lower Lalo, Division B is from Monday to Thursday while Division C is from Friday to Sunday.

RIDA Subsystem. As shown in Figure 1, from the intake structure water flows to Barit River then impounded through the Upper Barit Dam. The Upper Barit Dam is the diversion structure intended for RIDA. RIDA has two Right Main Gravity Canal (RMGC) and these are the RMGC A whose length is 13.7 km and the RMGC B whose length is 17.3 km. RMGC A is the main canal from the Upper Barit Dam to San Francisco Creek while the RMGC B is the Main Canal from San Francisco Check gate to the tailend IA, the Binobong-Tagbong (Bintag) IA. The San Francisco Creek serves as the catching basin of the water from RMGC A then impounded at San Francisco check gate before it enters to the RMGC B.

The RIDA subsystem continuously adopts a rotation of water delivery scheme except when rain is abundant in the area. Monday to Thursday is the schedule of water delivery in Division C, while the Lateral Canals at Division A and B have continuous water inflows but controlled. From Friday-Sunday the schedule water delivery is for Divisions A and B. In the next few years, the source of water for RIDA will be reinforced by water from Waras Auxiliary Dam which is currently being constructed. Once fully operational, the Waras dam will provide additional irrigation water to augment availability and expand the service area of the RIDA system.

Barit Subsystem. From the Forebay structure, there is an intake structure going to the People's Energy Services Incorporated (PESI), the private hydroelectric power plant in the area (See Section 5.0 below). The wastewater from the power plant flows to the Daraga River and impounded at the Lower Barit Dam which serve as the source of water for the Barit sub-system. During period of water scarcity, where the hydro-electric power plant cannot operate, Barit gets water from the Upper Barit Dam as their source. This can only materialize by closing the gates going to RIDA in order to observe an overflow

going to downstream of Barit River up to the impounding area of the Lower Barit dam. In this scenario both RIDA and the Barit practice water delivery rotation in each subsystem. The period of irrigation in each division in the subsystem becomes longer. The rotational scheme of water delivery adopted in the Barit RIS are the following: Monday-Thursday for Division C, and Friday-Sunday for Divisions A and B, respectively.

4.1.3.3 Progress of farming activities, cropping calendar & cropping intensity at the subsystem level

Proposed and actual cropping calendars in Lower Lalo, RIDA and Barit for 2016 and 2017 dry seasons are shown in Figure 4.4. Cropping calendar shows the progress of cropping activities in the sub-system such as land soaking, land preparation, crop establishment, terminal drainage and harvesting for all farmers within a particular subsystem. This information is useful in the calculation/analysis of the total water input and water productivity at the subsystem level. A large variation between the start to end of crop establishment, for example, may result in higher water input and more prevalence of pests and diseases in the sub-system. In our study, non-synchronous rice crop establishment was largely observed in both 2016 and 2017 dry seasons in all sub-systems. There were also differences between the proposed and actual cropping calendars as shown in Figure 4.4.

In Lower Lalo, during the 2017 dry season, crop establishment started in the third week of November, but it took about 5 weeks to attain 50% completion, and about 14 weeks to fully complete the operation. Consequently, harvesting was delayed wherein about 50% of the area were only harvested in third week of March and 100% harvested in the first week of May. In general, the rate of progress of crop establishment in Lower Lalo had similar trends in both 2016 and 2017 dry seasons as shown in Figure 4.4a.

In RIDA sub-system (during 2017 dry season), the start and 50% completion of the crop establishment were similar to the Lower Lalo, but was only fully (100%) completed in the third week of March, which was three weeks longer than in the Lower Lalo. As a result, harvesting of crops were also late (third week of February up to the second week of May). In the 2016 dry season, crop establishment was slightly advanced (about 2 weeks) than in the 2017 dry season (last week of October), and

consequently crop establishment was fully completed two weeks earlier than in 2017 dry season. Harvesting for the 2016 dry season commenced in the second week of February and was fully completed in the first week of May.

In the Barit sub-system, the actual crop establishment schedule in the 2017 dry season was much later than 2016 dry season. It was also much later than Lower Lalo and RIDA during the same season. In fact, more than 50% of the area were only transplanted after the second week of February. This was because a large number of areas in Barit were flooded due to their proximity to Lake Baao, which was completely inundated for almost two months after the strong typhoon that hit the province in December 26, 2016 (see Section 4.3.1), and followed by moderate rains in January 2017. Farmers in these areas had to wait until the water in their fields subsided before they can transplant. Harvesting was also much later than the other sub-systems, with most of the crops harvested through last weeks of May.

Cropping intensity varies across subsystem, season, and year (Table 4.2). Cropping intensity for a subsystem is calculated by dividing the benefitted area (or actual irrigated area) in the subsystem by the total service area of the subsystem. On average, Lower Lalo had the highest cropping intensity at 84.9% in the wet season and 84.4% in the dry season. For the wet season, Barit had the lowest average cropping intensity (64.8%), as a substantial portion of the subsystem is near Lake Baao and is sometimes submerged/flooded. In the dry season, average cropping intensity for Barit and RIDA are similar (72.3%). There was no difference in cropping intensity for the dry versus the wet season in RIDA because, in the dry season, some portion of tail-end TSAs of the subsystem could not be irrigated, and in the wet season, some portions of the subsystem are submerged and uncultivated. During our study in 2017 dry season, cropping intensity was highest in Lower Lalo (90.4%), followed by RIDA (86.7%) and Barit (66.5%) sub-systems, respectively.

4.1.3.4 Irrigation diversion at the subsystem level

Weekly average irrigation diversion for Lower Lalo, RIDA and Barit subsystems are shown in Figure 4.5. Data for the Upper Lalo subsystem (upper portion of the Buhi-Lalo area) were not yet available for analysis at the time of writing and data from this subsystem is not presented here. Following a proposed

cropping calendar, a “theoretical” irrigation diversion requirement was estimated by NIA even before the start of season by considering operational area of the sub-system, and estimated parameters such as saturation requirement, evapotranspiration, seepage and percolation losses, soil moisture characteristics (saturation and wilting point), percent conveyance loss of water, percent loss of water at the farmers’ fields, canal efficiency, and effective rainfall.

In Lower Lalo, during the past two dry seasons (2016 and 2017), actual diversion was lower than the proposed/theoretical diversion requirement of the subsystem during the first three months of irrigation delivery. Based on available data, with high rainfall from October to mid-February, actual irrigation diversion was only 28% of the theoretical diversion requirement during 2017 dry season, and 38% during 2016 dry season. After the typhoon in December 26, 2017, irrigation diversion was halted for three weeks, then was resumed in the second week of January. Because of prolonged duration of cropping activities due to non-synchronous land preparation and crop establishment, irrigation water was still supplied in the canal up to third week of April at the discharge rate of about 1900 L/s. After this, irrigation diversion was stopped after most of the farmers harvested their crops.

In RIDA, a similar situation with regards to actual irrigation diversion was observed. Actual irrigation diversion was also lower than the theoretical irrigation diversion requirement (42% in 2016 dry season and 16% in 2017 dry season) in the first three months of irrigation delivery. The much lower irrigation delivery in 2017 dry season during the first three months was due to high rainfall in December (i.e., the typhoon). Irrigation diversion was also extended up to early May to irrigate farmer’s fields that were transplanted late (especially areas near Baao Lake such as Barlin IA). Also during 2017 dry season in RIDA, a few farmers (especially those who established their crops in October and harvested in mid-January) planted a third rice crop (after harvesting their dry season rice crop) to hopefully get the back some of the losses incurred in their crops due to the typhoon in December.

A similar trend (with Lower Lalo and RIDA) was also observed in the Barit subsystem where more than 50% of farmers were not able to establish their crops until mid-February during 2017 dry season. Irrigation delivery in Barit even continued until the second week of May.

4.1.3.5 Irrigation diversion dynamics at the turnout (TSAG level)

Irrigation inflows in terms of water levels at the gaging stations of the six selected turnouts are presented in Figure 4.6. Note that these water levels were then converted to irrigation volumes, and summed up though crop growth duration (from transplanting to harvesting) to calculate irrigation input at the TSA level. In the graphs, water levels at the gaging stations fluctuated over time, and episodes of no water releases were also evident. The graphs (particularly for the RIDA and Barit case) also showed high water levels at the turnout gaging stations after the December typhoon in the study area. In Barit, RAMC-26B and RAMC-26 were two TSAs that were close to Lake Baao, and high water levels from December 26 to the last week of January were recorded by the data loggers. Thus, farmers in these TSAs were only able to plant after the water in the area has receded.

4.1.3.6 Farmer's field water level dynamics

Figure 4.7 shows a sample water level fluctuations between AWD and control fields in the study site during the 2017 dry season[19] (the rest of the graphs of field water level fluctuations for all sample farmers with field water tube readings are presented in Appendix Figure 4.4 and Appendix Figure 4.5). In Figure 4.7, both graphs (4.7a and 4.7b) suggest that regardless of whether the field is an AWD- or control-treatment, there was a level of alternate wetting and drying conditions in each field (i.e., intermittent flooding). This means that control farmers in the site have already been adopting some level of AWD by default without them knowing, contrary to the old belief that farmers always use continuous flooding. However, although "control" farmers seemed to have been doing some milder form of AWD already, there was still some differences between AWD and control fields.

Under AWD conditions, a number of wetting and drying cycles is to be expected, but the number of cycles vary according to the level of AWD implementation, soil type, weather conditions (i.e., particularly the amount of rainfall), stage of the crop growth, bund management (i.e., more water losses if bunds are leaky), and other hydrological differences in each farmer's field (i.e., water table depths). As

[19] Note that this is the same graphs presented in Figure 3.5 (discussed in the micro-level economic impact analysis) and is only briefly described here.

shown in Table 4.3, there statistically significant differences in the total number of drying cycles over the season between AWD and control fields in the Buhi-Lalo area and RIDA (i.e., the only exception is Barit). The average number of drying cycles (regardless of location or subsystem) for farmers in AWD treated TSAGs was 5.5 days as against 4.4 days for farmers in the control TSAGs. About 57.1% of the fields in AWD sites have 6-7 cycles compared to 42.9% in non-AWD sites (Table 4.4).

Farmers in AWD treated TSAGs also had statistically more total number of drying days (over the season) relative to farmers in non-AWD control TSAGs (by about 6 days). However, this statistical difference in terms of total number of dying days was not observed in RIDA and for farmers in midstream locations. In terms of number of drying days per cycle (i.e., number of days the field water fell below the ground surface within the same cycle before irrigation was applied), we did not find any significant difference when utilizing the overall data set (for all subsystems). However, some statistically significant differences were observed in RIDA and those fields classified as "midstream" where control fields had 1 to 1.6 days higher in number drying days per cycle. In terms of number of irrigations, farmers in the control TSAGs tend to have statistically more frequent irrigations than those farmers in the AWD treated TSAGs (based on the recorded water depth readings from the regularly monitored field water tubes).[20]

4.1.3.7 Effect of AWD on water input and water savings at different spatial scales

As already noted in previous sections, water productivity calculations was not possible at the time of writing due to the incomplete 2017 dry season data. Hence, only preliminary results from the analysis of water input and water savings are presented in this section. Water productivity measures will be calculated once the yield data set is complete.

Farmer's Field Level. The total amount of rainfall that the crops received from transplanting to harvesting at the farmer's field level varies across treatments and/or subsystems (See Table 4.5), as well

[20] Note that this last result is different from the preliminary results observed in the micro-level economic analysis using the partial data set from 257 farmers (i.e., where we did not observe any statistical difference in the irrigation frequency of treatment and control farmers). We will plan to further examine (and hopefully reconcile) the results from the economic analysis of the survey data and the results from these monitored farmer fields as we move forward.

as across treatments and/or locations (Table 4.6), as this depended on the timing of the crop establishments by the individual farmers, and, in general, on the characteristics of the subsystems themselves. As discussed in an earlier section, farmers planting around October to early December will usually receive more rainfall than those who planted after December, as more rains come in the early part of the season. For example, at the field level, many sample farmers in the Barit subsystem established their rice crops late in the 2017 dry season (February to March), and therefore rainfall received by farmers in this subsystem was much lower than the other areas with early crop establishment.

In terms of irrigation levels, there was also some variability in the irrigation amount across sub-systems. The lesser the total amount of rainfall received, the higher the irrigation input added. Irrigation input between AWD and control fields also showed statistically significant differences. Farmers in control areas applied statistically more irrigation water than farmers in AWD sites. This is somewhat expected given that we already found that the monitored farmers in non-AWD control TSAGs had more number of irrigation events than those in AWD TSAGs (as presented in Table 4.3). The total water input (rainfall plus irrigation applied) was also statistically lower for the monitored farmers in AWD areas as compared to the monitored farmers in the control areas. However, we did not see any statistically significant difference in terms of the total water input across sub-systems (Table 4.5) and locations (Table 4.6), within the same treatment. For the whole system, the percent amount of water saved by AWD is about 12% (based on the field level figures collected from 168 monitored farmers in RIIS). If categorized according to subsystem, water savings at the farmer's field level through the use of AWD was 13.8% in Buhi-Lalo (mainly Lower Lalo), 11.3% in RIDA and 17.3% in Barit.

Turnout (TSAG) level. As shown in Table 4.7, there are differences between the selected AWD and control TSAGs in terms of the irrigation input levels measured at the turnouts. A lower irrigation input amount was observed in the turnouts of the AWD-TSAGs (relative to the control TSAGs), for both the Buhi-Lalo and RIDA subsystems. However, in the Barit subsystem, a higher irrigation input amount was calculated in the AWD-TSAG as compared to the irrigation input for the control-TSAG. This was probably because the selected control TSAG (RALCC-A4) was close to Lake Baao, and the overflow

water from the typhoon stayed longer in the fields, and thus required relatively less irrigation than the AWD treatment TSAG (RALCC-A3) in Barit. Nonetheless, with the exception of Barit, we can argue that AWD exposure in the treatment TSAGs may have influenced the reduction of irrigation input at the turnout level. The percent water savings (or percent difference in total water input) was 22% in Buhi-Lalo and 33% in RIDA.

Subsystem level. Total water input in the 2017 dry season was relatively lower than that of the 2016 dry season (See Table 4.8). This was due in part to the higher water input from both rainfall and irrigation in the 2016 dry season. Using a "before and after" comparison, RIDA received the highest difference in total water input (42% lower in 2017), while Buhi-Lalo and Barit had 17% and 11% (lower input in 2017), respectively. However, it is difficult to attribute the difference in total water inputs (in any of the subsystems) solely to AWD exposure at selected TSAs because AWD was not really implemented by all the farmers in the entire subsystem. Nevertheless, there is an indication that the implementation of AWD at the selected TSAs might have influenced the lower total irrigation input in the subsystem (in 2017).

Moreover, between subsystems, RIDA received the highest total water input in the 2016 dry season, while Buhi-Lalo received the highest total water input in the 2017 dry season. The high total water input in RIDA in the 2017 dry season was quite surprising considering that RIDA is usually thought of as a mid- to downstream subsystem of RIIS. Under lowland irrigated systems, total water input for rice normally ranges from 800 to 1,500 mm, but at the system level, this can go up to over 3,000 mm. As water flows in the supply canal of the subsystem, some will be drained to the next subsystem level, and eventually to lakes and seas, and some will be lost in the ground, but this can be reused downstream of the system, especially if farmers have access to groundwater pumps.

4.1.4 Preliminary Conclusions: Water Savings at Higher Spatial Scales

In general, water availability for rice production in RIIS has been a major challenge faced by many farmers within the system. This is exacerbated by non-synchronous crop establishment in the area that made water management relatively inefficient. Crop establishment duration at the time of the study was

long in the dry season, and consequently extending the duration of irrigation delivery in the system. Cropping intensity in both wet and dry seasons in the system was below 85%, and, in fact, much lower cropping intensities were observed in the lower subsystems of RIIS, such as in RIDA and Barit. Good water management through AWD seem to be a practical option to reduce the impact of water shortages in some parts of the season, within the system. Based primarily on data from water depth readings for 168 monitored farmers (i.e., 84 in AWD treatment TSAGs and 84 in non-AWD control TSAGs) and from water data loggers installed at 6 turnouts (i.e., 3 in AWD TSAGs and 3 in non-AWD TSAGs), AWD seem to have been successfully implemented at field and turnout levels, as manifested in the water level dynamics and reduction of water inputs observed for farmers in AWD treatment sites (versus non-AWD control sites). Although the system was hit by a strong typhoon in December, we still found water savings at both farmer's field and turnout levels. With AWD, water savings at farmers' field level ranged from about 11-17%, while at the turnout level, water savings ranged from 22-33%. At the subsystem level, the "before and after" comparison indicated a water input difference of 11-42% in all three subsystems. Note again that average yields and, consequently, water productivity measures, were not calculated and included in this report due to the incomplete 2017 farm survey data.

4.2 Assessing the Impact of AWD on Methane Emissions

4.2.1 Introduction/Objective/Significance

Flooded rice fields are an important source of global anthropogenic greenhouse gas (GHG) emissions. In fact, it is the second largest source after ruminant livestock. The major GHG in wetlands is methane (CH_4). It is produced by methanogenetic bacteria under anaerobic conditions such as they exist in rice fields due to a standing water layer on top of the soil. Aeration of the field (e.g. through drainage) inhibits these bacteria and thus reduces methane emissions by up to 50%. A second GHG in all agricultural systems is nitrous oxide (N_2O). It is also produced by bacteria involved in nitrification and denitrification processes. N_2O is mainly dependent on the nitrogen (N) input in a field.

In the Philippines, rice is grown in around 4.7 million ha of land annually (PSA, 2017). According to the Philippines' most recent 'National Communication' to the UNFCCC (CCC, 2014), 29% of the country's GHG emissions stem from the agriculture sector, almost half of it from rice production. AWD has the highest potential to reduce GHG emissions from rice production among all climate-smart rice production technologies. It is currently being outscaled nationwide through national programs with the main implementing agency being PhilRice. This is also backed by an administrative order by the Department of Agriculture from 2009 on "Guidelines for the adoption of water saving technologies in irrigated rice production systems in the Philippines".

In this study, we assess the GHG mitigation potential of AWD in Camarines Sur province through upscaling of evidence from the Rinconada Integrated Irrigation System (RIIS).

4.2.2 Materials and Methods

Six municipalities in the province of Camarines Sur were covered in the baseline and follow-up survey namely Baao, Buhi, Iriga City, Bula, Nabua, and Pili. See Section 3 for details. From the survey data collected, we extracted relevant information for estimating GHG emissions, which strongly depends on farming practices used. We used the IPCC guidelines 2006 (IPCC, 2006) for calculating the GHG emissions for the surveyed area, upscaled to the respective municipality level (data not shown due to legal restrictions), aggregated for the whole RIIS (7,031ha) and further extrapolated to the province level using data from CountryStat Philippines (PSA, 2017). The following factors ("Scaling Factors", SFs) strongly influence GHG emissions from rice fields and were considered in the calculations:

1) *Crop growth duration:* extracted from the survey
2) *Water management:* for the initial estimation, the distinction between continuous flooding (CF) and non-continuous flooding (intermittent irrigation, IF) was made
3) *Pre-season field condition:* extracted from the survey
4) *Organic amendments to the rice field:* According to the survey, no manure was applied to the field. Note that, at the time of writing, there was no information about straw management in the

survey, so this factor was not considered in the calculations so far. We will incorporate straw management in the calculations when 2nd year data from the survey is complete.

The emission factors (EFs) used are based on the 2nd Philippine National Communication to UNFCC (CCC, 2014). Emission factors for CH_4 were 1.46kg CH_4/ha/day for the dry season (DS) and 2.95 kg CH_4/ha/day for the wet season (WS). For the N_2O, a default EF of 0.003kg N_20/kg N fertilizer was used. In order to compare the different GHG's, the emissions were converted to their CO_2 equivalent (CO_2-e). 1kg CH_4 is equivalent to 28kg CO_2 while 1kg N_2O is equivalent to 265kg CO_2 (IPCC, 2013).

The harvested area in 2016 in Camarines Sur for the first semester (i.e., the dry season (DS)) was 61,131 ha for irrigated and 23,244 ha for rainfed rice. For the second semester (i.e., the wet season (WS)), 75,355 ha was harvested for irrigated rice and 20,853 ha for rainfed rice.

The initial survey did not allow distinction between different forms of intermittent irrigation, e.g. single aeration or multiple aeration. Therefore, we applied the more conservative factor for single aeration ($SF_w = 0.6$) to the intermittently flooded area.

We assume that the complete area in RIIS is irrigated and that all survey results are from irrigated conditions. In a former analysis of the climatic suitability for AWD in the Philippines it was found that most area in the Bicol region is moderately suitable for AWD in DS, as well as in WS (Sander et al., 2017). The reason lies in the relatively even distribution of precipitation across the year. There is no distinct DS or WS in Bicol judging from monthly rainfall data and we therefore assume that AWD can be applied on 75% of all irrigated rice area throughout the year. However, we will use the terms DS and WS for the first and the second semester of a year, respectively, as this terminology is common in the Philippines.

For upscaling to the province level we take the disaggregation between irrigated and rainfed rice into account. For the rainfed rice area we applied the IPCC suggested SF of 0.28, while for irrigated rice we assume the same share of CF and IF as in RIIS during the dry season. In the wet season, we consider the complete irrigated area as continuously flooded.

We only include on-field GHG emissions (CH_4 and N_2O) in this study. Off-field emissions such as emissions stemming from the production of fertilizer and pesticides, transportation of products or seed/seedling production are disregarded in this analysis.

4.2.3 Preliminary Results and Discussion

In all GHG estimations, independent of scale, methane has a far greater contribution to the overall emission than nitrous oxide. This trend has been confirmed in a large number of experiments across different environments for flooded rice. However, an increase of N_2O by switching from CF to IF is frequently found. This increase in N_2O might off-set up to 10% of the reduction in CH_4. The IPCC methodology, however, does not offer formulas to account for this so that in our estimations N_2O emissions are not influenced by water management.

Figure 4.8 shows the share of CF and IF in the survey area. About 79% of the area is already managed under some kind of non-continuous flooding. We assume the same share for the whole of RIIS and the whole province.

Figure 4.9 shows estimations of the emission rates (in t CO_2-e/ha) of CF and IF fields following the survey data. Emission rates are higher in the WS due to higher EFs (2.95 kg CH_4/ha/day in WS *vs.* 1.46 kg CH_4/ha/day in DS). Annually, IF fields emit almost 5t CO_2-eq/ha less than CF fields. Nitrous oxide emission rates are low and not affected by the season or growing environment.

From the emission rate in the dry season and the respective rice yield the carbon footprint of the product ("GHG intensity") under different production systems can be calculated. Figure 4.10 shows the GHG intensity (in kg CO_2-e per kg of paddy) for rice that is produced under CF and IF conditions but also for rice that is produced under AWD.

The total cumulative emissions of RIIS and Camarines Sur are shown in Figure 4.11. The trend is comparable to the emission rate in Figure 4.9 because most of the area is irrigated. Cumulative GHG emissions are about twice as high during WS than during DS which results from higher EFs in the WS. In total, around 57,000 and 641,000 t CO_2-eq are being emitted annually from rice fields in RIIS and Camarines Sur, respectively.

Figure 4.12 shows the GHG emissions in RIIS and Camarines Sur under the current conditions as well as for an alternative scenario. In this scenario we assume that AWD is being adopted on all irrigated rice fields that are currently managed intermittently flooded in both seasons. In this scenario SF_w=0.52 is being applied for the AWD area. Emissions under the AWD scenario are around 10% lower than under the current conditions which simply results from the different SFs for water management. A total amount of 52,000 and 5,000 t CO_2-e could be saved annually in Camarines Sur and RIIS, respectively, with the implementation of AWD (under the assumption that the current IF practice reduces methane emissions by 40% as compared to CF as reflected in the applied SF_w=0.6 for the current IF practice). Note, however, that even with this emission reduction potential of AWD, the magnitudes of emission reduction still suggests that the overall GHG reduction potential of AWD seems low in this area due to the seemingly high adoption rate of intermittent flooding. Further analysis is required to validate this observation.

4.2.4 Preliminary Conclusions: Impact of AWD on Methane Emissions

From the preliminary results of the first survey it appears that the adoption of non-continuous flooded rice farming is high in the survey area (79%). However, from the initial survey it is not clear what kind of water-saving technique is being practiced. With regards to GHG calculations the missing information is whether fields are drained once or multiple times during the growing season. We applied a conservative factor for single drainage in our calculations and found that total on-field GHG emissions in Camarines Sur could be further reduced by 52,000 t CO_2-e per year by ensuring the adoption of AWD on the area that currently is managed under some kind of intermittent flooding. This number suggests a relatively low GHG reduction potential (mainly because of the substantial area already devoted to some form of intermittent flooding).

In order to verify these estimations, baseline measurements of GHG emissions from rice fields in Camarines Sur should be conducted. This would serve a dual purpose: Firstly, it would provide more accurate EFs for rice production in the Bicol region which would also benefit the national GHG inventory. Secondly, the effectiveness of current drainage practices on GHG emissions could be verified. It is well possible the current water management practices do not reduce methane emissions as compared

to continuous flooding, e.g. because fields are not drained properly or long enough so that the estimated current emissions are lower than in reality.

The baseline survey did not provide information about straw management in the area. Different straw management practices can strongly influence field emissions (Romasanta et al., 2017). Incorporation of straw, straw burning or using rice straw off-field will have a big impact on the overall GHG emissions from rice production in Camarines Sur. The follow-up survey is going to provide this information so that GHG estimates can be further refined in the near future.

5.0 Socio-Cultural Impacts: The Effect of AWD on Electric Power Companies and Fisher Folks

5.1 Introduction/Objective/Significance

Alternate wetting and drying (AWD) requires change in the practice of farmers, from continuously flooding their fields to irrigating at intervals that allow for saturated or dry episodes rather than flooded paddies. When introduced within irrigation systems, such change in practice may affect not only farmers but also other stakeholders within the system. The change in control and timing of water availability could potentially result in conflicts over use of scarce water resources. In some irrigation systems, farmer stakeholders compete for water and some groups have conflicts over inequitable access (Sibayan et al. 2010). AWD has been proven useful in addressing this with various positive effects for rice farm stakeholders (e.g. Sibayan et al. 2010, Palis et al. 2012, Rejesus et al. 2013). Among the impacts for farmers and irrigation managers is the easing of conflicts around access to water (Valdivia et al. 2016). While the impacts for farmer stakeholders are documented, there has been no study that looked at the impact of AWD on the other stakeholders who are not involved in rice farming. The current study addresses this gap in knowledge through an exploration of the potential impact of the implementation of AWD in irrigation systems where there are non-farm stakeholders who share the water resource.

It is important to understand the potential impacts of AWD implementation on non-farm stakeholders for two reasons. First, understanding these possible impacts can help decision makers to balance the likely consequences of their decisions on rice farmers and other stakeholders, and identify strategies to mitigate negative effects on specific stakeholder groups. Second, documenting potential impacts can give insights on the sustainability of AWD adoption within irrigation systems. Change within systems that have multiple users entail complex interdependencies and interaction among stakeholders who may have diverging interests (Kpera et al. 2012). Such interests build upon or perpetuate formal or informal rules and arrangements that influence behavior of stakeholders in a system (Giddens 1984). Therefore change towards widespread adoption of AWD could be constrained by actors beyond the domain of the farms.

The aim of this study is to qualitatively explore whether the implementation of AWD in an irrigation system would have effects on non-farm stakeholders, specifically fisher folks or power generation companies. We studied a case of an irrigation system where AWD has been introduced for more than five years, and a case where system managers are beginning to introduce AWD.

5.2 Methodology

The overarching method for this social impact assessment is a hypothetical comparison of current conditions and a future scenario after intervention (Johnson 1998). We also used case studies to compare the effects considering different conditions. We based the selection of cases in the Philippines on the following criteria: a large irrigation system, AWD has been introduced or started to be implemented, and the system has multiple users (not only rice farmers). The two cases are: The Upper Pampanga River Integrated Irrigation System (UPRIIS) where AWD has been introduced since 2012 and is being implemented by NIA with farmers providing input via irrigators' associations (IAs); and the Rinconada Integrated Irrigation System (RIIS) where AWD is still in early stages of implementation, started in 2016.

5.2.1 Stakeholder Analysis

For each case, we began with a stakeholder analysis to identify who is part of the system, and to characterize the main stakeholder groups involved. This entailed an interview of key informants (irrigation system managers and researchers) who have knowledge about the irrigation system. Questions revolved around who are the users of water, what their roles are, how they link with each other and how they could be affected by AWD implementation.

5.2.2 Assessment on the implementation of AWD in the system

We explored how AWD is being implemented in the irrigation system as a take-off point to ask key stakeholders about the effects on them. This entailed focus group discussions (FGDs) on how water is managed, with AWD enforced for farmer groups, and whether this is working in the system. Four FGDs were done in UPRIIS (13-15 participants per FGD). Of the participants, 5% were women. In the case where AWD is not yet implemented, interviews of key persons who manage the irrigation system were done to assess how they planned to implement AWD and what they perceive are the likely effects.

5.2.3 Interviews on the (possible) effects of AWD implementation

From the stakeholder analysis, we identified and interviewed non-farmer stakeholders (these included key representatives of system managers, power plant managers, fisher folk, and local authorities). Four interviews were done for stakeholders in UPRIIS; then five interviews and two small group discussions were done in RIIS (3-4 participants, with 1-2 women each). A group discussion with 48 fisherfolk in RIIS was also done where 15% of the participants were women. The questions were on their involvement in the irrigation system, their experience with current water management conditions, and their perceptions of effects from AWD implementation at a system level.

5.2.4 Limitation of the Analysis

At present, there are no large irrigation systems in the Philippines wherein AWD is implemented for the whole system (with the possible exception of the Bohol Integrated Irrigation System (BIIS)). In our two case studies, trainings on AWD have been implemented (and the practice adopted at the farm level), or AWD has been enforced through water schedules in some divisions but not for the whole system. This means that system managers have been using AWD to improve the management of water for more farmers in the system, but this did not affect the volume of water that would be available for non-farmer stakeholders. Hence, we assumed that impacts discussed by stakeholders in this study were more "perceived" or "likely" impacts rather than actual conditions.

5.3 Results and Discussion

5.3.1 Stakeholders in the UPRIIS and RIIS cases

The stakeholders in the two cases studied can be categorized into three groups: farm stakeholders, system managers, and non-farm stakeholders (Figure 5.1). For this study we will focus on the non-farmer stakeholders, but also looking at relationships with other stakeholders where relevant.

5.3.1.1 Relationships in the use of water for UPRIIS Stakeholders

The National Irrigation Administration (NIA) is the focal point and manager of this system (Figure 5.1.A). It has organized farmer-users into five divisions and, further divided into irrigation associations (IAs), clustered as a federation of IAs. IAs also have smaller units called turnout service area groups

(TSAGs) that provides the structure for water distribution and efficient collection of irrigation service fees. NIA furthermore connects with non-farmer stakeholders such as researchers from the Philippine Rice Research Institute (PhilRice) who have been working with NIA for years on training, implementing and monitoring of AWD (interviews with NIA and PhilRice). Another important stakeholder is First Gen Hydro Power Corporation (FirstGen) which is supportive of AWD implementation in the system. FirstGen is a private company that has sole partnership with the government (mainly NIA) on operation and maintenance of power generation capability from the dam.

The main source of irrigation and power generation for NIA and FirstGen is Pantabangan Dam. Throughout the year, Pantabangan Dam irrigates 122,000 hectares in the five irrigation divisions in Nueva Ecija, Bulacan, Pampanga and Tarlac provinces. Through AWD, NIA has prioritized timely delivery, efficient water management and distribution of irrigation water, which resulted in higher revenues from farmer users (Padolina 2013, interview with NIA managers 2016). Pantabangan Dam is also the main power generation source for FirstGen, through a power plant that produces 1200 megawatt hrs (MWh) per day on average. A smaller dam, Masiway, takes water from Pantabangan and further produces 240 MWh per day (interview with FirstGen).

NIA and the FirstGen formulated an agreement in 2006 that enabled privatization of power generation. FirstGen pays NIA for the water that passes through the plant turbines. A significant portion of NIA's income is derived from the FirstGen water service fee. For example, of the total revenue from UPRIIS in 2012, fees from FirstGen comprised 28% (amounting to Php 133M or USD 2.7M) (Padolina 2013). This means that NIA and FirstGen jointly manage the water from the dam. According to FirstGen, they source water from Pantabangan and Masiway dams, but 'NIA's needs (i.e., irrigation for farmers) is the priority." However, if the volume of water available is low, less power is also generated. During low season production, Pantabangan produces 800 MWh and Masiway 180 MWh per day.

5.3.1.2 Relationships in the use of water for RIIS Stakeholders

The RIIS set-up is similar to UPRIIS in terms of the interaction between NIA and farmers (Figure 5.1B). Similarly, farmer users are organized into IAs and TSAGs over four sub-systems in Iriga, Bato, Nabua,

Baao, Pili, Bula and Buhi townships. There is however, a difference when non-farm stakeholders are considered (Figure 5.1.B). The management of the RIIS is shared between NIA and the Local Government of Buhi (LGU Buhi) since the main source of water of NIA-RIIS is Lake Buhi. Originally the surface elevation of Lake Buhi was 79.5 meters. In the early 1980s, NIA built a control structure that allowed a surface elevation of 83.5 meters. The additional 4 meters increase in surface elevation is intended to provide irrigation to farmers in specific months (Figure 5.2).

Furthermore, LGU-Buhi also coordinates with power generation stakeholders. From the Lake Buhi control structure, water passes through the National Power Corporation (NPC) forebay where water goes to (a) the People's Energy Services Inc. (PESI) and (b) to the Left connector Canal (LCC) (Figure 5.3). PESI generates electricity with the water discharged from the turbines flowing to Lower Barit. The discharge from the LCC is distributed to smaller irrigation systems at the lower portion of the RIIS, namely: the Upper/Lower Lalo sub-system, RIDA sub-system, and Barit sub-system (Figure 5.3). This means that water that is used for power generation, also runs off to the farms. Thus, the NIA and PESI have to co-manage the water made available for both. The power generated is sent through the NPC grid for distribution to clients.

Another important stakeholder is Buhi-Barit Watershed managers (BBWatershed in Figure 5.1B). This is the agency mandated to develop, protect or rehabilitate Lake Buhi. Thus, it coordinates the different stakeholders using the Lake Buhi water resources. With the LGU-Buhi, BBWatershed managers plan to establish a watershed management council to regulate water use in the lake.

5.3.2 Impact of AWD implementation on non-farmer stakeholders in UPRIIS and RIIS

At present, the full impact of AWD on non-rice-farmer stakeholders in both UPRIIS and RIIS could not yet be observed because its implementation either just started or is limited to only some parts of the system. However, in our focus group discussion and key informant interviews, various stakeholders were still able to express their perceptions and views about how a system-wide implementation of AWD could potentially affect them. Some of these views and perceptions are presented below.

5.3.2.1 Impact on stakeholders for power generation

The impact of AWD on power generation would be felt if NIA restricts the total volume of water passing through the power generators and the water saved for irrigation. There is some fear of this from the stakeholders who produce electricity, but there is also an indication that AWD would not have an impact on these stakeholders. In fact, other stakeholders assume that 'AWD can limit the volume of water given to irrigation thereby increasing the available for power generation'.

5.3.2.1.1 The Case of UPRIIS

Discussions with farmers, NIA and FirstGen indicate that the water saved through AWD is used to expand the irrigated area, and enable more farmers to access irrigation water. Furthermore, only three of the five divisions in UPRIIS have implemented AWD. This indicates that the water 'saved' because of AWD implementation increases the amount of water for irrigation rather than used for other purposes at the system level (i.e., possibly for power generation).

There is however, some fear that the scheduling and reduction in volume of water at a specific time could affect power generation. The available volume of water for FirstGen depends on the number of hectares that NIA plans to irrigate (through the dam). If NIA decreases the water volume, or restricts the release of water to the farms (through the main canal), FirstGen will also get a lower volume for electricity generation. According to FirstGen, their peak need of water for power production is December to March. This corresponds with the regular dry season crop in the UPRIIS cropping calendar (http://ugnayan.com/ph/nuevaecija/gapan/photo/J0A).

Presently, NIA controls the same volume of water, but schedules the irrigation users such that farmers are somewhat forced to implement AWD based on the rotation of water availability. The water 'saved' is then allocated to farmers at the tail end of the irrigation system. This has no effect on the total volume of water passing through the dam, or to FirstGen. An alternative scenario is for NIA to restrict the flow of water via AWD implementation for all farmers in the system (i.e., in all five divisions). FirstGen explained that they have a daily average water requirement when there is water passing through the dam towards the irrigation canals. This is however, significantly reduced during off-peak season when the NIA

does not want too much water to flow to the canals (Table 5.1). If this scenario happens, FirstGen will significantly reduce power generation. If we consider the low production during off-season, power generation is reduced by 460 Megawatt hrs per day, and this translates to a reduction in the households served with electricity. In the current set-up however, both stakeholders strive to balance their needs. (i.e., expanding the irrigated area for NIA, and generating as much electricity for FirstGen)

5.3.2.1.2 The Case of RIIS

Among the non-rice-farmer stakeholders in RIIS, power generation companies are perceived to be the least affected by AWD due to the set-up of the system (Figure 5.3). All the water that NIA takes from the lake passes through the NPC forebay for power generation by PESI. This is governed by the water right of NIA that limits the amount of water it can take out from the lake. The aim of providing more water for irrigation does not affect the volume of water for PESI. According to NIA, there is still 4.3 cm depth of water in the lake that NIA believed to be wasted, even if the water passes through the generators and discharged to farms for irrigation. The PESI power plant can generate a maximum of 1800 kilowatt hours per month which is then sold to the wholesale electricity spot market linked with the NPC grid.

PESI operates simultaneously with NIA-RIIS and is aware that water from NIA is mainly for irrigation. Conflict on the water limit and timing of release of water between NIA and PESI sometimes arise since PESI can only generate power when NIA releases water to the canals. PESI mentioned conflicts with respect to priority in the use of the water regardless of the water right. This issue also has something to do with the other users of water in Lake Buhi, which limits the amount of water that NIA can take out from the lake. NIA and PESI try to resolve this by adjusting the use of water according to its availability. Thus, the implementation of AWD by farmer stakeholders will likely not affect power generation in RIIS. Although PESI at certain periods experienced difficulties in obtaining the amount of water needed to meet its power generation targets, this is not due to AWD water management.

5.3.2.2 Impact on fisher folks

The RIIS case is different in that it has fisher folks as non-rice stakeholders in the system. These are fishpond and fish cage operators who require different conditions relative to water in the system. The

implementation of AWD in RIIS is expected to affect them differently, with fishpond operators likely to be affected negatively (see discussion below). These two types of fisher folks are also dependent on each other, so that a negative impact on one will likely affect the other.

5.3.2.2.1 Impact on fish cage operators

Fish cage operators, whose operations are on the lake, are highly dependent on the lake's water level. Currently, they experience conflicts with NIA because of less water available in certain periods (Figure 5.2) when NIA needs to discharge water into the irrigation canals. This situation has resulted in fish kills. According to NIA, their implementation of AWD will ensure that they can manage water needs during peak periods, such that they will not take out too much water from the lake. Thus, the full implementation of AWD in the RIIS is expected to benefit fish cage owners because more water will be made available as a result of less competition and extraction of water from Lake Buhi. This also implies that fish kill occurrences will likely be minimized.

Fish cage operators can earn a net income ranging from PhP35,000 to PhP75,000 (700-1500USD; per 5000 pcs of tilapia) in 4-5 months. When the water depth is low, and fish kills occur, this translates to a loss of as much as PhP50,000 (1000USD; per 5000 pcs of tilapia). There is an assumption that AWD can help them minimize these losses (given the reduction in the amount of water for irrigation purposes). On the other hand, they may also experience a trickle effect should AWD negatively impact fishpond owners who operate in the irrigation canals. The fish cage operators depend on the fishpond owners for fingerlings and, without a steady supply, they may have to obtain fingerlings elsewhere, thereby increasing costs.

5.3.2.2.2 Impact on fishpond operators

Fishpond operators in RIIS typically utilize the water available in the irrigation canals to produce fingerlings, which takes about 45 days. Whenever water is available in the canals (about 100 days), they may have to drain or add more water into their ponds twice. A water depth of at least 3 feet is maintained in the ponds to avoid fish kill. Currently, they experience conflicts in terms of scheduling their operations concurrently when water is provided to farmers. To address this issue, NIA has advised them to follow

the cropping calendar. However, convincing them to follow the cropping calendar has been a challenge because of the nature of fingerling production cycles. Both NIA and fishpond operators expect that with system-wide AWD implementation, fishpond operators will experience less water availability.

Fishpond operators with ponds in the upper or middle portion of the irrigation system are used to having water all the time, while those downstream are used to water-scarce conditions. Operators in the upstream to middle-stream will not favor AWD implementation because they prefer to continuously allow water to come in and out of their ponds to avoid fish kill. Fishpond operators in the FGDs mentioned that allowing the field to be alternately dry and wet 'will force them to go back to rice farming'. Less water in their ponds means that they are more prone to failure in growing fingerlings. Most of the fish pond owners in the downstream are not worried if AWD will be implemented since they have learned to address the insufficient supply of water in their area by using deep well pumps. Very few operators from the tail end said 'they will go back to rice farming since growing fingerlings will be too risky for them' if AWD is implemented.

Most fishpond owners abandoned rice farming because of the quick production turnaround and better incomes in growing fingerlings, even if it involves more capital and labor (Table5.2). Fishpond owners from the upstream can harvest 4 to 5 times a year and earn higher income compared with those in the midstream (harvest 3 to 5 times), and downstream (harvest 2 to 3 times). Compared with rice production, fishpond operators can earn 66% more a year in one hectare. If AWD will be implemented they may no longer operate the fishponds, foregoing the additional income.

Furthermore, these operators are dependent on other fisher folk within the system. Their main source of tilapia fry (baby fish) are also within the system, while the main outlets of their fingerlings are fish cage owners. Any fish kill in the system translates to limited supply of fry or no buyers of fingerlings.

5.3.2.3 Impact on other stakeholders

There are other stakeholders who have varied interests relating to the implementation of AWD in the system. Most of these concern the equitable management of resources, and ensuring a balance of the interests of different users. For example, between LGU-Buhi and NIA, there has been a slight conflict

around the change in the 'limit' for NIA's use of water from the lake. LGU-Buhi changed the 83.5 meters limit to 82.4, which means NIA can only extract water of 1.1 m depth (previously at 4 m) (Figure 5.2). At the moment, NIA has a service area of about 6457 ha but its operational area is only 5048 ha because of limited water availability. NIA-RIIS could 'reach more areas if the limit set by LGU-Buhi has remained at 83.5 meters'. Rotational scheduling of water distribution in the area has been implemented by NIA-RIIS to irrigate more areas. They expect that with AWD, they can expand rice production by about 200 hectares. Water availability has been declining and is more critical during summer season, thus, their introduction of AWD is considered timely for NIA and farmers.

The LGU of Buhi has recognized the need to protect the lake since both the quality and quantity of water has started to decline. Some of the factors affecting water quality of the Lake are the solid and liquid wastes coming from users of the lake. Also, there are weather disturbances which affected the availability of water in the lake. Creation of the Lake Buhi water quality management board and water quality management area (WAQMA) and partnership with Buhi-Barit Watershed to do reforestations and agro-reforestation are among the efforts being undertaken by LGU-Buhi to address this concern. For these stakeholders, the more effective rotation for irrigation users, and less pollution into the lake (from limiting fish cultivation) can be a positive outcome from AWD.

5.4 Conclusions: Socio-Cultural Impact of AWD on Non-Farm Stakeholders

We presented the UPRIIS and RIIS cases to qualitatively examine whether the implementation of AWD in an irrigation system would have effects on non-farm stakeholders such as fisher folk or power generation companies. Based on the two cases, impacts from AWD are not observed by non-farm stakeholders unless AWD is implemented system-wide (in all irrigation divisions/sub-systems). In cases where only a few divisions implement AWD, the NIA only makes minor changes in the rotational schedules so that the overall release of water in the system (i.e., mainly for irrigation) is not affected.

In both cases, NIA could balance its operations with the stakeholders generating electricity. There is a perception that full AWD implementation may affect them, but there is clear indication that it will not have a significant effect on power generation. NIA will ensure the amount of water used for irrigation and

passing through the power generators is maintained to enable them to expand the irrigated area. Thus, AWD implementation as a strategy implemented by NIA to improve efficiency in irrigation, will not affect power generation in general. The assumption that 'saved' water through AWD will be used for power generation is not substantiated in either case. The volume of water that flows to irrigation canals is the same water that is used for power generation. As much as possible, NIA would not restrict the overall volume of water that flows to irrigation canals. The risk for power generation is when there is not enough water from the dam or lake, but this is not a consequence of AWD implementation.

AWD will have more impact in systems where there are fisher folks. These are the stakeholders who are directly affected with changing water depth or water availability. In the RIIS case, those managing fishponds are likely to be negatively affected by AWD than those using fish cages. With the control in the release of water and limits in the available water in the canals at specific periods of time (relating to the rice-crop growth), the fishpond owners who mainly produce fingerlings think they will not be able to operate. This means they will have to revert back to rice production, and likely accept lower profit levels. On the other hand, fisher folks in the same system producing fish in cages (and whose operations are located in the lake) are expected to benefit from AWD implementation. If the depth of water in the lake is maintained, there is less risk of fish kills and operators reduce the risk of losing more than 50% of their annual income. There are also interdependencies to be considered among the two types of fisher folk. If one of them loses because of AWD, there will be an effect on the other because their businesses are interconnected.

Other intangible benefits are expected for stakeholders who are managing the system. AWD allows them to balance the needs of various stakeholders. For this, there seems to be a positive attitude particularly from system managers to support implementation of AWD by farmers. In implementing AWD, the level of control of system managers on the water resource is crucial. In the case of UPRIIS, the NIA has more control and can direct the implementation. With RIIS, the NIA has to co-manage the water with LGU Buhi. In this latter case, it will be more important to ensure the involvement of LGU Buhi in

AWD trainings and information dissemination, so that it becomes clear how they and the stakeholders jointly use the water resources more efficiently.

6.0 Preliminary Conclusions, Limitations, and Future Research Plans

Overall, based on incomplete data and initial analytical approaches, our preliminary results indicate that the impact of AWD on micro-economic outcomes (e.g., water use, yield), GHG emissions, and non-rice-producing stakeholders may be limited. Only the water saving analysis at different spatial scales provided some indication that AWD adoption in the study area statistically reduced irrigation input amounts (at least at the farmer field and turnout level). However, especially for the economic and environmental assessments, further analysis utilizing the complete two-year data set collected is still needed to produce more reliable inferences, stronger conclusions, and (hopefully) more consistent results.

It is important to note that most of the results presented in this report are "preliminary" mainly because, at the time of writing, the 2nd year (follow-up) data from our farmer survey has not been fully encoded. This survey data is critical because this is the dry season when farmers in randomly selected treatment TSAGs where exposed to AWD. Collection of the 2nd year survey data was only completely collected for all 820 sample farmers in late June 2017. Part of the delay was due to the typhoon that hit the study area in December 2016. Basing results on this "incomplete" 2nd year follow-up data is the main limitation to keep in mind when reading and assessing this report.

Nonetheless, we expect to work on additional tasks and expand the analysis presented in this report going forward. Given the main limitation discussed above, out next step is to complete the encoding and "cleaning" of the 2nd year survey data. Further data validation will be conducted on the both the baseline and follow-up data sets to ensure that data entries for the important impact outcome and control variables are reasonable and well-justified (i.e., especially the outliers).

For the micro-level economic impact analysis, after the full two-year survey data sets are validated, we expect to investigate alternative specifications of our impact equations by incorporating weather variables and other relevant control variables (as well as considering other irrigation outcomes as dependent variables). In addition, several other econometric estimation procedures will be examined and implemented (if appropriate) to provide more convincing impact estimates. Entropy balancing, "zero" stage IV estimation, and nonlinear DID estimation will be explored.

The water productivity component of the AWD analysis at different spatial scales will also be completed by utilizing the fully encoded yield data from the 2nd year survey. Furthermore, the statistical analysis of the field level water readings will be re-run after some of the missing water depth reading data (i.e., from Upper Lalo) are received. With regards to the GHG/methane analysis, data from the follow-up survey on straw management practices and yields will be utilized to improve the GHG calculations. Further exploration of drainage practices in the area and its implications for GHG emissions will also be conducted. Lastly, we will explore whether a more quantitative assessment of the impact of AWD on non-rice-producing stakeholders may be warranted in the future.

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Table 2.1 AWD Adoption in the Philippines: (A) As reported in Lampayan (2014b), and (B) Based on official estimates from NIA (as of Sept 2016)

Philippine Region	(A) From Lampayan (2014)		(B) From NIA	
	Area (ha)	No. of Farmers	Area (ha)	No. of Farmers
Cordillera Region (CAR)	10,910	10,888		
Region 1 (Ilocos Region)	4,099	10,102		
Region 2 (Cagayan Valley)	3,312	4,941	38,439	27,456
Region 3 (Central Luzon)	26,652	20,938	45,503	32,502
Region 4a (SouthernTagalog)				
Region 4b (Southwestern Tagalog)				
Region 5 (Bicol Region)				
Region 6 (Western Visayas)	195	147		
Region 7 (Central Visayas)	8,232	7,577		
Region 8 (Samar, Leyte, Negros Island)			842	601
Region 9 (Zamboanga Peninsula)				
Region 10 (Northern Mindanao)				
Region 11 (Davao Region)	27,853	17,294		
Region 12 (Cotabato Region)	11,760	9,800		
Region 13 (CARAGA Region)				
Bangsamoro (former ARM)				
Total	93,014	81,687	84,784	60,559

Table 3.1 Distribution of Selected Treatment and Control TSAGs in RIIS

Treatment Status	Stream Location	Sub-System Name	IA Name	TSAG Name
Treated Group	Upstream	RIDA	Barlin IA	D1-1A
	Upstream	Upper Lalo	SAJUFIA	RALCC-1
	Upstream	Upper Lalo	SAJUFIA	RALCC-A-1
	Upstream	Upper Lalo	SAJUFIA	RALCC-A-4
	Midstream	Lower Lalo	MASAFIA	Ralat N-1
	Midstream	RIDA	RIDA Div. B IA	RALAT-D-3
	Midstream	RIDA	RIDA Div. B IA	RALAT-E-SPTO
	Midstream	RIDA	RIDA Div. B IA	RAMC-12
	Midstream	RIDA	RIDA Div. B IA	RAMC-13
	Midstream	RIDA	RIDA Div. B IA	RAMC-16
	Midstream	Lower Lalo	SASFIA	RALAT L-4
	Downstream	RIDA	BINTAG IA	Lateral B
	Downstream	RIDA	BINTAG IA	Lateral D-1
	Downstream	RIDA	BINTAG IA	RAMC-7
	Downstream	BARIT	DIVCFIA	RALAT E-6
	Downstream	BARIT	LAPSEFIA	LATERAL G-2-A
	Downstream	BARIT	LAPSEFIA	LATERAL H-1
	Downstream	BARIT	LAPSEFIA	RAMC 26-B
	Downstream	BARIT	LAPSEFIA	RAMC 27-A
	Downstream	Lower Lalo	LOPALFIA	Ralat L-7
	Downstream	RIDA	SDAPIA	RAMC 7
Control Group	Upstream	Upper Lalo	MAGFIA	RAMC 12
	Upstream	Upper Lalo	MAGFIA	RAMC 13
	Upstream	Upper Lalo	SAJUFIA	RALCC-A-3
	Upstream	Upper Lalo	SAJUFIA	RALCC-A-SP-2
	Midstream	RIDA	RIDA Div. B IA	RALAT-E-3
	Midstream	RIDA	RIDA Div. B IA	RALAT-E-3A
	Midstream	RIDA	RIDA Div. B IA	RALAT-E-4
	Midstream	RIDA	RIDA Div. B IA	RALAT-F-1
	Midstream	RIDA	RIDA Div. B IA	RALAT-F-SP-1
	Midstream	RIDA	RIDA Div. B IA	RAMC-10
	Midstream	RIDA	RIDA Div. B IA	RAMC-15
	Downstream	RIDA	BINTAG IA	Lateral C-2
	Downstream	RIDA	BINTAG IA	Lateral C-3
	Downstream	BARIT	DIVCFIA	RALAT E-4
	Downstream	BARIT	LAPSEFIA	LATERAL G-1
	Downstream	BARIT	LAPSEFIA	LATERAL H-2
	Downstream	BARIT	LAPSEFIA	LATERAL H-3
	Downstream	BARIT	LAPSEFIA	RAMC 23
	Downstream	BARIT	LAPSEFIA	RAMC 24
	Downstream	BARIT	LAPSEFIA	RAMC 25-A
	Downstream	BARIT	LAPSEFIA	RAMC 26

Table 3.2 Mean Comparisons (t-tests) of the Baseline (2016) Socio-Demographic Variables: Treated vs. Control Farmers (Total no. of obs. = 820 farmers; 414 treated and 406 control)

Variable	AWD Treatment TSAs (T)	Non-AWD Control TSAs(C)	Difference (T-C)	P-value[1]
Gender (Male = 1, Female = 0)	0.83	0.84	-0.2	0.532
Age (#)	57.97	58.43	-0.46	0.589
No. of years farming (#)	26.65	27.87	-1.22	0.289
Years of Schooling (#)	9.07	8.80	0.27	0.216
Total farm size (ha)	0.58	0.54	0.04	0.413
Total no. of parcels in farm (#)	1.22	1.22	0.00	0.882
Size of main rice parcel (ha)	0.45	0.41	0.04	0.162
Total household income (PhP/yr)[2]	36,445	32,602	3,843	0.295

Notes: [1] *, **, *** significant difference at the 10%, 5%, 1% level. [2] Total household income is the sum of all self-reported on-farm and off-farm income from all members of the household (in Philippines Pesos (PhP)/yr)

Table 3.3 Mean Comparisons (t-tests) of the Baseline (2016) Irrigation-related Variables: Treated vs. Control Farmers (Total no. of obs. = 820 farmers; 414 treated and 406 control)

Variable	AWD Treatment TSAs (T)	Non-AWD Control TSAs (C)	Difference (T-C)	p-value[1]
Irrigation Frequency (#)	16.01	18.13	-2.12	0.027**
Days main parcel w/o water (#)	4.11	4.01	0.10	0.674
Ave. water depth before irrig. (cm)[2]	0.25	0.22	0.03	0.477
Ave. water depth after irrig. (cm)[2]	3.54	3.43	0.11	0.309
No. of hours irrig. (hours/season)	43.90	46.79	-2.89	0.037**
Total labor used in irrig. (mandays/ha)	8.24	10.16	-1.92	0.116
Experienced water shortage in area (%)	76.47	82.83	-6.36	0.025**
Experienced water conflicts in area (%)	35.05	42.29	-7.24	0.034**
Experienced water theft in area (%)	39.61	46.91	-7.30	0.035**

Notes: [1] *, **, *** significant difference at the 10%, 5%, 1% level. [2] This refers to the average depth of irrigation water (cm) before and after a farmer irrigates during the period after transplanting (until harvesting).

Table 3.4 Mean Comparisons (t-tests) of the Baseline (2016) Input, Rice Yield, and Income Variables: Treated vs. Control Farmers (Total no. of obs. = 820 farmers; 414 treated and 406 control)

Variable	AWD Treatment TSAs (T)	Non-AWD Control TSAs (C)	Difference (T-C)	P-value[1]
Amt. of seed utilized (kg/ha)	176.48	194.14	-17.66	0.075*
N fertilizer (kg/ha)	125.56	162.99	-37.43	0.004***
P fertilizer (kg/ha)	9.48	9.57	-0.09	0.940
K fertilizer (kg/ha)	20.77	27.41	-6.64	0.128
Herbicide application (li/ha)	2.40	2.62	-0.22	0.399
Pesticide application (li/ha)[2]	7.58	15.36	-7.78	<0.01***
Total labor used (mandays/ha)[3]	89.06	106.72	-17.66	0.020**
Rice yield for 2016 dry season (kg/ha)	3,966.96	4,914.33	-947	0.001***
Rice yield for 2015 dry season (kg/ha)	4,649.66	5,823.08	-1,173	0.001***
Rice yield for 2014 dry season (kg/ha	4,565.42	5,726.35	-1,160	0.001***
Self-reported gross rice income (PhP/ha)[4]	66,337.47	76,605.30	-10,267	0.072*
Calculated gross rice income (PhP/ha)[5]	65,113.39	81,254.69	-16,141	0.002***
Net rice income (PhP/ha)[6]	20,756.04	31,735.77	-10,979	0.008***

Notes: [1] *, **, *** significant difference at the 10%, 5%, 1% level. [2] Pesticide application includes insecticides, molluscicides, and rodenticide applications. [3] Total labor includes both hired and non-hired labor for all production activities in the dry season (such as: land prep., crop estab., fertilizing, weeding, etc.) [4] This is a self-reported gross rice income elicited in the survey for dry season 2016. [5] This is gross rice income calculated from the yield and price estimates provided for dry season 2016. [6] The net rice income is calculated from the gross rice income less the estimated cost of all inputs (elicited from the survey for dry season 2016).

Table 3.5 Mean Comparisons (t-tests) of Selected Variables from the Preliminary Panel Data Set with Baseline (2016 dry season) and Follow-up (2017 dry season) Information: Treated vs. Control Farmers (Total no. of obs. = 257 farmers; 164 treated and 93 control)[1]

Variable	AWD Treatment TSAs (T)	Non-AWD Control TSAs (C)	Difference (T-C)	P-value[2]
---------- Baseline (2016) Data for 257 farmers ----------				
Total farm size (ha)	0.43	0.36	0.07	0.172
Total no. of parcels in farm (#)	1.20	1.09	0.11	0.118
Size of main rice parcel (ha)	0.38	0.34	0.04	0.352
Irrigation Frequency (#)	15.17	18.29	-3.12	0.132
Days main parcel w/o water (#)	3.72	5.13	-1.41	0.002***
Experienced water shortage in area (%)	69.75	70.79	-1.04	0.865
Experienced water conflicts in area (%)	36.02	40.66	-4.64	0.468
Experienced water theft in area (%)	39.02	45.16	-6.14	0.339
Rice yield for 2016 (kg/ha)	4,047.52	5,447.56	-1.400.04	0.001***
Rice yield for 2015 (kg/ha)	4,569.03	6,563.70	-2,089.09	0.003***
Rice yield for 2014 (kg/ha)	4,735.33	6,658.12	-1,922.79	0.004***
Self-rep. gross rice income (PhP/ha)[3]	63,645.44	77,786.08	-14,140.64	0.091*
---------- Follow-up (2017) Data for 257 farmers ----------				
Total farm size (ha)	0.68	0.56	0.12	0.180
Total no. of parcels in farm (#)	1.76	1.63	0.13	0.408
Size of main rice parcel (ha)	0.38	0.32	0.06	0.115
Irrigation Frequency (#)	11.87	11.13	0.74	0.286
Days main parcel w/o water (#)	17.23	18.96	-1.73	0.381
Experienced water shortage in area (%)	60.87	66.67	-5.80	0.359
Experienced water conflicts in area (%)	49.03	65.22	-16.19	0.013**
Experienced water theft in area (%)	57.14	68.48	-11.34	0.078*
Rice yield for 2017 (kg/ha)	3,967.95	4,860.46	-892.51	0.028**
Self-rep. gross rice income (PhP/ha)[3]	26,918.91	19,965.92	6,952.99	0.010**

Notes: [1] The complete 2017 data set have not been encoded at the time of writing. Hence, only summary statistics for 257 farmers (31% of the full sample) and only for selected socio-demographic, irrigation-related, and yield/income-related variables are presented in the tables above. [2] *, **, *** significant difference at the 10%, 5%, 1% level. [3] This is a self-reported gross rice income elicited in the survey for dry season.

Table 3.6 Distribution of Farmers in the Treated and Control Farmers by Stream Location, 2017 Partial Sample (for 257 farmers)

Full System	No. of farmers in this location = 257 (100%)			
	Random AWD Treated = 164 (64%)			Control = 93 (36%)
	Practice AWD = 89 (35%)		Not Practice AWD = 67 (26%)	-
	Used pipe = 73 (28%)	Not use pipe = 10 (4%)	-	-
Upstream	No. of farmers in this location = 139 (100%)			
	Random AWD Treated = 67 (48%)			Control = 72 (52%)
	Practice AWD = 33 (24%)		Not Practice AWD = 31 (22%)	-
	Used pipe = 28 (20%)	Not use pipe = 2 (1%)	-	-
Midstream	No. of farmers in this location = 54 (100%)			
	Random AWD Treated = 45 (83%)			Control = 9 (17%)
	Practice AWD = 26 (48%)		Not Practice AWD = 19 (35%)	-
	Used pipe = 21 (39%)	Not use pipe = 5 (9%)	-	-
Downstream	No. of farmers in this location = 64 (100%)			
	Random AWD Treated = 52 (81%)			Control = 12 (19%)
	Practice AWD = 30 (47%)		Not Practice AWD = 17 (26%)	-
	Used pipe = 24 (37%)	Not use pipe = 3 (5%)	-	-

Table 3.7 Results from the Alternative Difference-in-Differences (DID) Regressions: Impact of AWD on Selected Outcome Variables ((Total no. of obs. = 257 farmers; 164 treated and 93 control)

Outcome Variables	Standard DID Impact Estimate: [Indep. Var.: Random AWD Treatment at TSA level][1]	IV-DID Impact Estimate [Indep. Var.: Non-Random Indiv. AWD Practice Adoption][1]	IV-DID Impact Estimate [Indep. Var.: Non-Random Indiv. PVC pipe Adoption][1]
Irrigation Frequency (#)	1.82 (0.401)	3.98 (0.319)	-0.65 (0.831)
Days main parcel w/o water (#)	-0.032 (0.988)	1.31 (0.717)	8.91 (0.130)
Rice yield for 2017 (kg/ha)	440.13 (0.335)	931.09 (0.267)	1,975.88 (0.118)
Self-rep. gross rice income (PhP/ha)[3]	21,276.56** (0.019)	40,846.49** (0.015)	7,874.95 (0.473)
Size of main rice parcel (ha)	0.026** (0.015)	0.049** (0.014)	0.094** (0.020)

Notes: [1] Figures in parentheses are p-values. *, **, *** significant difference at the 10%, 5%, 1% level.

Table 4.1 List of AWD-TSAs with data loggers

Location	AWD- TSA	Control-TSA
Upstream (SAJUFIA, Upper Lalo Subsystem)	RALCC-A-4	RALCC-A-3
Midstream (RIDA Div B IA, RIDA Subsystem)	RAMC16	RAMC-15
Downstream (LAPSEFIA, Barit subsytem)	RAMC26B	RAMC26

Table 4.2 Cropping intensity from 2012-2017 (Data from NIA).

Season	Year	Cropping Intensity (%)		
		Upper Lalo and Lower Lalo*	RIDA	Barit
Wet season	2012	92.0	83.9	87.0
	2013	81.6	63.4	53.0
	2014	83.3	70.2	63.5
	2015	83.0	72.8	59.2
	2016	84.4	68.0	61.4
	Average	84.9	71.7	64.8
Dry season	2013	70.5	53.4	65.6
	2014	85.4	73.8	83.5
	2015	85.0	73.7	74.8
	2016	90.5	74.0	71.0
	2017**	90.4	86.7	66.5
	Average	84.4	72.3	72.3

* Data for the 2016-2017 wet and dry season were only from Lower Lalo sub-system.
** Only partial data was used for calculating the 2017 dry season figures in the table, since benefitted area from 4 IAs in Lower Lalo, Barit, and RIDA were missing at the time of writing.

Table 4.3 Comparison between of AWD and control fields in terms of number of drying cycles, total drying days (whole season from transplanting to harvesting, average number of drying days per cycle, and total number of irrigations).

Classification	Number of drying cycles			Total drying days (days)			Number of drying days per cycle			Number of irrigations		
	AWD	Control	Difference (AWD-Control)	AWD	Control	Difference (AWD-Control)	AWD	Control	Difference (AWD-control)	AWD	Control	Difference (AWD-Control)
Subsystem												
Buhi-Lalo (n = 24)	4.8	3.2	1.6**	27.4	17.1	10.3**	5.7	5.2	0.4ns	5.4	8.3	-2.9**
RIDA	6.1	5.3	0.9**	32.9	30.8	2.1ns	5.1	6.2	-1.1**	5.7	6.4	-0.7*
Barit	4.9	4.0	0.9 ns	27.9	19.2	8.8**	5.8	4.9	1.0ns	11.6	13.6	-2.0**
Location with respect to water source												
Upstream	4.5	3.2	1.3*	24.2	17.1	7.1*	5.5	5.2	0.2ns	4.9	8.3	-3.3**
Midstream	6.2	5.4	0.8*	34.9	34.4	0.5ns	5.2	6.8	-1.6**	5.5	6.5	-1.1**
Downstream	5.4	4.2	1.2**	29.2	19.0	10.2**	5.5	4.7	0.8ns	8.0	11.9	-3.9**
All	5.5	4.4	1.1**	30.4	24.0	6.4**	5.4	5.5	-0.2ns	6.7	9.3	-2.6**

** significant at 1% level of probability using t-test; * significant at 5% level of probability using t-test; ns = not significant

Table 4.4 Percent frequency distribution of the number of drying cycles for AWD and control fields in the study area, 2017 dry season.

Number of cycles	Frequency (%)	
	AWD (n=84)	Control (n=80)*
0-1	0.0	5.0
2-3	10.8	23.8
4-5	32.1	42.5
6-7	57.1	25.0
8-9	0.0	7.0

*There were 4 missing data in control

Table 4.5 Water input, grain yield and water productivity at the field level by sub-system, 2017 dry season (data presented here are those from the sample farmers with field water level observations).

Particulars	AWD	Control	Difference (AWD-control)
Upper and Lower Lalo[a]			
Yield (kg/ha)	-	-	-
Rainfall (mm)	546.8	441.7	105.1**
Irrigation (mm)	314.3	557.4	-243.1**
Total water input	861.1	999.01	-137.9**
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-
RIDA			
Yield (kg/ha)	-	-	-
Rainfall (mm)	646.9	660.9	-14.0ns
Irrigation (mm)	308.2	415.8	-107.6**
Total water input	955.1	1076.7	-121.6**
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-
Barit			
Yield (kg/ha)	-	-	-
Rainfall (mm)	159.6	177.6	-18*
Irrigation (mm)	632.2	779.2	-147**
Total water input	791.7	956.8	-165.1**
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-
Overall			
Yield (kg/ha)	-	-	-
Rainfall (mm)	525.4	447.9	77.5*
Irrigation (mm)	371.6	571.3	-199.7**
Total water input	897.1	1019.2	-122.1**
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-

*, **= respectively, significant at 5% and 1% levels of probability, using t-test.

[a] Data used were from Lower Lalo only.

Note: Yield data not yet available as of this writing, hence yield and water productivity entries above are blank (-). Will complete this table once 2nd year survey data is complete.

Table 4.6 Water input, yield and water productivity at the field level by stream location to the source.

Particulars	AWD	Control	Difference (AWD-control)
Upstream			
Yield (kg/ha)	-	-	-
Rainfall (mm)	460.7	441.7	19ns
Irrigation (mm)	299.2	557.4	-258.2**
Total water input	759.9	999.1	-239.2**
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-
Midstream			
Yield (kg/ha)	-	-	-
Rainfall (mm)	686.4	651.8	34.6ns
Irrigation (mm)	294.0	430.7	-136,7**
Total water input	980.4	1082.5	-102.1**
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-
Downstream			
Yield (kg/ha)	-	-	-
Rainfall (mm)	440.7	292.1	148.6**
Irrigation (mm)	440.8	686.9	-246.1**
Total water input	881.5	978.9	-97.4**
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-

*, **= respectively, significant at 5% and 1% levels of probability, using t-test.

Note: Yield data not yet available as of this writing, hence yield and water productivity entries above are blank (-). Will complete this table once 2nd year survey data is complete.

Table 4.7 Water input, grain yield and water productivity at the turnout level, 2017 dry season (data on irrigation input were from data loggers installed in the gaging station of the selected turnout).

Particulars	AWD	Control	Difference (AWD-control)
Lalo-Buhi	RALCC-A4	RALCC-A3	
Yield (kg/ha)	-	-	-
Rainfall (mm)	466.5	466.5	0.0
Irrigation (mm)	923.5	1310.5	-387.0
Total water input	1390.0	1777.3	-387.0
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-
RIDA	RAMC-16	RAMC-15	
Yield (kg/ha)	-	-	-
Rainfall (mm)	646.0	646.0	0
Irrigation (mm)	591.5	1207.9	-616.4
Total water input	1237.5	1853.9	-616.4
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-
Barit	RAMC-26B	RAMC-26	
Yield (kg/ha)	-	-	-
Rainfall (mm)	135.1	182.4	-47.3
Irrigation (mm)	1750.8	842.5	908.3
Total water input	1885.9	1024.9	861.0
Water productivity			
- Irrigation water productivity (WP_I)	-	-	-
- Total water productivity (WP_T)	-	-	-

*, **= respectively, significant at 5% and 1% levels of probability, using t-test.

Note: Yield data not yet available as of this writing, hence yield and water productivity entries above are blank (-). Will complete this table once 2nd year survey data is complete.

Table 4.8 Average yield, rainfall, irrigation and total water input, and water productivity at the sub-system level, 2016 and 2017 dry seasons.

Particulars	Subsystem		
	Buhi-Lalo	RIDA	Barit
2016 dry season			
Average yield (kg/ha)	-	-	-
Rainfall (mm)	949.4	1038.9	779.6
Irrigation (mm)	1124.7	1494.4	990.4
Total water input (mm)	2074.1	2533.3	1770.0
Water productivity (kg/m^3)			
- Irrigation water productivity	-	-	-
- Total water productivity	-	-	-
2017 dry season			
Average yield (kg/ha)	-	-	-
Rainfall (mm)	779.6	771.6	680.9
Irrigation (mm)	933.8	708.4	803.1
Total water input (mm)	1713.4	1480.0	1572.0
Water productivity (kg/m^3)			
- Irrigation water productivity	-	-	-
- Total water productivity	-	-	-

Note: Yield data not yet available as of this writing, hence yield and water productivity entries above are blank (-). Will complete this table once 2nd year survey data is complete.

Table 5.1 Average power production in UPRIIS (in Megawatt hrs per day), and estimated number of households (HH) served per month.

Power generation	Pantabangan dam	Masiway Dam	Total	HH served based on ave. consumption (300Kwatt Hrs/HH) per mo.
Average	1200	240	1440	144000
Off-peak	800	180	980	98000

Source: Interview with FirstGen

Table 5.2 Range of annual income in PhP and USD for various fishpond operations and rice farming (per hectare)

Income source	Income range (PhP per ha)		Income range (USD per ha)	
	Low	High	Low	High
Fishpond operation (upstream)	116100	278100	2326	5572
Fishpond operation (midstream)	74800	219200	1499	4392
Fishpond operation (downstream)	43248	133248	867	2670
Rice farming	28332	38518	568	772

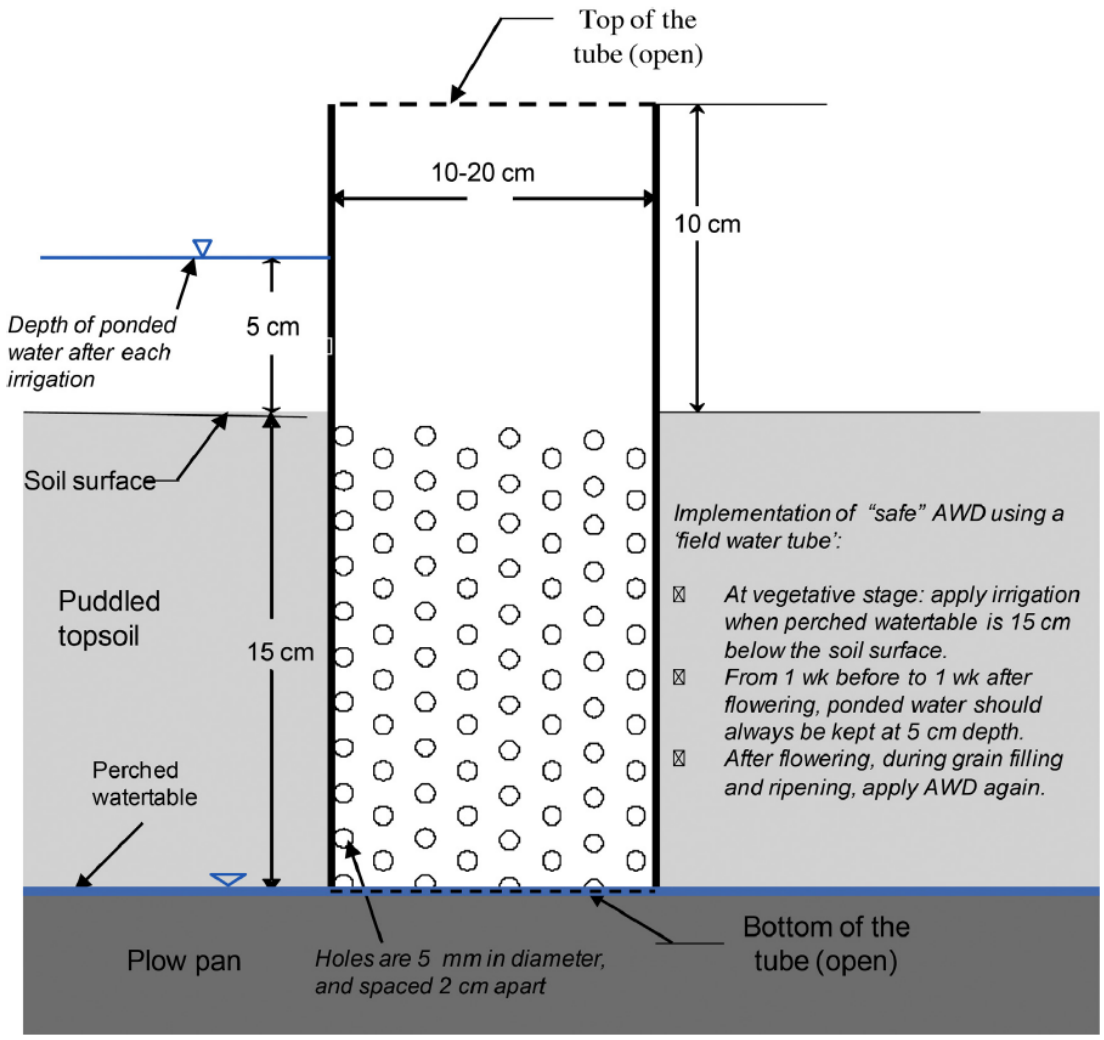


Figure 1.1 Field water tube as a simple tool to implement "Safe" AWD (adapted from Bouman et al (2007) and Lampayan et al (2015))

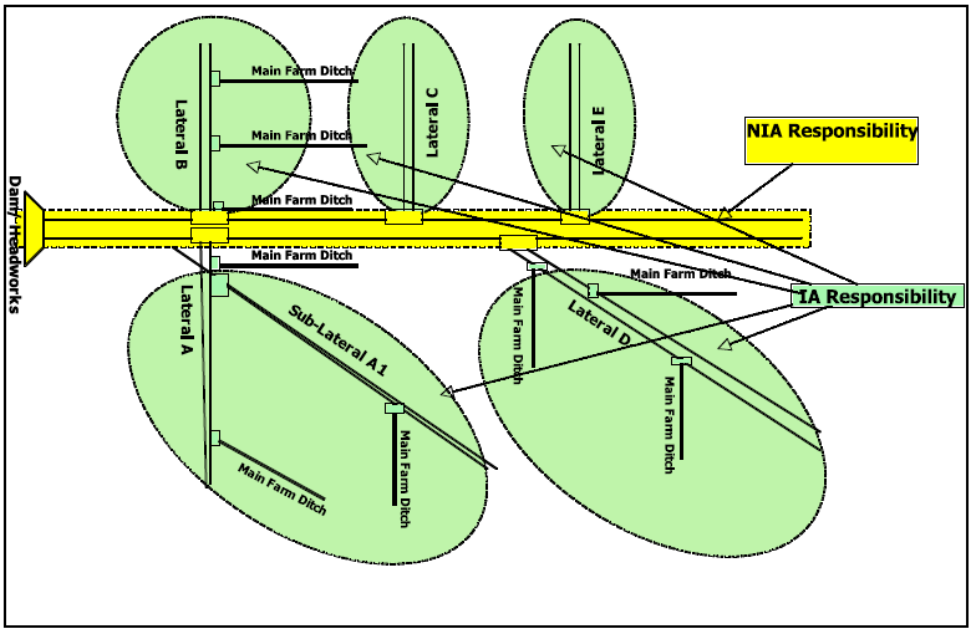


Figure 2.1 Pictorial representation of the typical responsibilities of IAs vs. NIA.
Source: Bedore, 2008

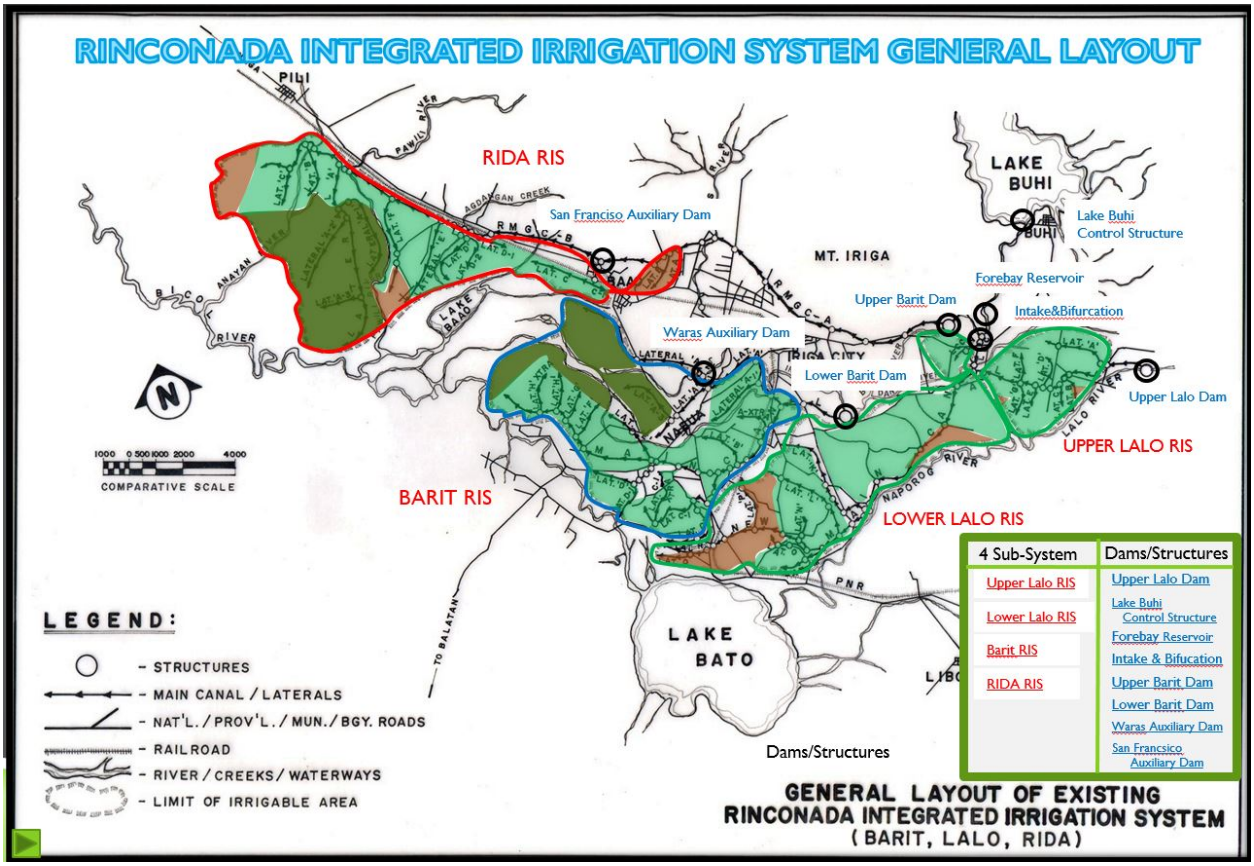


Figure 3.1 Map of the Study Area: RIIS with the 4 Sub-System Locations

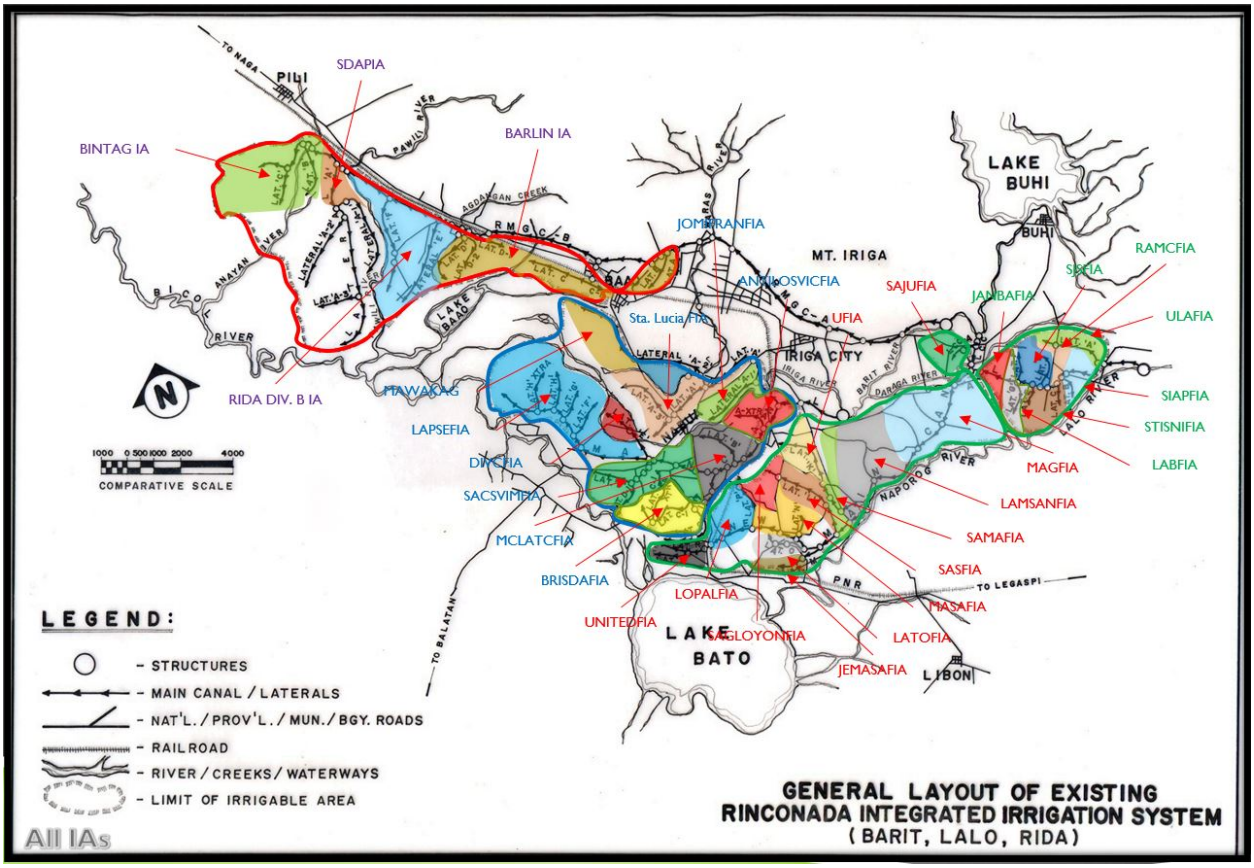


Figure 3.2 Map of the Study Area: RIIS with the Locations of the Irrigator's Associations (IAs)

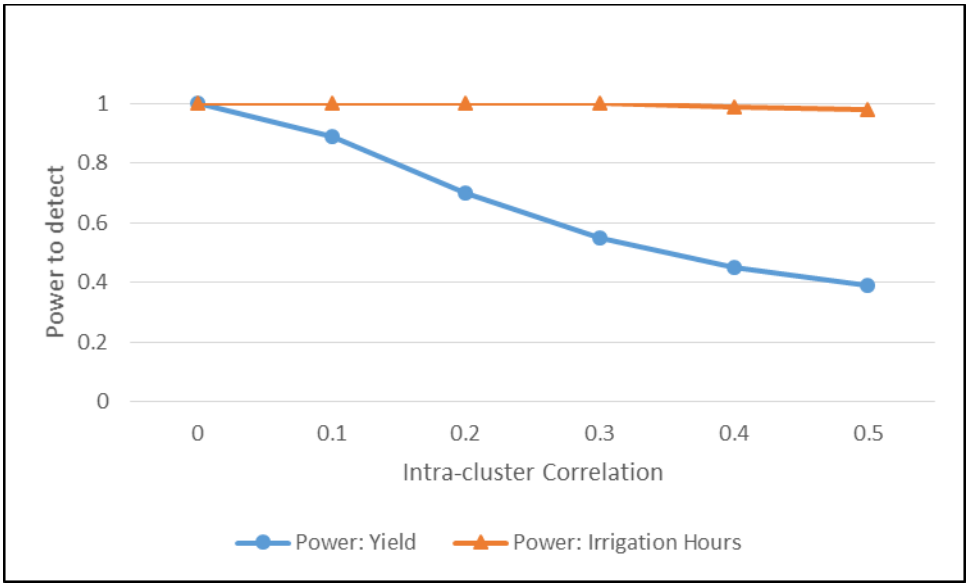


Figure 3.3 Power calculations for detecting differences in yield and irrigation hours (under various intra-cluster correlation assumptions)

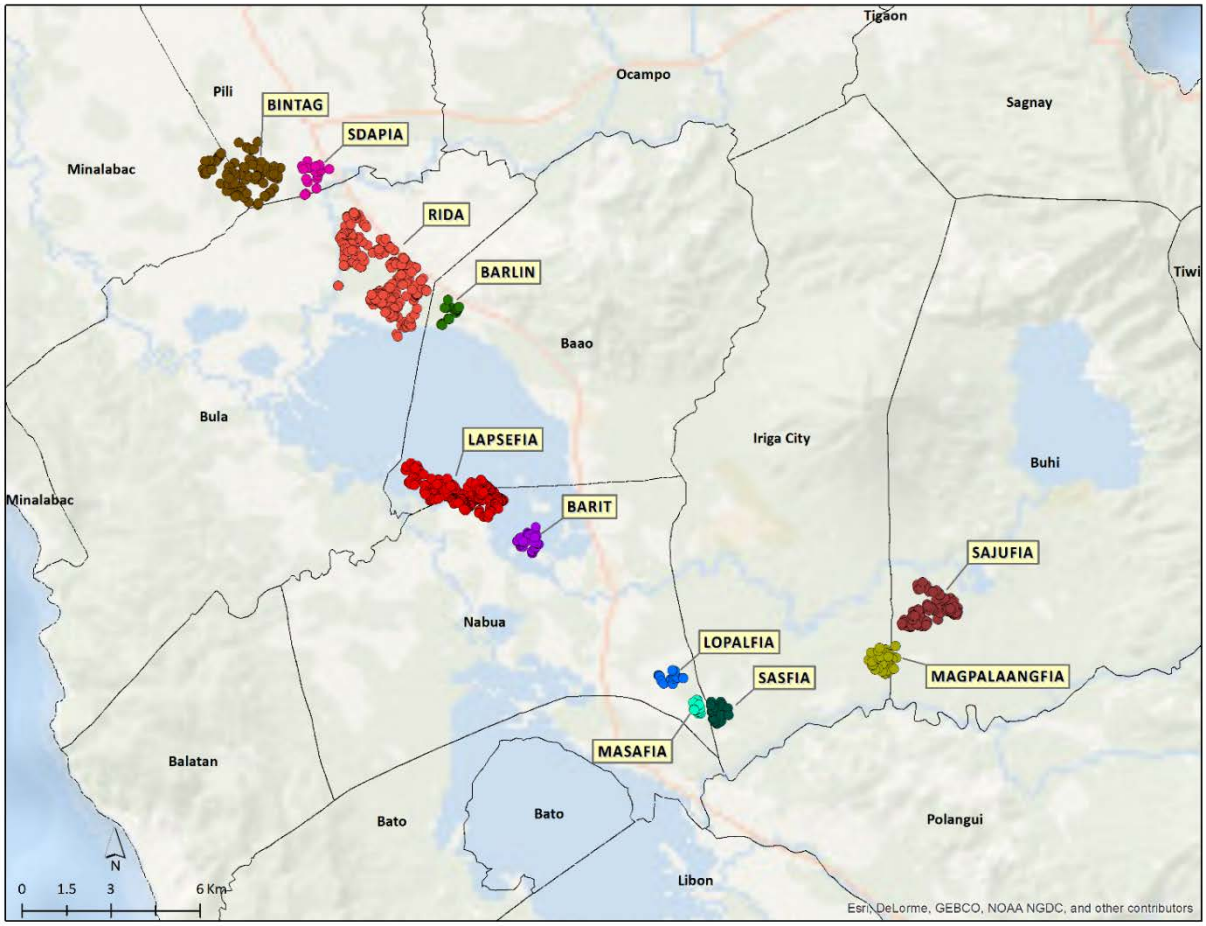
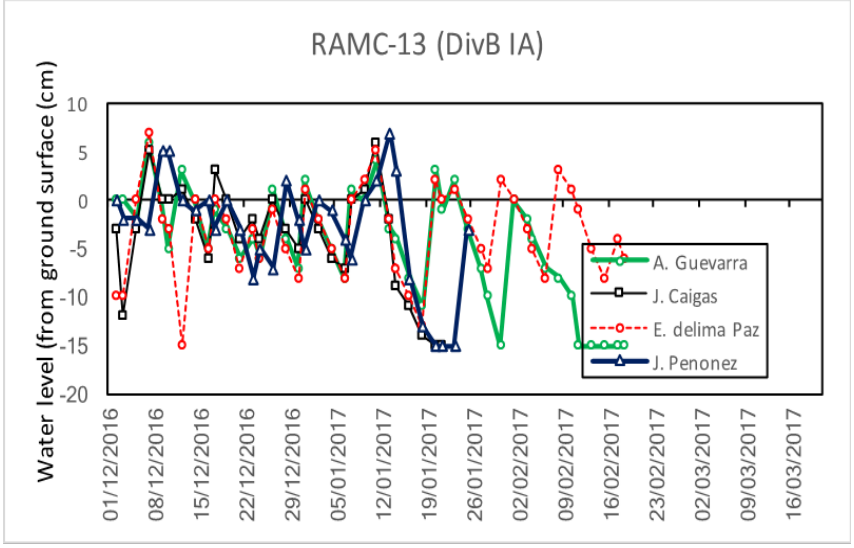
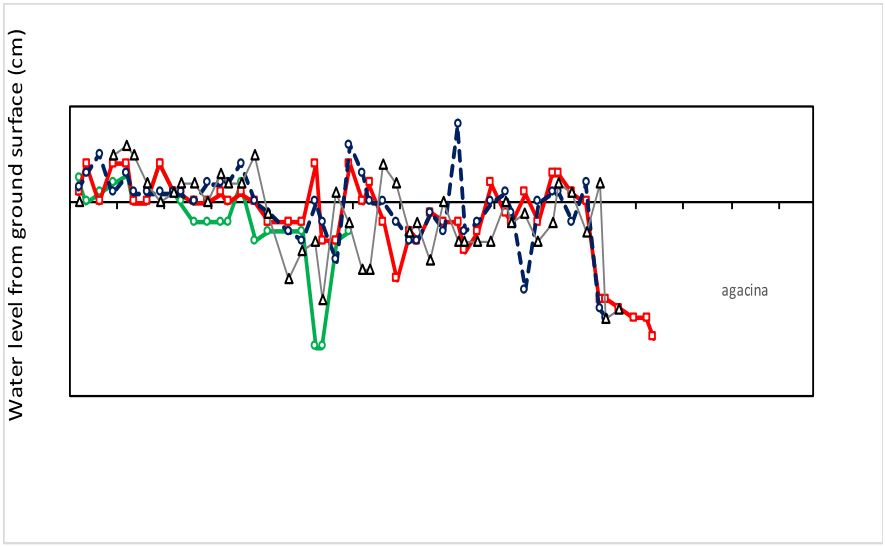


Figure 3.4 Spatial Distribution of Study Respondents in RIIS (by IA)



A. Water Readings for 4 Farmers in a Treatment TSAG



B. Water Readings for 4 Farmers in a Control TSAG

Figure 3.5 Example Water Depth Readings for Farmers in a Treatment and Control TSAG
(Note: These TSAGs are within the RIDA Div B. IA)

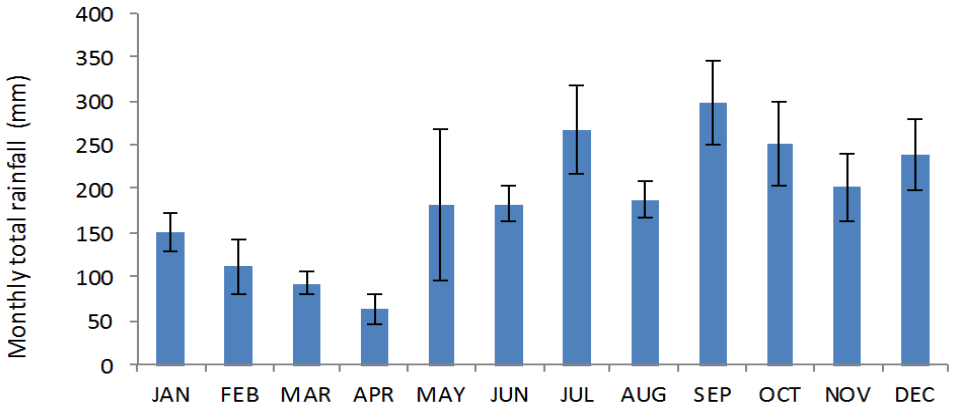


Figure 4.1 Ten-year (2006-2015) average monthly total rainfall (mm) in the study site.

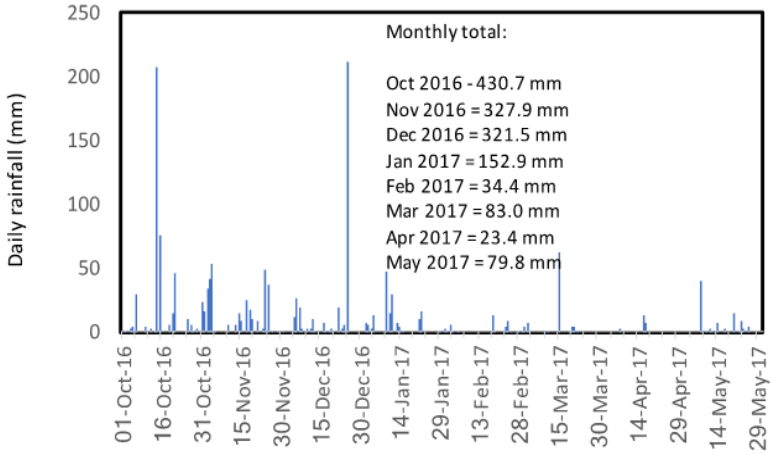


Figure 4.2 Daily and total monthly rainfall (mm) recorded in study site during the 2017 dry season (from October 2016-May 2017).

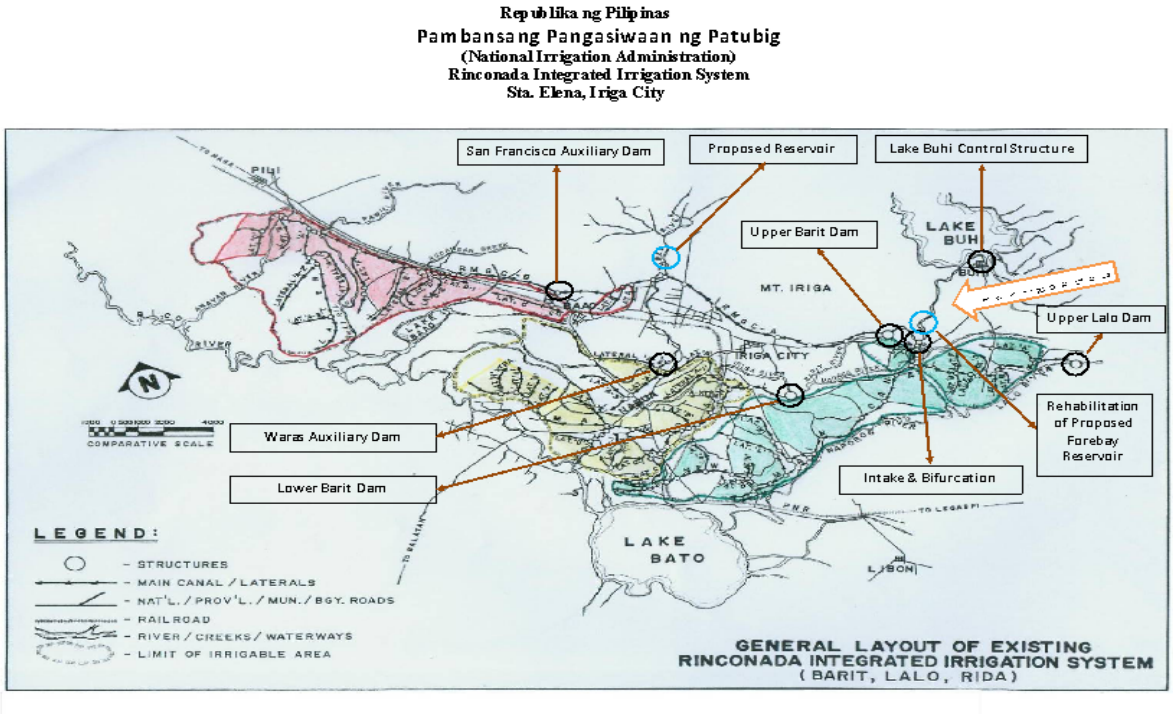
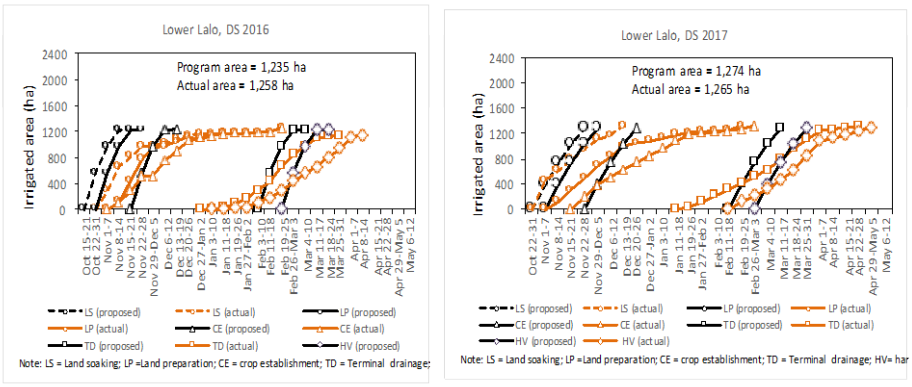
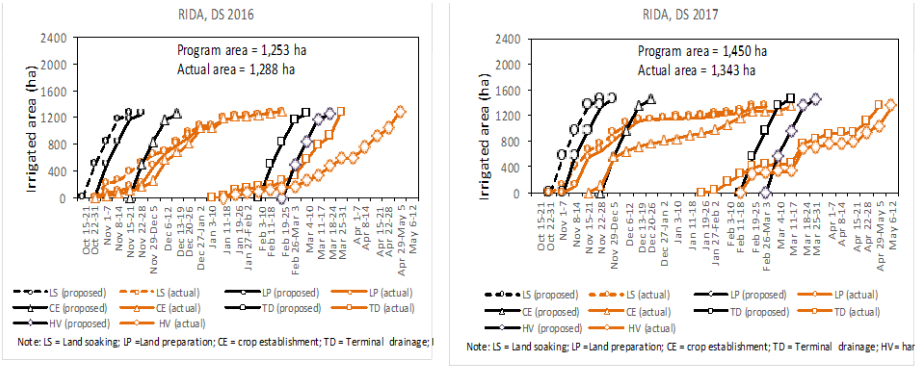


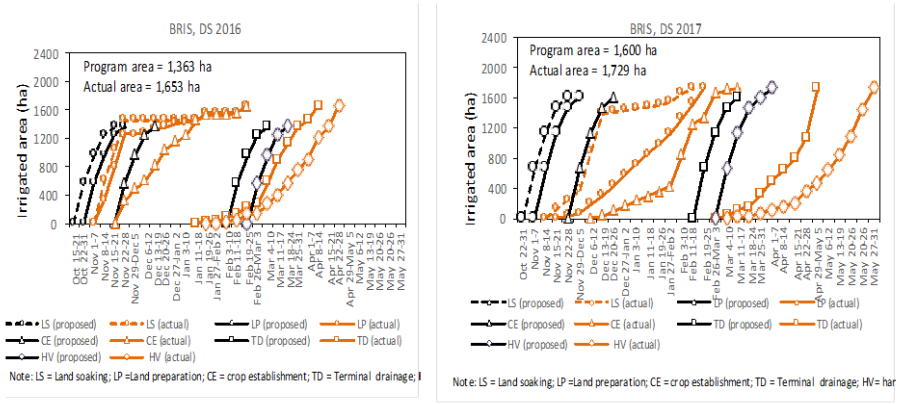
Figure 4.3 General Layout of Major Irrigation Structures in RIIS
Source: NIA Region V



a) Lower Lalo area of Buhi-Lalo

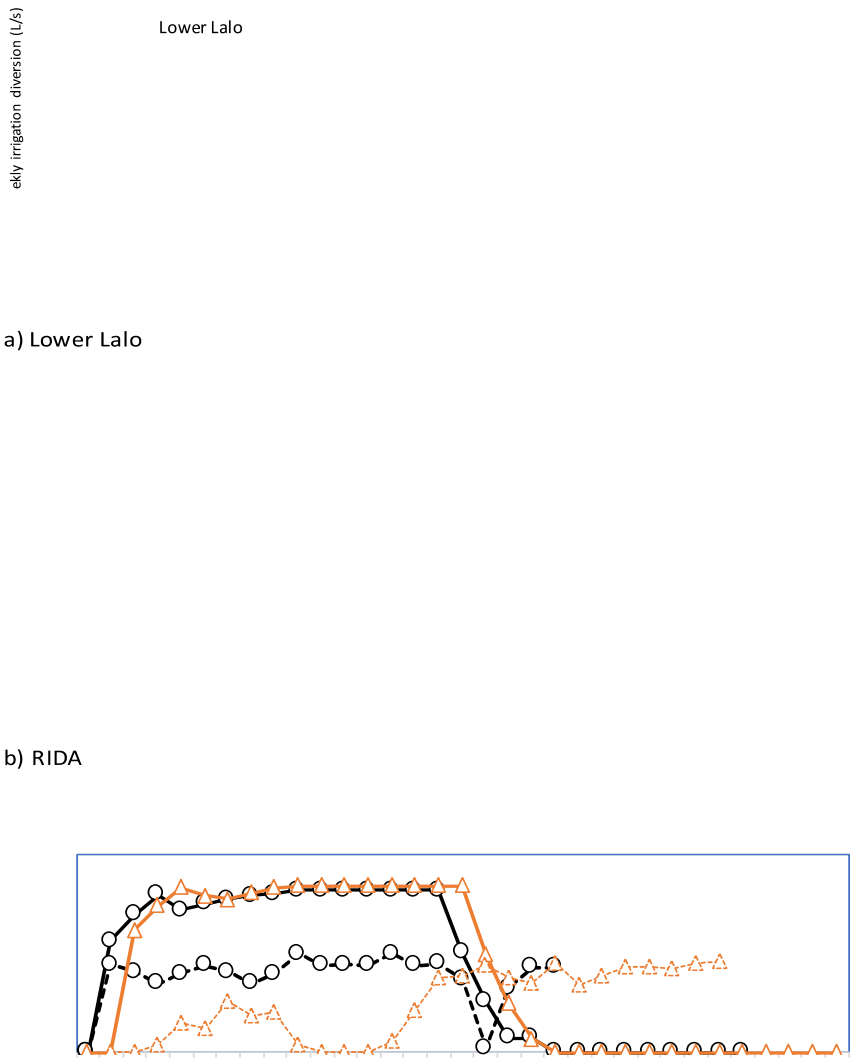


b) RIDA



c) Barit

Figure 4.4 Proposed and actual cropping calendar in three subsystems during 2016 and 2017 dry seasons, showing progress of land soaking, land preparation, planting, terminal drainage and harvesting.



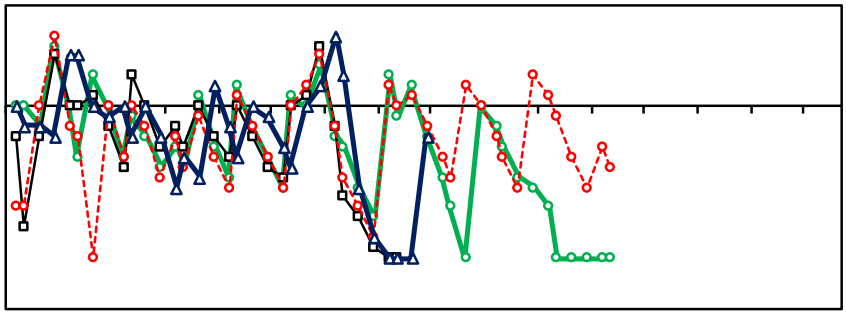
a) Lower Lalo

b) RIDA

c) Barit

Figure 4.5 Weekly average irrigation diversions (L/s) during 2016 and 2017 dry seasons in the subsystems in RIIS (Data from NIA).

Figure 4.6 Water level recorded by the water loggers at the gaging stations of the selected TSAs, 2017 dry season.



(cm)

b) Control field (non-AWD)

Figure 4.7 Sample field water depths for AWD and Control farmers in a selected IA (RIDA), 2017 dry season

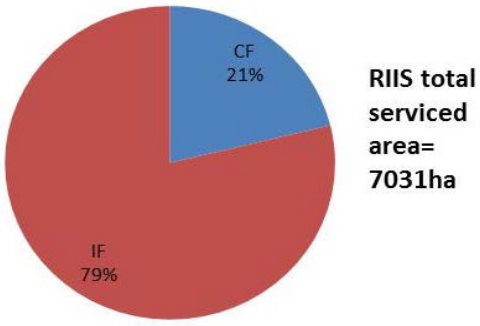


Figure 4.8 Percentage of continuously flooded (CF) areas and intermittently flooded (IF) areas in Rinconada Integrated Irrigation System (RIIS) serviced areas.

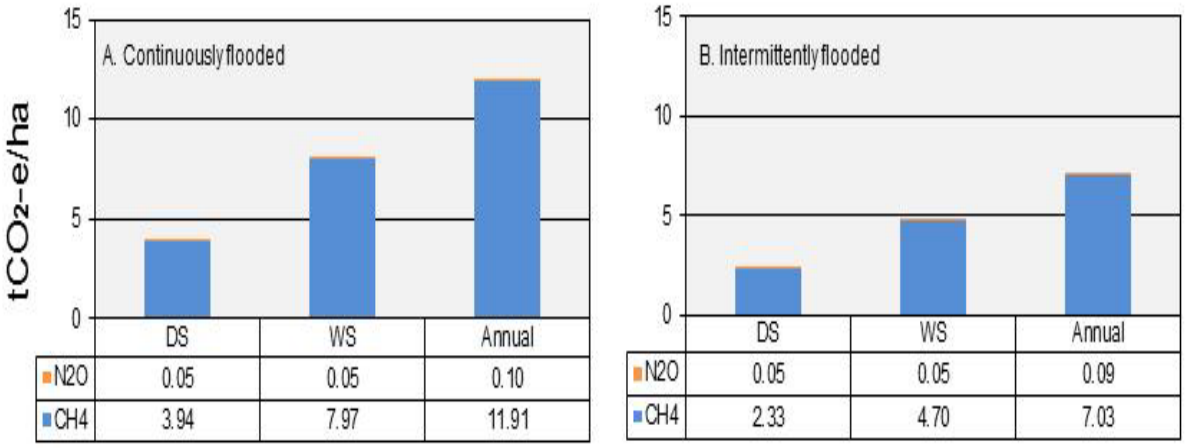


Figure 4.9 Greenhouse gas emission rates (in t CO_2-eq/ha) of continuously flooded and intermittently flooded fields.

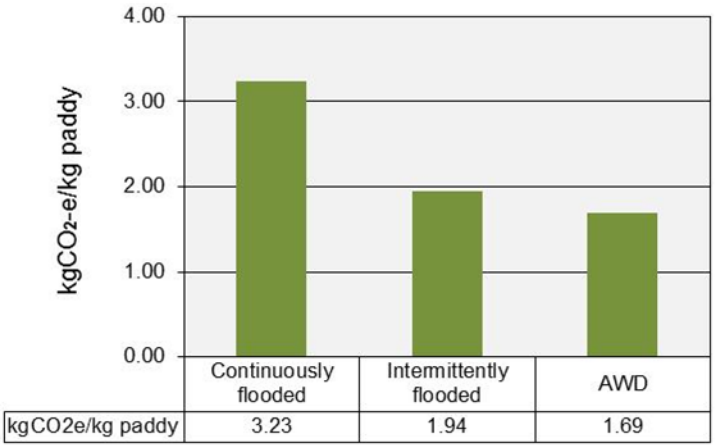


Figure 4.10 Comparison of GHG intensity between rice produced continuously flooded, intermittently flooded, and under an AWD scenario in Camarines Sur in DS.

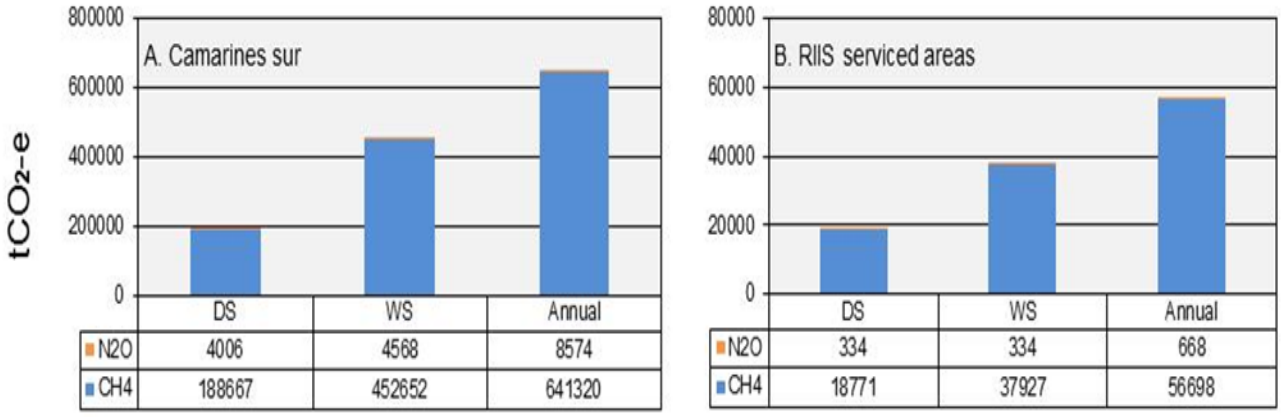


Figure 4.11 Total greenhouse gas emissions from Camarines Sur and RISS serviced areas

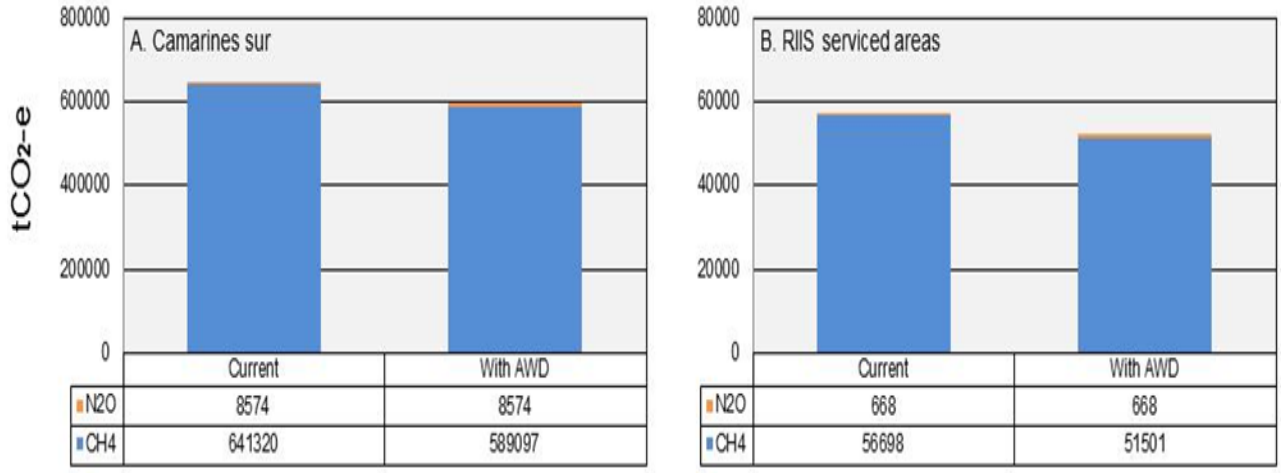


Figure 4.12 Comparison of total annual GHG emission rates between the current emissions and an AWD scenario in Camarines Sur and RIIS serviced areas

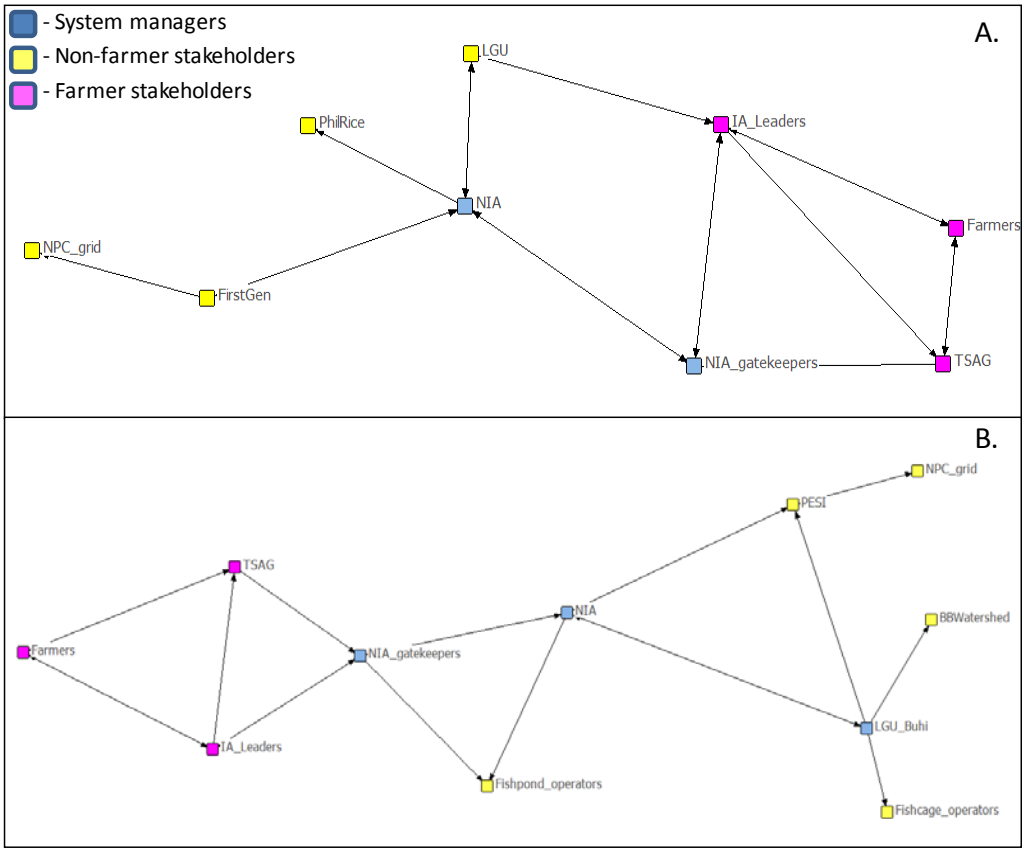


Figure 5.1 Stakeholder groups in: (A) Upper Pampanga River Integrated Irrigation System (UPRIIS, top) and (B) Rinconada Integrated Irrigation System (RIIS, bottom) showing relationships as flow of information (in arrows) and node colors based on stakeholder type (blue=system managers, yellow=non-farmer stakeholders, pink=farmer stakeholders)
Source: interviews with managers and researchers

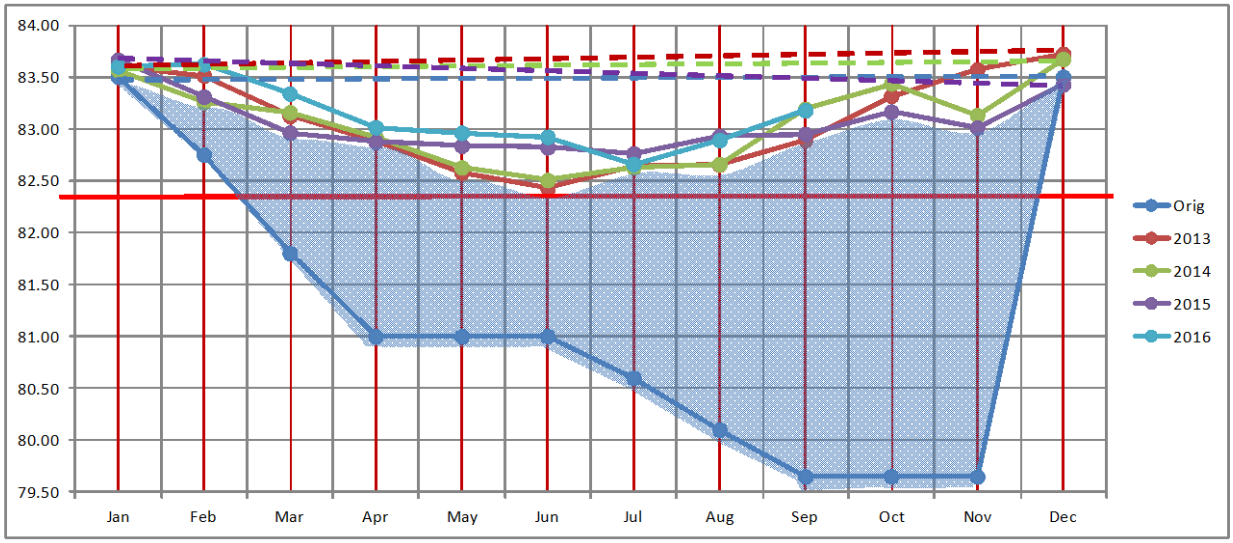


Figure 5.2 Water depth (m) at Lake Buhi across months, and differences in water depth over the years (Source: NIA-RIIS, 2017)

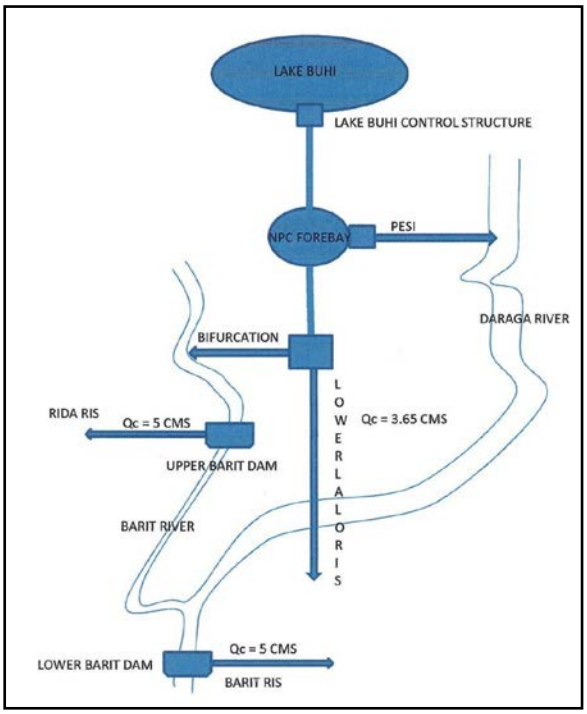
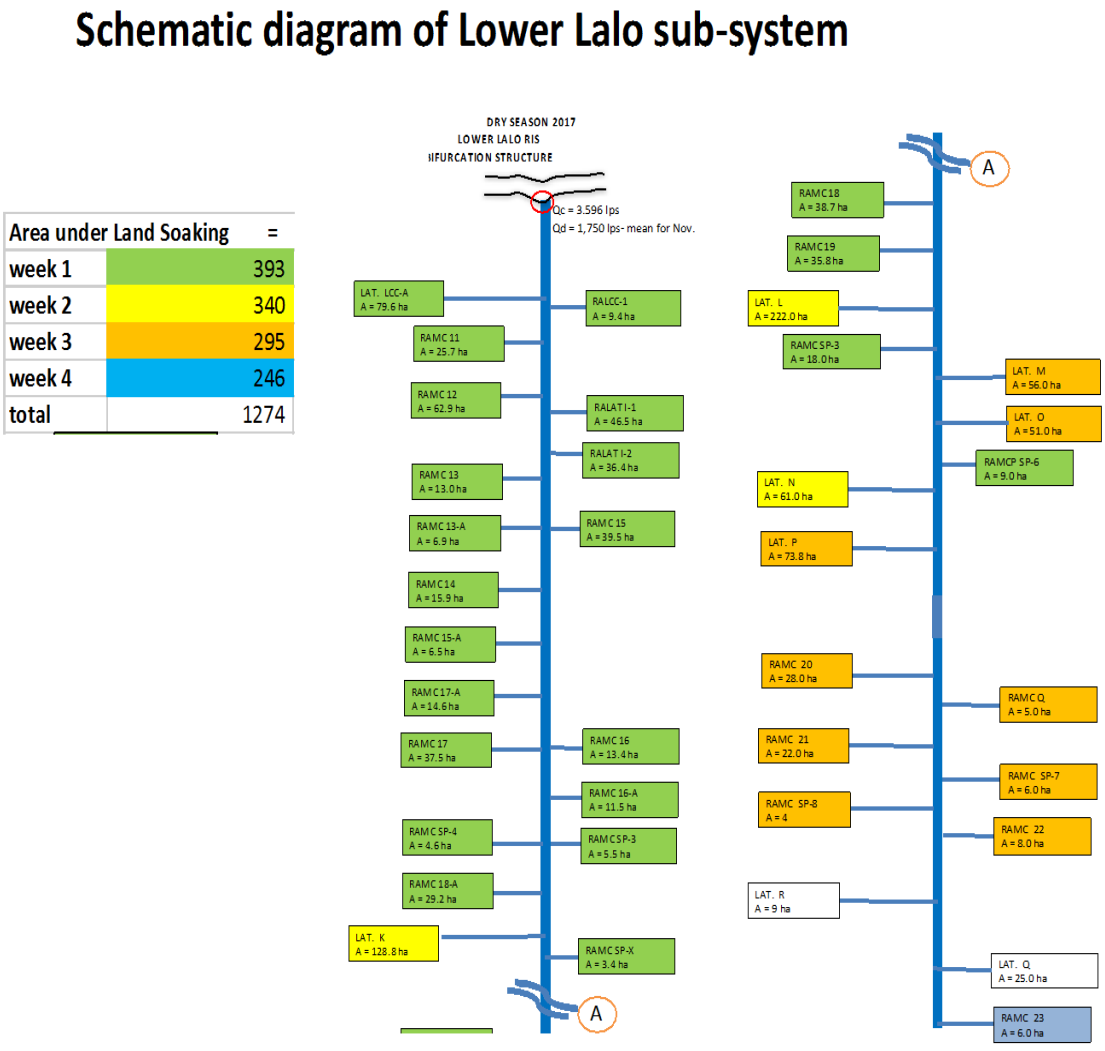


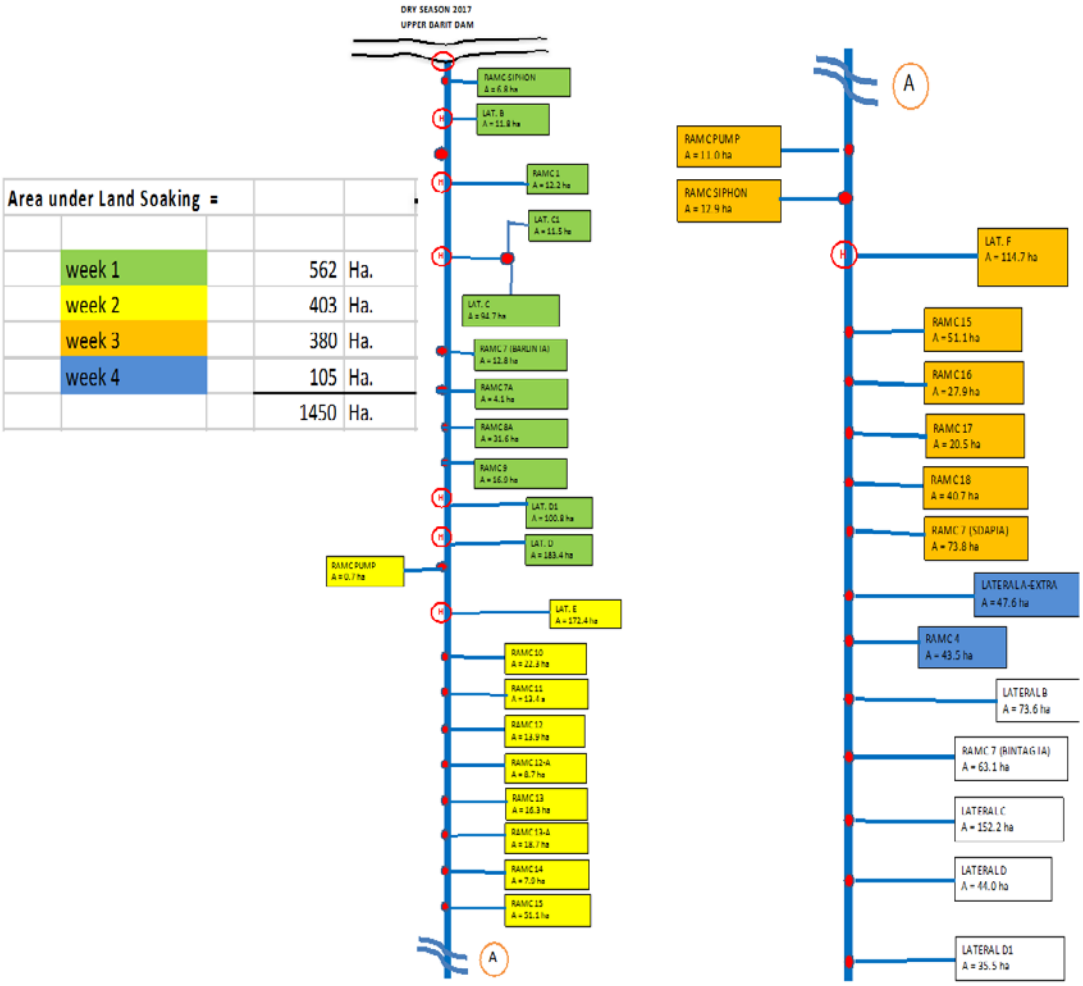
Figure 5.3 Flow of water from Lake Buhi to Rinconada Integrated Irrigation System (RIIS) stakeholders for irrigation and power generation (Source: NIA-RIIS, 2017)

APPENDIX FIGURES



Appendix Figure 4.1 Schematic diagram of the irrigation delivery schedule (land soaking) at Lower Lalo area of Buhi-Lalo sub-system during 2017 dry season.

RIDA sub-system

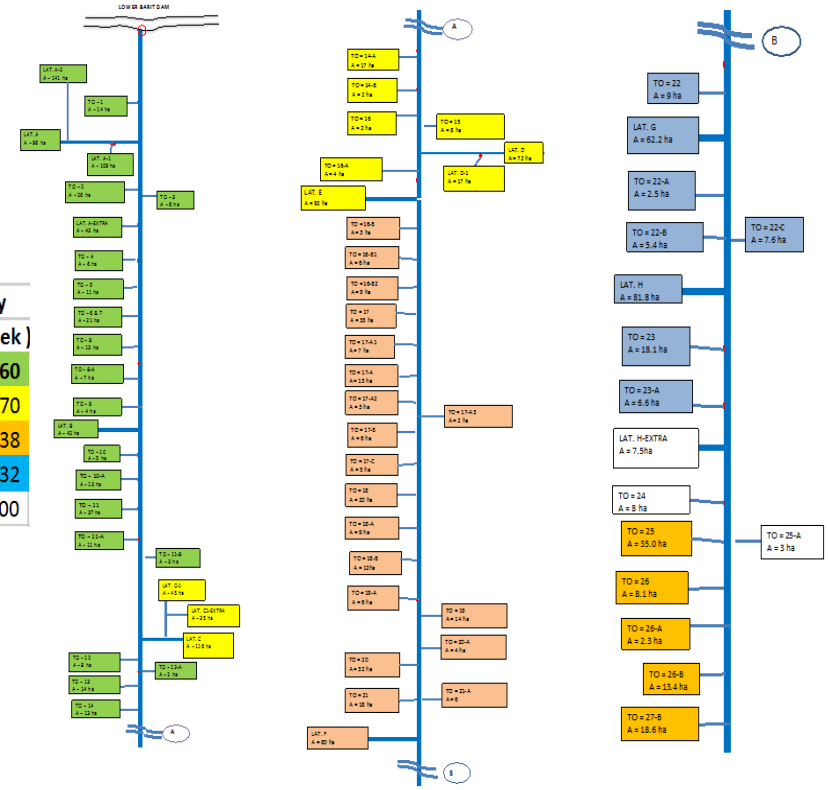


Area under Land Soaking =		
week 1	562	Ha.
week 2	403	Ha.
week 3	380	Ha.
week 4	105	Ha.
	1450	Ha.

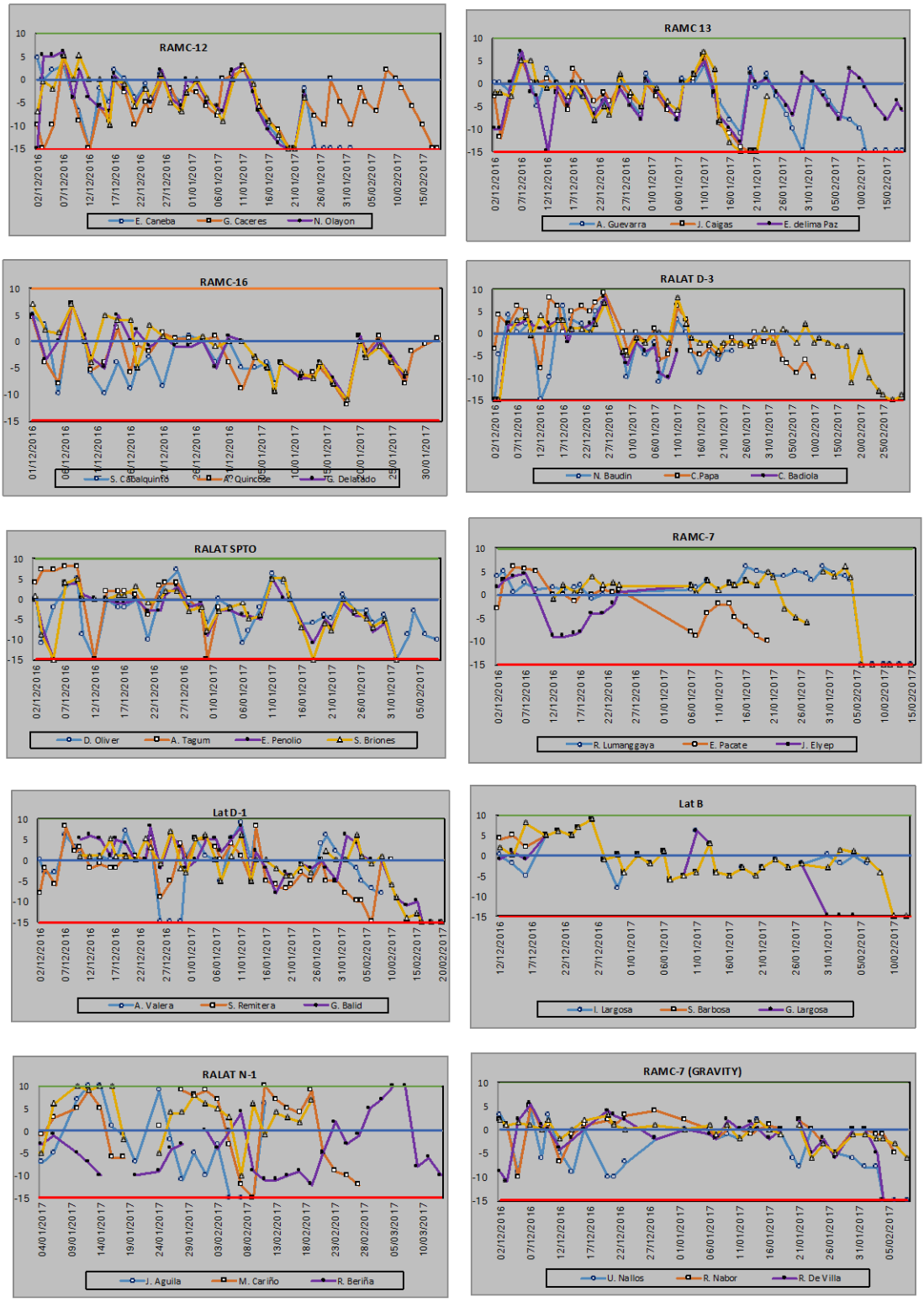
Appendix Figure 4.2 Schematic diagram of the irrigation delivery schedule (for land soaking) in RIDA sub-system during 2017 dry season.

Barit sub-system

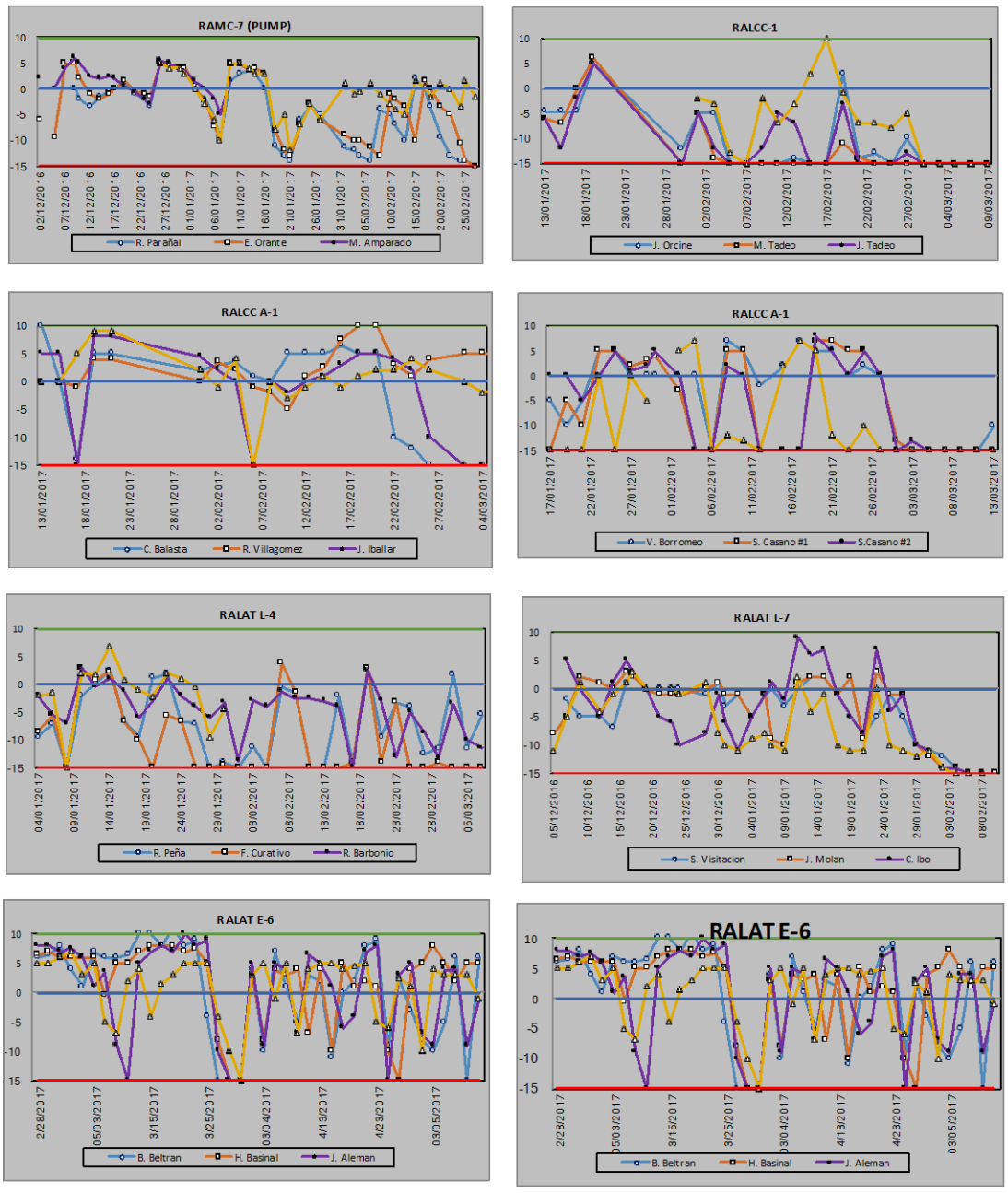
Schedule of Water Delivery	
(Schematic Diagram by week)	
week 1	660
week 2	470
week 3	338
week 4	132
total	1600



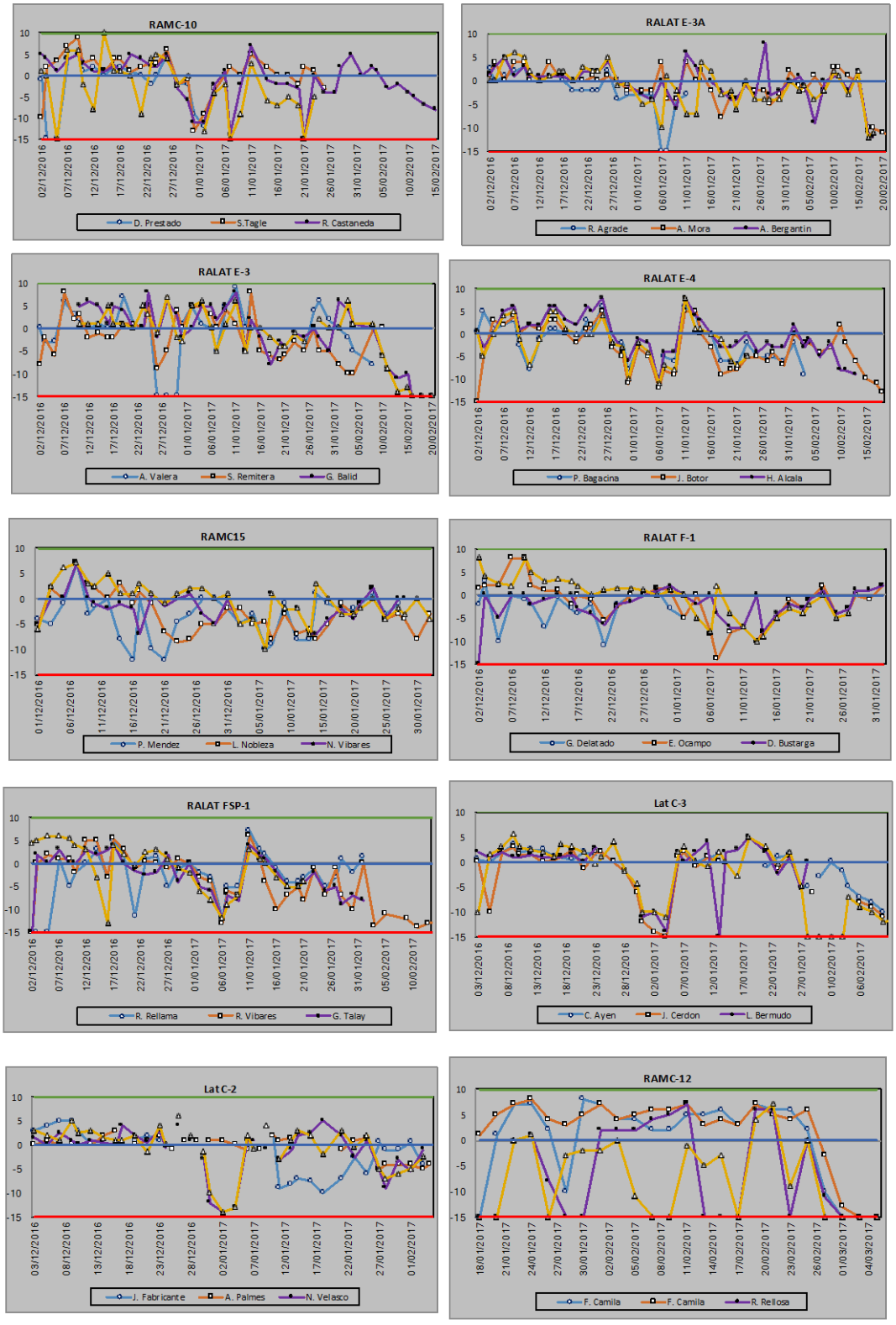
Appendix Figure 4.3 Schematic diagram of the irrigation delivery schedule (for land soaking) in Barit sub-system during 2017 dry season.



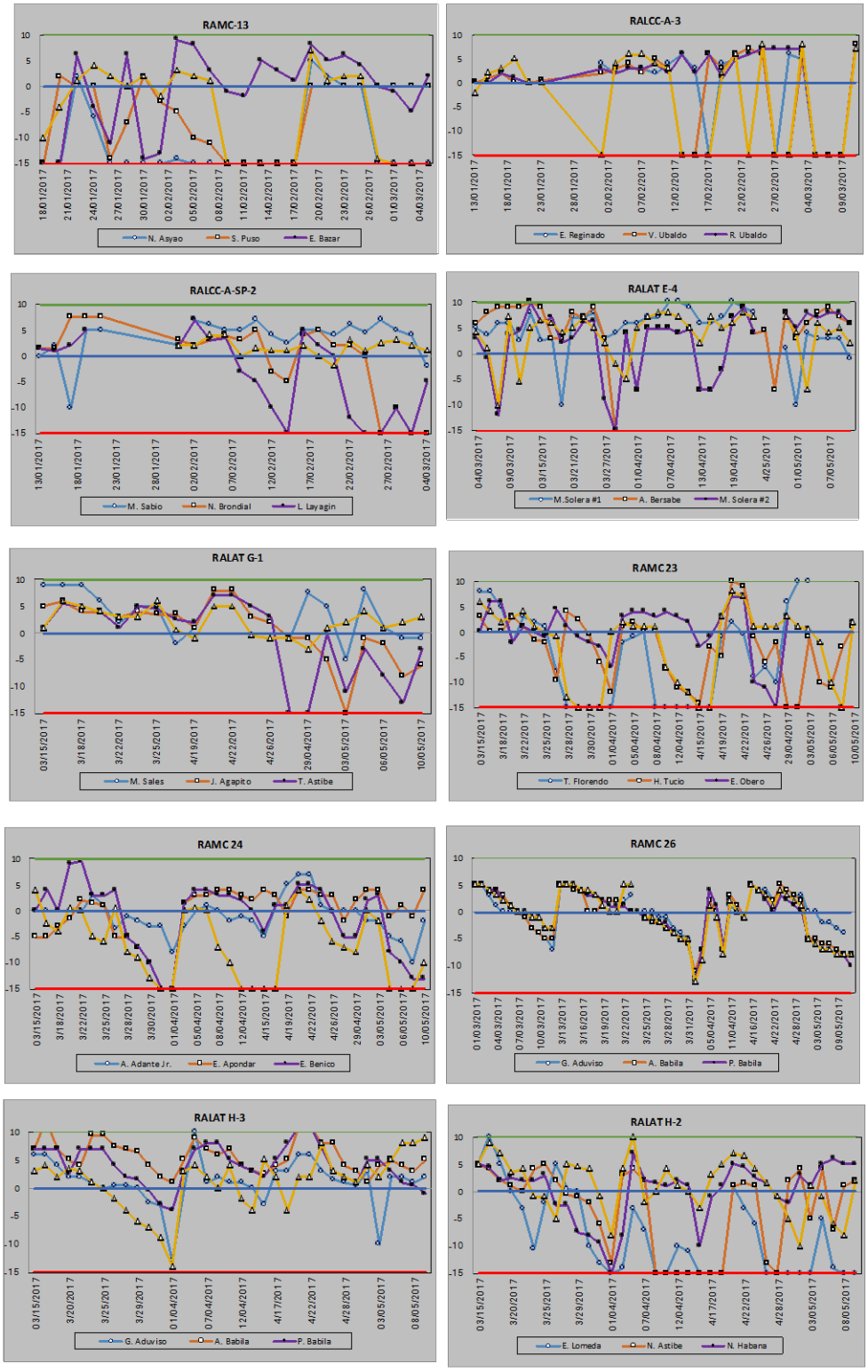
Appendix Figure 4.4a Field water dynamics at the selected farmer's fields with AWD during 2017 dry season



Appendix Figure 4.4b Field water dynamics at the selected farmer's fields with AWD during 2017 dry season.



Appendix Figure 4.5a Field water dynamics at the selected farmer's fields at 'control' fields during 2017 dry season.



Appendix Figure 4.5b Field water dynamics at the selected farmer's fields at 'control' fields during 2017 dry season.