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RESEARCH ARTICLE

Lessons from Volumetric Water Pricing Trials at the Three Surface Irrigation Systems in Northern Luzon, Philippines

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Abstract: Volumetric irrigation water pricing, to replace area-based pricing, was experimentally introduced in two surface irrigation systems in Northern Luzon, Philippines. A survey was conducted in 2012 (baseline) and in 2013 (after the treatment). This paper draws lessons from this pilot project for future studies. We find that the impacts are not against the expected benefit of volumetric pricing: reduced discharge (water saving), more water for lower stream (equitable water distribution), and stricter water management. At the same time, we realized the tremendous difficulty in accurate volume measurement in surface irrigation systems. Given the difficulty, a volumetric system design may be feasible to measure volume at the headgate of a primal-level canal with a firm measurement structure and charge the fee to the group of farmers in the canal. This approach, however, demands for the successful collective management among the large group of farmers. An alternative design may be to charge water fee to a much smaller unit (e.g., water users group) for their easier collective management. However, this requires investment in infrastructure for group-level volume measurement and water control. An appropriate system in the reality seems to lie in the spectrum of these two options, depending on different environmental and socio-economic background.

Keywords: micro analysis of farm firms, farm input markets, volumetric water pricing, surface irrigation systems

JEL Classifications: Q12, Q18, Q25

The analysis of the Philippine's national representative agricultural data (Department of Agriculture-Bureau of Agricultural Statistics, DA-BAS) by Mataia, Jamora, Moya, Francisco, and Dawe (2011) shows that the recent increase in rice production is attributed mostly to the improvement in irrigation water access. This means that the country's rice production depends crucially on the performance of its irrigation schemes. However, regardless of its relatively abundant water resource endowment, the country's irrigation potential appears not to be fully utilized. A critical problem is the prevalence of the so-called "upstream-downstream problem" in gravity irrigation systems. This makes the actual irrigated area much smaller than the designed service area because upstream farmers tend to overuse water by abusing their locational privilege.

A traditional approach to tackling this problem in the international development society has been the empowerment of irrigators' associations (IAs) and the transfer of management to the IAs. The Philippines has not been the exception to this trend. This social approach assumes that the stakeholders (farmers) have the capacity to solve the issues on the local resource management through negotiation and collaboration among them. However, the results are not satisfactory as the success of this approach depends so much on the local context, in particular, the existence of a good leader.

Facing the limited impacts of this social approach, the emphasis has been shifting to economic aspects, that is, the volumetric irrigation water pricing. The aim is to introduce economic incentives to farmers, expecting that they use less water under a higher water price and then the water saved can be used in downstream plots. The international development society, particularly the World Bank, has high hope for this economic approach.

However, the effectiveness of volumetric pricing depends on three crucial issues. First, some people argue that the demand for irrigation water is inelastic, and farmers do not change their behaviors significantly, even under high water prices (Yang, Zhang, & Zehnder, 2003).

Second, in a surface gravity irrigation system, which is the major mode for paddy production, effective collective action among water users is needed to save water. This is because a feasible pricing method measures the volume at a canal's intake, and the total fee is charged to the water user group (WUG) rather than to individual farmers. The total fee is then divided among the WUG members by cultivated area. Therefore, the group has an incentive to save water, while individual farmers *within* a group may overuse water unless they are closely supervised. However, only a few attempts have been made to explore this issue (Kajisa & Dong, 2017; Vos a& Vincent, 2011; Dono, Giraldo, & Severini, 2010; Huang et al. 2010).

Third, if the second issue is relevant, we have to think about an optimal size of the group to which the irrigation scheme charges water fee. The larger the group size is, the fewer measurement points along the canal are needed (thus, less investment is needed); at the same time, however, it becomes more difficult to achieve successful collective action by a large group. On the other hand, the smaller the group size, more investment is needed. Existing literature has shown that an optimal design of water users group largely depends on the local context (Ostrom, 2007; Meinzen-Dick, 2007). As a past example from our study site, Lewis (1980) reported that a successful irrigation society in Ilocos Norte (the northwestern part of Luzon facing the South China sea) was not able to be transferred to Isabela (the northeastern part of Luzon facing the Pacific Ocean, the area close to our study site), although the irrigation societies there were originally created by Ilocano migrants. In practice, we have to think about an optimal design of the volumetric pricing system and associated cost, given the difficulty of the collective management under the local context of the irrigation scheme of our interest.

The aim of this paper is to draw lessons for the appropriate design of the volumetric pricing system from the cases of three surface gravity irrigation schemes in the Philippines. As we will explain later, since a regulation by the government did not allow us to have variation in water price level, we cannot discuss the first issue (price elasticity) in this paper. We focus on the second and third issues (i.e., collective management and infrastructure design) and draw lessons.

Background and Study Sites

The International Rice Research Institute (IRRI) and National Irrigation Administration (NIA) jointly

Figure 1. Map of the volumetric project sites.

Table 1. *Study Sites*

Irrigation system	*System A*	*System B*	*System C*
Water source	Reservoir	Run-of-the-river	Pump
Lateral	D2b	A	B
Service area (ha.)	1686	694	300 (150 is under const.)
Length of lateral (km)	21	7	2.4
Lateral condition	earth	Lined	earth
No. of IAs	6 IA in 1 CIA	3 sectoral IA	1
No. of Turn outs	65	31	8
Water measurement device	Reploggle flume at the headgate & calibrated staff gages at other points	Calibrated staff gages	Calibrated staff gages
Volumetric water price applied in 2013 DS	Pesos 0.083 /m^3.	Pesos 0.109 / m^3.	N.I.

N.I.: not interviewed.

conducted a volumetric pricing study. Three sites were selected in Region II of the national irrigation system, which is the northeastern part of Luzon, in such a way that each represents a different type of irrigation system. For anonymity, we call each as System A, B, and C (Figure 1). The characteristics of each system are summarized in Table 1.

System A represents a reservoir irrigation system. The survey team selected this system among many because a similar study was conducted at this site

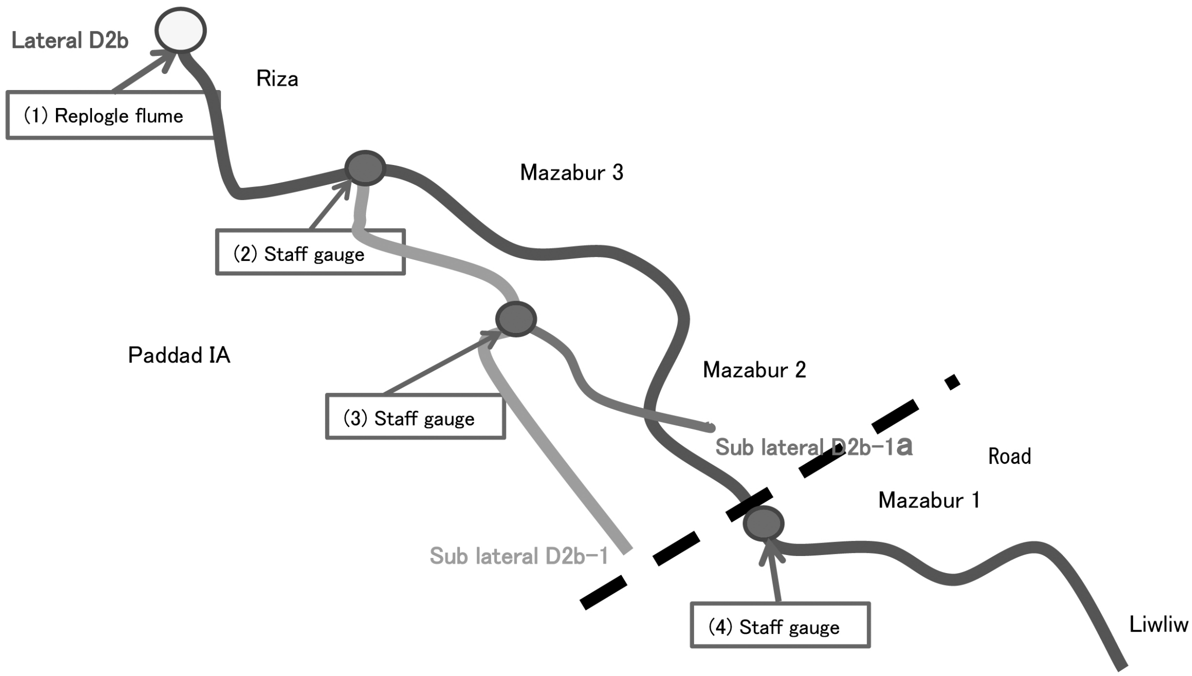


Figure 2. Location of water measurement devices and IAs in System A.

in 2002. The lateral chosen for the previous survey, Lateral D2b, was chosen for this study again. The service area is 1,686 ha, which is much larger than the other two study sites. The length of the canal is 21 km, consisting of six Irrigators Associations (IAs) under one Central Irrigators Association (CIA). Most parts of the lateral are earthen. The Replogle flume remained at the headgate since the last study (Figure 2). Additionally, we installed three staff gauges so that we could estimate the distribution of water within the CIA. The common rice variety grown in System A is Jasmine Dinorado.

System B belongs to the run-of-the-river type of irrigation system. Lateral A, which has its water source from the Palawig River, is selected for the study. The service area of this lateral is 694 ha, serving one IA (Dagupan IA), which is divided further into three sectoral IAs. The lateral is lined by concrete. Four staff gauges are installed along the lateral (Figure 3). The common rice variety grown in System B is NSIC Rc222.

System C uses large pumps to lift water from a river. We selected the upstream portion of Lateral B for our study since the downstream portion is still under construction. The service area of the upstream portion is 150 ha, having one IA. The lateral is earthen. Two staff gauges were installed so that we could observe the water allocation between the upper part and lower part within the upstream portion. The common rice variety grown in System C is SL8. As we will explain later, System C did not implement the volumetric pricing. Hence, we use this case just as a reference to the others.

Study Design

Timing of Intervention

The survey was carried out in the dry season for two reasons: first, to minimize the influence of rainfall on water volume; second, the lessons for water savings based on the water-scarce season are more valuable. The first dry season (2011–12 DS) was used as a baseline survey. Hence, we measured the volume and collected related variables under the prevailing pricing system (area-based irrigation service fee [ISF] collection). In the next dry season (2012–13 DS), we introduced volumetric pricing. For comparison with the baseline, we measured the water volume and related variables.

Implementation of Volumetric Pricing

The setting of volumetric pricing must satisfy two conditions. First, the measured volume must be used exclusively by a unit to which the fee is charged (exclusiveness condition). Second, the unit should have a right and a device to control water so that it

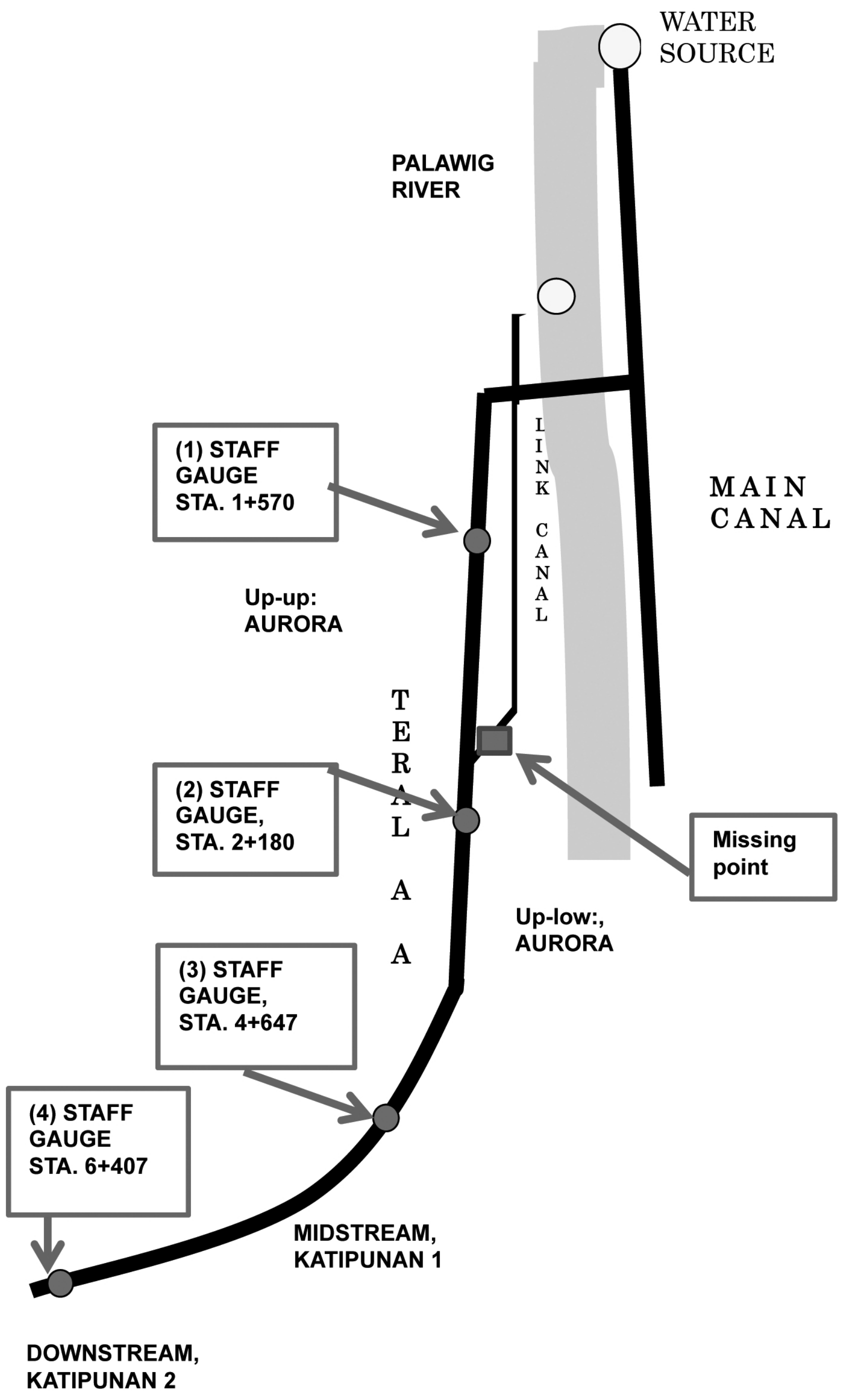


Figure 3. Location of water measurement devices and sectoral IAs in System B.

can regulate the inflow of water to accomplish water savings (controllable condition). We use a CIA for System A and an IA for System C and System B as a satisfactory unit. A unit smaller than these violates the exclusiveness condition because a smaller unit's boundary is ambiguous and water can more easily flow beyond the boundary. A smaller unit is also likely to violate the controllable condition as many of the smaller units do not have water control devices (e.g., concrete turnout with a spindle water gate).

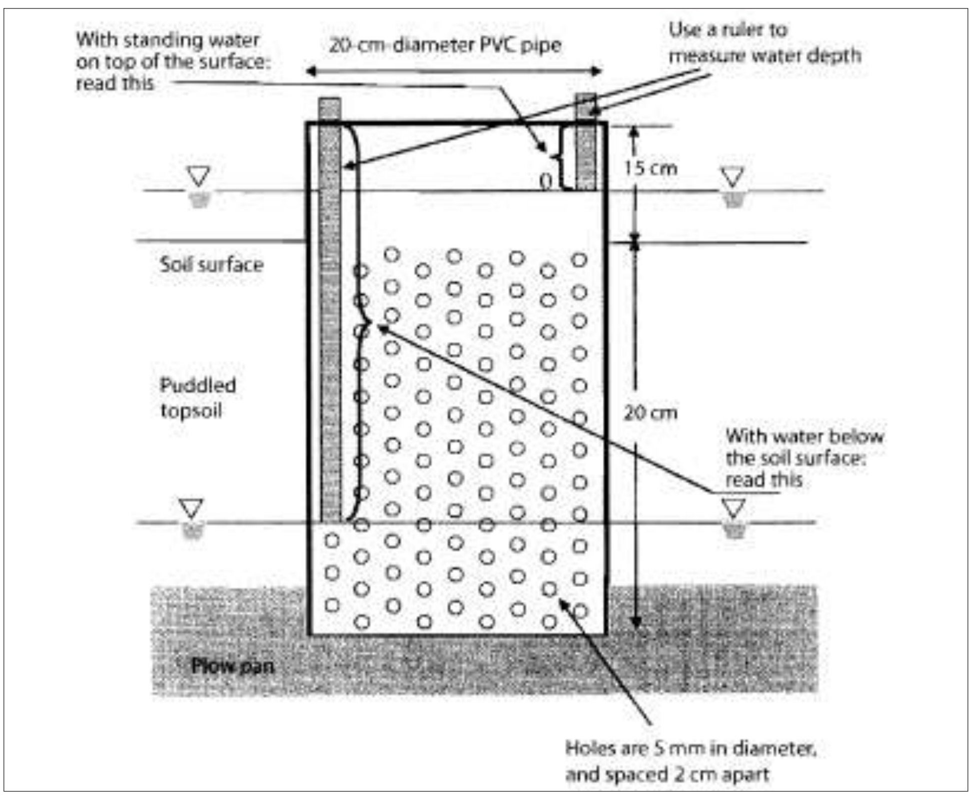
The price of water was set equivalent to the current ISF which is 3 cavans/ha in the DS, rather than at full cost recovery level. The team decided so, first, to avoid the risk of the decline of volumetric pricing by farmers and, second, to avoid the risk of violation of the government rule that regulates the current ISF rate. The volumetric prices applied in the 2013 DS are reported at the bottom of Table 1.

The principles of volumetric pricing and the draft Memorandum of Agreement (MOA) were presented and discussed with the farmers. Reactions were mixed among the farmers. The CIA in System A readily accepted volumetric pricing but farmers in System B were divided. One IA, Aurora, did not like it but two IAs, Katipunan 1 and Katipunan 2, decided to try it. Farmers in System C were also hesitant to try it. After a long discussion, the IA of System C finally declined the MOA. Therefore, we used the data of System C for reference only.

The important facts of the volumetric pricing experiment are summarized in the box.

Setting of volumetric pricing experiment

- Price of water: equivalent to the current irrigation service fee (ISF) (i.e., if farmers use the normal volume, the water fee will be equivalent to the current ISF, which is 3 cavans/ha in the DS in System A and System B).
- System A: the CIA (six IAs) agreed to use volumetric pricing. All data are valid for analysis.
  - ➢ Volumetric price: PHP 0.083/m^3 in 2013 DS.
- System B: Of three sectoral IAs, two downstream IAs agreed to use volumetric pricing.
  - ➢ Only two downstream IAs' data are valid.
  - ➢ Volumetric price: PHP 0.109/m^3 in 2013 DS.
- System C: declined the offer of volumetric pricing.
  - ➢ Not valid for analysis and use just for reference.



Source: Bouman, Lampayan, and Tuong (2007).

Figure 4. Field water tube.

Data Collection

Water volume measurements are made at least twice a day by a hired observer together with the IA officials. We continued this for four seasons in two years: Dry Season (DS) 2012, Wet Season (WS) 2012, DS 2013, and WS 2013, where our main focus is DS data, using WS data just for references.

A farm-level survey was also conducted at the end of the baseline DS and the second DS to capture the change in farmers' behaviors. To capture variation along the lateral, our strategy was to select three sample farmers randomly every 1 kilometer along the lateral (study canal). In addition, to monitor the water level on the sample farms, one field water tube was installed on each sample farmer's plot (Figure 4). The water volume observers kept a record of the water depth of the installed water tubes.[1] We also interviewed IAs and Turnout Service Areas (TSAs) at the end of the baseline DS and the second DS. TSA is the smallest unit of a formal water users group. This survey aimed to capture what effort the groups had made to save water and how the groups had changed their water institutions for water savings.

Results of Survey

To reveal the differential conditions by hydrological location, we classify our sample based on the distance from the headgate of the study lateral. In System A and System B, observations are divided into three hydrological location groups: upstream, midstream, and downstream along the lateral. Since the distance is relatively short in System C (Table 1), the lateral is divided into upstream and downstream. The location and name of IAs along the canal, as well as the number of interviewed IAs, TSAs, and households, are summarized in Table 2.

Irrigation Water Discharge

Figures 5 to 7 show the water discharge (million cubic meters, MCM), irrigated area (ha), and water discharge per ha (000 cm^3/ha) by location and season. The irrigated area is computed as follows: NIA issues an invoice for the ISF with an indication of the size of the area irrigated by NIA water. We use this area as the area irrigated by NIA water. An increase in irrigated area in downstream can benefit from water savings in upstream. Lastly, the water discharge per ha is computed using water use and irrigated area. This figure indicates changes in water shortage/abundance between locations.

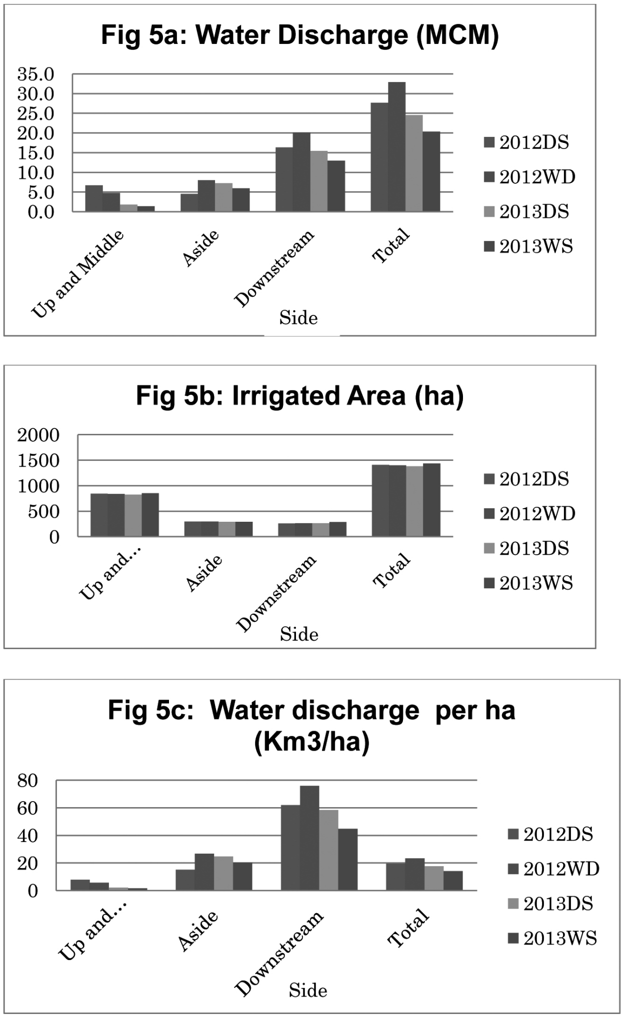
The discharge volumes in System A and System B are computed as follows. The number in parentheses corresponds to the volume measured by the flume or the gauge indicated in Figure 2 or 3.

- System A (Figure 2)
  - ➢ Up and mid volume = (1) – [(2) – (3)] − (4)
  - ➢ Side volume = (2) − (3)
  - ➢ Down volume = (4)

Note that the volume of (2) diverts to the side stream and then the volume of (3) returns to the midstream.

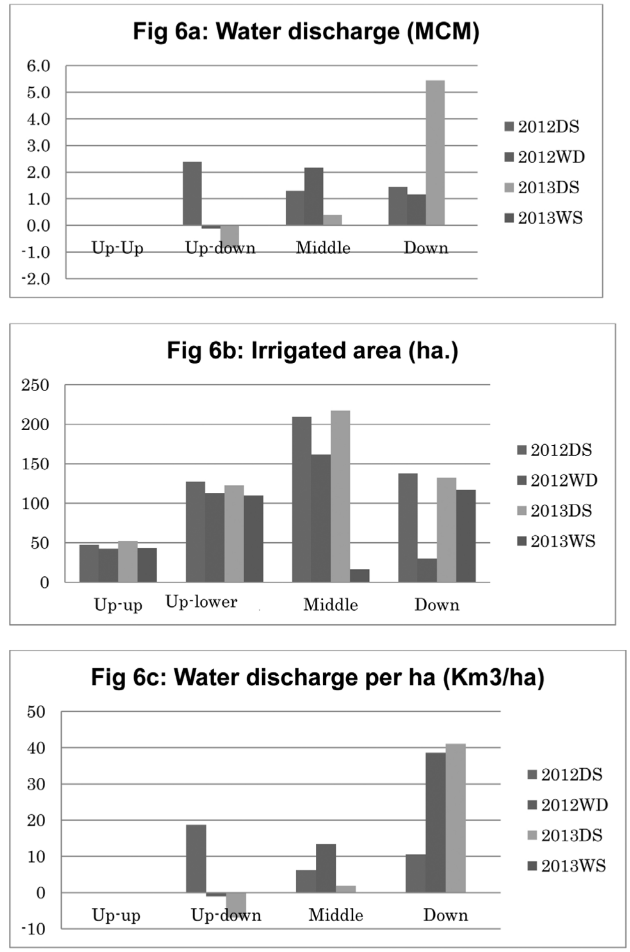
Table 2. *Sample Distribution by Location and Study Site*

	------------------ System A -------------------				------------- System B ------------				-------- System C ---------		
	Total	Upstream	Midstream	Downstream	Total	Upstream	Midstream	Downstream	Total	Upstream	Downstream
No. of IA	6	2	2	2	3	1	1	1	1	na	na
Name of IA		Rizal	Paddad, Mazabur 3 and 2	Mazabur 1 and Liwliwa		Aurora	Katipunan 1	Katipunan 2	Northern Solana River Producers IA		
No of IA interviewed	6	2	2	2	3	1	1	1	1	na	na
No of TSA interviewed	67	15	34	18	26	8	12	6	5	3	2
No of HH interviewed	56	11	27	18	28	11	12	5	14	9	5



Note: Up (Rizal), Middle (M-3, M-2, part of M-1), Side (Padad), Down (part of M-1, Liwliwa)

Figure 5. System A's water discharge, irrigated area, and water discharge per area by location and season.



Note: Up-up (Up of Aurora) Up-lower (Lower of Aurora) Middle (Katipunan 1) Down (Katipunan 2), Only Katipunan 1 and 2 agreed to practice volumetric pricing.

Figure 6. System B's water discharge, irrigated area, and water discharge per area by location and season.

- System B (Figure 3)
  - ➢ Upper upstream: not available
  - ➢ Lower upstream volume = (2) − (3)
  - ➢ Mid volume = (3) − (4)
  - ➢ Down volume = (4)

Note that, since we were not able to measure the inflow from the supplementary channel (indicated as a missing point in Figure 3), we were not able to measure the volume of upper upstream in System B.

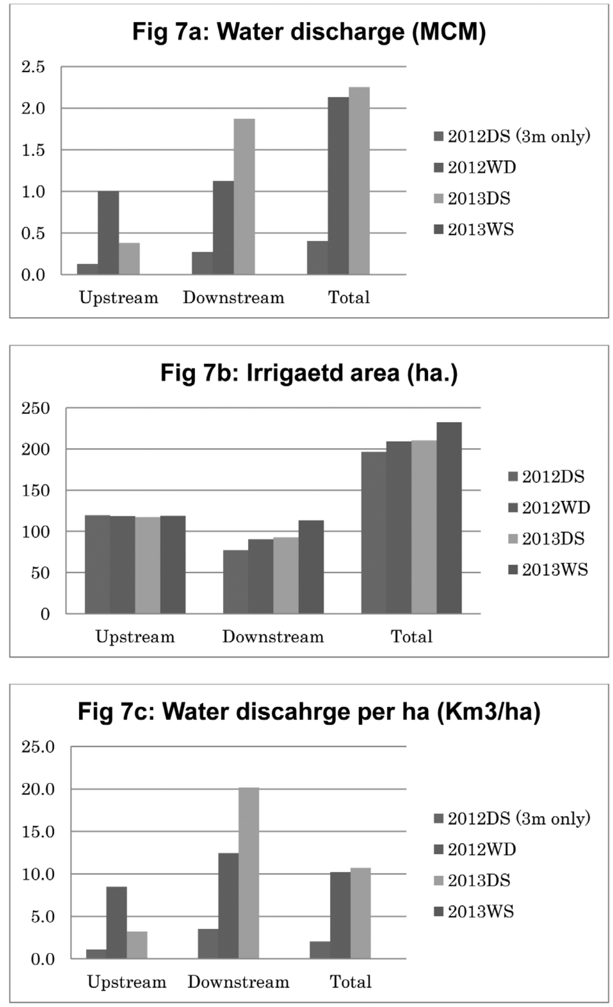
We experienced extreme difficulties in accurately measuring the water volume along a lateral. In System A in Figure 5, contrary to our field observations, the upstream and midstream received, by far, the least amount of discharge while the downstream looked to be enjoying the largest proportion of total discharge. Moreover, in System B (Figure 6), the volume was computed as negative in the upstream's lower portion in the 2012 WS and 2013 DS. It is important for the future research to investigate why measurement was so difficult that it did not produce reliable data. The following are possible reasons:

- The Replogle flume has a permanent concrete structure, which makes flow stable and measurement accurate. Hence, the volume measured at the headgate of System A must be reliable. Meanwhile, similar to other gravity systems of the country, large portions of the lateral are earthen. Although we installed staff gauges on the points with relatively stable water flow, it is practically very difficult to maintain a stable flow on an earth canal because the shape of the canal is changeable and weeds and earth become obstacles on the bank of the canal.

- Below the headgate, backflow of water from the paddy field to the canal may occur, which makes water volume double counted.
- Along the canal, a natural water supply (e.g., creek, rainfall, etc.) may be added, which makes the total volume greater than the volume released from NIA.
- Water flow takes time. Simultaneous measurement may make downstream volume lower than the volume actually released.

Initially, we assumed that these were minor issues, but in practice, we realized the errors were not negligible. An important lesson from this experience is that as long as the infrastructure of the irrigation system is an earthen open canal, it seems impossible to measure water volume accurately along the canals, except when the volume is measured at a headgate with a concrete structure.

Therefore, we used only the total volume measured by the Replogle flume at the headgate in System A for analysis. Comparing total discharge between the 2012 DS and 2013 DS (Figure 5a), we can see a reduction in volume of 3.1 MCM after the introduction of volumetric pricing: from 27.7 MCM to 24.6 MCM. Another potential benefit of volumetric pricing is the expansion of irrigated area (Figure 5b). However, the total irrigated area changed little in the survey period. Therefore, the water availability measured by the volume per ha (Figure 5c) shows the same change as that of total volume. Needless to say, water discharge in System A may have decreased for some other reasons such as more rainfall in the 2013 DS or the introduction of new technologies or practices, which a case study type of analysis cannot disentangle. Nevertheless, we can at least claim that the result is not against the water-saving effect of volumetric pricing.



Note: Up (up of NSRP) Down (down of NSRP), NSRP did not agree to practice volumetric pricing.

Figure 7. System C's water discharge, irrigated area, and water discharge per area by location and season.

Field Water Level

This subsection reviews the summary data of field water level measured by a field water tube at sample household's field. For appropriate interpretations, it should be noted that the water level in the field and water discharge are not exactly the same because the former may include supplementary water from sources different from NIA such as natural creeks and private pumps. However, it can still serve as a good proxy of water access at the field level and we can discuss how access changed because of the introduction of volumetric pricing. Different from the measurement of discharge volume, the measurement of field water level is rather simple and accurate. The results are consistent with our field observations and, therefore, we analyze the data from all locations of all study sites.

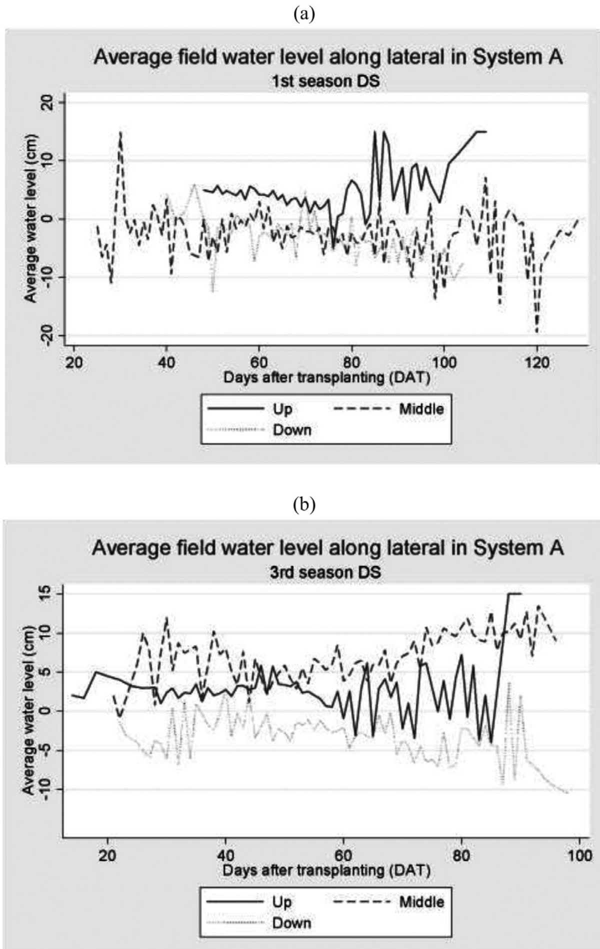


Figure 8. Average field water level along lateral DS in System A.

Figures 8 to 10 show how the average field water level has changed during the cultivation season by location at each study site. Note that the level is the average of the field water tubes installed in the survey parcels. For the sake of comparison, each figure shows two years of the same season. For example, Figure 8 shows the 2012 DS and 2013 DS of System A, where the latter shows water level after the implementation of volumetric pricing. The figures show field water level series over days after transplanting (DAT). As the summary of these figures, Table 3 shows average water level over DAT by location and season. Since the figures are the average of installed tubes, we can conduct a statistical test of mean difference in the same table. To understand the degree of water stress, it is better to note that the study on alternate wetting and drying (AWD) practice revealed that water stress became severe when the level went below 15 cm below ground level.

In System A, data in Figure 8 indicate that throughout the period the upstream enjoys a higher level of water, while the midstream and downstream are lower than the upstream. According to Table 3 in the DS in System A, the average water level is 4.4 cm upstream, −2.7 cm midstream, and −3.0 cm downstream, supporting the advantage of the upstream. After the introduction of volumetric pricing, the upstream reduced the level to 2.4 cm and the midstream increased it to 6.4 cm, and the changes were statistically significant, while the downstream remained at almost the same level (−3.1 cm) with no significant difference

Table 3. *Average Water Level From Ground Level Measured by Field Water Tube Along Lateral by Irrigation System (cm)*

	------------------------ Dry Season ----------------------		
	Upstream	**Midstream**	**Downstream**
System A			
2011-12	4.4	-2.7	-3.0
2012-13	2.4***	6.4***	-3.1
System B			
2011-12	3.2	0.6	-2.1
2012-13	5.1***	3.4***	1.6***

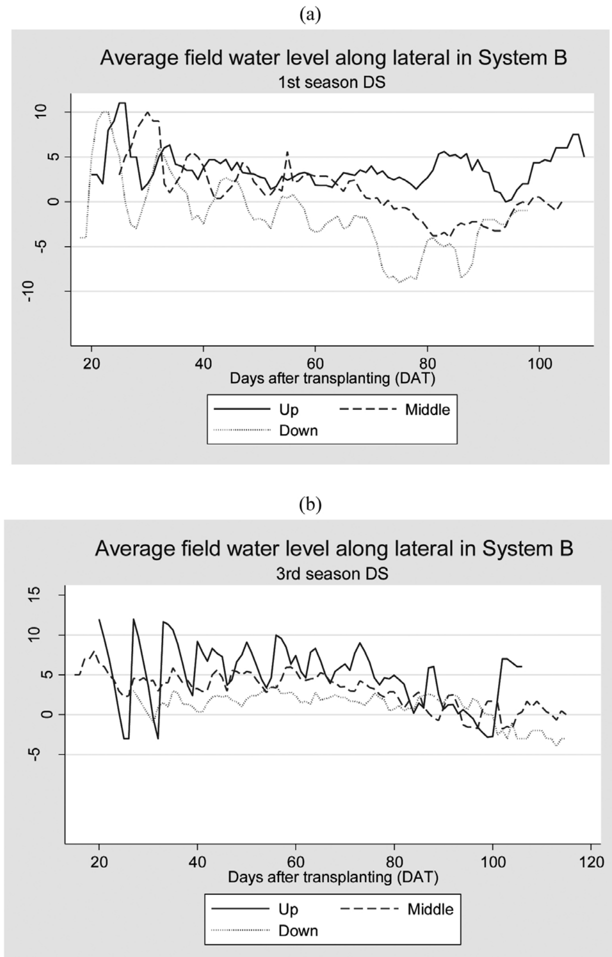


Figure 9. Average field water level along lateral in DS in System B.

at conventional significance levels. We can observe this feature also from Figure 8b: the benefit of water savings by the upstream did not go to the downstream but was captured by the midstream, which showed the highest level throughout the 2013 DS. Note, however, that in any location the water level did not reach lower than 15 cm, indicating that no location suffered severe water stress on average.

System B data in Figure 9 and Table 3 show a similar initial condition to that in System A, that is, the hydrological advantage in upper streams. For System B, the order did not change after the introduction of volumetric pricing. On the other hand, all the locations on average increased water levels, which we can regard as improved water access. Table 3 shows that the improvement in water level is statistically significant. Figure 9 additionally shows that the disadvantage of the downstream, which became more obvious toward the end of the cropping season in the 2012 DS (Figure 9a), disappeared in the 2013 DS (Figure 9b), indicating more equitable water distribution. Similar to System A, no paddy plots suffered severe water shortage (i.e., water level less than 15 cm).

Different from the two sites above, System C did not show an obvious difference between upstream and downstream (Figure 10 and Table 3). Presumably, this is because the length of the study lateral is much shorter in System C than in the other two areas, which results in little difference between upstream and downstream (Table 1). The difference between the 2012 DS and 2013 DS is not obvious either and not statistically significant at any conventional significance levels (Table 3). This result is not surprising because volumetric pricing was not implemented in System C.

Changes in Water Access and Water Management

Irrigators association. The changes in selected IA variables from 2011 (or 2012 DS) to 2012 (or 2013 DS) are summarized in Tables 4 and 5. Among the numbers of variables we collected, we show those which show typical changes.

Table 4 shows the case of System A. The situation of water access at the IA level is captured by the number of complaints, which shows either a decrease or no change. The decrease in Padad IA (midstream) is consistent with the field water level data (Figure 8 and Table 3). An interesting result is the sharp decline in the number of complaints from 10 to 2 in the tail-end IA, Liwliwa, although the water level did not increase at the field level.

The variables from (2) and (3) show the responsibility of the maintenance activities by IA, TSA, and individual farmers. In most of the cases, an IA is involved in the activities. The Rizal IA (upstream IA) does not take care of scheduling and rotation, reflecting that water is so abundant that they do simultaneous irrigation as indicated by variable (6). Since scheduling is the crucial component for efficient water use, there still seems to be room for improvement in water savings in the Rizal IA.

Variables from (4) to (8) explain the activeness of collective management and water tender. In addition to the continuity of simultaneous irrigation in Rizal, a few concerns exist about efficient water use. First, in most of the IAs, the participation rate

Table 4. *Change of Water Access and Water Management by IA in System A*

		System A											
		Rizal IA		Paddad IA		Mazabur3 IA		Mazabur2 IA		Mazabur1 IA		Liwliwa	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Irrigation water access													
1	Number of complaints on water shortage by TSAs	2	1	3	2	2	0	0	0	0	0	10	2
Responsibilities													
2	Rotation scheduling among TSAs	none	no rotation	IA, TSA, Farmer	IA	IA	IA	IA	IA, TSA	IA	IA, TSA	IA	IA
3	Rotation schedule adjustment among TSAs	none	no rotation	IA	IA	IA	IA	TSA	IA, TSA	IA	TSA	IA, TSA	IA, TSA
Collective Management													
4	Average participation rate to IA monthly meeting	83	100	83	50	100	100	88	50	89	100	30	75
5	Average participation rate to IA canal maintenance	95	60	100	79	100	100	100	90	100	60	100	64
6	System of water rotation	Simultaneous	Simultaneous	Up to down	Up to down	simultaneous	simultaneous	down to up	simultaneous	up to down	Simultaneous	up to down	up to down
7	Supervision of water rotation	No		TSA chair	TSA chair	No		IA chairman		TSA chair		water patrol hired by IA	TSA chair
Water Tender													
8	No. of water tender hired by this IA	1	0	1	0	0	0	1	0	0	0	1	0

Table 5. *Change of Water Access and Water Management by IA in System B and System C*

		Sysmte B						System C	
		Aurora		Katipunan 1		Katipunan 2		Northern Solana River Producers	
		2011	2012	2011	2012	2011	2012	2011	2012
Irrigation water access									
1	Number of complaints on water shortage by TSAs	0	0	0	0	3	2	4	3
Responsibilities									
2	Rotation scheduling among TSAs	IA	no rotation	NIA, IA	NIA, IA	IA	IA	NIA	NIA
3	Rotation schedule adjustment among TSAs	IA	no rotation	NIA, IA	NIA, IA	TSA	IA, TSA	NIA, IA	NIA
Collective Management									
4	Average participation rate to IA monthly meeting	54	95	82	85	75	53	77	61
5	Average participation rate to IA canal maintenance	83	74	79	86	89	60	100	79
6	System of water rotation	down to up	simultaneous	up to dowb	simultaneous	up to down	down to up	up to down	up to down
7	Supervision of water rotation	water tender		IA officials		TSA chair	IA officials	NIA staff	water tender hired by NIA
Water Tender									
8	No. of water tender hired by this IA	0	0	0	0	0	0	0	0

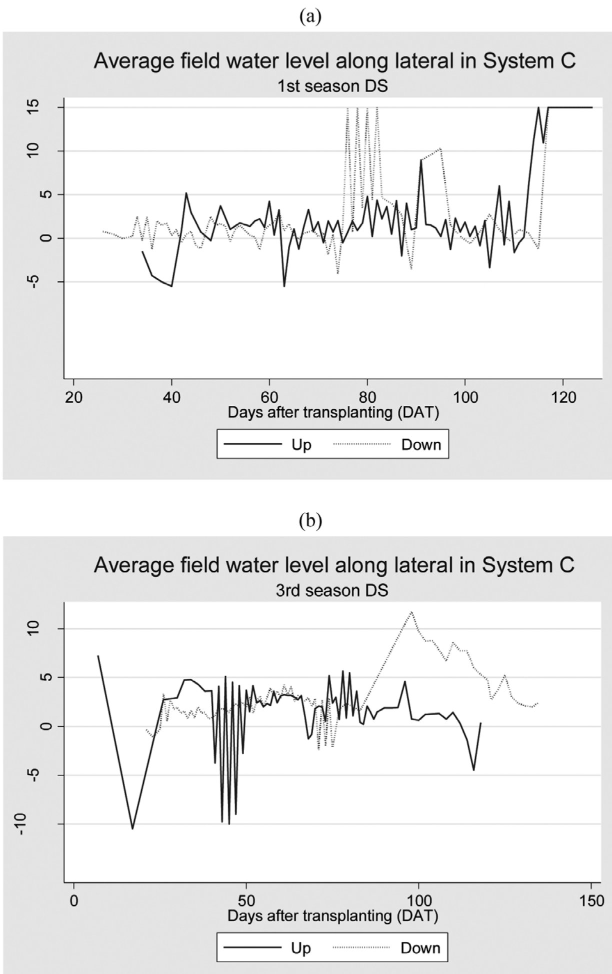


Figure 10. Average field water level along lateral in DS in System C.

for IA activities declined. Second, in some IAs, the water schedule changed to a simultaneous one and accordingly the supervisor of rotation disappeared from these IAs.

Now we turn to System B (Table 5). The tail-end IA (Katipunan 2) experienced water shortage in both years, but the number of complaints went down from three to two. This is consistent with the improvement in water access downstream, indicated by the field water level data (Table 3). However, the possible downside of improved water access is observed in System B. The participation rate for IA management declined in most of the cases, and, in Aurora and Katipunan 1, the water rotation became simultaneous without a supervisor.

In System C (Table 5), little change is observed. This is consistent with the little change in water discharge or in field water level.

In summary, we observed a reduced number of complaints after the introduction of volumetric pricing. This is consistent with the improved water access in the lower portions of the lateral as we observed in the summary of field water level data. There seems to be room for further improvement for more efficient water use (i.e., scheduled water rotation and strict supervision).

TSA. Tables 6 to 9 present characteristics of the TSAs by their location (upstream, midstream, and downstream) along the laterals of each study site. See Table 2 for the distribution of TSAs along the lateral.

Table 6 summarizes the membership and collective management activities. The membership structure of TSAs is rather simple. The average member sizes are similar within the lateral and it becomes larger gradually from System A to System B, and then to System C (variable (1)). The member size changed little from 2011 to 2012.[2]

The activeness of collective management in terms of participation rate (variable (2)) and the number of activities (variable (3)) show no dramatic change between two dry seasons. Regarding management activities during the season (variables (4)−(7)), the use of a penalty rule and monitoring are not so popular in any TSA. We expected an evolution in such rules and activities after the introduction of volumetric pricing, but the figures seem to not support this hypothesis. Likewise, contrary to our expectation, the coordination of rice cultivation practices (variables (8)−(11)) looks to be declining overall. Drastic institutional changes did not occur.

Table 7 shows the change in infrastructure condition. Among overflow, illegal turnouts, and insufficient water (variables (1)−(3)), a noticeable reduction trend is found in the second variable in System B, where illegal turnouts disappeared completely in all locations. We might interpret this as a change toward stricter TSA management.

Table 8 summarizes changes in water rotation schedule adopted by TSAs and in the number of water tenders in TSAs. Regarding water rotation, locations with relatively sufficient water (upstream and midstream) use no rotation rule and, thus, irrigate simultaneously among TSA members (variable (3)). Thus, it still holds that simultaneous irrigation is likely to be observed in relatively water-sufficient places. Again, the implementation of scheduled water rotation

Table 6. *Changes of TSA Membership and Collective Management by Location and Site*

		System A						System B						System C			
		up		middle		down		up		middle		down		up		down	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
1	Registered member	18	17	16	18	15	15	23	19	22	23	36	39	41	41	58	58
2	Average attendance rate (number attended/total supposed to attend)	83	64	76	78	66	72	90	96	64	73	100	86	no meetings	76	50	55
3	Number of collective canal maintenance activities	2	2	2	3	1	2	2	5	2	3	2	3	4	4	2	5
4	Proportion of TSAs having penalty rule against meeting absence	20	7	34	17	18	0	57	55	42	9	20	20	0	67	0	0
5	Proportion of TSAs having penalty rule against voluntary work absence	47	13	63	57	12	0	57	100	75	91	40	100	0	33	0	0
6	Proportion of TSAs having penalty rule against water stealing	13		9	7	0	0	14	0	17	9	20	0	0	0	0	0
7	No. of participants to monitoring	3	8	6	5	6	6	11	2	16	6	7	3	3	1	10	1
8	Proportion of TSA coordinating varietal selection	67	67	22	27	35	35	43	67	25	0	60	55	50	73	50	40
9	Proportion of TSA synclonize transplanting	80	80	38	53	53	41	57	0	33	0	80	100		91	50	80
10	Proportion of TSA coordinating bund maintenance/weeding	13	7	13	13	6	0	0	0	8	0	20	0	0	0	0	0
11	Proportion of TSA coordinating use of carabao/tractor	7	7	9	3	6	0	0	0	12	0	40	0	0	0	0	0
12	Sample size	15	15	32	30	17	17	7	11	12	11	5	5	3	3	2	2

Table 7. *Change of TSA Infrastructure Condition*

		System A						System B						System C			
		up		middle		down		up		middle		down		up		down	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
1	From how many TSAs this TSA receive overflow water	1	0	1	1	0	0	1	0	2	0	3	0	1	0	6	0
2	No. of illegal turnouts	2	5	1	0	2	2	2	0	2	0	1	0	1	0	0	0
3	Proportion not able to get suficient water	1	1	6	7	2	16	2	0	4	21	39	31	7	0	10	5
4	Sample size	15	15	32	30	17	17	7	11	12	11	5	5	3	3	2	2

Table 8. *Change of Water Rotation and Appointment of Water Tender*

		System A						System B						System C			
		up		middle		down		up		middle		down		up		down	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
1	No. of TSA rotating water down to up	0	0	2	1	0	0	0	0	0	1	1	3	0	0	0	0
2	No. of TSA rotating water up to down	1	3	17	18	14	9	0	0	2	0	2	1	2	1	2	0
3	No. of TSA rotating water simultaneously	14	12	12	11	3	8	7	11	11	10	1	1	1	2	0	2
4	No of water tender	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Sample size	15	15	32	30	17	17	7	11	12	11	5	5	3	3	2	2

Table 9. *Change of Yield, Cultivated Area and Rice Variety*

	System A						System B						System C			
	up		middle		down		up		middle		down		up		down	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Yield (t/ha) mean	5.7	6.0	6.1	6.5	6.2	5.8	4.4	5.1	3.7	5.7	3.9	4.5	7.5	2.8	7.3	4.8
st dev	1.0	1.7	1.7	1.5	1.7	1.7	1.5	1.1	1.3	0.9	0.6	1.9	3.8	1.4	3.3	1.6
Average area of record-keeping pacel (ha)	2.7	2.6	2.1	2.2	1.5	1.5	0.9	0.9	0.8	0.8	1.0	1.0	1.2	1.3	1.1	1.1
Name of most popular variety	Dinorado	Dinorado	NSIC Rc222	Dinorado & Diamond X	NSIC Rc222	Diamond X	NSIC Rc132H (SL8)	TH2 & NSIC Rc222	NSIC Rc122 (Angelica)	NSIC Rc122 (Angelica)	NSIC Rc222	NSIC Rc128	NSIC Rc132H (SL8)	NSIC Rc132H (SL8)	no particular variety	NSIC Rc124H
Proportaion of users (%)	27	58	14	27	33	23	21	67	60	40	30	33	50	50		60
Sample size	11	12	27	30	18	18	11	15	12	5	5	9	9	8	5	5

Table 10. *Change of Irrigation Frequency, Soil Condition, Water Depth, Duration, and Reliance on Other Irrigation Source*

	System A						System B						System C			
	up		middle		down		up		middle		down		up		down	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Frequency of irrigation	14	17	17	17	19	11	28	20	14	10	22	12	38	17	28	18
Frequency of dry soil	3	0	4	2	4	0	3	0	1	0	3	0	2	0	1	0
Frequency of wet soil	8	14	12	14	8	9	14	13	5	8	4	10	11	14	24	13
Frequency of standing water	10	4	7	4	11	4	17	11	9	2	2	3	25	3	15	7
Cummulative depth of water (cm)	93	106	82	83	111	62	125	89	80	61	120	54	215	130	223	122
Total duration of irrigation (hrs)	163	202	329	193	349	98	472	191	159	64	533	76	602	106	401	84
Duration of pump irrigation (hrs)	0.0	61.0	13.0	3.00	1.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	68.0	44.0	38.0
Nomber of pumps owned (in 2011)	1.6		1.2		1.5		0.0		1.0		1.0		1.0		1.0	
Sample size	11	12	27	30	18	18	11	15	12	5	5	9	9	8	5	5

Table 11. *Change of Labor and Monetary Contribution to Irrigation Management Activities*

	System A						System B						System C			
	up		middle		down		up		middle		down		up		down	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Labor contribution to MC cleaning (hours)	2.0	0.0	3.9		4.8	0.0	4.0	5.1	8.0	4.0	8.0	4.0	.		.	
Labor contribution to lateral canal cleaning (hours)	1.0	4.5	4.9	5.5	4.3	3.9	3.4	4.8	5.6	4.0	7.0	4.4	0.0	3.8	12.0	4.0
Labor contribution to MFD cleaning (hours)	2.9	3.1	2.8	4.2	3.8	3.6	1.8	2.8	4.1	4.0	5.5	4.1	4.0	3.8	4.0	4.0
Labor contribution to TSA meeting (hours)	1.9	2.4	2.5	2.5	2.4	3.0	3.5	3.3	2.3	3.3	4.0	3.8	2.8	4.0	.	4.0
Labor contribution to IA meeting (hours)	2.9	3.5	3.1	2.3	2.5	3.6	4.0	2.3	3.1	4.0	4.0	4.0	1.0		2.0	
Labor contribution to irrigation monitoring (hours)	0.0	8.0	2.0	1.8	2.5	5.3	.	.	.	.	.	.	.	.	.	.
Sum of labor contribution (hours)	10.7	21.5	19.2	16.3	20.4	19.3	16.7	18.4	23.1	19.3	28.5	20.4	7.8	11.7	18.0	12.0
Sample size	11	12	27	30	18	18	11	15	12	5	5	9	9	8	5	5

seems to be a key element that needs to be implemented for water savings in our study area.

In Table 8, we find no TSA that appointed a water tender in any year (variable (4)). Existing empirical studies stress the importance of water tenders not only for more efficient water rotation but also for leadership for maintenance activities. An introduction of volumetric pricing is expected to increase the necessity of such activities and to induce the appointment of a water tender. However, this did not happen at our study site (at least in one year).

Farm household. Tables 9 to 11 show the change in household-level variables from 2011 to 2012. Table 9 presents the change in yield and major rice varieties. To capture the variation in yield, we report also the standard deviation. In System A, while upstream and midstream users experienced an increased yield (from 5.7 to 6.0 t/ha upstream and from 6.1 to 6.5 t/ha in midstream), downstream users suffered a yield reduction from 6.2 to 5.8 t/ha. Overall, however, the change from 2011 to 2012 as well as the difference among locations are small in System A. This indicates that, although water access is different along the lateral, it does not negatively affect productivity.

In System B, we observed a yield increase in all locations (from 4.4 to 5.1 t/ha upstream, from 3.7 to 5.7 t/ha midstream, and from 3.9 to 4.5 t/ha downstream). This is consistent with the improvement in field water level in all locations in System B (Table 3). Note, however, that the standard deviation of yield increased dramatically downstream. One possible reason is that the improvement in water access may not be equal among downstream farmers.

Surprisingly, in System C, yield suffered a big reduction in 2012 (from 7.5 to 2.8 t/ha upstream and from 7.3 to 4.8 t/ha downstream), regardless of similar water access in two years. Some other yield reduction effects must have occurred.

Table 10 presents the change in frequency of irrigation, soil condition, cumulative water depth, and the duration of irrigation. Although cumulative depth and duration changed dramatically in a nonsystematic manner between two years, a common feature is that the number of dry soil conditions decreased in all locations, indicating that they circumvented possible water stress. This is consistent with our field water level data showing no case in which the water level became less than a minus 15-cm threshold.

In System A, farmers used pumps for supplementary irrigation. In 2011, only midstream and downstream users used pumps. In 2012, however, upstream users started using pumps and midstream users reduced their use, reflecting increased water access midstream. Our concern was that lower streams assured water access with a higher cost for pump irrigation. However, this concern did not hold in our cases at least in System A.

Table11 shows the change in labor contribution to irrigation management activities. Two features are observed there. First, in the baseline year, downstream farmers used more labor for cleaning, meeting, and monitoring (except for the monetary contribution in System C). Second, such a difference along the lateral almost disappeared in 2012 as the figures in upstream cases increased while those in midstream and downstream cases decreased. In particular, a notable change was the increase in labor contribution to monitoring in upstream System A. In an earlier section, we observed no drastic institutional change in water management. However, some minor changes seemed to have occurred toward stricter water management.

Discussion and Concluding Remarks

First of all, three limitations of this study are explained so that we can avoid misunderstanding our remarks. First, the project took a case study approach, using three laterals as the cases. Furthermore, System C declined the introduction of volumetric pricing, leaving only two cases, namely, System A and System B. Therefore, we must refrain from generalizing the findings. Rather, we should take this project as a pilot study from which the lessons will be used for designing a full-scale and longer-term survey in the future.

Second, the survey period covers only two years (or four cropping seasons) and the comparison is made between the 2012 DS and 2013 DS as before and after the introduction of volumetric pricing. Hence, this project captures only a short-run impact. Changes in irrigation activities require institutional changes, which require a rather longer time to take place. Moreover, changes require trial and error until the farmers finally find the appropriate style of irrigation management and cultivation that fits the volumetric pricing system. Therefore, we should interpret the results as short-run reactions (possibly including erratic reactions), rather than long-run impacts.

Third, regarding the impact of volumetric pricing, the change from the 2012 DS to 2013 DS might be attributed to some other factors that commonly occurred in the period at our study sites. We need a careful interpretation of the results. This is another limitation of the case study approach. Hence, again, we would rather take this as a pilot study for future projects.

With these aforementioned remarks in mind, we summarize the lessons as follows. The outcomes from the two cases (System A and System B) are not against the expected benefit of volumetric pricing: (1) reduced discharge in System A, (2) equitable water distribution at the field level in System A and System B, (3) and minor management changes for stricter water management in System A and System B.

Although these positive impacts could be expected, we also realized the tremendous practical difficulty in the implementation of the volumetric pricing system, in particular, the measurement of water volume. It is still possible to measure the volume at the headgate when the headgate has a firm structure (e.g., Replogle flume with concrete lining). However, along the canal, because of the uncontrollability of additional water inflow and the unstable water flow on the earthen canal, an accurate measurement below the headgate is very difficult, unless an extensive canal modernization is implemented. Examples include concrete lining and upgrading of water intake for water control and measurement.

Given these situations, we can consider two approaches for the implementation of volumetric pricing. The first one may be to measure the volume only at the headgate of a lateral with a firm measurement structure and charge the fee to the group of farmers who use the lateral. In this case, NIA will serve as a wholesaler of irrigation water to the large group of farmers and let the group decide how to divide the fee among the member farmers. This case works only when the large group of members can coordinate each other and conduct strict water distribution management.

If such coordination is impossible under current socio-economic environment, a second feasible approach may be to install more sophisticated irrigation infrastructure, so that volume measurement and water control become possible to a much smaller size of the group or ultimately to each individual farmers.

The first approach requires more management labor effort and more social capital among them, while the second one requires relatively more physical capital investment. An appropriate approach lies in between these two, depending on the relative scarcity of labor, social capital, and physical capital. One important lesson from our case study is that we have to take into account this point when we try to introduce the volumetric pricing system in the areas of different socio-economic conditions.

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Notes

1 Field water tubes were installed in the sample farmers' fields 30 days after transplanting to measure the level of water applied by the farmers throughout the season. Readings were taken every other day.

2 Nonregistered members do not exist and most of the members belong to only one TSA except for midstream and downstream in System B.

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