Farm-Level Water Management for Rice-Based Farming Systems in the Philippines

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INTRODUCTION

IRRIGATION SYSTEMS IN the Philippines and many other Asian countries have been developed essentially for rice-rice cropping systems. The scarcity of water supply in the dry season (DS) has, however, consistently caused low cropping intensities (average 126 percent) in most Philippine national irrigation systems (Rosegrant et al. 1987). The areas at the tail-end sections of most irrigation systems are predominantly deprived of DS crops because of scarcity in water supply. Furthermore, the riceland productivity under the rice-rice cropping is showing signs of either decline or stagnation. However, about 50-75 percent of irrigated ricelands in Asia are physically suited for growing nonrice crops (Ko 1987). In the Philippines, about 20 percent of the total irrigable areas of the National Irrigation Systems are suitable for diversified cropping (Vergel 1987).

In recent years, there has been increasing concern on how the low levels of land utilization, cropping intensity, income from rice production and irrigation system performance could be improved, and how the favorable soil conditions could be fully utilized for sustaining productivity. Among the alternative approaches considered by irrigation authorities and planners are crop diversification, system rehabilitation, augmentation of the scarce water supply, efficient use of residual soil moisture after rice for growing nonrice crops, and improved water control and management. However, information on the requirements for farm-level water control and management, water augmentation and the use of residual soil moisture after rice for growing nonrice crops in the DS in typical irrigation systems is still inadequate.

This paper describes under four major issues the studies undertaken under the IIMI-IRRI project to evaluate alternative approaches for improving the productivity of land and scarce water supply and thus increase and sustain farmer's income in irrigated rice systems.

COMPONENT ON FARM-LEVEL WATER MANAGEMENT STUDIES

Compatibility and Adequacy of the Farm-Level Water Control Facilities in a Rice Irrigation System for Nonrice Crops

The existing irrigation infrastructures in rice irrigation systems has been reported as a major constraint to crop diversification (Miranda and Panabokke 1987). For this reason, some authors have indicated the need for rehabilitating or upgrading the irrigation hardware to introduce the flexibility needed to allow large-scale crop diversification within the system. But this requires a knowledge of how the canal network should be designed or modified to enable better control of the system and how the water should be managed and applied (Bhuiyan 1989).

During the 1988 to 1990 DS a study was undertaken to determine the needs for farm-level water control and management that would allow flexibility for farmers to exercise DS cropping options between rice and nonrice crops in areas served by typical irrigation systems.

The study was conducted in the Upper Talavera River Irrigation System (UTRIS) in Nueva Ecija during the 1988 and 1989 DS and in the San Fabian River Irrigation System (SFRIS) in Pangasinan during the 1990 DS to further evaluate the findings from UTRIS and its practical applicability for other nonrice crops not found in UTRIS (Figure 1). The selected systems have different soil classes, distinct wet and dry rainfall patterns and have diversified cropping.

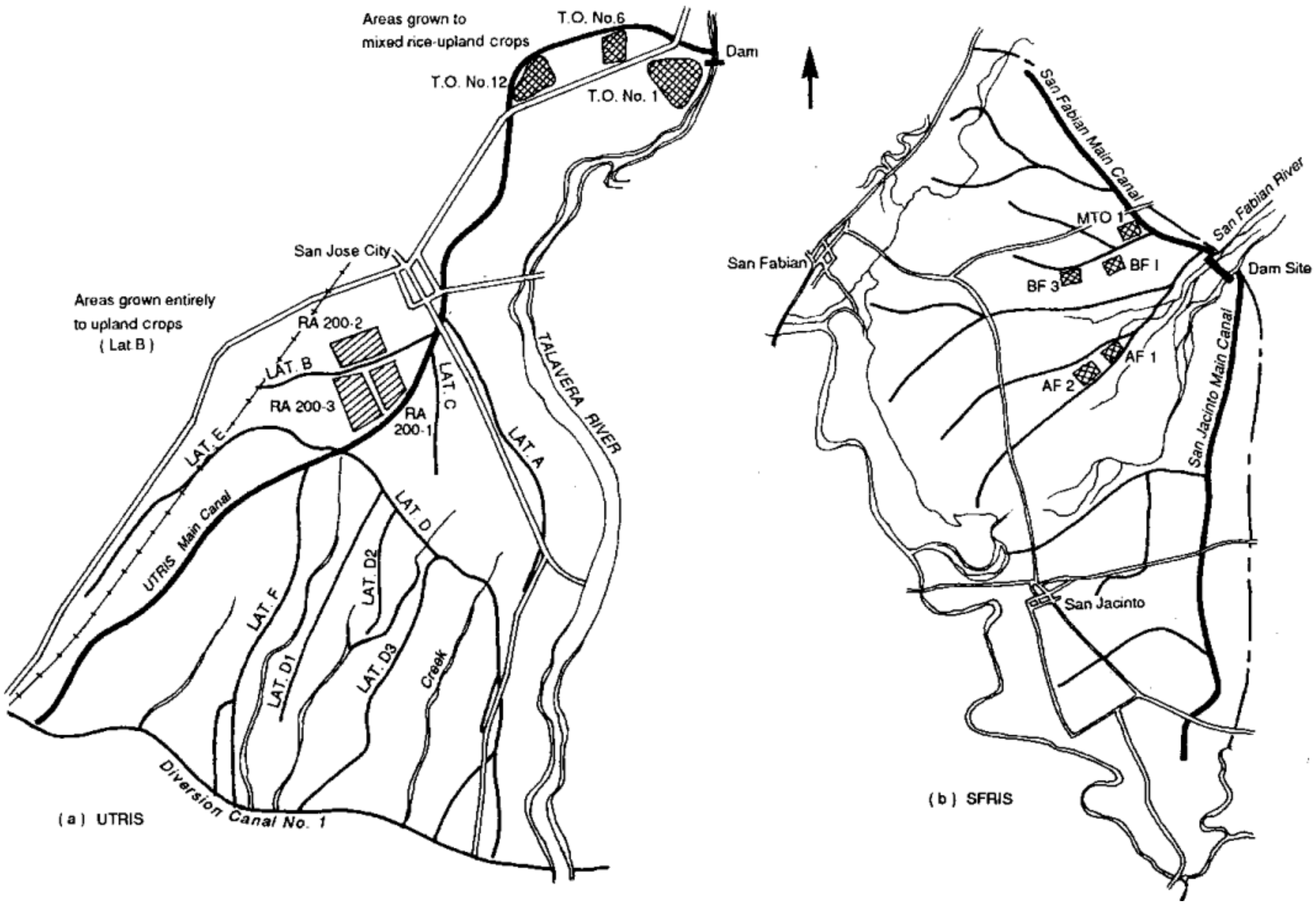
During the DS, when water supply is generally low, only 20-25 percent and about 60 percent of the potential imgable areas of UTRIS and SFRIS, respectively, are grown to rice and nonrice crops. The major DS crops are rice and onion in UTRIS, and rice and tobacco in SFRIS. Soil in the top 45-cm depth in each system is clay loam.

Six turnout service areas (TSAs) were selected in UTRIS, and 5 TSAs were selected within SFRIS (Figure 1). Field data, collected at turnout and farm levels, included irrigation water flows, farm-level water control facilities, irrigation schedule, water allocation and distribution methods, soil water status, water conservation practices, crops and water use. The study revealed that additional water control facilities were constructed and maintained by the farmers on both individual farms and the TSA of both irrigation systems to support diversified cropping in the DS.

Farm-level facilities. Additional on-farm infrastructures were constructed by farmers during the DS, but the intensity varied between the two systems which grew two different nonrice crops. In UTRIS, the farmers divided and reshaped their original rice plots which are larger than 500 m^2 into two or more subplots to grow onion. In contrast, the SFRIS farmers (n=20), who grew tobacco after rice, maintained the original size and shape of the rice plots.

The average size of the onion plots in UTRIS ranged from 676 to 1,018 m^2, with an average of 850 m^2 (Table 1). However, only about 80 percent of the plot area is effectively used for growing onion and the remainder *is* used as buffer and for the construction of multipurpose ditches along the perimeter of each plot or subplot. These multipurpose ditches are used (i) to intercept seepage from adjacent rice or onion plots, and (ii) to facilitate irrigation water application and the removal of excess water. In SFRIS, the entire plot area (average = 880 m’) is generally utilized for growing tobacco. The difference in the farm-level facilities used in onion and tobacco plots could be attributed to the sensitivity of onion to waterlogging, particularly during the bulb formation period when surface water must not submerge the neck of the bulb or dumping off may occur.

Figure 1. General layout of the Upper Talavera River Irrigation System (UTRIS) in Nueva Ecija, the San Fabian Irrigation System (SFRIS) in Pangasinan showing the relative location of the study sites.



(a) UTRIS

(b) SFRIS

Table 1. Average plot size (m^2), net area planted to rice and upland (onion or tobacco) crops, and percent area used for on-farm water control in selected farms in UTRIS, Nueva Ecija and SFRIS, Pangasinan, 1988, 1989, and 1990 DS.

Particulars	Rice	U IS		SFRIS
		Mulched onion	Unmulched onion	Unmulched tobacco
Plot area, m^2	1006	1018	676	879
Net cropped area				
· m^2	1006	834	549	879
. percent	100	82	81	100
Percent area used for water control	0	18	19	0

TSA-level facilities. Additional and temporary farm ditches and supplementary farm ditches are used by the farmers in conveying water from the supply (main or lateral) canal and the main farm ditch to their farms in the DS. The average farm ditch density (FDD) used during the WS for rice within UTRIS is about 70 m/ha (Table 2). In the DS, the average FDD in irrigating nonrice crops is 225 m/ha which is about 3.7 times more than the FDD in the WS. In SFRIS, only about 30 percent more farm ditches are used during the DS than during the WS when only rice is grown. The increase in FDD in the DS in both irrigation systems is caused by the construction of temporary farm ditches, which are removed together with the multipurpose ditches, during the WS and the area released is planted to rice. In general, only the main farm ditch is maintained during the WS to irrigate rice. The land area used for the construction of temporary farm ditches is 315 m^2/ha in UTRIS, but only 60 m^2/ha in SFRIS. The difference between the onion and tobacco plots is due to the different water application methods used for these crops.

It can thus be inferred that the main farm ditch and the essential water control structures such as turnouts with gates, division boxes and check drops (where necessary) which are maintained for WS rice are compatible and could adequately support the basic requirements of diversified cropping in the DS. Additional supplementary farm ditches required only for areas with topographic limitations must also be constructed. Farm ditches and other water control facilities needed for growing nonrice crops will vary, depending on the crop choice and these can be adequately handled by the farmers.

Table 2. Average potential irrigable area and density of farm-level facilities of selected TSA in UTRIS, Nueva Ecija, and SFRIS, Pangasinan, the Philippines, the WS rice and DS nonrice cropping.

Particulars	UTRIS	SFRIS
Potential irrigable area, ha	48	9
Farm ditch density, m/ha		
· WS	70	124
· DS	255	159
. Ratio, DS:WS	3.7	1.3
Area used for the construction of temporary farm ditches, m^2	316	60

Water Management Practices to Provide Flexibility of Farmers' Crop Choice, and to Improve the Water Use Efficiency and Land Productivity.

Potential nonrice crops are not readily accepted during the DS because of deficiencies in managing irrigation systems (Miranda and Panabokke 1987). Water deliveries as required by intermittent water application for nonrice crops are rarely precise or reliable, particularly during the DS. Hence, to promote crop diversification, appropriate techniques of farm-level water management must be developed to promote reliable water deliveries.

Data were evaluated to ascertain the current water management practices and develop a model of improved water scheduling and distribution within the turnout service area of an irrigation canal which would promote higher water use efficiency and provide farmers the flexibility of crop choice in the DS.

Water delivery and distribution. Water deliveries to the different TSAs varied between and within the two irrigation systems. In UTRIS, daily water deliveries were made to the different TSAs from January to April during the 1989 DS at an average flow of 2.8 lps/ha for about 6 days a week (Table 3). In SFRIS, the average water deliveries to the different TSAs was 3.7 lps/ha for an average duration of 5 days/week. From February to April 1990, when water supply was low, high water flows (average 6.9 lps/ha) were delivered at least one day a week for a duration of 4-19 hours during the farmers' irrigation schedule.

Table 3. Average flow rates and duration of water deliveries to the different TSAs from January *to April, UTRIS, Nueva Ecija and SFRIS, Pangasinan,* Philippines, *1989 and 1990 DS.*

Particulars	UTRIS	SFRIS
Average potential irrigable area, ha	36.0	9.3
Average flow rates		
, lps	101.0	34.3
. lps/ha	2.8	3.7
Duration of seasonal water deliveries		
. no. of weeks	17.0	16.0
. no. of days/week	6.4	4.9

In UTRIS, water was issued in rotational sequence among farmers from the upstream to the downstream areas of the main farm ditch. In SFRIS, the farmers within a TSA were generally divided into two groups and each group was given a schedule to irrigate every week. If a farmer failed to irrigate his farm during the scheduled day(s), he was allowed to irrigate the following day. The rotational schedule was more systematically and rigorously practiced in SFRIS than in UTRIS.

Water application and conservation. "Flush flooding" was practiced by both the onion and the tobacco farmers. The onion farmers in UTRIS applied irrigation water *plot-by-plot* in alternate sequence using the temporary farm ditch constructed for the purpose. In contrast, tobacco farmers in SFRIS applied water *plot-to-plot*. Farmers from both systems reported that they could manage excess water problems, if created.

Mulching with about 10-15 cm thick rice straw is the most common method of conserving water for onion. It was especially practiced by farmers in areas where water supply was scarce. Farmers' reasons for mulching onion plots are (i) to conserve water and thus allow a longer interval between irrigations, (ii) to control weed growth, and (iii) to produce shiny bulbs and create higher market value. Tobacco farmers in SFRIS, and onion farmers of UTRIS whose farms were near the source of irrigation, did not use mulch.

Water use, application and delivery efficiency. Farms in which mulching was practiced used about 50 percent less water than those where it was not practiced (Table 4). The amount of water used for rice was about 877 mm which is almost the same as that used for unmulched onion. Tobacco crops in SFRIS used an average of about 700 mm of water.

The average water application efficiency, defined as the ratio of the net water applied to the plot to the total water delivered to the plot, was 89 percent for the onion plots of UTRIS in 1988 and 1989 DS. (Net water applied is the difference between the amounts of water applied to and drained from the plot). The average highest attained water storage efficiency, defined as the ratio of the amount of water stored in the soil after irrigation to the net water applied to the plot was about 54 percent. Mulched plots, however, had a slightly higher water application efficiency (average 90 percent) than the unmulched plots (88 percent) (Table 4). In SFRIS where tobacco plots were not drained, the water application efficiency was close to 100 percent.

The effectiveness of the water delivery mechanism within the different TSAs was evaluated in terms of the irrigation delivery efficiency (IDE) defined as the ratio of the total irrigation water delivered to the plots to the total water diverted from the turnout.

Table 4. Average water use of rice, onion and tobacco, UTRIS, Nueva Ecija and SFRIS, Pangasinan. 1988, 1989, 1990 DS.

Particulars	Rice	UTRIS		SFRIS
		Jnmulched onion	Mulched onion	Unmulchec tobacco
Total water applied, mm	175	855	433	610
Total water drained, mm		103	48	0
Net water applied, mm	775	752	385	610
Effective rainfall, mm	102	83	56	82
Total water use, mm	877	834	442	692
Interval of irrigation, days	7	8	16	15
Rate of water application, lps	10	17	16	31
No. of irrigations	12	9	4	6
Average depth per water application, mm	62	95	101	102
Average duration of water application, minutes	106	55	86	43
Water application efficiency (%)	77	88	90	100
Seasonal irrigation period, days		78	63	71

The average irrigation delivery efficiency (IDE) at UTRIS was about 30 percent whereas at SFRIS it was about 70 percent (Table 5). The low IDE in UTRIS could be attributed to the continuous water deliveries made to the farm ditches in most head-end sites compared to the rotational deliveries in SFRIS.

Table 5. Average seasonal water delivered, water diverted and irrigation delivery efficiency at the TSA level, UTRIS, Nueva Ecija and SFRIS, Pangasinan, Philippines, 1989 and 1990 DS.

Particulars	UTRIS	SFRIS
Average water delivered, mm	497	610
Average water diverted, mm	1323	863
Irrigation delivery efficiency (%)	38	70

The regression model is significant at 1-percent level and it explained about 90 percent of the variations in plot area irrigated (Table 6). This model was then integrated into a water scheduling and distribution model (WASDMOD) which was developed to estimate the water diversion requirement at the turnout, the area that can be imgated per day, and irrigation delivery efficiency for upland crops, with a continuous or rotational water delivery within the main system. Rainfall during the DS was considered negligible.

The input variables for WASDMOD are selected soil parameters (field capacity, wilting point, bulk density, depth of root zone), TSA size, rate and duration of irrigation water application per plot, pan evaporation, duration of irrigation water delivery to the TSA, allowable soil water depletion, methods of water delivery, soil water conservation methods, seasonal irrigation period, and water application, storage and conveyance efficiencies.

Table 6. Estimated coefficients of the function[1] relating area of plot irrigated (Ar) to water flow (Qu), duration of irrigation (Du), irrigation interval (Ii), and dummy variable for mulched onion and unmulcked onion and tobacco plots (Dm), UTRIS, Nueva Ecija and SFRIS, Pangasinan, 1988, 1989 and 1990 DS.

Variables	Pooled regression	Standard
Constant	-180	
Qu (lps)	28.3**[2]	0.9
Du (min)	5.9**	0.2
Ii (days)	-2.9**	0.8
Dm	+8.4**	23.8
R-squared	0.9	
F-ratio	407.4**	
No. of observations	194.0	

Ap = f(Qu, Du, Ii, Dm); Dm = 1 for mulched; o for unmulched

[2] Coefficients with two asterisks (**) are significant at 0.01 level

WASDMOD was evaluated by substituting the average values of the above-mentioned parameters to one TSA (area = 53 ha) at the head-end section of UTRIS. The results are shown in Table 7. To increase the irrigation delivery efficiency from its low value of 29 percent to at least 75 percent, the following alternative options are given by the model

1. A continuous or 24-hour water delivery to the turnout at 164 lps for 3.5 days a week. This option could be adopted if water allocation in the main system is by section-wise rotation.

2. Water delivery of 155 lps for 10 hours per day. This could be employed for a continuous supply situation in the main system. The water saved by this method could be delivered to the downstream section of the system for night storage and/or use by other farmers.

3. A continuous water delivery of 65 lps each day. Although this option could increase the irrigation delivery efficiency, the low flow rate may not be practical and acceptable to the farmers because it will not be sufficient for their requirements.

Table 7. ***Current practice and corresponding alternative options of water delivery to the TSA to increase irrigation delivery efficiency for diversified crops.***

Parameters	Current	Alternative Options		
	0	1	2	3
Duration of water delivery				
(hours)	**24.0**	**24.0**	**10.0**	**24.0**
(days/week)	**7**	**3.5**	**7**	**7**
Water delivery rate (Ips)	**169**	**164**	**155**	**65**
Turnout area, ha	**58**	**53**	**53**	**53**
Seasonal water delivered, m	**6834**	**684**	**684**	**684**
Seasonal water diverted, m	**2366**	**912**	**922**	**912**
Irrigation delivery efficiency, percent	**29.0**	**75.0**	**75.0**	**75.0**
Irrigation interval, days	**9**	**9**	**9**	***9***
Area irrigated per day, ha	**16**	**15**	**6**	**6**
Remarks	ontinuous ater deli- :ry at gh flow ites	.otational rater deli- ery at igh flow ıte for .5 days	)-hour ıily water :livery at gh **flow** ıte	:ontinuous rater deli- ery at low ow rate

Note: The average values used in the **WASDMOD** are as follows:

FC=23.75 percent, **PWP** = 9.66 percent, Drz = 30.00 cm, **BD** = **1.46 gm/cc**
Epan = 6.80 mm/day, **Qu** = **17.2** Ips, Turnout area = **53.3** ha, **Du** = **55.20** minutes
Es = 50.0 percent, Ea = **RR.2** percent and Ec = **75.0** percent for unmulched plots.

Option (1) is superior to the others; it can irrigate almost the same area of 15 ha, as currently irrigated by the farmers, but with **a** 2.5-fold increase in irrigation delivery efficiency.

The foregoing results showed that:

The water application efficiency in each system is generally **high** (about 90 percent and above). However, the irrigation delivery efficiency is lower in UTRIS (38 percent) than in **SFRIS** (70 percent), because of the continuous delivery to farm ditches in most upstream sites in the former. In contrast, SFRIS deliveries were on intermittent schedules dictated by the rotational supply of water in the main system.

Based on the WASDMOD evaluation, the low irrigation delivery efficiency in UTRIS could be improved to at least 75 percent by reducing either the number of hours of water delivery to the turnout per day or the number of days of delivery in a week.

Control of Shallow Water Table in Irrigated Ricelands for Diversified Cropping

One of the physical constraints on the production of nonrice crops in irrigated riceland is the shallow water table that is created by seepage from canals, and/or adjacent flooded rice farms. However, if this could be effectively regulated, the shallow water table can be used for meeting part or all of the crop water requirement.

A field experiment was conducted at the Lower Talavera River Irrigation System (LTRIS) to address the problems encountered by the farmers in growing upland crops adjacent to irrigation canals or rice areas. The objective was to design and evaluate practical techniques of controlling shallow water table on farms adjacent to flooded irrigated rice for growing nonrice crops and determine the relative costs of and returns from the use of the techniques.

An **RCB** design with five water table control treatments, each with **four** replications was used in the field experiment in which corn was grown. The five treatments consisted of four (T1 to T4) different levels of drainage-cum-interceptor channels established strategically in relation to the source of excess water and one (T5) without a channel serving as a control.

The channels had nearly rectangular cross-sections and each was about **30** cm wide which drained to a main drain. Each treatment was applied on an area of 200 m^2 (10 m x 20 m) and was surrounded on two sides by irrigated rice plots. The field had a slope of about 0.24 percent perpendicularly away from the canal bank and along the length of the experimental plots. Soil was silty clay loam.

Hybrid yellow corn, variety **SMC** 305, was seeded at 20 cm x **70** cm. Fertilizer was applied to all plots at the rate of 160-40-40 kg NPK/ha. Other cultural practices were the same for all treatments.

The regression analysis showed that corn grain yield increased significantly with increasing water table depth (Figure 2). High yields were found at the middle of the plot and decreasing towards the drainage-cum-interceptor. The yield gradient was due to the relatively shallow water table near the drainage ditch and deeper water table at the middle. Among the different drainage ——-interceptor systems, treatment (T1) gave significantly higher yield of **7.3** t/ha compared to the other treatments (Table 8). The yields between (T2) and (T3) did not differ significantly but are significantly greater than the yields in (T4) and (T5). The slightly higher (but not significant) yield in (T4) compared to (T5) was due to the drainage improvement made during the post-vegetative growth period of the crop.

Table 8. ***Average corn grain yield (t/ha), water table depth, plant height, and gross margin in each water control treatment, LTRIS, 1990 DS.***

Water control treatment	Drainage cum-intemptor channel depth (cm)	No.	Average water table depth (cm)	Plant height (cm)	Average yield (t/ha[1])	Gross[2] margin US$/ha
1	50	2	15	139	7.3a	948
2	30	2	13	126	5.5b	644
3	30	3	12	123	5.6b	652
4	20	3	5	110	3.5c	320
5	0	0	5	111	3.3c	287
Rice from adjacent rice fields						754

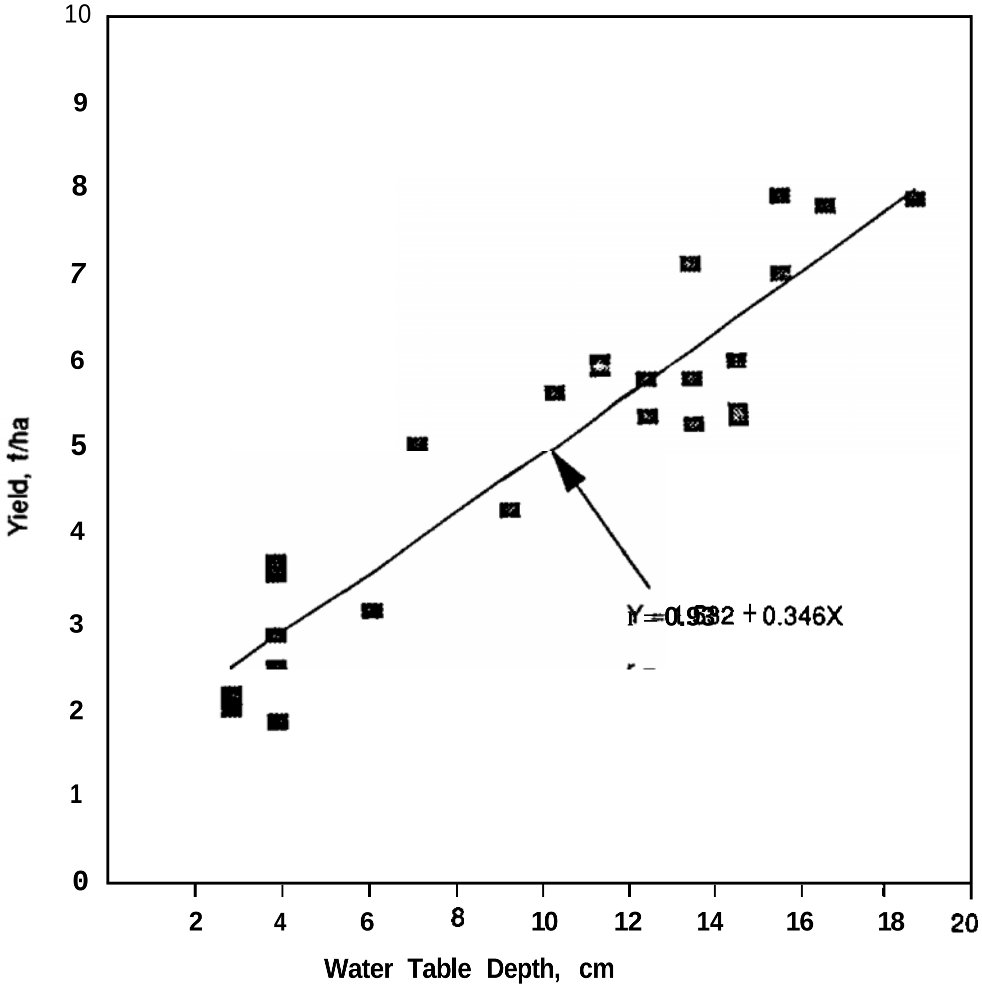
[1] Within column, numbers followed by a common letter are significantly different at 1 percent level. The [illegible] yield of rice in the adja[illegible] plot is 6.2 t/ha with a gross [illegible] of US$754/ha.

[2] Output prices used are government support prices of US$ 0.20 per kg of both rice and corn. US$1.00 = Pesos 25.00

In the experiment, the 50-cm deep drainage-cum-interceptor channel proved to be more effective in the water table control and more profitable than the other systems with shallower channels that were tried. The corn crop did not need any irrigation during its entire growth cycle because the soil moisture within the root zone was adequate to support its growth. Water stress was not observed in any of the treatment areas during the 1990 DS.

The experiment showed that shallow water tables on the farm created by canal seepage and excess water application to adjacent rice paddies can be effectively lowered by the use of well-designed drainage-cum-interceptor channels. Results also indicate that corn production with such seasonal investment is more profitable than rice production.

Figure 2. *Relationship between corn grain yield and water table depth, Laoag-Vintar River Irrigation System, dry season, 1990.*



Agronomic and Irrigation Management Options to Increase DS Cropping Intensity, Yields and Income

What can be done in parts of imgation systems with inadequate irrigation supply to increase farmers' income? From 1987 to 1989 DS, two major research activities were undertaken in UTRIS and in other similar systems with the following objectives:

1. To develop appropriate techniques that would promote efficient use of post-rice residual water and limited irrigation water for growing nonrice crops.

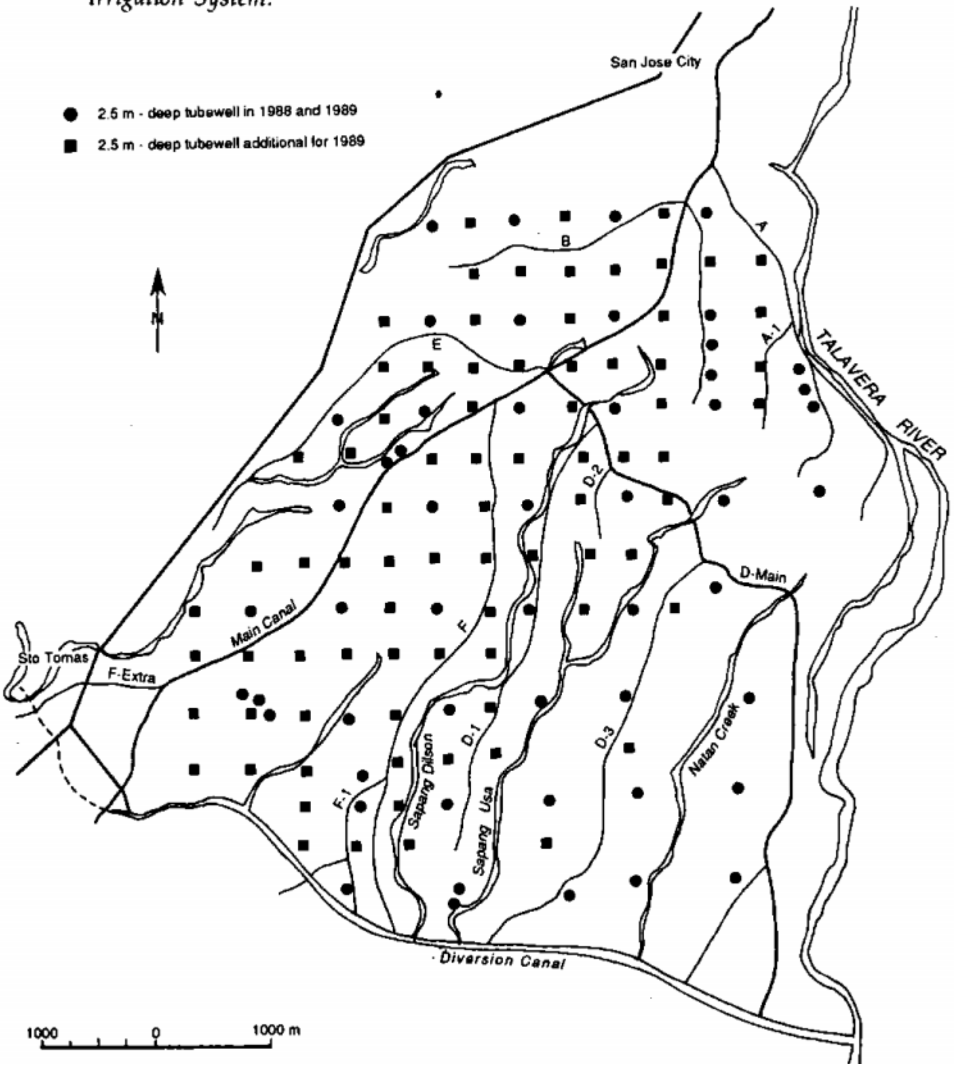
2. To document the nature and extent of water augmentation practices employed by farmers with limited irrigation water supply, and other information useful in policy formulation and decision making.

Use of post-rice shallow water fable. Soil-water persisting during the dry season after rice harvest can support legume crops by direct exploitation by legume roots, and farm pumps. This was explored in a survey of shallow water table using 2.5-m deep perforated tubewells located throughout UTRIS (Figure 3). During the 1988 DS, 52 sites on the non submerged fields were selected on rectangular grid basis for the monitoring of water table depths twice weekly. The additional 71 sites concentrated in the western areas were monitored in 1989 DS.

About 44 percent of the sites are irrigated or waterlogged riceland in December and 31 percent at the end of April. Among the nonirrigated/nonwaterlogged sampled sites, about 40 percent had usable resources of shallow water table early in the season in both 1988 and 1989, and about 25 percent still had usable resources at the end of the seasons in both years (Table 9). Geographically, within the system and early in the season, shallow water table was found near the main canal and near areas irrigated for the second rice. At the peak of the DS, shallow water tables were found along the lower portion of the main canal where fields were mostly irrigated by water pumped from the diversion canal (outside UTRIS).

Tillage *and* irrigation for *legumes*. During the 1989 DS, a field experiment was undertaken to measure and interpret the effects and interactions of tillage and irrigation on the growth and yield of legume following rice in previously puddled soil, and to identify management technology and irrigation scheduling to enable production substantially to be higher than that of the farmers. For DS cropping, the persistence of shallow water table is equally important as water table depth. Table 10 shows that findings in the 1988 and 1989 seasons were consistent. On the average, 25 percent of the sites had shallow water table for more than 20 days; an additional 25 percent of the sites had shallow water for 1-20 days which could possibly be managed for the benefit of nonrice DS crops.

Figure 3. 1989 Survey of resources of dry-season shallow groundwater in Upper Talavera River Irrigation System.



Depth range (cm)	Potential for aiding **DS** cropping	Proportion of sites at:					
		Early sampling			Late sampling		
		1988 DS (Dec) (%)	1989 DS (Feb) (%)	Mean (%)	1988 DS (%)	1989 DS (%)	Mean (%)
20-90	High	36	12	24	0	10	5
90-150	Slight	10	24	17	16	20	18
>150	None	54	64	59	84	70	71

Table 10. Persistence of shallow groundwater at UTRIS in 1988 and 1989 DS. Proportion of sample sites[1] (excluding irrigated and waterlogged) having water table persisting for various durations at depths 10-100 cm.

Duration (days)	Proportion of sites in:		
	1988[a]	1989[b]	Mean
21-27	16	33	24.5
1-20	26	30	28.0
0	58	37	47.5

[1] Excluding irrigated or waterlogged areas

[a] 52 uniformly distributed sites.

[b] 123 sites with greater concentration.

Four tillage/seeding and four imgation treatments for mungbean were field-tested in UTRIS. The heat-tolerant Taiwan green mungbean cultivar was used and seeded (with inoculant, fungicide, insecticide) on 25 November 1989, two days after rice harvest. There was no rainfall; irrigation water was pumped from the main canal by a delivery system that allowed precise application; all plots received 3.2 t/ha rice straw mulch, and all treatments were confined in Latin Square (LS) design with 4 replications of each combination. Harvest of mungbean (in 4 primings) was done during 1-20 February 1989.

The results of the experiment reveal that:

1. Shallow tillage — provided 0.60 million plants/hectare (Mp/ha) are established (as achieved with no tillage) and survive to harvest — should promote 0.9 t/ha of mungbean grain.

2. If DS irrigation is available, then interrow deep + shallow tillage — provided *0.60* Mp/ha survive — should promote **1.5** t/ha of mungbean grain.

3. There were substantial benefits from irrigation of **20** mm at **3** weeks after sowing (WAS)plus **30** mm at **4** WAS. Additional irrigation was used less efficiently.

4. Supporting studies in less heat-stressed environment (Friar Lands River Irrigation System, Santa Cruz RIS and IRRI) achieved production of **2** t/ha mungbean grain, substantially higher than the Philippine average of **0.5** t/ ha.

Water augmentation schemes. A survey of **32 UTRIS** farmers in Nueva Ecija and **5** SFRIS farmers in Pangasinan was undertaken to document **the** nature and extent of groundwater use to augment canal supplies by these farmers.

Farmers located at the tail-end sections of irrigation systems where water is limited, especially during the later part of the DS, supported their (diversified) nonrice crops with the use of shallow groundwater drawn by centrifugal pumps through open wells. The open wells which were constructed with concrete casings have a diameter of **0.75** m to **1.0** m and a depth from **3.5** m to **7.5** m. Most of the wells **(78** percent) are about **5-7** m deep (Table **11).** About **62** percent of the wells were developed before **1980** and the remaining **(38** percent) after **1980.** All of the wells in SFRIS were developed after **1980.** The wells in UTNS and SFRIS were developed at a unit cost of **US$25-US$150.**

The pump size used is from **3** to **5** inches **(7.5** to **12.5** cm) but the size of **86** percent of the pumps is **4** inches **(10** cm) (Table 12). Most of the pumps **(89** percent) have a rated discharge capacity of **300** gallons per minute (gpm) **(18.9 Ips)** and the rest **(11** percent) have a capacity from 400 to 600 gpm, **(25** to **38** lps). Diesel engines of different brands are generally used as prime movers of the pumps. The engine **capacity ratings range from** 3 to **7.5** kw **(4** to **10** hp), **but the most common (66 percent)** are from 3-6 kw **(4.8** hp).

The average static water table depth in the wells at UTNS (Lateral B area) is about **1.8** m below the ground-surface from June to January and increased gradually from **2.3** m in February to **3.0** m in April. Similarly, in SFRIS, the water table depth ranges from less than **1.0** m in August to November but increases to about **4.0** m in April and May. The average drawdown of pump wells in **UTNS** is **0.9** m for average discharge of **18** Ips whereas in SFRIS, the average drawdown is **0.7** m with a discharge rate of about **16** lps.

The average area served by the pumps ranges from 2 to a little more than **5** ha cultivated by **3** to **6** farmers (Table **12).** The most common nonrice crops irrigated by the farmers practicing the water augmentation scheme are onion, tobacco, and corn. Water is generally pumped done from February to April when the water

Table 11. Profile of wells used by farmers practicing augmentation and diversified cropping, UTRIS and SFRIS, 1990 DS.

Items	UTRIS	SFRIS	Total	
	N=32	n=5	n=37	%
Type of wells				
Open dug well with concrete casing	32	5	37	100
Depth of wells (m)				
n=35				
3-4	4	0	4	11.4
4-5	3	0	3	8.6
5-6	13	5	18	51.4
6-7	10	0	10	28.6
Year developed				
1960-1970	9	0	9	24.3
1970-1980	14	0	14	37.8
1980-1990	9	5	14	37.8
Cost of well development				
US$25 - 50	23	0	23	62.2
50 - 100	5	5	10	27.0
100 - 150	4	0	4	10.8

US$1.00 = Pesos 25.00

supply from both systems (UTRIS and SFRIS) is inadequate. The basin method of irrigation or "flush flooding" is used for onion and furrow irrigation for tobacco and corn. The average rates of water application are 18 lps, 8.3 lps, and 8.6 lps for onion, tobacco, and corn plots, respectively (Table 13). Data obtained in one irrigation application for each of these crops showed an average depth of 81 mm for onion, 90 mm for tobacco, and 50 mm for corn. These amounts are respectively 17 percent and 12 percent less than the amount applied for onion and tobacco in the gravity irrigated plots indicating that farmers using pumps for augmenting their irrigation needs are relatively more efficient in using water.

Table 12. Profile of pumps used by farmers practicing augmentation and diversified cropping, UTRIS and SFRIS 1990 DS.

Items	UTRIS	SFRIS	T I	
	N=32	n=5	n=37	%
Diameter of pump (cm)				
7.5 x 7.5	3	0	3	8.3
10.0 x 10.0	26	5	31	86.1
13.0 x 13.0	2	0	2	5.5
Capacity/discharge (lps)				
19	20	5	25	89.3
25	1	0	1	3.6
32	1	0	1	3.6
38	1	0	1	3.6
Engine KW				
3-5	12	0	12	34.3
5-7	9	5	14	40.0
7-8	6	0	6	17.9
>8	3	0	3	8.6
Area served (ha)				
<2	10	0	10	28.6
2-3	5	0	5	14.3
3-4	7	0	7	20.0
4-5	4	3	7	20.0
>5	4	2	6	17.1
No. of farmers served				
<3	12	0	12	46.1
4-5	5	0	5	19.2
>6	4	5	9	34.6

Water augmentation through shallow well pumps was found beneficial to the downstream farmers with limited supply of irrigation water. Their crops are insured against drought during the latter part of the DS. Owners and users of the augmentation system do not compete anymore with the upstream farmers for irrigation water supply.

Crop planted	Average farm area (m^2)	Duration of irrigation (min)	Discharge (lps)	Depth of water applied (mm)	Method of water application
Onion	2826	210	17.7	81	Basin
Tobacco	3049	512	8 3	90	Furrow
Corn	2793	335	8.6	50	Furrow

CONCLUSIONS AND RECOMMENDATIONS

1. The basic and essential permanent farm-level facilities needed to support WS rice and DS diversified cropping are the main farm ditch and the water control structures such as turnouts with gates, diversion boxes and check drops (when necessary). Additional supplementary farm ditches required only for areas with topographic limitations must also be constructed. Farm ditches and other water control facilities needed for growing nonrice crops will vary depending on the crop choice and these can be adequately handled by the farmers.

2. Water application techniques of the farmers in both systems are "flush flooding." For onion, water is applied within a farm *plot-by-plot* whereas for tobacco water is applied *plot-to-plot.* In each case the adopted technique is suited to the water supply rate and the crops' tolerance to excess water.

3. Water application efficiency in onion as well as in tobacco was high. Mulched plots had a slightly higher water application efficiency (90 percent) than the unmulched plots (88 percent), but in SFRIS, where tobacco plots were not drained, the water application efficiency was close to 100 percent. However, the *plot-to-plot* water application method that was practiced in tobacco irrigation would result in a relatively low water distribution efficiency. The irrigation delivery efficiency is lower in UTRIS (38 percent) than in SFRIS (70 percent). The low efficiency in UTRIS is due to the continuous delivery of water to the farm ditches in most upstream sites. SFNS deliveries were on an intermittent schedule dictated by the rotational supply of water in the main system.

4. Based on the WASDMOD evaluation, the low irrigation delivery efficiency in UTRIS could be improved to at least 75 percent by reducing the number of hours of water delivery to the turnout per day or the number of days of water delivery in a week.

5. Corn grain yield can be significantly increased by lowering the shallow water table depth created by seepage and excess water application to neighboring rice paddies by a 50-cm depth drainage and interception channel.

6. Usable resources of the post-rice shallow water table persists on about 40 percent of **the** UTRIS area. Both the persistence and the area might be increased by rice irrigation management. Residual moisture with appropriate seeding and tillage has potential for 0.9 t/ha at UTRIS (less favorable environment), and 2.0 t/ha in more favorable environments.

7. Water augmentation utilizing shallow water table through open concrete cased-well and pump systems in the tail-end areas of irrigation systems is feasible and highly recommended for diversified crops.

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