Chapter 5

Comparative Assessment of On-farm Water-Saving Irrigation Techniques in the Zhanghe Irrigation System

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Abstract

Introduction

The *alternate wetting and drying* (AWD) irrigation technique has been introduced to farmers to save water, in the belief that it will increase yield. However, the adoption of AWD among the farmers was slow because of traditional concepts and habits, a high risk of lodging with AWD and lack of training and guidance (Dong and Loeve 2000). In many areas of ZIS, farmers still practice *continuous water application*.

A comparative assessment was conducted of these two methods of on-farm water-management strategies for rice in two sites within the Zhanghe Irrigation System (ZIS). It was conducted during the wet season rice crops of 1999 and 2000. The objective was to evaluate the impact of AWD irrigation techniques on crop management and the profitability of rice production. The study also investigated whether farmers in sites where AWD techniques were introduced were knowledgeable about them and were actually practicing it. The townships of Tuanlin (TL) and Wenjiaxiang (WJX) were selected for the study; TL represents the area where AWD techniques are supposed to be practiced by the farmers while WJX represents the site where these techniques are not being practiced. Detailed data regarding on-farm water-management strategies, such as frequency and timing of irrigation, depth of water applied, sources of water, pond and pump use, were collected from 30 sample farmers from each site through farmer interviews. Input and output data of rice production including prices were also collected to make an economic comparison of the two sites in terms of rice production and profitability.

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Site and Sample Description

Thirty sample farmers from the Shuangbei village near the TL Experimental Station were selected in the site where the AWD irrigation techniques are being practiced. The area is served by the first branch of the third main canal of ZIS. Similarly, 30 other sample farmers were selected from the Wanyan village at the Lengshui township where AWD is not practiced but where continuous irrigation is practiced. Lengshui is near the township of WJX where the fourth main canal is located and the east branch of this canal of ZIS irrigates this area. The elevation of farmers' fields vary and, therefore, the samples were selected in such a way that 10 farmers from each site had fields on a higher elevation, 10 on a medium elevation and 10 on a lower elevation. To be consistent with earlier reports we will use TL to refer to the site where AWD is practiced and WJX to refer to the site where AWD is not practiced .

The mean farm size of the samples from both sites ranged from 0.65 to 0.70 hectare (table 1). The sample farmers have more or less similar socioeconomic characteristics as shown by the similar magnitudes of their age, family size and level of education. On average, farmers from TL and WJX have annual incomes of about 8,800 yuan and 12,000 yuan, respectively.

Table 1. Basic farm and household characteristics of sample farmers, TL and WJX, ZIS, Hubei, China.

	TL	WJX
Number of sample		
1999	22	30
2000	30	30
Mean farm size		
1999	0.66	0.68
2000	0.70	0.65
Mean household size	4.2	4.3
Mean age of farmer	40.8	40.7
Mean education of the farmer	9.1	9.4
Sources of household income (%)		
Rice crop	48	36
Non-rice crop	18	3
Livestock and poultry	11	11
Income from labor	0	0
Other sources	23	50
Total household income (yuan)	8,810	12,078

US$1.00=Yuan 8.27 in 2000.

On-Farm Water Management Practices of Farmers in TL and WJX

Many farms in the study sites are located at a higher altitude than the irrigation canals so that a majority of the farmers in TL and WJX keep farm ponds or small reservoirs for storing rainfall and pumped water from the ZIS irrigation canals to be used for on-farm irrigation. Farmers use water from these ponds or small reservoirs in more than one-fourth of irrigation events at both sites (table 2).

Table 2. Comparative uses of ponds among rice farmers in the two sample sites, ZIS, China.

	TL (%)	WJX (%)
Frequency of use of ponds as a source of water per irrigation event	28	25
Ownership of ponds		
Individually owned	54	41
Farmer group	0	22
Other farmer	13	30
Village	33	7
Other uses of ponds		
Aside from irrigation		
Raising fish	42	41
Lotus	4	4

In seasons with less rain, like the 2000 wet season, 70 percent of farmers in TL and 63 percent in WJX experienced problems of inadequate water supply in the various stages of the rice production cycle (table 3.). But in a rainy season like the 1999 wet season, 45 percent and 53 percent of the farmers from TL and WJX, respectively, sustained excessive water problems in their fields. Hence, the two seasons when observations on AWD were made could bring about different water application behaviors by farmers, especially so because the two areas are supposedly practicing different techniques of water application. In the section that follows, the basic parameters—such as frequency, duration, and depth of water application—of on-farm water application of the two sites will be analyzed and compared.

Table 3. Number of farmers with water availability problems at different crop growth stages, TL and WJX, ZIS.

Crop stages	No water				With excess water			
	TL		WJX		TL		WJX	
	1999	2000	1999	2000	1999	2000	1999	2000
Land preparation	1	1	6	5		1	2	0
Transplanting	0	6	6	8		1	1	1
Vegetative	2	11	4	11	9	3	9	5
Reproductive	3	10	5	16	1	2	4	1
Total*	5	21	15	19	10	3	16	6
Percent of total sample	23	70	50	63	45	10	53	20

*Some farmers who had problems with two or more crop stages were counted once in the total.

Frequency and Depth of Irrigation Application

A summary of the frequency of irrigation (from land preparation to harvesting) of the farmers from the two sites showed that the number of irrigation application of farmers from TL is slightly lower than that from WJX for both seasons (table 4). However, the difference is not statistically significant. In the 1999 wet season, farmers from WJX irrigated their crops more frequently when there was still standing water in the soil (2.8 times) than when the soil was either saturated or dry. As expected, farmers from TL practiced the opposite strategy and more commonly applied water when the soil in the field was dry (2.6 times on average) than when it was either wet or had standing water. In the 2000 wet season, when there was little rain, farmers in both sites irrigated their fields more frequently under dry-soil conditions.

Table 4. Frequency of irrigation application according to soil condition immediately Before the irrigation event.[1]

	WS rice, 1999		WS rice, 2000	
Soil condition	TL	WJX	TL	WJX
With standing water	2.0	2.8	0.6	0.6
Saturated (wet)	1.1	1.3	2.5	2.6
Dry	2.6	2.2	2.8	3.2
Total number of irrigation applications	5.8	6.3	5.8	6.4

[1]Includes all irrigation applications from land preparation to harvesting.
Note: WS rice=Wet-season rice in this table and in others.

The amount of irrigation water applied varied by crop-growth stages and by sites in both the 1999 and 2000 wet seasons (table 5). The total seasonal water depth applied by farmers in WJX was 42 percent higher than that in TL during the 1999 wet season but it was only 3 percent higher in the 2000 wet season, a relatively dry year. During the crop-growth period, the total amount of water applied by WJX farmers was about 80 percent higher than that applied by TL farmers during the 1999 wet season but only 4 percent higher in the 2000 wet season. The result indicated that nearly all farmers practice a form of AWD when less water is available.

Table 5. Depth of standing water at the end of irrigation events by different crop stages, TL and WJX, ZIS, Hubei, China.

	WS rice, 1999		WS rice, 2000		Average	
	TL	WJX	TL	WJX	TL	WJX
Water applied by crop stage (mm)						
Land preparation	47	55	88	86	70	71
Transplanting	25	60*	38	40	32	50*
Crop growth	133	239*	266	277	210	258
Total depth	205	354*	392	403	312	379*

*Mean values are significantly higher than at TL.

AWD in Farmers' Fields

The alternate wetting and drying (AWD) system of irrigation for rice implies that rice fields are not kept continuously submerged but that they are allowed to dry intermittently beginning 30 days after transplanting. During this period, farmers adopting this system are expected to irrigate only when their fields are either saturated or dry. Thus, all irrigation events during land preparation, seedbed preparation and transplanting were not considered in our analysis of on-farm water-management practices. Table 6 shows the average number of irrigation applications during the crop-growth period that begins 30 days after transplanting. In 1999, farmers in TL allowed the soil to become dry before applying irrigation water more frequently than those in WJX, and the latter were more likely to irrigate when the fields were either saturated or with standing water. But, during dry periods as in 2000, the behavior of farmers at the two sites was quite similar. There was not much difference in the total number of irrigation applications between the two sites in either year.

Table 6. Average number of irrigation applications during the crop-growth period,[1] according to the soil-water condition immediately before the irrigation event, ZIS, Hubei, China.

	WS rice, 1999		WS rice, 2000	
Soil-water status	TL	WJX	TL	WJX
With standing water	0.75	0.81	0.0	0.19
Saturated (wet)	0.31	0.58	1.17	0.76
Dry	0.94	0.69	1.33	1.38
Total	2.0	2.08	2.5	2.33

[1]Includes all irrigation events on the 30th day or 30 days after transplanting.

Additional information collected from the survey reveals that not all farmers in TL where AWD was introduced have a knowledge of AWD techniques. Roughly 13 percent of our sample in TL said that they had no knowledge of AWD and were not practicing it. On the other hand, 43 percent of the sample from WJX was aware of AWD, and six of these farmers stated that they were practicing it (table 7). Only one farmer at WJX claimed to have undergone training in AWD techniques. No farmer in TL reported attending such training.

Table 7. Knowledge of AWD irrigation techniques among sample farmers, ZIS, Hubei, China.

Sites	No. of sample	With knowledge (%)	Without knowledge (%)	Adaptor
TL	30	26 (87)	4 (13)	25
WJX	30	13 (43)	17 (57)	6

AWD Scores

To compare individual farmer's irrigation strategies and to determine whether they are, in fact, practicing AWD or not, we established a scoring system, ranging from 0 to 1. The following equation was used in computing the AWD score of an irrigator:

$$\text{AWDscore} = \frac{X \times 1 + Y \times 0.5 + Z \times 0}{X + Y + Z}$$

where,

X = number of times a farmer irrigates when the soil is dry,

Y = number of times a farmer irrigates when the soil is wet or saturated,

Z = number of times a farmer irrigates when the soil is with standing water, and

1, 0.5 and 0 are arbitrary weights assigned to dry, wet or saturated, and standing water conditions, respectively, at the time of water application.

Only irrigation events on the 30th day or 30 days after transplanting of the crop and until the crop was harvested were considered in computing the AWD score. On an individual farmer basis, if all his or her irrigation application happened only when the soil was dry then a farmer gets a score of 1. A score of 0 results if all his or her irrigation applications happened when there was still standing water in the soil, and the AWD score is between 0 and 1 if a farmer had irrigated at a combination of different soil-water statuses. The score then will indicate if the farmer tends to practice AWD or not, with higher scores indicating a greater adoption of AWD.

Farmer AWD Irrigation System

Figure 1a shows a scatter plot of the AWD score of the farmers from two different water distribution schemes, in the 1999 wet season. Many farmers from WJX always kept the soil submerged during the crop-growth period as shown by their score of 0. Surprisingly, there were also some farmers in TL who did the same.

In contrast to 1999, the rice crop in the year 2000 was quite different in terms of AWD score patterns (figure 1b). All farmers except one got an AWD score of 0.5 or higher and 16 got 1 indicating that in 2000 (a dry year) the majority of farmers tended to practice the AWD system of irrigation regardless of whether they belonged to a site where AWD had been introduced. In 1999, the mean AWD scores of all farmers in TL and WJX were 0.58 and 0.42, respectively, but in 2000 their scores were almost equal, about 0.8 (table 8).

In general, AWD scores were higher for farmers who claimed to practice AWD, as would be expected. The AWD scores indicate that most farmers did not practice a pure form of either AWD or continuous flooding.

Figure 1a. Alternate wet dry scores, 1999 WS rice, ZIS, China.

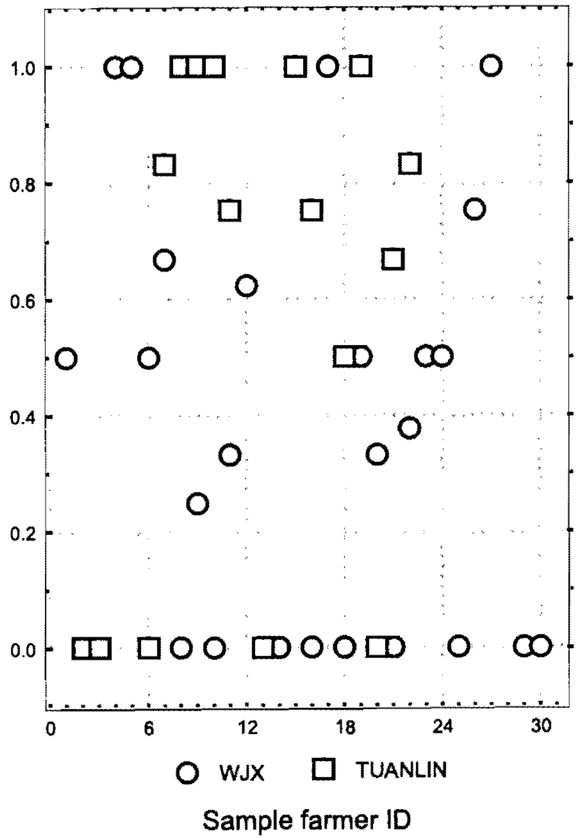


Figure 1b. Alternate wet dry scores, 2000 WS rice, ZIS, China.

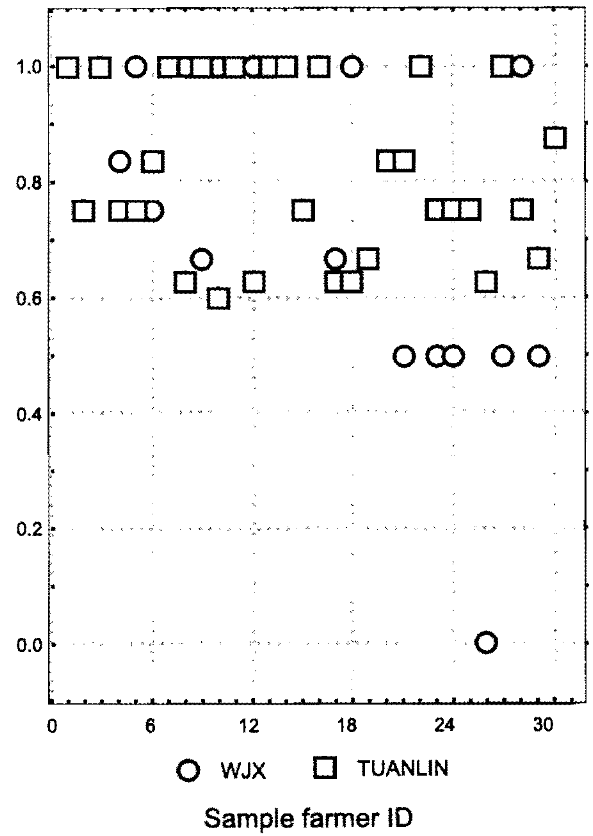


Table 8. Comparative AWD scores of farmers stratified by site, year, and reported practice of AWD.

	AWD	Non-AWD	All	Both years
TL				
1999	0.58	0.61	0.58	0.73
2000	0.80	0.92	0.82	
WJX				
1999	0.51	0.39	0.42	0.58
2000	0.88	0.74	0.78	
Both sites and years	0.72	0.59		

AWD and Input Use

A comparison of raw material input use by farmers showed that, on average, the WJX farmers applied more nitrogen fertilizer and organic manure to the rice crop than the TL farmers, and spent more money on pesticides (table 9). On the other hand, the TL farmers used more seeds per hectare (the WJX farmers used hybrid rice more frequently than the TL farmers) and applied more potassium than the WJX farmers.

In general, WJX farmers used much more labor for rice production than the TL farmers. On average, total labor use of WJX farmers was about 145 person-days compared to only 91 person-days in TL (table 10). This difference may be due to thorough land preparation, additional canal maintenance, a different method of transplanting the crop, and higher yield (which requires more labor for threshing and harvesting).

Table 9. Comparative yield and input use, irrigated WS rice, TL and WJX, ZIS, Hubei, China.

	WS rice 1999		WS rice 2000		Average	
	TL	WJX	TL	WJX	TL	WJX
Yield per hectare (tons/ha)	7.82	8.53*	6.66	7.84*	7.15	8.18*
Fertilizer use (kg/ha)						
Nitrogen	153	165	160	208*	157	187*
Phosphorus	44	43	44	51*	44	47
Potassium	7	0	36	3	24*	1.5*
Seed use (kg/ha)	26*	20	30*	22	28*	21
Manure (t/ha)						
Pesticide use (yuan/ha)	3.2	4.8	1.1	5.0*	2.0	4.9*
Insecticide	114	124	72	92	90	108
Herbicide	36	59*	25	44*	29	52*

*Mean values are significantly higher than at the others site at the 5 percent level.

Table 10. Labor use for wet-season rice production, TL and WJX, ZIS, China, 1999–2000.

	WS rice 1999		WS rice 2000		Average	
	TL	WJX	TL	WJX	TL	WJX
	(Person-days per hectare)					
Land preparation	8	10	8	21*	8	15*
Crop establishment	19	23	30	55*	25	39*
Crop care	18	29*	15	45*	16	37*
Hand weeding	4*	2	2	1	3*	1
Irrigation labor	8	16*	6	30*	7	23*
Harvesting and threshing	37	48	46	59*	42	54*
Total labor use	82	110*	98	181*	91	145*
Family labor	72	105*	87	174*	81	139*
Hired labor	11	5	11	7	11*	6

*Mean values are significantly higher than at the other site at the 5 percent level.

Excluding labor for canal maintenance, the value of 11.2 person-days per hectare spent for actual irrigation of the rice field by WJX farmers is significantly higher than the value of 6 person-days/ha spent by TL farmers. This may be due to the larger number of irrigation applications and more water applied per irrigation.

It is a general belief that continuous submergence of rice fields is often practiced by farmers to control weeds, thus reducing labor for weeding or minimizing the use of herbicides. With the adoption of AWD techniques, farmers might be expected to control weeds either through more intensive hand weeding or through the application of additional herbicides. In TL, where AWD is more common, farmers spent more labor for hand weeding than WJX farmers in both years. However, the amount of labor spent for this particular activity was smaller in magnitude than that spent for other rice production activities.

To further determine if AWD is correlated with herbicide use, hand weeding or nitrogen fertilizer, we regressed the quantity of each of these inputs against AWD scores, site and year dummies, and interactions of AWD scores with the dummy variables. The coefficients of the AWD score and its interactions were not significant in any of the regressions (table 11). Thus, there appears to be little effect of AWD on input use.

Table 11. Regression estimates of the models used in relating AWD scores to input use, wet season rice 1999–2000, ZIS, Hubei, China.

Parameters	Model 1 (NHA)		Model 2 (HW lab)		Model 3 (Herb cost)	
	Coefficient estimate	Standard error	Coefficient estimate	Standard error	Coefficient estimate	Standard error
Intercept	179.2	37.2	1.84	1.87	48.4	14.2
AWD score	25.1	45.6	-1.62	2.16	0.3	17.4
Site dummy 1=TL 0= WJX	-9.6	30.0	2.72	1.43	-8.4	11.7
Year dummy 1=1999 0=2000	-11.2	39.1	-0.34	1.85	2.8	14.9
AWD score* site dummy	-30.5	39.8	-0.39	1.90	-20.4	15.1
AWD score* year dummy	-21.6	49.9	3.33	2.36	5.2	19.2
Herbicide cost			-0.01	0.01		
Hand-weeding labor					-0.7	0.9
Adjusted R^2	0.04		0.19		0.22	
R^2	0.08		0.24		0.27	

Model 1 - N fertilizer use at kg/ha as dependent variable.
Model 2 - Hand weeding labor (person-days/ha) as dependent variable.
Model 3 - Herbicide cost (yuan/ha) as dependent variable.

Effect of AWD on Yield

There are no data yet at the farm level to show that farmers adopting the AWD irrigation produced a significantly higher yield than those using other irrigation strategies.

Mean rice yields at WJX were significantly higher than those at TL in both years. The average yield of WJX for the two wet seasons was 8.18 tons per hectare compared to only 7.15 tons per ha for TL (table 9).

Although farmers at TL are more likely to use AWD strategies, it does not necessarily follow that AWD causes the lower yields at that site. In fact, experimental data given in chapter 4 of this publication show no significant effect of AWD on yield. The use of hybrid rice is more common in WJX and might account for the higher yields there. However, within TL, farm-level yield was not correlated with the use of hybrid seed, casting some doubt on this explanation.

Because farmers at the two sites do not practice a pure form of either continuous flooding or AWD, a comparison of yields between the two sites is not necessarily meaningful. Thus, as a first step, yield was correlated with the AWD score (see figures 2a and 2b for a scatter plot of these two variables for each year separately). The coefficient was negative and significant at the 10 percent level, suggesting a negative effect of AWD on yield of approximately 1 ton per hectare. (Since a low AWD score indicates irrigation management that is closer to continuous flooding, a negative coefficient indicates that continuous flooding is associated with higher yield).

Figure 2a. Yield versus AWD scores, 1999 WS rice, ZIS, China.

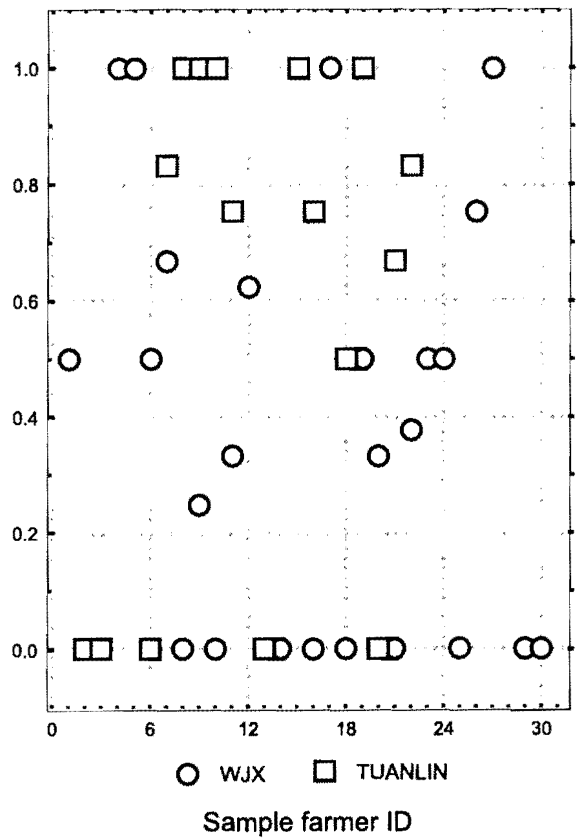
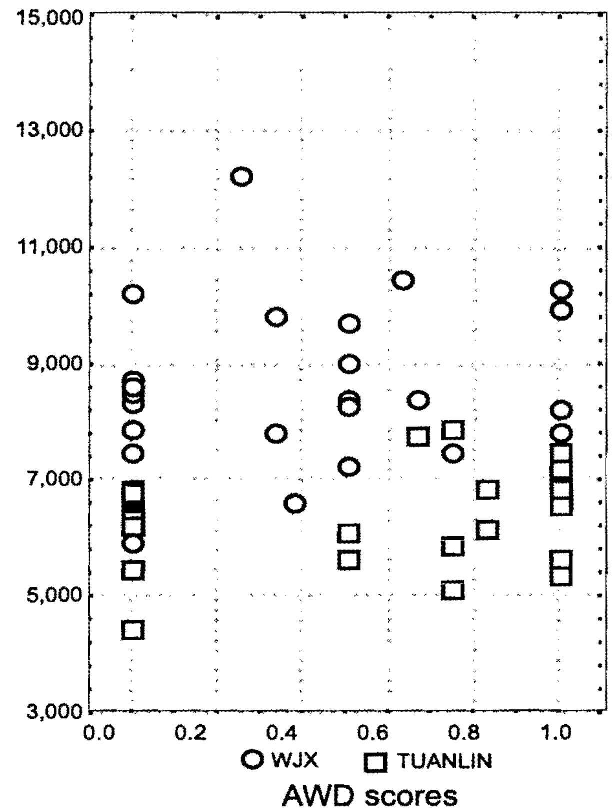


Figure 2b. Yield versus AWD scores, 2000 WS rice, ZIS, China.



But this correlation between the AWD score and yield may simply reflect the higher yields at WJX, where farmers' irrigation management was closer to continuous flooding than in TL. While different techniques of irrigation management could be responsible for the higher yields at WJX, there are other factors that could be responsible as well, such as input use (which was higher at WJX) or unobserved soil quality. In an attempt to control these effects, we estimated a production function with per-hectare yield as the dependent variable. Independent variables included various inputs (e.g., fertilizer, labor), dummy variables for sites and years, the AWD score, and interactions of the AWD score with the year and site dummies (see table 12).

Other than the constant term, only two variables were statistically significant at the 5 percent and 10 percent levels: One was herbicide cost, and the other, insecticide cost (with a negative sign). Using appropriate combinations of the interaction terms, estimates of the effect of AWD on yield were constructed for each combination of site and season (see table 13). The largest effect was noted for WJX in 1999, with increased soil-drying being associated with *increased* yields of about 385 kg per hectare (this estimate was constructed as the coefficient on AWD score plus the coefficient of the AWD score-year interaction).

Table 12. Regression parameters and coefficients of the model used in relating AWD irrigation techniques to rice yield, wet season rice 1999–2000, ZIS, Hubei, China.

Parameters	Coefficient	Standard error
Constant	5,869***	1,185
AWD score	188	1,180
Site dummy	432	773
1= TL		
0= WJX		
Year dummy	1,068	1,005
1=1999, 0=2000		
AWD score * site	-1,101	1,068
AWD score * year	197	1,277
Herbicide (yuan/ha)	15.3**	7.1
Insecticide (yuan/ha)	-5.8*	3.0
Crop care labor (person- days/ha)	15.0	12.6
Nitrogen (kg/ha)	0.5	2.8
Phosphorus (kg/ha)	16.6	14.1
Potassium (kg/ha)	2.8	4.6
Manure (kg/ha)	0.02	0.04
Adjusted R^2	0.22	
R^2	0.32	

*10 percent level of significance.
**5 percent level of significance.
***1 percent level of significance.

Table 13. Estimates of effect of AWD on yield, by site and year.

Sum appropriate regression coefficients		
	1999	2000
TL	-716	-913
WJX	385	188
Standard errors and t-statistics of estimated effects		
	1999	2000
TL	2740	1693
	(t=0.26)	(t=0.5193)
WJX	2348	1180
	(t=0.16)	(t=0.16)

However, the standard error for this effect was more than 2 tons per hectare (see the second matrix in table 13), so that the effect of AWD on yield was statistically insignificant. The estimates of the effects of AWD on yield for other site-season combinations in table 13 were also not significant. Thus, after controlling for effects of sites and years and input use, our conclusion is that AWD has essentially no discernible effects on yield, in agreement with the experiments reported in chapter 4 of this publication.

Profitability of Rice Production

A major determinant of the acceptability of any technology at the farm level is the economic benefit that the farmers stand to derive from the adoption of the technology. This applies to the AWD method of irrigation currently being introduced to the farmers in ZIS. Farmers will be more likely to adopt this technology only if they will clearly get an economic benefit from its adoption. So we assessed the economic feasibility of AWD based on the profitability of rice production of TL and WJX farmers. This section focuses on the comparison of the economic performance of rice production in the two sites through a detailed analysis of costs and returns for the two seasons covered by the study.

Costs of Rice Production

Costs consist of all expenses incurred from land preparation up to the time the unhusked rice is sold or stored for future use. The costs of production are classified into two main categories; the costs for material inputs and labor costs. The costs for material inputs include money spent on fertilizers, insecticides, herbicides, seeds, power (fuel and oil and rental costs for machinery) and on water as represented by irrigation fee payments. Labor costs include hired labor and imputed family labor. The standard procedure of valuing family labor at the mean wage rate of hired labor within the area of study was used in estimating the imputed labor costs. The evaluation procedures assume that the opportunity cost of family labor is equivalent to the wage rate that a family member will receive if he or she works in another farm. These imputed costs are likely to be overestimated if the opportunity cost of family labor is lower than the wage rate.

Among all items of costs, the dominant item was labor, roughly 53 percent for TL and 55 percent for WJX (table 14). Ninety percent of this labor cost is imputed as labor costs. This caused a big discrepancy between the total paid-out costs and total costs. Only a minimal amount was paid out to hired laborers outside of the family.

Table 14. Comparative profitability of wet-season rice production, TL and WJX, ZIS, Hubei, China.

	WS rice, 1999		WS rice, 2000		Average	
	TL	WJX	TL	WJX	TL	WJX
Gross return (yuan/ha)	6,956	7,514	5,312	6,966*	6,008	7,240*
Costs of production (yuan/ha)						
Material inputs						
Fertilizer cost	726	749	753	852	741	800
Insecticide cost	114	124	72	92	90	108
Herbicide cost	36	59*	25	44*	29	52*
Seed cost	229	416*	121	356*	167	386*
Irrigation fee	338	564*	254	621*	290	593*
Power cost	245	237	257	385	252	311
Other costs	288	396	262	261	273	328
Labor costs						
Hired labor cost	233	124	256*	138	246*	131
Imputed labor cost	1,610	2,803*	2,048	3,439*	1,862	3,121*
Total paid-out cost	2,208	2,670*	2,000	2,748	2,088	2,709*
Total cost	3,818	5,472*	4,048	6,187*	3,950	5,829*
Returns over paid-out cost	4,748	4,845	3,312	4,219*	3,920	4,531*
Net return	3,138*	2,042	1,265	780	2,057	1,411

*Mean values are significantly higher than at the other site at the 5 percent level of significance.

The amount spent on fertilizer does not differ much between the two sites. On average, both sites spent about 740 to 800 yuan per hectare or about 14 to 19 percent of total costs. The WJX farmers spent more for seeds and paid higher irrigation fees than the TL farmers. The WJX farmers used pure hybrid seeds that were costlier than the seeds of conventional varieties. Since volumetric pricing of water is practiced at ZIS and pumping costs are directly proportional to the amount of water pumped, WJX farmers who consumed more water paid higher irrigation fees than TL farmers.

Of the material inputs, insecticide and herbicide costs are the least important considering that the costs account only for about 2 percent of the total costs. In summary, the average per hectare costs of producing one wet-season rice crop for WJX amounts to 5,879 yuan per hectare, which is significantly much higher than the 3,950 yuan for TL. A similar relationship holds true for total paid-out costs even though the magnitude of the difference is not statistically large. Half of the difference in paid-out costs between the two sites is due to more money spent on irrigation. However, this is not all due to greater water consumption in WJX. Unfortunately, we do not have data on water applied to the field although the WJX farmers tended to have a greater depth of water at the end of the irrigation event.

Returns to Rice Production

The gross return to rice production was computed by multiplying the yield per hectare by the price of unhusked rice (yuan/kg). The average gross value of production differed substantially between the two sites, with the farmers in WJX and TL receiving per hectare gross returns of 7,240 yuan and 6,008 yuan, respectively (table 14). The difference was due to both higher yields and higher farmgate prices in WJX. The mean price of unhusked rice that the TL farmers received was lower by about 0.09 yuan per kg than what the WJX farmers received; the TL and WJX farmers received an average price of 0.83 yuan per kg and 0.92 yuan per kg, respectively. This price difference could be attributed to differences in the variety that farmers planted and to some specific factors peculiar to a site.

The returns over paid-out costs are estimated by deducting the total paid-out costs from the gross returns (table 14). This represents the returns to family labor, management and land, and the way that farmers usually considered their farm income. But, as explained earlier, we should attach some opportunity costs (value) to family labor. On average, the returns over paid-out costs in TL and WJX were about 3, 900 yuan and 4,531 yuan, respectively. The WJX farmers got significantly higher returns over paid-out costs than the TL farmers. However, the TL farmers obtained a net return overall cost of 2,057 yuan/ha while the WJX farmers obtained only 1,411 yuan/ha. As indicated elsewhere this was due to the heavy use of family labor by the WJX farmers.

Summary and Conclusions

Urbanization and industrialization posed a serious threat to water usually allocated to agriculture. While water commands a higher price in the urban and industrial sectors, it is being wasted by inefficient use for irrigation of agricultural production systems. For quite sometime now, agronomists, economists and water and irrigation scientists have been attempting to manipulate the basic irrigation parameters to cut the total amounts of water applied to irrigated rice production systems through WSI techniques.

In general, the TL farmers were more likely than the WJX farmers to wait until their fields were dry before applying irrigation water, as evidenced by their higher AWD scores. However, there was less difference than was initially expected between the two sites in terms of adoption of water-saving practices. This was especially true in the year 2000, a relatively dry year, when farmers at both sites allowed their fields to go dry before applying irrigation water (unfortunately, we do not have data on whether or not this soil-drying was voluntary or was forced upon them by the operation of the irrigation system). It is important to note that the soil status immediately before irrigation events varied considerably among farms, and that many farmers did not practice a pure form of either AWD or continuous flooding.

The adoption of AWD appears to have little effect on input use. While rice yields were significantly higher for farmers in WJX, our analysis indicated that, controlling for site effects, year effects, and input use, adoption of AWD has no significant effect on yield, either positive or negative.

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