On-Farm Water Management for Rice-Based Farming Systems in Indonesia

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INTRODUCTION

AS IN MOST countries which have attained self-sufficiency in rice, Indonesia is paying increasingly more attention to diversification in association with rice in their irrigated areas. This approach is to provide fanners with better cropping options and greater opportunities to generate higher farm income. However, the success of this endeavor would largely depend on various hydrologic, agronomic, economic and socio-institutional factors or constraints that would influence a wide-scale diversification program.

Water is a critical input in crop production. In the dry season, when water supply in the irrigation system declines, the availability of water for crop production becomes a crucial factor for cropping as well as for crop choice. Farmers usually achieve a o p intensification diversification and income by growing nonrice crops such as legumes (particularly soybean and mungbean) or maize or in some small regions, chili or onion which may be grown after the harvest of one or two rice crops.

The relationships between irrigation-water-related factors such as availability, reliability and distribution, and farmers' cropping and crop choices should be better understood by planners and implemmtors of agricultural development programs. This paper focuses on the selected water and crop-related issues to better understand the on-farm level water management for rice-based cropping.

METHODOLOGY

The Study Area

Different component studies were conducted at the Cikeusik (also called Manuengteung) Imgation System located at Cirebon, West Java. The system has a command area of about 7,511 ha and has 114 tertiary blocks. The average annual rainfall in the area is about 1,600 mm (1984-1988 average).

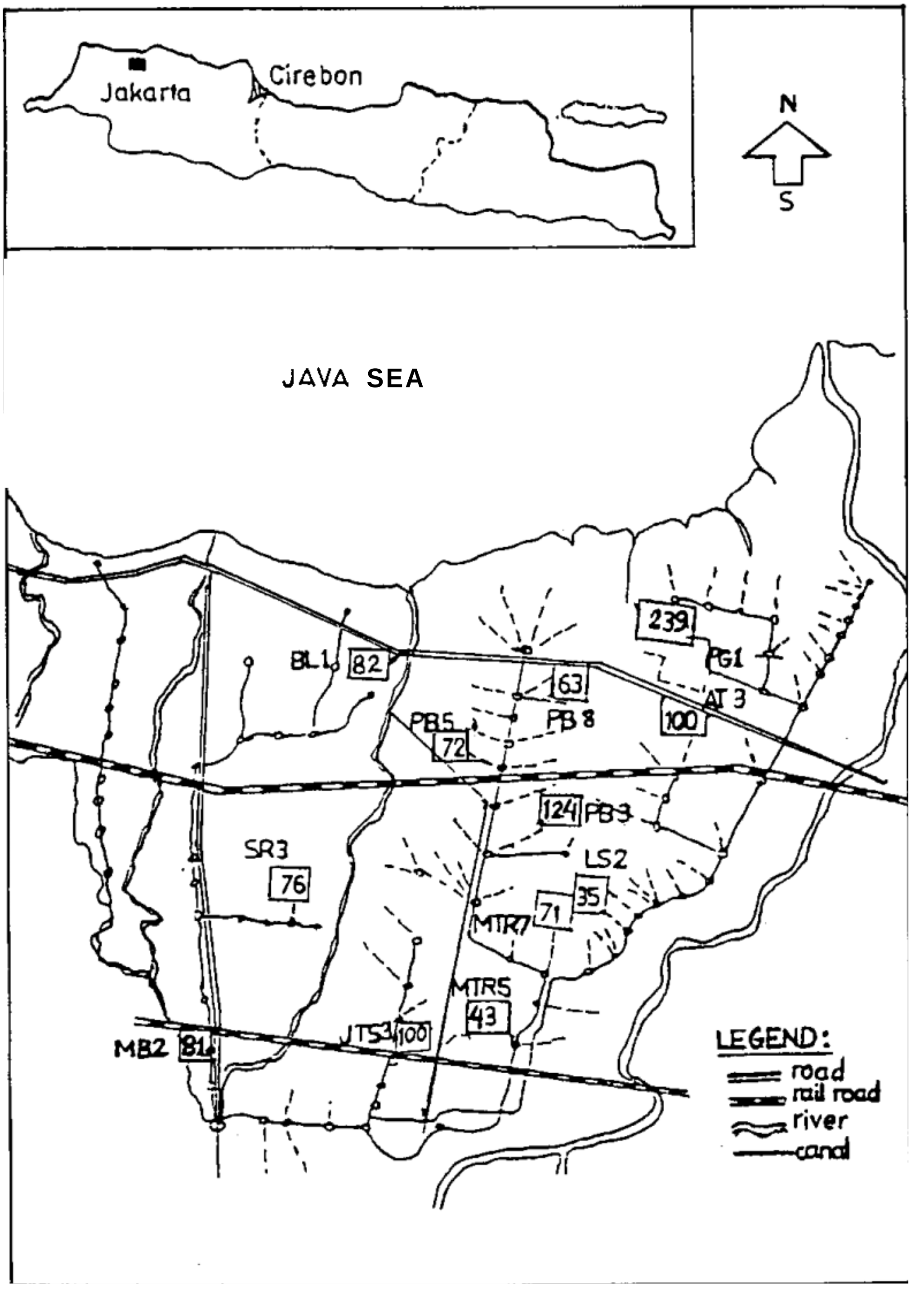
Rice is the principal crop grown, particularly in areas with sufficient water supply. Some areas even have three rice crops a year. However, in areas where imgation water supply is scarce, nonrice crops such as onion, chili, stringbean, mungbean, corn and others are mostly grown during the dry season. Rice is the dominant crop during the wet season which starts in December and ends in April. The first dry season (DS I) is from May to July and the second (DSII) from August to October.

Data Collection and Analysis

To determine water relations to dry-season crop choice and profitability, 12 tertiary blocks were selected within the irrigation system, 4 each at the head, middle, and tail sections of the system (Figure 1) (Wardana et al. 1990). Seventy nine sample farms were randomly selected from these tertiary service areas. Information on canal water availability, groundwater use, crop choices, relevant agronomic practices, yield, farm receipts and expenditures, and farmer background were obtained from the sample farmers through farm surveys. For certain water-related information, the *ulu-ulu* (water tender) was interviewed. Tertiary level water discharge data were collected daily.

The effects on the growth and yield of maize and mungbean of farmer-acceptable tillage practices and of realistic irrigation regimes defined in relation to soil-water holding capacity and ongoing crop-water usage were determined at three toposequence elevations (representing the irrigation system's head, middle, and tail regions, and drainage hydrologies), two crop sequences, maize-mungbean and mungbean-maize grown from May to October 1989 comprising Dry Seasons I and II (Juliardi et al. 1990). Mungbean cultivar No. 129 and maize hybrid cultivar C-1 were used in the study.

Figure 1. *Map* showing *the location of the* 12 sample *tertiary blocks, Cikeusik Irrigation System, Cirebon, West Java, Indonesia.*



Three tillage systems, zero tillage (To), strip tillage (Ts), and maximum tillage (Tm) were compared. For both maize and mungbean, seeds were sown by hand into manually dibbled holes at a spacing of 40 x 50 cm and 40 x 10 cm for maize and mungbean, respectively. Maize was fertilized with 120:90:60 kg/ha N:P:K applied in portions at 7, 30 and 45 days after seeding (DAS).

For mungbean, 45:45:45 kg/ha N:P:K was divided between application at 7 and 21 DAS, the first in combination with Furadan (17 kg/ha) to combat soil-bome insects. Hand weeding was made every 10-14 days from seedling emergence to flowering, and insecticidal sprays were applied every 7-10 days during 10-40 DAS.

Three irrigation regimes were investigated at each elevation and for each crop sequence. The least-irrigated plots (I-S) received a single irrigation of 20 mm the day before seeding. An intermediate level of irrigation (I-80) comprised a 20-mm pre-seeding watering, together with reirrigation to field capacity within the root zone whenever its water content was depleted of 80 percent of its available water. The most-irrigated treatment (I-40) involved a 20-mm pre-seeding watering together with reirrigation to field capacity whenever 40 percent of available water had been used.

Regular measurements were made for all plots (and for each crop elevation). Rainfall, depth to groundwater table, soil water content and bulk density and soil strength throughout the crop rooting zone, seedling emergence percentage and time of emergence, plant height and rooting depth and density, yields of grain and total dry matter, and components of grain yield were regularly measured.

At the Kuningan Experimental Farm in West Java, the effect of population density on the irrigation use efficiency of mungbean in addition to tillage and imgation was also studied (Abas et al. 1990).

RESULTS

Water Availability, Crop Choice and Cropped Area

About 41 percent of middle- and 79 percent of tail-section farmers considered the supplies of water insufficient (Table 1). More than 50 percent of the head section farmers were of the same opinion. Inequity problems resulted from the inappropriate system of water rotation and the "water-grab" mentality of upstream farmers who have more access to the limited canal supplies.

Figures 2a to 2c show the declining tertiary canal supplies with the advance of the 1988 dry season in the head, middle and tail tertiaries. The first and second 15-day average discharge values for each month illustrate the canal supply behavior as the seasons progressed. The decreasing water supplies in the tertiary canals from April to September are evident.

The head section had greater discharge per unit area than the lower sections. Most farmers would plant *palawija* crops in May if they are supplied with adequate water to establish the crops. To supplement the low discharge during the middle

Table 1. Factors contributing to water shortage and inequity problems, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I[a].

Item	Head	Middle	Tail	All farms
No. of samples	26			79
Irrigation water supply insufficient (percent)	58			59
Rotation is not appropriate (percent)	19			27
"Water-grab" mentality of upstream farmers (Percent)	35			30

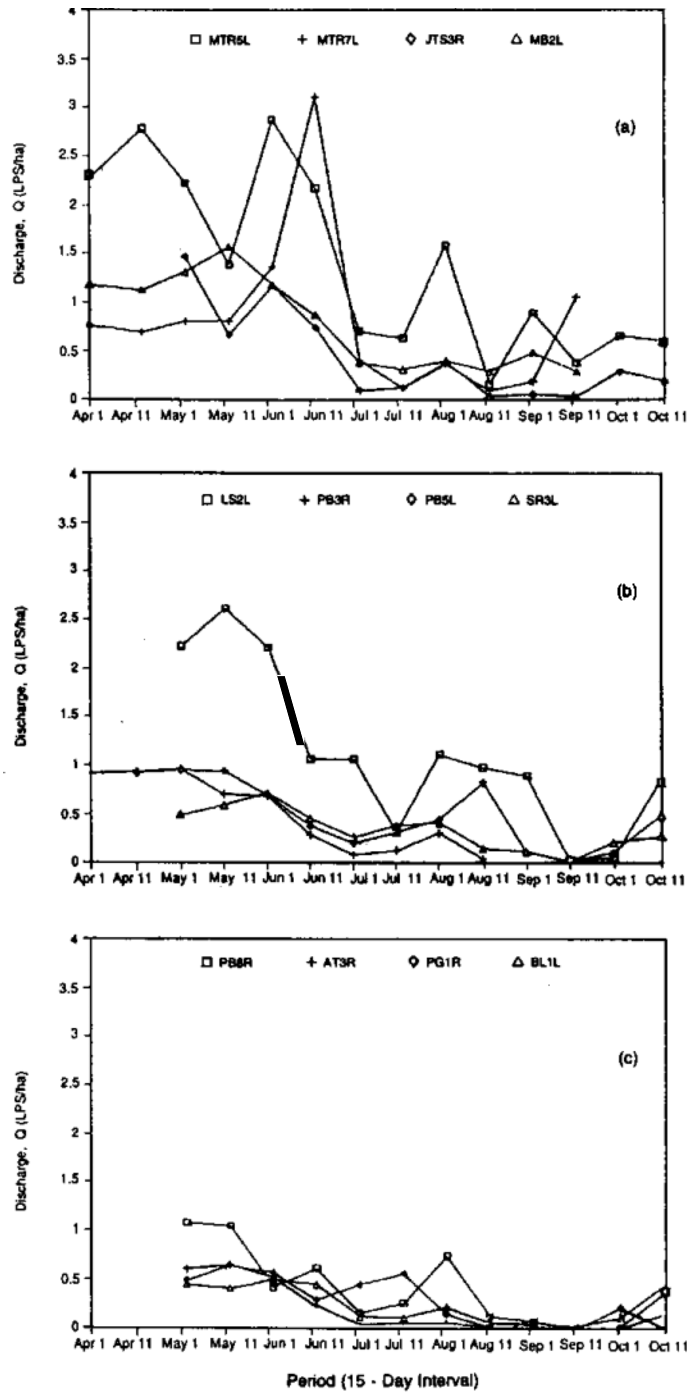
[a] Some farmers gave more than one answer.

and later part of the season, some farmers used dugwells. It should be noted that larger areas in three tertiary blocks of the section were planted to sugarcane (Table 2). It could be that the head section was scheduled to be planted with the mandatory sugarcane crop during that year.

Table 2. Extent of rice and nonrice crops grown in Cikeusik lmgation System, Cirebon, West Jaw, Indonesia, 1988 DS I and DS II.

Tertiary	DS I					DS II		
	Area (ha)	Rice	P.wija	S.cane	Fallow	P. wija	S. cane	Fallow
Head								
MTR5L	43	8	20	9	6	10	17	16
MTR7L	71	0	29	22	20	6	22	43
JTS3R	100	12	27	56	5	5	61	34
MB2L	81	0	34	44	0	3	44	34
Middle								
LS2L	35	0	8	27	0	5	27	3
PB3R	124	0	45	54	25	20	54	50
PB5L	72	0	30	29	13	24	29	19
SR3L	76	35	2	39	0	0	39	37
Tail								
PB8R	63	11	30	0	22	30	0	33
AT3R	100	70	30	0	0	30	0	70
PG1R	239	0	17	0	222	7	0	232
BL1L	82	6	12	0	64	0	0	82

Figure 2. Discharge (Q) per unit area for 4 tertiaries of the head section (a), middle section (b), and tail section (c), Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I and DS II.



For the middle farms, only tertiary block LSZL had a discharge greater than the rice crop water requirement (Figure 2b). Like the head section, it also had large areas planted to sugarcane. In one tertiary block, SR3L, about 50 percent of the area was planted to rice in DS I despite a relatively low canal discharge. In this tertiary, the farmers used groundwater during the season to supplement the canal water supply. The other tertiary blocks planted all or most of their areas to nonrice crops since the canal discharge was not enough to meet the rice crop water requirement in DS I. Although tertiary LSZL had a higher discharge rate for most of the May to September period, no rice was grown, with over **75** percent of the area grown to sugarcane. The rest of the area was grown to palawija crops. Like tertiary MTR5L of the head section, this tertiary had a relatively higher discharge rate because of its smaller area.

The canal discharge in the tail section was lower than in the upstream section (Figure 2c). Yet **two** of the sample tertiary blocks (PBER and AT3R) planted rice in DS I. Tertiary block AT3R planted 70 percent of its area to rice with supplemental water pumped from the drainage canal serving several upstream tertiaries. Furthermore, over 90 percent of the area of tertiary PG1R had no crop (fallow) in either both DSI or DS II. This is because since the second week of June, the canal discharge, which was very low from the beginning of DS I, started to decline and reached virtually zero flow towards the end of DS I. Moreover, this section received no water in DS II.

Comparing tertiary MTR5L in the head section and LS2L in the middle section, which are the **only two** tertiaries with a discharge high enough to grow rice in DS 1, it was observed that sugarcane and palawija were the dominant crops grown. Tertiary LSZL area had no rice at all. Clearly, farmers' crop choice was influenced not by water availability alone. In general, farmers in the head reaches, who have more access to adequate canal water supplies, can exercise their crop choice considering the other important factors such as economic returns and income stability. For middle and tail-end farmers, alternative sources of water had to be tapped to have this flexibility.

Groundwater Use

To supplement canal water during the dry months, some farmers utilized groundwater and some others pumped water from drainage canals. Dugwells were common in the head-end area while tubewells of about 10-30 m depth were common in the middle and tail areas. Shallower tubewells in the tail areas would yield salty water from the sea.

More than 50 percent of the head and middle section farmers used groundwater in DS II (Table 3). Because of salt problems, **tail farmers used less groundwater.** The farmers utilized groundwater mostly to supplement canal supply, as pointed out by 100 percent of the groundwater **users** in the head and middle sections in DS I and 75 percent of the groundwater users at the tail area. During DS II, groundwater had been used to meet the full crop water requirement. This reflects the greater scarcity of canal supplies in DS II relative to DS I.

Table 3. Groundwater use by section and by season, Cikeusik Irrigation System, Cirebon, West Jaw, Indonesia, 1988 DS I and II.

Item	Head n=26	Middle n=29	Tail n=24	All farms n=79
Perecent of farmers using groundwater (%)				
DS I	23	3	17	14
DS II	58	52	4	38
Purpose of groundwater use:				
a. To supplement canal supply (%)				
DS I	100	100	75	92
DS II	20	27	0	16
b. For full crop water requirement (%)				
DS I	0	0	25	8
DS II	80	13	100	84
Percent of farmers owning the well (%)				
DS I	100	100	25	75
DS II	93	60	0	51
Cost of grounwater use US$ /ha per season				
DS I	69	45	53	56
DS II	51	58	100	69

US$1.00 = Rp.1,800. Only variable costs are included

The majority of the groundwater users in DS I and DS II in the head area owned the wells. Groundwater users in the tail section, on the other hand, paid rents for the use of wells in DS II. The average cost of groundwater use ranged from US$45 to US$69 per hectare per season in DS I, and from US$51 to US$100 per hectare in DS II.

Table 4 shows significantly higher mean yield per hectare of onion (10.74 t/ha) in DS II for the groundwater users. Thus, even if they incurred higher cost of production, it could be compensated for by the significantly higher returns above paid-out costs and gross margin per hectare than the nonusers. In fact, the average nonuser incurred a net loss of about US$100 per hectare.

The use of groundwater to alleviate canal water shortages and increase the cropping intensity and farm income should be highly encouraged. However, studies to establish the availability of groundwater in space and over time should be conducted.

Table 4. Comparative costs of and returns from onion, groundwater users versus nonusers, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS II.

Item	Users	Nonusers	Difference
No. of samples	15	24	
Mean yield (t/ha)	10.74	6.02	4.72***
Total value of production (US$/ha)	2,129	1,020	1,109***
Costs of production (US$/ha)			
Seeds	499	404	95
Fertilizer	144	90	54**
Insecticide	220	113	107***
Labor			
Hired	375	283	92*
Family	207	141	66*
Other costs	107	91	16
Total paid-out costs of production (US$/ha)	1,345	981	364**
Total variable costs of production (US$/ha)	1,552	1.122	430***
Returns above paid-out costs (US$/ha)	784	39	745***
Gross margin (US$/ha)	577	(102)	679**

UM1.00 = Rp.1,800.
***,**,*. significant at 1 percent, 5 percent and 10 percent, respectively.

Fertilizer Use

The level of N fertilizer use in DS I was high, with an average of **212** and **209** kg/ha for the sample farms for rice and onion, respectively (Table 5). However, it was observed that the farmers at the head section used less N-fertilizer for rice than those in the other two sections. In contrast, the head-end farmers used more N and P fertilizers for onion, i.e., **224** and **94** kg/ha, respectively.

Table 5. Fertilizer use by crop and by section of the Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS 1.

Crop/fertilizer	Head	Middle	Tail	All farms
Rice				
No. of samples	5	6	I	12
N (kg/ha)	157	245	295	212
P (kg/ha)	27	39	95	39
K (kg/ha)	20	45	71	37
Onion				
No. of samples	18	19	23	60
N (kg/ha)	224	212	195	209
P (kg/ha)	94	85	57	77
K (kg/ha)	93	120	48	a4
Chili				
No. of samples	1	0	0	1
N (kg/ha)	347	-	-	341
P (kg/ha)	57	-	-	57
K (kg/ha)	66	-	-	66

In DS 11, the head farmers used a higher level of N fertilizer (**246** kg/ha) for onion (Table 6). On the other hand, an average farmer in the middle section used more P and K fertilizers for onion, i.e., 87 and 117 kg/ha, respectively. The highest level of K fertilizer was for chili in the middle farms. It must be mentioned that to benefit from high doses of fertilizer, appropriate crop and water management practices and good timing of application must be adopted.

Table 6. Fertilizer use by crop and by section, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS II.

Crop/fertilizer	Head	Middle	Tail	All farms
Onion				
No. of samples	12	16	11	39
N (kg/ha)	246	194	36	65
P (kg/ha)	63	87	36	65
K (kg/ha)	85	117	29	82
Chili				
No. of samples	13	2	1	16
N (kg/ha)	183	201	360	196
P (kg/ha)	65	57	108	63
K (kg/ha)	44	129	28	54

Profitability and Land Tenure

Table 7 shows the costs and returns per hectare of onion by land tenure in DS I. Although the mean yield per hectare of onion was similar for both owner-operators and leaseholders, the value of production of the leaseholders was higher by US$126 per hectare. This can be attributed to the variations in the prices received by the farmers. Leaseholders, however, incurred higher production costs, mostly land rents, as well as total variable costs which resulted in a net loss of about US$39 per hectare.

A similar trend was also observed for rice farmers. Leaseholders spent more in seed and fertilizer than the owner-operators (Table 8). Despite the higher input use of the leaseholders, however, their mean rice yield was about 0.9 t/ha lower.

Profitability and Area Location

In DS I, the mean yield per hectare of rice did not vary much between the head and middle farms (Table 9). However, in a farm in the tail section, where only one farmer planted rice, the yield was very low (2.43 t/ha). Thus, the total value of production per hectare for this section was also very low, only about 40 percent of what the head and middle farms obtained.

Table 7. Comparative costs and returns of onion by land tenure, Cikeusik Irrigation System, Cirebon, West lava, Indonesia, 1988 DS J

Item	Owner-Operator	Leaseholder	Difference
No. of samples	29	31	
Mean yield (t/ha)	9.61	9.33	0.28
Mean price of onion (US$/kg)	0.16	0.17	(0.01)
Total value of production (US$/ha)	1.525	1.651	(126)
Costs of production (US$/ha)			
Seeds	421	374	47
Fertilizer	121	112	9
Insecticide	207	156	51
Labor			
Hired	495	461	34
Family	231	333	(102)
Other costs	5	254	(249)
Total paid-out costs of production (US$/ha)	1,249	1.357	(108)
Total variable costs of production (US$/ha)	1,480	1.690	(210)
Returns above paid-out costs (US$/ha)	216	294	(18)
Gross margin (US$/ha)	45	(39)	(39)

US$ 1.00 = Rp. 1,800

Table 8. Comparative costs and returns *of* rice *by land* tenure, Cikeusik Irrigation *System, Cirebon,* West *Java,* Indonesia, 1988 DS I.

Item	Owner-operator	Leaseholder	Difference
No. of samples	6	6	
Mean yield (t/ha)	4.65	3.78	0.87
Total value of production (US$/ha)	595	475	120
Costs of production (US$/ha)			
Seeds	10	17	(7)
Fertilizer	42	131	(89)
Insecticide	16	21	(5)
Labor			
Hired	147	264	(177)
Family	34	I12	78
Other costs	3	230	(277)
Total paid-out costs of production (US$/ha)	218	663	(445)
Total variable costs of production (US$/ha)	252	775	(523)
Returns above paid-out costs (US$/ha)	377	(188)	(565)
Grass margin (US$/ha)	343	(300)	643

US$1.00 = Rp.1,800

Table 9. Cost and returns of rice by section, Cikeusik Irrigation System Cirebon, West Java, Indonesia, 1988 DS (Gadu) I.

Item	Head	Middle	Tail	All farm
No. of samples	5	6	I	12
Mean yield (t/ha)	4.4	4.36	2 43	3.73
Total value of production (US$/ha)	550	574	229	535
Costs of production (US$/ha)				
Seeds	14	14	16	14
Fertilizer	44	46	16	73
Insecticide	18	19	18	18
Labor				
Hired	151	244	129	206
Family	116	46	16	13
Other costs	122	95	265	166
Total paid-out costs of production (US$/ha)	339	495	628	440
Total variable costs of production (US$/ha)	455	541	644	513
Returns above paid-out costs (US$/ha)	211	19	(399)	95
Gross margin (US$/ha)	95	33	(415)	22

S$1.00 = Rp.1,800

The head farmers spent less for fertilizer (since they applied less fertilizer), insecticides and hired labor, but utilized more family labor as manifested by the higher average imputed cost. Still, the head farmers incurred lower total paid-out and total variable costs per hectare compared to farmers in the other sections. As expected, the head farmers produced higher returns above paid-out costs and gross margin, US$211 and US$95 per hectare. In contrast, farmers in the tail section incurred a net loss of about US$415 per hectare for rice.

For onion, the middle farmers had a slightly higher yield than the head farmers, 10.5 and 9.7 t/ha, respectively (Table 10). However, the price of onion received by the farmers in all sections (US$0.16 per kg on the average), was much lower than the normal price range of US$0.28 - US$0.55/kg. Since the total paid-out and totalvariable costs did not vary much among the secrions, the deficit (net loss) in gross margin for both head and tail farmers can be attributed to low output prices.

Table 10. Costs and *returns of onion by section, Cikeusik Irrigation System, Cirebon,* West *Java,* Indonesia, 1988 DS I.

Item	Head	Middle	Tail	All farms
	26	29	24	79
No. of samples	9.7	10.5	8.4	9.5
Mean yield (t/ha)	0.16	0.17	0.16	0.16
Total value of production (US$/ha)	1616	1822	1332	1590
Costs of production (US$/ha)				
Seeds	494	421	301	396
Fertilizer	137	134	89	116
Insecticide	177	231	143	181
Labor				
Hired	556	468	423	411
Family	150	16	168	134
Other costs	150	16	168	134
Total paid-out costs of production (US$/ha)	1514	1330	1121	1304
Total variable costs of production (US$/ha)	1928	1545	1360	1588
Returns above paid-out costs (US$/ha)	162	496	211	286
Gross margin (US$/ha)	(252)	211	(28)	2

US$1.00 = Rp.1,800.

With regard to other crops grown in DS II, chili gave greater returns per hectare in the different sections (Table 11). Despite a lower yield for the tail section, chili still gave a higher total value of production than in the middle farms, which could be due to price variations between sections. Similarly, the tail section produced the highest gross margin from chili, US$1,688 per hectare while the middle farms had an average of US$912 per hectare.

Mungbean'gave positive returns in all sections in DS II. The returns about paid-out costs ranged from US$95 to US$149 per hectare in the head and tail sections, respectively, while the gross margin ranged from US$30 to US$96 per hectare.

Table 11. ***Costs and returns*** of chili, corn ***and mungbean by section, Cikeusion Imgation System, Cirebon, West Java, Indonesia, 1988, DS II.***

Item	Head	Middle	Tail	All farms
Chill				
No. of samples	13	2	I	16
Mean yield (t/ha)	8.87	6.52	4.00	8.27
Total value of production (US$/ha)	2,564	1,507	2,222	2,41I
Total paid-out costs (US$/ha)	738	505	531	696
Total variable costs (US$/ha)	849	534	595	924
Returns above paid-out costs (US$/ha)	1.826	1,002	1.691	1.715
Gross margin (US$/ha)	1,640	912	1,688	1,562
Corn				
No. of samples	1	5	1	7
Mean yield (t/ha)	2.5	2.9	3.6	2.9
Total value of production (US$/ha)	111	I30	159	131
Total paid-out costs (US$/ha)	53	232	131	192
Total variable costs (US$/ha)	54	374	387	330
Returns above paid-out costs (US$/ha)	58	(102)	28	(61)
Gross margin (US$/ha)	57	(244)	(228)	(199)
Mungbean				
No. of samples	3	3	2	8
Mean yield (t/ha)	0.52	0.71	0.73	0.64
Total value of production (US$/ha)	225	306	303	275
Total paid-out costs (US$/ha)	130	190	154	I59
Total variable costs (US$/ha)	I36	276	207	206
Returns above paid-out costs (US$/ha)	95	116	149	116
Gross margin (US$/ha)	89	30	96	69

S$1.00 = Rp.1,800.

Profitability and Land Size

In DS I, the mean rice yields per hectare of the four land size categories were very similar, about 4 t/ha (Table 12). However, Category I, which has the smallest farms, incurred the highest total paid-out cost of US$433 and total variable cost of US$502 per hectare. This resulted in a net loss of about US$11 per hectare. In contrast, the other three categories obtained a higher gross margin per hectare, ranging from US$181 to US$227 on the average.

Table 12. Costs and returns of rice and a w n by land size, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I.

Item	Land sire			
	I	II	III	IV
Rice				
No. of samples	4	3	4	I
Mean yield (t/ha)	4.09	4 10	4.50	4.00
Total value of production (US$/ha)	491	643	522	444
Total paid-out costs (US$/ha)	433	354	302	86
Total variable costs (US$/ha)	502	416	328	263
Returns above paid-out costs (US$/ha)	58	289	220	358
Gross margin (US$/ha)	(11)	227	194	181
Gross margin (US$/ha)	(11)	227	194	181
Onion				
No. of samples	I2	16	14	18
Mean yield (t/ha)	11.9	9.6	9.0	8.I
Total value of production (US$/ha)	2.029	1,740	1,235	1,441
Total paid-out costs (US$/ha)	1,617	1,408	1,160	1,120
Total variable costs (US$/ha)	2,222	1,634	1,507	1,191
Returns above paid-out costs (US$/ha)	412	332	75	321
Gross margin (US$/ha)	(193)	106	(272)	250

For onion, the lowest yield was in Category IV or those fanners larger than 0.74 ha. However, its value of production was higher than that of Category III lands, which could be attributed to output variations among farms. The returns above paid-out costs ranged from US$75 to US$412 per hectare. Categories I and III had net losses which could have been avoided if farmers were able to sell their harvest at normal prices during the season.

Tillage, Irrigation and Crop Yields

In 1989, plant height of both maize and mungbean was affected more by season and elevation than by tillage or irrigation. At the head elevation, the plant height of maize reached about 2.7 m in DS I but only 2.0 m in DS II. On the other hand, mungbean plants in DS I were 0.49 m high and 0.53 m in DS II. At the tail elevation, maize was 2.3 m high in DS I while mungbean was 0.40 m.

Rooting depth of both crops and in both elevations was determined primarily by the depth to the water table. In DS I, at both head and tail elevations, the rooting depth of maize reached **35** cm and mungbean, 20 cm. In DS II, maize at the head elevation also reached 35 cm (but more quickly than in DS I because of the deeper water table). Similarly, mungbean at both elevations benefited from deeper water table to roots down to 29 cm depth.

Root mass density in the tilled zone (0-10 cm) responded slightly to tillage (especially intensive tillage), but more for maize than for mungbean, and more in DS II than in DS I. **Root mass within the whole rooting zone responded** to irrigation, at both elevations for both crops. These responses were consistent with the observed patterns of soil strength.

Grain **yields for maize and mungbean as affected** by tillage are presented in Table 13. Averaged over crops, season, and elevation, the benefit from maximum tillage (Tm) was higher than from strip tillage (Ts) and even much higher in the wetter than in the drier season. Maximum tillage gave slightly more benefit to the shallower-rooting mungbean than to the deeper-rooting maize.

Maize gave a lower yield/million plants with tillage (average of Ts and Tm) compared to no tillage (To). However, for the shallower-rooting mungbean, yield/plant with tillage was higher than without tillage.

Maize and mungbean responded to both 1-80 and I-40 irrigation treatments (Table 14). For maize, the incremental efficiency indicates that incremental water could be used effectively as the total water uptake of 201 mm was substantially below the potential season crop water requirement of about 300 mm. For mungbean, however, total water use of 134 mm comprised a larger portion of the potential requirement of about 170 mm, and the incremental efficiency of irrigation was lower.

For both mungbean and maize, total water use was similar for I-80 and 1-40 indicating that less irrigated plants have been able to take up additional soil matric water. Similarly, the least irrigated plants (I-S) made effective use of the postrice residual soil moisture and the pre-seeding 20 mm irrigation to produce almost 1 t/ha of mungbean grain and more than **4** t/ha of maize. For mungbean, tillage increased the effectiveness of using the postrice residual moisture.

Table 13. Effect of tillage on grain yield of mungbean and maize in various seasons and at various elevations at the Cikeusik Irrigation System, Cirebon, West Java, Indonesia.

Tillage	Head					Middle	Tail	
	1988/W	1989/I	1989/I	1989/II	1989/II	1988/I	1989/I	1989/I
	Mungbean							
	No. of reps included							
	5	5	5	5	3	5	5	3
	Grain yield (t/ha)							
None	0.95	1.19	-	-	0.98	0.73	-	0.95
Strip	-	0.98	-	-	1.06	0.85	-	1.01
Maximum	0.89	1.21	-	-	1.09	0.96	-	0.98
Std error	0.05	0.04	-	-	0.06	0.04	-	0.05
	Maize							
	No. of reps included							
	5	5	4	5	4	5	5	4
	Grain yield (t/ha)							
None	-	5.03	5.15	5.42	5.42	-	4.30	4.41
Strip	-	4.93	5.06	5.19	5.26	-	4.38	4.33
Maximum	-	5.10	5.13	4.57	4.79	-	5.07	5.32
Std. error	-	0.15	0.14	0.48	0.48	-	0.16	0.16

Notes: W = wet season.
I, II = DS I, DS II.
Experiments in 1988 DS I (head and tail), 1988 WS and 1989 DS 11 at tail elevation were destroyed by rats and viruses.
Std.= Standard

The economic value of the incremental yield gain from irrigation could correspond to irrigation deliveries of 10 mm every 5 days during 0-20 DAS and 20 mm every 7 days thereafter to 34 DAS. This would increase mungbean grain value from US$75 to US$100 and maize grain value from US$60 to US$90.

Elevations and Crop Sequences

Averaged over all tillage treatments, yields of mungbean and maize were higher at the head than at the tail elevation (Table 13). The lower yields at the tail may be due to the generally shallower water tables, higher plant population density for mungbean and partly to highest pest pressures.

Averaged over all tillage and irrigation treatments, grain yield of maize was higher in DS II than in DS I, while mungbean yield was higher in DS I than in DS II. Thus, the mungbean-maize sequence had higher productivity than the maize-mungbean sequence.

Table 14. Effect of irrigation on grain yield and grain yield per plant for mungbean and maize in 1989 DS II at the head elevation in Cikeusik Irrigation System, Cirebon, West Java, Indonesia.

Irrigation	Irrigation total (mm)	Total water use (mm)	Grain yield (t/ha) (kg/ha/mm)	Yield per mm total water (kg/Mp/mm)	Yield per plant (t/Mp)	Yield per plant per mm total water (kg/Mp/mm)
I-s	20	116	0.95	8.2	2.68	23
I-80	45	128	1.03	8.0	2.50	20
1-40	58	134	1.15	8.6	3.12	23
Std. error	2	10	0.07	1.1	0.21	3
I-s	20	153	4.20	27.5	52	340
1-80	65	201	5.65	28.1	64	320
I-40	78	200	5.61	28.1	66	330
Std. error	3	15	0.22	1.8	3	20

Note: Std. = Standard
Mp = Million plants.

Growth of Mungbean at Kuningan Experimental Farm

Differences between crop growth at the two elevations were apparent both in terms of plant height and grain yield. Maximum plant height at 7 weeks after seeding (WAS) averaged 47 cm at the upper elevation and 35 cm at the lower. The differences are substantial and began to develop at 5 WAS. Mungbean grain yield was also higher at the upper elevation.

At either elevation, plants were highest on the most irrigated plots (I-40). At the upper location, plants were marginally higher with tillage than without tillage. Plant height was similar for all tillage treatments at the lower elevation.

The effect of irrigation was confounded by the variability of drainage of the experimental fields. After normalizing the grain yields relative to the yield of the least-irrigated treatment and averaged over both elevations for all three tillage/ plant population treatments, yield progressively increased as irrigation total increased to 120 mm. This amount of irrigation corresponds to reirrigation at the 1-40 criterion. Higher irrigation resulted in yield decline probably because of rainfall occurrence, wetting recently irrigated soil and reducing the aeration to a level too low for effective root metabolic activity. At either elevation, highest yield would be achieved with no tillage, the 35 X 10 cm spacing and reirrigation when about 40 percent of the plant available water had been used.

CONCLUSIONS AND RECOMMENDATIONS

During the dry season, beginning from DS I to the end of DS II, canal water supplies of the irrigation system consistently declined (Wardana et al. 1990). In almost all canal areas, these discharges were too small to meet rice crop water requirements. This problem was more pronounced in the tail section than in the head section of the system.

Farmers are able to better exercise their options for crop choice, if canal water supplies are adequate for various crops, or if they have alternative sources of water supply such as groundwater. The benefit from using groundwater mostly came from higher yields due to alleviation of water stress and the higher levels of material and labor inputs used.

With respect to the actual choice of crops, farmers have to consider other important factors such as higher and more stable net returns. With its more stable price, rice is often preferred. Onion and chili farmers usually suffered the consequences of unstable price. The price fluctuation problem should be appropriately addressed by the concerned agencies. Appropriate marketing infrastructure, postharvest facilities and market information systems should be introduced to establish price stability of crops, particularly certain palawija crops such as **onion** and chili.

Further research should be conducted to establish the role of water availability, price stability and profitability in farmers' decision-making process in irrigated crop production systems.

Irrigation is done to rewet soil to field capacity whenever the 40 percent of the available water in the root zone is used which gives worthwhile returns of 28 kg grain/ha/mm water for maize and 8 kg/ha/mm for mungbean (Juliardi et al. 1990 and Abas et al. 1990). This corresponds to irrigation application (during rainless periods on soils of 50-60 percent clay) of 10 mm every 4-5 days during 0-20 DAS, and 20 mm every 6-7 days thereafter. Analyses of irrigation responses in terms of yield per plant per mm water indicated that technologies that establish and sustain high plant population densities (0.10 Mp/ha for maize and 0.50 Mp/ha for mungbean [Mp = million plants]) are also likely to promote efficient use of irrigation water. Irrigation also gives benefit by maintaining soil strength below the limit that constrains root and plant growth.

Persistence of groundwater as shallow as 30 cm constrained rooting and crop productivity in DS I at all elevations, and in DS II at the tail elevation. Because of shallow water table, productivity of both maize and mungbean was about 10 percent higher at the head than at the tail elevation, and about 5 percent higher in DS I than in DS II.

Postrice soil matric water (particularly if supported by a single pre-seeding irrigation) without further irrigation had potential to support 1t/ha of mungbean grain or 4 t/ha of maize. These yields are worthwhile for smallholder farmers.

The availability of postrice soil matric water might be manipulated to the advantage of the palawija crops by appropriate scheduling of the rice-phase irrigation. For shallow rooting mungbean, yield of a residual moisture crop can be increased by 33 percent by shallow tillage. And this tillage, and the subsequent seeding (for maize or mungbean), can be economically and effectively accomplished if the preceding rice is sown or transplanted in rows alternately spaced at 7 and 28 cm. The 28-cm spacing affords easy postrice access for operators and implements. Tillage also gives useful increases in mungbean emergence and helps ensure plant population densities sufficiently high that full benefit can be derived from irrigation.

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