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Study on Main Factors Affecting on Irrigation Water during Growing Stages of Paddy Crops

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Irrigation water is one of the most essential things that has to be concerned for the growth of paddy crops. In this study, first objective aimed to discuss about the main factors influencing the amount of irrigation water during growing stages of paddy crops based on historical data in Asakura Town, Fukuoka Prefecture, Japan. Second objective will focus on recent study of 1998 conducted on the same location as the former study for clarifying the actual irrigation water phenomena in the fields.

Historical data were analyzed using method of Quantitative Analysis I. Objective variables consisted of water consumption, field management and canal management, were examined for analyzing the irrigation water phenomena. Furthermore, main focus of recent study was to evaluate the concerning components of water balance in the fields.

Results showed that irrigation water for water consumption was strongly influenced by natural condition such as rainfall, but it was not affected by the action of farmers. On the contrary, irrigation water for field management and canal management were influenced by the principle action of farmers in managing the irrigation water to paddy crops. Total of irrigation water obtained from average data of 5 years observations that was required for water consumption, field management and canal management ranged of 57–113.45 mm/day. Furthermore, recent study showed the total of irrigation water that was necessary for water consumption, field management and canal management ranged of 46.33–236.32 mm/day. There was no significant change of irrigation water for water consumption in both the studies. However, relative percentage of irrigation water for field management and canal management increased 8% and 14% respectively comparing to the former study. These facts indicated that the actual irrigation water operated under traditional water right had been applied in higher range than the necessary, especially for field management and canal management. Farmers seem not intended to apply the irrigation water in a strict condition.

BACKGROUND

Amount of irrigation water given to paddy crops is one of the most essential things that has to be analyzed not only for providing crop need to sustained high yield but also for reducing management loss of water operation in the system (Basri *et al.*, 1998). In this area, the irrigation water given to paddy crops is decided by LID (Land Improvement District), which is a water user association, operated under traditional water right. Kuroda *et al.* (1997) reported that amounts of intake water on concerning LID operated under traditional water right, in Kyushu Island of Japan are widely ranged of 26.10–212 mm/day.

The irrigation water applied to paddy crops is not only affected by the conditions of the natural resources, but also influenced by the actions of farmers. The second one seems related to the performance of farmer action in operating the irrigation water in the fields. It is important to clarify those phenomena by investigating the actual condition in the fields. Therefore, first objective of this study will discuss about the main factors in influencing the irrigation water during growing stages of paddy crops based on historical data by using the method of Quantitative Analysis I. Second objective will talk about the recent study of 1998 conducted in the same location used for the former study for clarifying the actual irrigation water phenomena in the fields.

QUANTITATIVE ANALYSIS ON FACTORS AFFECTING THE IRRIGATION WATER DURING GROWING STAGES OF PADDY CROPS

Description of Study Area

The study was conducted on area of 14.76 ha of paddy field system in Asakura Town, Kyushu Island, Japan. The yearly average temperature is 16 °C and the annual rainfall is approximately 1800 mm. The irrigation water for paddy crops in this area is taken from Yamada Weir that is delivered through open channel irrigation canal. Table 1 shows the physical data of surveyed area from 1979 to 1983.

Table 1. Physical data of surveyed area (1979–1983).

Year	Paddy fields (ha)	Upland fields (ha)	Greenhouses (ha)	Settlement areas (ha)	Total (ha)
1979	10.66	0.44	2.66	1	14.76
1980	10.00	1.10	2.66	1	14.76
1981	8.48	2.62	2.66	1	14.76
1982	8.52	2.28	2.96	1	14.76
1983	8.41	2.39	2.96	1	14.76

Purpose of the study

This study aimed to discuss about the main factors influencing the irrigation water during growing stages of paddy crops based on historical data (1979–1983) by using the method of Quantitative Analysis I.

Method of Analysis

Method of Quantitative Analysis I, developed by Hayashi (1991), was used for evaluating observed data. The formulas of quantitative analysis that mentioned in previous paper (Kuroda *et al.*, 1997) and historical data from 1979 to 1983 (Kuroda, 1985) were used for analyzing the items and categories. General formula of quantitative analysis is presented in equation (1).

$$Y_i = \sum_{J=1}^{R}\sum_{k=1}^{c_j} a_{jk} * \chi_{i(jk)} \quad (i=1, 2,..., n; j=1, 2,..., R; \; k=1, 2,...,c_j) \qquad (1)$$

in which: i is number of samples, R is number of items and c_j is number of categories. $\chi_{i(jk)}$ is the item–category respond given as dummy variable as presented in equation (2).

$$\chi_{i(jk)} = \begin{cases} 1 : \textit{means yes, if } i^{th} \textit{ sample responds to item } j \textit{ of category } k \\ 0 : \textit{means no, if } i^{th} \textit{ sample do not respond to item } j \textit{ of category } k \end{cases} \quad (2)$$

Furthermore, a_{jk} is given as the explanatory variables in the j^{th} category of the k^{th} item. Then the effect of each category is expressed as multiplying of $a_{jk} * \chi_{i(jk)}$.

There were 3 objective variables consisted of water consumption (WC), field management (FM) and canal management (CM), which were considered as factors that have to be observed in clarifying the irrigation water phenomena in the fields. The definition of each objective variable is presented in the explanation of equations 3–10. There were 6 items for each objective variable i.e., rainfall, seepage, irrigation water performance, canal–check, convulsively drainage and field management. Rainfall had 3 categories, and others had 2 categories as presented below. Detail information for items and categories can be seen in Table 2.

Item (1), Rainfall (R)

Item (1) consisted of 3 categories i.e., much (M), medium (Md) and little (Lt). Fig. 1 shows the flowchart that was used for judging the categories.

Item (2), Seepage (SP)

Item (2) consisted of 2 categories i.e., large (L) and small (S). The categories of item (2) were determined as follows.

If seepage > 5 mm/day ⟶ large (L)
If seepage < 5 mm/day ⟶ small(S)

Item (3), Irrigation water performance (IW)

Item (3) consisted of 2 categories i.e., good (G) and bad (B). The categories of item (3) were determined as follows.

If FM+CM ≧ min (50 mm/day, WC) ⟶ good (G)
If FM+CM < min (50 mm/day,WC) ⟶ bad (B)
FM : Field management, CM : Canal management , WC : Water consumption

Item (4), Canal–check (CC)

Item (4) consisted of 2 categories i.e., high(H) and low(L). Water supply for paddy plot delivered from irrigation canal through irrigation pipe installed beneath the levee. Instead of using water gate, this water controlled by using a stone arranged close to the inlet pipe. If the stone was vertical, the category was high (H). On the contrary, if the position of stone was horizontal, the category was low (L)

Item (5), Convulsively drainage (CD)

Item (5) consisted of 2 categories i.e., yes (Y) and no (N). The data were arranged from the results of questionnaire during this period.

Item (6), Field management (FM)

Item (6) consisted of 2 categories i.e., rough (R) and precise (P). The data were also arranged from the results of questionnaire during this period.

Table 2. Objective variables of irrigation water, items and categories (1979–1983).

Growing stages of paddy crops	Years	Samples	Purpose of variables			Items and Categories					
			WC	FM	CM	Item(1)	Item(2)	Item(3)	Item(4)	Item(5)	Item(6)
			(mm/day)	(mm/day)	(mm/day)	judged categories of items					
Tillering (7/1–7/20)	1979	1	36.80	13.20	26.50	1(M)	2(S)	1(G)	2(L)	2(N)	1(R)
	1980	2	27.70	13.20	30.50	1(M)	2(S)	1(G)	2(L)	2(N)	1(R)
	1981	3	48.10	15.00	51.70	1(M)	2(S)	1(G)	2(L)	2(N)	1(R)
	1982	4	38.80	6.80	4.00	1(M)	2(S)	2(B)	1(H)	2(N)	1(R)
	1983	5	63.10	17.10	51.20	3(Lt)	2(S)	1(G)	2(L)	2(N)	1(R)
Midsummer Drainage (7/21–7/31)	1979	6	57.20	8.20	14.30	3(Lt)	2(S)	2(B)	2(L)	1(Y)	2(P)
	1980	7	30.50	8.00	10.20	1(M)	2(S)	2(B)	2(L)	1(Y)	2(P)
	1981	8	47.70	2.10	35.20	1(M)	2(S)	2(B)	2(L)	1(Y)	2(P)
	1982	9	11.90	12.80	0.50	1(M)	2(S)	1(G)	1(H)	1(Y)	2(P)
	1983	10	19.90	7.30	22.80	3(Lt)	2(S)	1(G)	2(L)	1(Y)	2(P)
After Midsummer Drainage (8/1–8/11)	1979	11	40.70	45.90	19.60	3(Lt)	1(L)	1(G)	2(L)	2(N)	2(P)
	1980	12	15.40	14.30	11.10	1(M)	1(L)	1(G)	2(L)	1(Y)	2(P)
	1981	13	50.30	12.70	27.30	2(Md)	1(L)	2(B)	2(L)	2(N)	2(P)
	1982	14	25.00	15.30	4.40	2(Md)	1(L)	2(B)	1(H)	2(N)	2(P)
	1983	15	93.40	25.80	35.60	3(Lt)	1(L)	1(G)	1(H)	2(N)	2(P)
Growing and Booting (8/12–8/31)	1979	16	51.00	26.50	14.60	2(Md)	1(L)	2(B)	2(L)	2(N)	1(R)
	1980	17	48.10	42.90	11.70	1(M)	1(L)	1(G)	2(L)	1(Y)	1(R)
	1981	18	55.60	22.10	28.70	2(Md)	1(L)	1(G)	2(L)	2(N)	1(R)
	1982	19	41.90	24.40	8.10	1(M)	1(L)	2(B)	1(H)	1(Y)	1(R)
	1983	20	18.00	79.50	35.10	3(Lt)	1(L)	1(G)	1(H)	2(N)	1(R)
Heading and Flowering (9/1–9/10)	1979	21	59.10	23.60	0.00	1(M)	2(S)	2(B)	2(L)	1(Y)	2(P)
	1981	22	53.20	13.20	16.50	3(Lt)	2(S)	2(B)	2(L)	2(N)	2(P)
	1982	23	76.60	31.40	7.10	2(Md)	2(S)	2(B)	1(H)	2(N)	2(P)
	1983	24	34.70	58.70	40.00	3(Lt)	2(S)	1(G)	2(L)	2(N)	1(R)
Milk Ripening (9/11–9/20)	1979	25	71.10	21.50	0.00	3(Lt)	2(S)	2(B)	2(L)	2(N)	1(R)
	1981	26	35.90	41.90	20.90	2(Md)	2(S)	1(G)	2(L)	2(N)	1(R)
	1982	27	50.00	35.70	12.40	2(Md)	2(S)	2(B)	1(H)	2(N)	1(R)
	1983	28	31.80	60.30	49.80	3(Lt)	2(S)	1(G)	2(L)	1(Y)	1(R)
Drought Ripening (9/21–9/30)	1979	29	72.50	26.70	6.70	3(Lt)	2(S)	2(B)	2(L)	2(N)	1(R)
	1981	30	35.10	22.50	37.60	3(Lt)	2(S)	1(G)	2(L)	2(N)	1(R)
	1982	31	23.00	79.30	2.10	1(M)	2(S)	1(G)	1(H)	1(Y)	1(R)
	1983	32	74.80	23.10	50.40	3(Lt)	2(S)	1(G)	2(L)	2(N)	1(R)
Full Ripening (10/1–10/9)	1979	33	57.50	22.00	8.00	3(Lt)	2(S)	2(B)	2(L)	2(N)	1(R)
	1981	34	27.80	33.20	20.60	1(M)	2(S)	1(G)	2(L)	1(Y)	1(R)
	1983	35	27.80	31.10	49.80	1(M)	2(S)	1(G)	2(L)	2(N)	1(R)

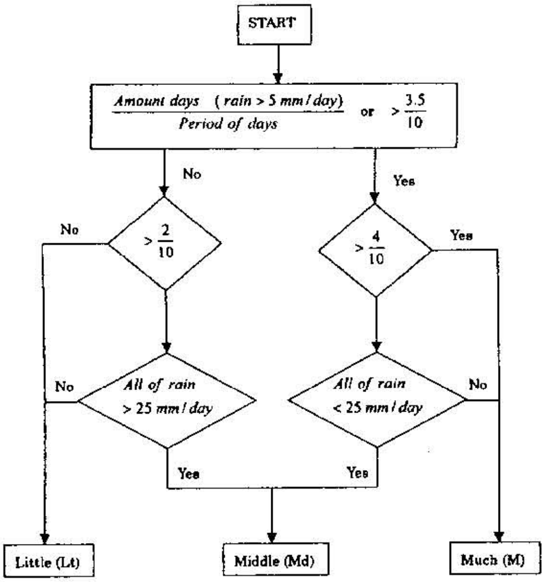

Fig. 1. Flowchart for judging the item (1).

Results and Discussion

Fig. 2, 3 and 4 show category–weight of irrigation water for water consumption, field management and canal management. The values of observed irrigation water (y_i) and predicted irrigation water (Y_i) for each objective variable are shown in Table 3. Multiple correlation coefficients (γ) between observed irrigation water and predicted irrigation water those using dummy variables are also shown in Table 3. The values of coefficient γ are significant in F test (α 0.05).

Category–weight

Water Consumption

Fig. 2 shows category weight of irrigation water for water consumption purpose. The category weight from up to bottom successively shows the influence of natural condition and farmer action on water consumption. The natural condition regarded rainfall and seepage, while the farmer action concerned irrigation water performance, canal check, convulsively drainage and field management.

Irrigation water for water consumption was strongly affected by the rainfall (partial correlation R=0.309) but was not affected by the seepage (R=0.031). In the case of no rainfall, the category weight shows the positive value, vice versa. It means that the water consumption tended to increase in this condition. On the contrary, the water consumption tended to decrease due to the existence of rainfall. In the case of seepage, it seems that no relationships between the seepage and the water consumption. The water consumption was also strongly influenced by the irrigation water performance (R=0.406) and the convulsively drainage (R=0.294), but was not affected by the canal check (R=0.096) and the field management (R=0.002).

Field Management

Fig. 3 shows that the irrigation water for field management purpose was strongly affected by the rainfall (R=0.420), the irrigation water performance (R=0.384), the canal–check (R=0.414), the convulsively drainage (R=0.349), the field management (R=0.492) and was slightly influenced by the seepage (R=0.148). The results of category weight show that the effect of rainfall tended to decrease. On the contrary, effects of the irrigation water performance, the canal check, the convulsively drainage and the field management tended to increase. It means that this kind of irrigation was more influenced by the action of farmers than the development of natural resources.

Canal Management

As shown in Fig. 4, irrigation water for the canal management purpose was strongly affected by the irrigation water performance (R=0.556), the canal–check (R=0.304), the convulsively drainage (R=0.314) and was slightly influenced by the rainfall (R=0.150). But, irrigation water was not affected by the seepage (R=0.070) and the field management (R=0.029). Those phenomena show that the canal management was also more influenced by the activity of farmers than the condition of natural resources. On the other words, the revealing of irrigation water applied into paddy crops due to the field management and the canal management was strongly influenced by the principle action of farmers.

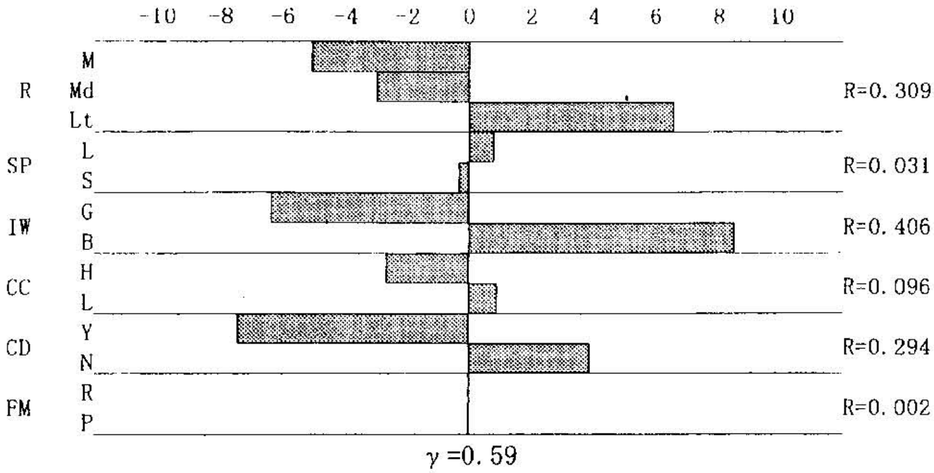

Fig. 2. Category–weight of irrigation water for the water consumption.

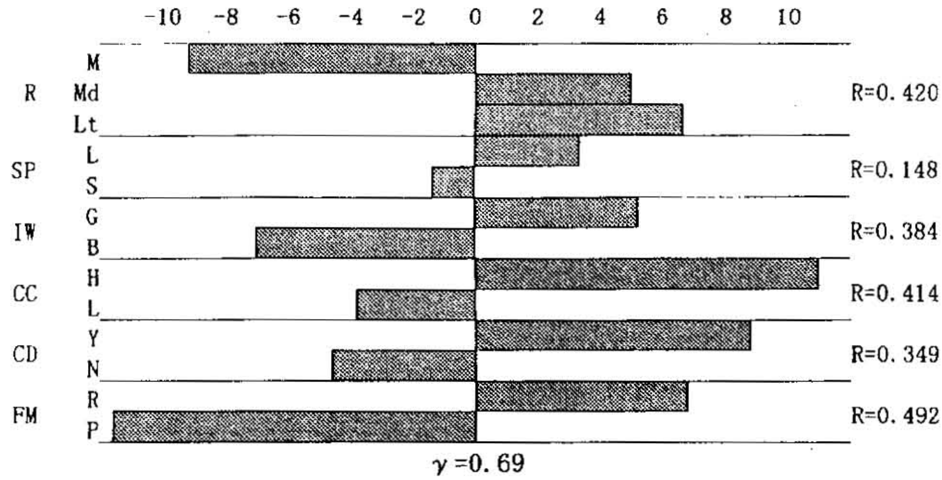

Fig. 3. Category–weight of irrigation water for the field management.

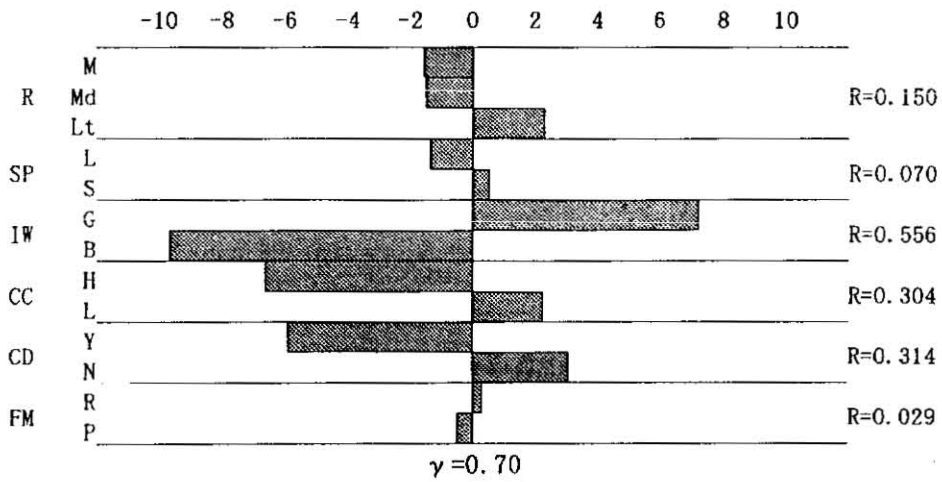

Fig. 4. Category–weight of irrigation water for the canal management.

Analysis of Irrigation Water

Table 3 shows that the observed and predicted values of irrigation water for each objective variable during growing stages of paddy crops varied from 1979 to 1983. In this case, the average values of irrigation water for each objective variable are important to be discussed. Furthermore, Fig. 5 shows the information of irrigation water for water consumption, field management and canal management.

Water Consumption

Table 3 and Fig. 5 show that irrigation water for the water consumption ranged of 33.44–55.90 mm/day. The highest water consumption was observed in the heading and flowering stages (55.90 mm/day). While, the lowest water consumption was observed in the mid summer drainage stage (33.44 mm/day). The water consumption of other stages seemed to be constant around 45 mm/day. Vertical percolation was the dominant factor in affecting the water consumption due to the high soil porosity in this area.

Field Management

As shown in Table 3 and Fig. 5, the irrigation water for field management during growing stages of paddy crops ranged of 7.68–39.85 mm/day. The irrigation water in the tillering stage was around 13.06 mm/day. The highest irrigation water was observed in the growing and developing of paddy crops ranged of 31.73–39.85 mm/day. The lowest irrigation water was found in the mid summer drainage stage (7.68 mm/day) and increased in the after midsummer drainage stages (22.80 mm/day). Furthermore, the irrigation water tended to decrease in the full ripening stage (28.77 mm/day). Maruyama *et al.* (1995) reported that irrigation water for field management conducted for various proposes such as drainage of ponded water, mid summer drainage, fertilizer or chemical solvent and water management labor.

Canal Management

Table 3 and Fig. 5 depict that the irrigation water for canal management ranged of 15.90–32.78 mm/day. The highest irrigation water was observed in the tillering stage (32.78 mm/day) and tended to decrease in the stages of mid summer drainage and after

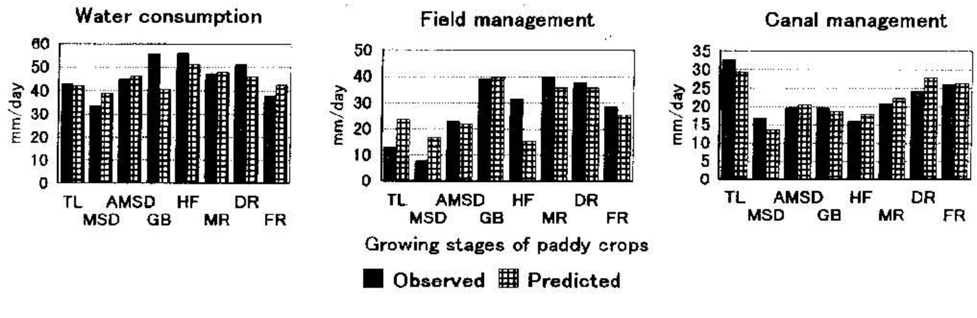

Fig. 5. Average values of irrigation water for each objective variable during growing stages of paddy crops (1979–1983).

Table 3. Observed (y_i) and predicted (Y_i) values of irrigation water for each objective variable during growing stages of paddy crops (1979–1983).

Growing stages of paddy crops	Years	Sample	Purpose of variables: Irrigation water for Water consumption (mm/day) (y_i)	(Y_i)	Irrigation water for Field management (mm/day) (y_i)	(Y_i)	Irrigation water for Canal management (mm/day) (y_i)	(Y_i)
Tillering (7/1–7/20)	1979	1	36.80	37.38	13.20	19.92	26.50	33.76
	1980	2	27.70	37.38	13.20	19.92	30.50	33.76
	1981	3	48.10	37.38	15.00	19.92	51.70	33.76
	1982	4	38.80	48.70	6.80	22.44	4.00	7.95
	1983	5	63.10	49.04	17.10	35.78	51.20	37.62
		Avg.	42.90	41.98	13.06	23.60	32.78	29.37
Midsummer Drainage (7/21–7/31)	1979	6	57.20	52.55	8.20	18.57	14.30	10.92
	1980	7	30.50	40.88	8.00	2.71	10.20	7.06
	1981	8	47.70	40.88	2.10	2.71	35.20	7.06
	1982	9	11.90	22.41	12.80	29.75	0.50	15.08
	1983	10	19.90	37.65	7.30	30.83	22.80	27.83
		Avg.	33.44	38.87	7.68	16.91	16.60	13.59
After Midsummer Drainage (8/1–8/11)	1979	11	40.70	50.10	45.90	22.14	19.60	34.91
	1980	12	15.40	27.11	14.30	19.71	11.10	22.08
	1981	13	50.30	55.43	12.70	8.20	27.30	14.19
	1982	14	25.00	51.86	15.30	22.98	4.40	5.29
	1983	15	93.40	46.53	25.80	36.91	35.60	26.01
		Avg.	44.96	46.21	22.80	21.99	19.60	20.50
Growing and Booting (8/12–8/31)	1979	16	51.00	55.50	26.50	26.59	14.60	15.00
	1980	17	48.10	27.18	42.90	38.10	11.70	22.89
	1981	18	55.60	40.60	22.10	38.85	28.70	31.92
	1982	19	41.90	38.50	24.40	40.61	8.10	-2.92
	1983	20	18.00	46.59	79.50	55.30	35.10	26.82
		Avg.	42.92	41.67	39.08	39.89	19.46	18.74
Heading and Flowering (9/1–9/10)	1979	21	59.10	40.88	23.60	2.71	0.00	7.06
	1981	22	53.20	63.87	13.20	5.14	16.50	19.89
	1982	23	76.60	50.73	31.40	18.24	7.10	7.19
	1983	24	34.70	49.04	58.70	35.78	40.00	37.62
		Avg.	55.90	51.13	31.73	15.47	15.90	17.94
Milk Ripening (9/11–9/20)	1979	25	71.10	63.94	21.50	23.52	0.00	20.70
	1981	26	35.90	39.48	41.90	34.11	20.90	33.81
	1982	27	50.00	50.80	35.70	36.63	12.40	8.00
	1983	28	31.80	37.72	60.30	49.22	49.80	26.64
		Avg.	47.20	47.99	39.85	35.87	20.78	22.29
Drought Ripening (9/21–9/30)	1979	29	72.50	63.94	26.70	23.52	6.70	20.70
	1981	30	35.10	49.04	22.50	35.78	37.60	37.62
	1982	31	23.00	22.48	79.30	48.13	2.10	15.89
	1983	32	74.80	49.04	23.10	35.78	50.40	37.62
		Avg.	51.35	46.13	37.90	35.80	24.20	27.96
Full Ripening (10/1–10/9)	1979	33	57.50	63.94	22.00	23.52	8.00	20.70
	1981	34	27.80	26.05	33.20	33.35	20.60	24.79
	1983	35	27.80	37.38	31.10	19.92	49.80	33.76
		Avg.	37.70	42.46	28.77	25.60	26.13	26.42
Multiple correlation coefficient(F test: α 0.05)			γ =0.59 (Significant)		γ =0.69 (Significant)		γ =0.70 (Significant)	

mid summer drainage ranged of 16.60–19.60 mm/day. Furthermore, the irrigation water in growing and booting stage was 19.64 mm/day and it was slightly decrease in heading and flowering stage (15.90 mm/day). In addition, the irrigation water in ripening stages tended to increase ranged of 20.78–26.13 mm/day.

Total of Irrigation Water

Fig. 6 show the total of irrigation water obtained from the total of average irrigation water for water consumption, field management and canal management. From Fig. 6, it can be seen that the total of irrigation water ranged of 57.72–113.45 mm/day. Mid

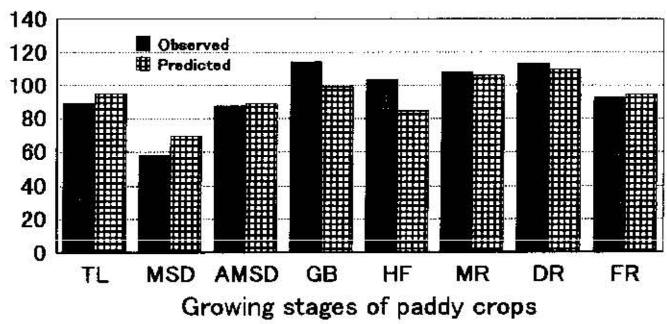

Fig. 6. Total of irrigation water during growing stages of paddy crops (1979–1983).

summer drainage and tillering stages showed the lowest irrigation water ranged of 57.72–88.74 mm/day. Total of irrigation water tended to increase up to 100 mm/day in the stages of growing and developing of paddy crops. And it was slightly decrease in the full ripening stage (92.6 mm/day). These phenomena showed that the increasing of irrigation water during the stages of growing and developing was reasonable for anticipating the adequate water due to the sensitivity of paddy crops for the water shortage in this condition.

Relative Percentage of Irrigation Water

Fig. 7 shows that relative percentage of irrigation water for water consumption ranged of 40.7–57%, which was higher than other purposes. It can be said that roughly half of the total irrigation water (48%) was used for completing the water consumption. The percentage of irrigation water for the field management ranged of 13.3–38%. Average of irrigation water due to the field management during growing stages was around 28%. Furthermore, the percentage of irrigation waters for canal management ranged of 15.4–36.9%. And the average of irrigation water for canal management was 24%. These facts indicated that the performance of water management in this condition was reasonable.

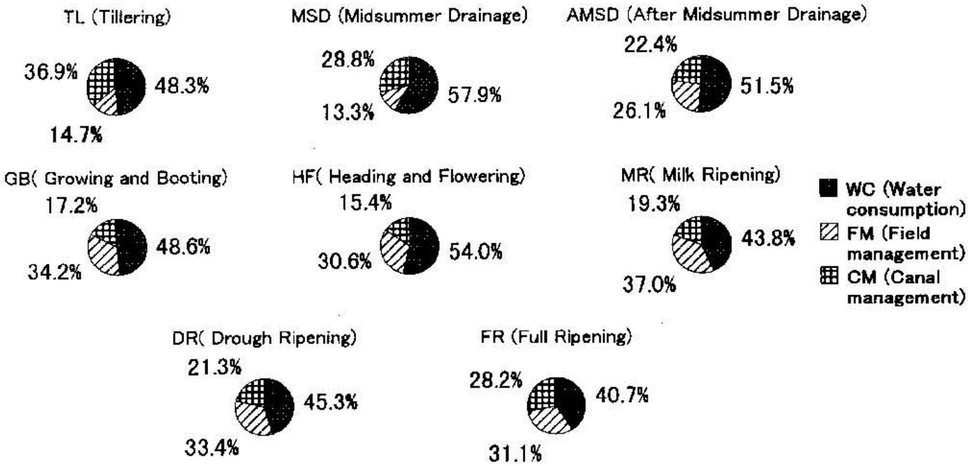

Fig. 7. Relative percentage of irrigation water for each objective variable during growing stages of paddy crops (1979–1983).

ACTUAL CONDITION OF IRRIGATION WATER DURING GROWING STAGES OF PADDY CROPS IN RECENT STUDY

Location of Study Area

The study was done on the area of 3.04 ha of paddy field system in Asakura Town, Kyushu Island of Japan in 1998; the same location used for the former study. Representation of study area is depicted in Fig. 8.

Purpose of the study

This study aimed to clarify the actual irrigation water phenomena by investigating the water balance components in the fields during growing stages of paddy crops in 1998. In addition, comparisons of the result with former study based on historical data are also presented.

Method of Analysis

Water balance components were investigated in the fields during growing stages of paddy crops. From Fig. 8, the formulas of water balance are expressed as follows.

Water Balance in Irrigation canal:

$$Qinic = Q_1 + (Q_4 - Q_5) \quad (3)$$

$$Qinp = Q_1 + (Q_4 - Q_5) - Q_6 \quad (4)$$

$$Qinp = Qinic - Q_6 \quad (5)$$

$$Qoutic = Q_6 \quad (6)$$

in which: *Qinic* is the total of water inflow into irrigation canal; *Qoutic* is the total of water outflow from drainage canal, which can be said as Canal management (*CM*); *Qinp* is water inflow from irrigation canal into paddy fields; Q_1, $Q_2 \ldots Q_8$ are observed discharges on concerning points. Those discharges were measured using Current meter.

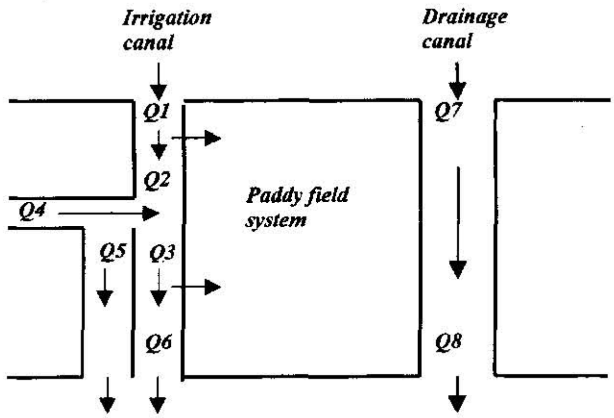

Fig. 8. Schematic representation of study area in Asakura Town, Fukuoka, Japan (1998).

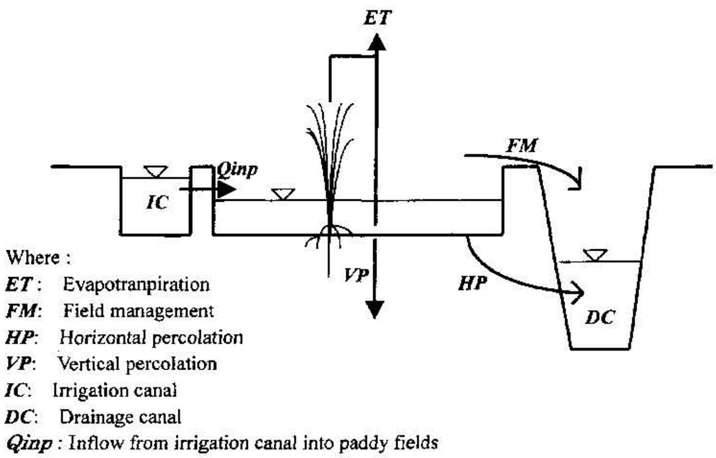

Fig. 9. Water balance components in the paddy fields and in the drainage canal (1998).

The water balance components in the paddy fields and in the drainage canal is presented in Fig. 9. From Fig. 9, the formulas of water balance can be expressed as follows.

Water balance in paddy fields:

$$WC = ET + VP + HP \tag{7}$$

$$Qinp = ET + VP + HP + FM \tag{8}$$

Water balance in drainage canal:

$$DC = HP + FM \tag{9}$$

$$HP = 0.122\ VP \tag{10}$$

in which: WC is water consumption (mm/day), which is observed using Hook gauge method.; ET is evapotranspiration (mm/day), which is calculated using Penman method. VP is vertical percolation (mm/day); HP is horizontal percolation (mm/day); DC is discharge in drainage canal (mm/day); FM is management of fields (mm/day). Equation (10) was able to be used for finding horizontal percolation in this area (Kuroda, 1985).

Results and Discussion

Table 4 shows the observed data of irrigation water for water consumption, field management and canal management. Those data were obtained using the above water balance formulas. For finding the reasonable results, the observation of data was replicated 2–3 times in the fields during the growing stage of paddy crops. Total of irrigation water received the location of the study can be seen from the *Qinic* data. Furthermore, *Qoutic* data represented the irrigation water for canal management (*CM*). For more clear informations, the average values of irrigation water for water consumption, field management and canal management is shown in Fig. 10.

Water Consumption

Table 4 and Fig. 10 show that the average values of irrigation water for water consumption purpose ranged of 15.00–54.00 mm/day. The highest water consumption was observed in the growing and booting stage (54.00 mm/day). On the contrary, the lowest water consumption was found in the ripening stage (15.00 mm/day). While, water consumption for other stages seemed to be constant around 31.40 mm/day. Those data were not so different comparing to the former analysis based historical data, which were ranged of 33.44–55.90 mm/day. It means that there was no significant changing in water consumption for paddy crops in the last 20 years in this area. Koga (1992) reported that the water consumption ranged of 20–30 mm/day and the optimum percolation rate ranged of 15–25 mm/day.

Besides the affect of soil porosity, it might be relate to the use of machinery in turning the soil that can influence the soil structure condition. Many cracks of bare soil were found in the fields, which stimulated percolation to be increase. Furthermore, the cracks affect permeability in a field. In particular, under flood conditions the influence is significant because water flows quickly down through the cracks (Ishiguro, 1992). It was recommended to find a method how to control the percolation. In this case, Koga (1992) reported that soil–dressing method could be implemented for controlling the percolation.

Field Management

Table 4 and Fig. 10 depict that the irrigation water for field management ranged of 5.32–100.61 mm/day. The highest irrigation water was observed in the growing and

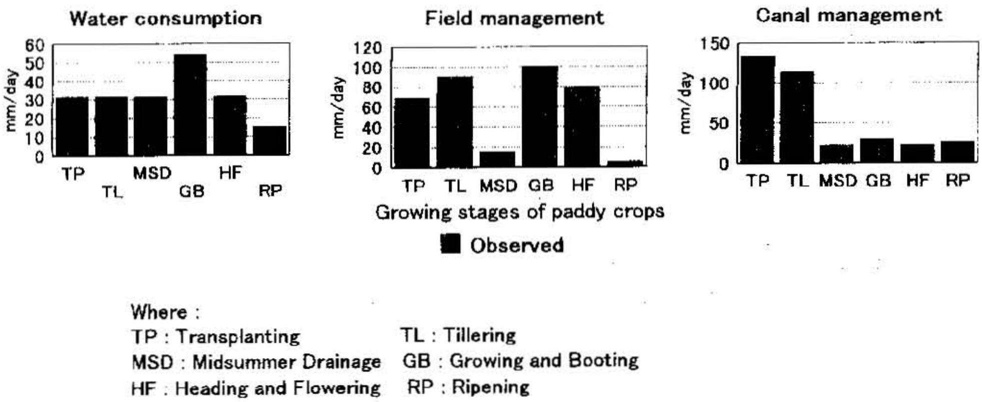

Fig. 10. Average values of irrigation water for each objective variable during growing stages of paddy crops (1998).

Table 4. Observed data of irrigation water for water consumption, field management and canal management (1998).

Growing Stages of paddy crops	Time of observations	*Qinic* (mm/day) ①	*Qoutic(CM)* (mm/day) ②	*Qinp* (mm/day) ③	*WC* (mm/day) ④	*FM* (mm/day) ⑤	*VP* (mm/day) ⑥	*HP* (mm/day) ⑦	*ET* (mm/day) ⑧
23-6-1998 (Transplanting)	12:15–13:20	220.26	121.64	98.62	31.40	67.22	25.94	3.16	2.30
	14:35–15:25	241.58	150.92	90.66	31.40	59.26	25.94	3.16	2.30
	16:25–16:58	237.88	127.33	110.56	31.40	79.16	25.94	3.16	2.30
	AVG.	233.24	133.29	99.95	31.40	68.55	25.94	3.16	2.30
3-7-1998 (Tillering)	11:46–12:39	231.92	115.67	116.24	31.40	84.84	22.82	2.78	5.80
	15:30–16:30	240.73	113.12	127.61	31.40	96.21	22.82	2.78	5.80
	AVG.	236.32	114.39	121.93	31.40	90.53	22.82	2.78	5.80
24-7-1998 (Midsummer Drainage)	10:55–12:00	61.11	22.17	38.94	31.40	7.54	22.82	2.78	5.80
	14:00–14:35	61.96	26.43	35.53	31.40	4.13	22.82	2.78	5.80
	16:00–16:30	86.97	19.61	67.36	31.40	35.96	22.82	2.78	5.80
	AVG.	70.01	22.74	47.27	31.40	15.87	22.82	2.78	5.80
7-8-1998 (Growing and Booting)	11:03–11:54	180.76	28.42	152.34	54.00	98.34	42.69	5.21	6.10
	13:15–14:25	189.00	32.12	156.88	54.00	102.88	42.69	5.21	6.10
	AVG.	184.88	30.27	154.61	54.00	100.61	42.69	5.21	6.10
28-8-1998 (Heading and Flowering)	11:00–11:50	136.42	23.02	113.40	31.40	82.00	24.24	2.96	4.20
	15:00–15:35	131.59	23.31	108.28	31.40	76.88	24.24	2.96	4.20
	AVG.	134.01	23.16	110.84	31.40	79.44	24.24	2.96	4.20
18-9-1998 (Ripening)	10:51–11:35	52.58	23.87	28.71	15.00	13.71	10.16	1.24	3.60
	14:20–14:54	40.07	28.14	11.94	15.00	-3.06	10.16	1.24	3.60
	AVG.	46.33	26.01	20.32	15.00	5.32	10.16	1.24	3.60

booting stage (100.61 mm/day). It was 3 times higher than the former result (39.08 mm/day). Such phenomena occurred also in the other stages ranged of 68.55–90.53 mm/day, except in the mid summer drainage stage and the ripening stage ranged of 5.32–15.87 mm/day. It can be said that farmers applied the irrigation water for field management was inefficient. These phenomena seemed relate to the action of farmers that were nervous to operate the field management in strict conditions.

Canal Management

As shown also in Table 4 and Fig. 10, the irrigation water for the canal management ranged of 22.74–133.29 mm/day. The highest water consumption was found in the transplanting stage and the tillering stage ranged of 114.39–133.29 mm/day, which was 3 times higher than the former study (32.78 mm/day). But irrigation water for other stages ranged of 22.74–30.27 mm/day, which were slightly different compared to the former study ranged of 15.90–26 mm/day. In this case, water loss caused by canal management during the transplanting stage and tillering stage can be categorized inefficient.

Total of Irrigation Water

Fig. 11 shows that total irrigation water resulted from the summation of water consumption, field management and canal management ranged of 46.33–236 mm/day. The total irrigation water during the transplanting stage and the tillering stage ranged of 233.24–236.32 mm/day, which were 2.5 times higher than the former study (88.74 mm/day). Furthermore, total irrigation during the heading and flowering stage was 134.01 mm/day, which was slightly higher than the former study (103.53 mm/day). But the total irrigation during the ripening stage (46.33 mm/day) was slightly lower than the former study (ranged of 92.6–113.45 mm/day).

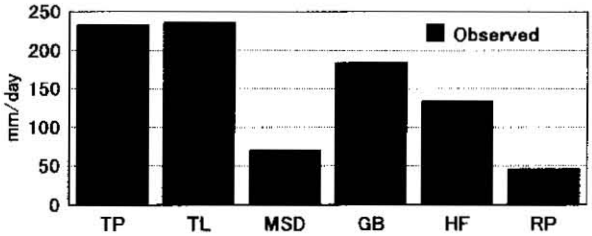

Fig. 11. Total irrigation water during growing stages of paddy crops (1998).

Relative Percentage of Irrigation Water

Transplanting stage and Tillering stage

Fig. 12 shows that relative percentage of irrigation water for each objective variable. The percentage of irrigation water for water consumption during the transplanting and tillering stages ranged of 13.3–13.5% and was lower than irrigation water for field management ranged of 29.4–38.3%. On the contrary, the percentage of irrigation water for canal management was higher than the other purposes (48.4–57.1%). It means that the water loss tended to increase in these stages. These facts were also shown in Table 4 and Fig. 10. These data depicted that farmers seemed to be nervous in starting the application of irrigation water into paddy crops with strict condition. However, those phenomena showed the low performance actions of farmers in operating the irrigation water.

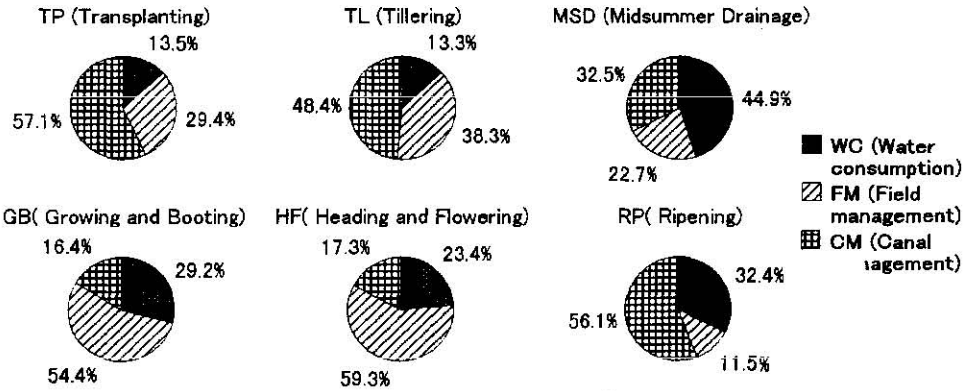

Fig. 12. Relative percentage of irrigation water for each objective variable during growing stages of paddy crops (1998).

Midsummer Drainage stage

The percentage of irrigation water for water consumption in mid summer drainage stage (44.9%) was higher than the other purposes (22.7–32.5%) as presented in Fig. 12. The low total of irrigation water during mid summer drainage as shown in Fig. 11 was proposed for improving of growth condition. In addition, most of irrigation water in this stage was only conducted for fulfilling the water consumption purpose consisted of percolation, seepage and evapotranspiration. Therefore, the relative percentage of field management and canal management seemed to decrease. In this case, the water application conducted by farmers was reasonable.

Growing and Booting stage, and Heading and Flowering stage

An interesting phenomenon presented in these stages was that the percentage of irrigation water for field management (54.4–59.3%) was also higher than the other purposes, which were for canal management (16.4–17.3%) and for water consumption (23.4–29.2%) as shown in Fig. 12. These facts indicated that irrigation water for field management during these stages was conducted roughly by farmers. Farmers seemed to avoid the risk of water shortage on the paddy growth in these stages. However, it was suggested to consider this action in drought season in which the availability of irrigation water was decrease.

Ripening stage

As shown in Fig. 12, the percentage of irrigation water for canal management (56.1%) was higher than those for other purposes in which for field management and water consumption were 11.5% and 32.4%, respectively. These facts were reasonable, because the irrigation water for water consumption in ripening stage was only proposed for keeping the condition of the paddy crops. In addition, although the relative percentage of canal management was high, the actual irrigation water for canal management was the lowest compared to the other stages as shown in Fig. 12.

Average percentages of irrigation water for the water consumption, the field management and the canal management were around 26%, 36% and 38%, respectively. The percentage of the field management and the canal management tended to increase 8 % and 14% comparing to former study. These facts mean that the water loss from the system was also higher than the former study. Actually, improving the knowledge of farmers in operating the irrigation water could prevent this phenomenon

CONCLUSIONS

Results based on historical data showed that water consumption was strongly influenced by natural condition such as rainfall, but it was not affected by the action of farmers. On the contrary, irrigation water for field management and canal management were strongly affected by the principle action of farmers in managing the application of irrigation water to paddy crops. Method of Quantitative Analysis I was applicable to be used for analyzing the main factors affecting the irrigation water during growing stage of paddy crops. Average irrigation water for water consumption, field management and canal management based on historical data ranged of 33.44–55.90 mm/day, 7.68–39.85 mm/day and 15.90–32.78 mm/day, respectively. Total irrigation resulted from the summation of those average values ranged of 57.72–113.45 mm/day. In addition, relative percentages of irrigation water for water consumption, field management and canal management were around 48%, 28% and 24%, respectively.

Recent studies showed that average of irrigation water for water consumption, field management and canal management ranged of 15.00–54.00 mm/day, 5.32–100.61 mm/day and 22.74–133.29 mm/day, respectively. There was no significant change in irrigation water for water consumption of paddy crops. In addition, total irrigation water resulted from the summation of those average values ranged of 46.33–236.2 mm/day. Relative percentages of irrigation water for water consumption, field management and canal management were around 26%, 36% and 38%, respectively. These data depicted that the percentages of field management and canal management tended to increase 8% and 14%, respectively.

Obtained fact indicated that there was a new trend of irrigation water application in the fields operated under traditional water right, especially due to field management and canal management. Farmers seemed nervous in applying the irrigation water in the strict condition. The performances of farmer action in managing the irrigation water are important to upgrade, especially for canal management and field management purposes. Therefore, it is suggested to improve the knowledge of farmers in operating the irrigation water for yielding the high efficiency of water management in this area.

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