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Analysis of Intake Water of Agricultural Water Use Operated under Traditional Water Right in Japan

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This study aimed to analyze the primary factors affecting the actual intake water of agricultural water use from water facility. The study was conducted on 19 locations of water user association called Land Improvement District (LID) which were operated under traditional water right in Kyushu Island, Japan during irrigation period of 1997.

Quantitative analysis I, developed by Hayashi, was applied for the analyses. The explanatory variables consisted of 6 items and 18 categories. Each explanatory variable (item and category) was given as dummy variable such as 1 or zero.

Results showed that the intake water was affected by the location of beneficiary area, the intake water for another purposes and the size of beneficiary area. The intake water varied to the concerning LID. The observed intake water ranged from 26.10 mm/day to 212.10 mm/day and the predicted intake water ranged from 24.53 mm/day to 210.53 mm/day (Case 1, γ=0.96). The obtained results were reasonable to explain the characteristics of the factors affecting the actual intake water of agricultural water use in those areas.

INTRODUCTION

Kuroda et. al (1997) reported that there are 99.000 of the total of institutions of intake water of agricultural water use in Japan consisted of 88.000 of institutions (88.9%) are operated under traditional water right and 11.000 of institutions (11.1%) are operated under permitted water right. Furthermore, the total of beneficiary area are 2.400.000 ha consisted of 1.160.000 ha (48.3%) are managed under traditional water right and 1.240.000 ha (51.7%) are handled under permitted water right.

The above data show those most of intake water of agricultural water use and half of total beneficiary areas are operated under traditional water right. The application of the intake water to the beneficiary area follows the operating rules stated by traditional water right.

The study was conducted on 19 locations of water use association called Land Improvement District (LID) which were operated under traditional water right in Kyushu Island of Japan during irrigation period of 1997 for investigating the primary factors affecting the actual intake water of agricultural water use. In this study, some factors are considered as items affecting the amount of intake water i.e., river management, location of beneficiary area, intake water for other purposes, size of beneficiary area, length of irrigation canal and ratio between length of irrigation canal and size of beneficiary area.

METHOD OF ANALYSIS

Observed data were analyzed using quantitative analysis I, which is one kind of the discriminant analysis theories developed by Hayashi (1991) concerning the multivariate analysis theories. The intake water of agricultural use has a numerical value (mm/day) as an objective variable or outside criterion variable. It is tried to predict such quantitative objective variable by combination of several quantitative indexes.

General formula of quantitative analysis is presented in equation (1).

$$Y_i = \sum_{j=1}^{R}\sum_{k=1}^{C_j} a_{jk} * x_{i(jk)} \qquad (i=1, 2,\cdots, n\,; j=1, 2, \cdots, R\,;\; k=1, 2, \cdots, c_j\;) \qquad (1)$$

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

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

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 $a_{jk}*x_{(jk)}$. Equation (1) is converted into equation (3) for normalizing the numerical treatments using the mean of outside variables $\overline{Y}$.

$$Y_i = \overline{Y} + \sum_{j=1}^{R}\sum_{k=1}^{c_j} (a^{\bullet}_{jk} * x_{i(jk)}) \qquad (3)$$

$$\text{in which: } a^{\bullet}_{jk} = a_{jk} - \frac{1}{n} * \sum_{l=1}^{c_j} (n_{jl} * a_{jl}) \qquad (4)$$

This analysis aimed to obtain suitable set of category weights a_{jk} for explaining suitable set of objective variable Y_i. The method of least square presented in equation (5) was applied for making a reasonable prediction of the category weights.

$$Q = \min \sum_{i=1}^{n} (y_i - Y_i)^2 \qquad (5)$$

in which y_i is the observed intake water on the concerned location (mm/day) and Y_i is the predicted intake water (mm/day) as objective variable.

In this study, there were 6 items to be evaluated for finding the reasonable prediction of intake water of agricultural water use and each item has 3 categories as presented below.

Item (1), River management (RM)

The river management is monitored due to its function as natural water resources. Item (1) consisted of 3 categories i.e., (1) class A river (CA), (2) class B river (CB), and (3) class C river (CC).

Item (2), Location of beneficiary area (LC)

The location of beneficiary area has also to be considered as an item, assuming intake water respects to location of beneficiary area. Item (2) consisted of 3 categories i.e., (1) in urban area (UA), (2) in flat rural area (FR), and (3) in hilled rural area (HR).

Item (3), Intake water for another purposes (IWO)

Besides water taking from water facility is used for agricultural water; it is also used for another purpose. The intake water for another proposes is considered as Item (3) consisted of 3 categories i.e., (1). intake water for settlement (ST), (2) intake water for landscape (LS), and (3) intake water for raise of fish (RF).

Item (4), Size of beneficiary area (BA)

In recent years, intake water for agricultural water use seems to be increased due to the change of land use distribution. As the beneficiary area is broadening, the amount of intake water is always increase. The size of beneficiary area called item (4) has 3 categories i.e., (1) less than 200 ha (S), (2) between 200–500 ha (M), and (3) larger than 500 ha (L).

Item (5), Length of irrigation canal (LI)

Water flow from water intake point to command area delivered through irrigation canal is some times reduced due to seepage, percolation and evaporation. Therefore, the length of irrigation canal is considered as item (5) consisted of 3 categories i.e., (1) less than 7000 m (S), (2) between 7000–16000 m (M), and (3) longer than 16000 m (L).

Item (6), Length of irrigation canal/size of beneficiary area (LI/BA)

Ratio between the length irrigation canal and the size of beneficiary area is considered as Item (6). As the ratio tends to increase, the amount of intake water may be increase too. Item (6) consisted of 3 categories i.e., (1) less than 40 m/ha (S), (2) between 40–65 m/ha (M), and (3) larger than 65 m/ha (L). Furthermore, Table 1 shows amount of intake water and explanation variables.

Table 1. Amount of intake water on concerning LID and explanatory variables.

No.	Name of LID	Intake water (mm/day)	Item(1) RM	Item(2) LC	Item(3) IWO	Item(4) BA	Item(5) LI	Item(6) LI/BA
			Judged Categories of Items					
①	Utohacisui	52.10	*2(CB)*	*1(UA)*	*3(RF)*	*3(L)*	*3(L)*	*1(S)*
②	Toga	28.70	*1(CA)*	*1(UA)*	*1(ST)*	*3(L)*	*3(L)*	*2(M)*
③	Sugikami	50.10	*2(CB)*	*2(FR)*	*1(ST)*	*3(L)*	*2(M)*	*1(S)*
④	Utohacisui	26.10	*1(CA)*	*2(FR)*	*2(LS)*	*3(L)*	*1(S)*	*1(S)*
⑤	Jisenchuryuiki	77.50	*2(CB)*	*2(FR)*	*1(ST)*	*2(M)*	*2(M)*	*2(M)*
⑥	Kukinomura	56.80	*1(CA)*	*3(HR)*	*2(LS)*	*2(M)*	*2(M)*	*2(M)*
⑦	Kousachou	127.90	*2(CB)*	*2(FR)*	*3(RF)*	*2(M)*	*2(M)*	*2(M)*
⑧	Kukinomura	61.60	*1(CA)*	*1(UA)*	*1(ST)*	*2(M)*	*2(M)*	*2(M)*
⑨	Takachiho	48.10	*1(CA)*	*3(HR)*	*1(ST)*	*1(S)*	*3(L)*	*3(L)*
⑩	Kokubun	47.80	*3(CC)*	*2(FR)*	*1(ST)*	*2(M)*	*3(L)*	*2(M)*
⑪	Kokubun	141.50	*3(CC)*	*2(FR)*	*1(ST)*	*1(S)*	*1(S)*	*3(L)*
⑫	Kokubun	36.20	*3(CC)*	*2(FR)*	*1(ST)*	*2(M)*	*2(M)*	*2(M)*
⑬	Kurinomachi	34.90	*1(CA)*	*3(HR)*	*1(ST)*	*1(S)*	*1(S)*	*1(S)*
⑭	Fukurono	52.90	*2(CB)*	*2(FR)*	*1(ST)*	*3(L)*	*2(M)*	*1(S)*
⑮	Yamada weir	67.90	*2(CB)*	*2(FR)*	*3(RF)*	*3(L)*	*3(L)*	*1(S)*
⑯	Shimauuchi	212.10	*2(CB)*	*2(FR)*	*3(RF)*	*1(S)*	*1(S)*	*3(L)*
⑰	Ishisuiro	92.20	*2(CB)*	*3(HR)*	*3(RF)*	*1(S)*	*1(S)*	*2(M)*
⑱	Forogen	44.10	*2(CB)*	*3(HR)*	*3(RF)*	*1(S)*	*2(M)*	*3(L)*
⑲	Kaminaka	56.70	*2(CB)*	*3(HR)*	*3(RF)*	*1(S)*	*1(S)*	*3(L)*

RESULTS AND DISCUSSION

Category Weight

All of items used in the simulation were clarified as independent factors. Items were grouped into several cases for obtaining the reasonable results. Furthermore, analysis of category weight for several cases can be seen below.

Case 1

Case 1 was consisted of 5 items i.e., RM, LC, IWO, BA and LI. Fig. 1 shows that observed intake water (y_i) and predicted intake water (Y_i) those using dummy variables was significant in F test (α=0.05) and had multiple correlation coefficient (γ=0.96).

Fig. 2 shows that the intake water was affected by the river management (partial

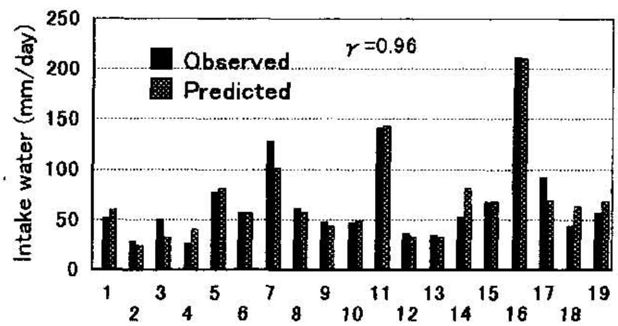

Fig. 1. Observed and predicted of intake water for Case 1.

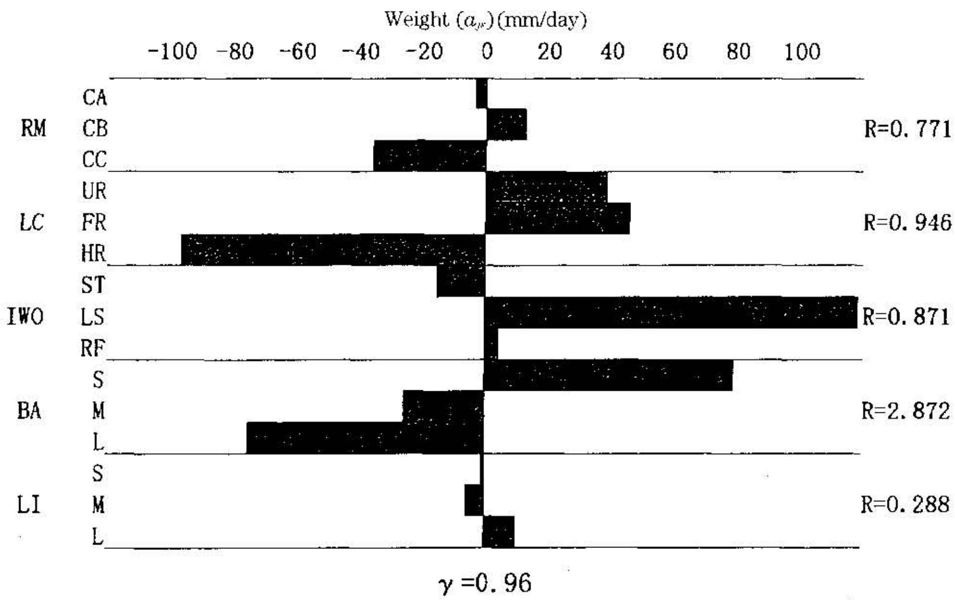

Fig. 2. Category-weight of intake water for Case 1.

correlation coefficient R=0.771) and strongly affected by the location of beneficiary area (R=0.946), the intake water for another purposes (R=0.871) and the size of beneficiary area (R=2.872). But intake water was slightly influenced by the length of canal irrigation (R=0.288). However, 15 categories were too many for the 19 of samples. Therefore, it was important to reduce the items again in following analysis for finding the reasonable results.

Case 2

Based on the analysis results of Case 1, the item 1 (River management) was reduced in Case 2. Besides, there were few samples; the reflecting of circumstances of specific of a river basin was hope rather than the river management itself.

In this case, Case 2 consisted of 4 items i.e., LC, IWO, BA and LI. Fig. 3 shows that

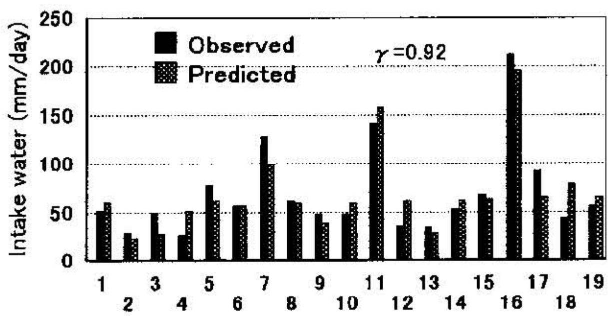

Fig. 3. Observed and predicted of intake water for Case 2

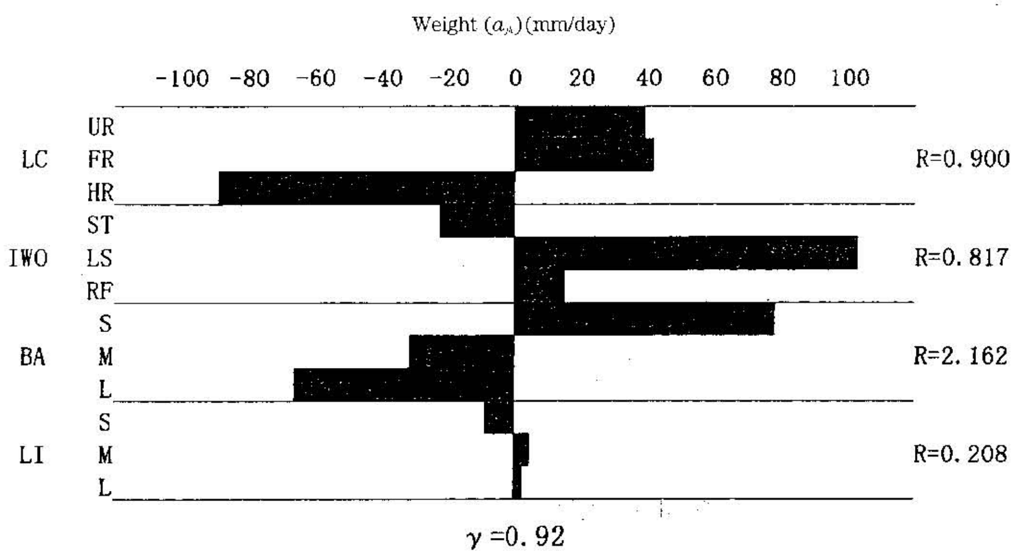

Fig. 4. Category–weight of intake water for Case 2.

relationship between observed intake water (y_i) and predicted intake water (Y_i) was significant in F test (α=0.05) and had multiple correlation coefficient γ=0.92. Fig. 4 shows that the intake water was strongly affected by the location of beneficiary area (R=0.900), the intake water for another purposes (R=0.817) and the beneficiary area (R=2.162). But intake water was not influenced by the length of canal irrigation (R=0.208).

Case 3

As mentioned in Case 2, the item of length of canal irrigation (LI) had the small value of partial correlation coefficient (R=0.208), which means that LI had not contribution in affecting the intake water. Therefore, this item should be reduced in Case 3. As the result, Case 3 consisted of 3 items i.e., LC, IWO and BA.

Fig. 5 shows that relationship between observed intake water (y_i) and predicted intake water (Y_i) for Case 3 was also significant in F test (α=0.05) and had multiple correlation coefficient γ=0.92. Fig. 6 depicts that the intake water was strongly affected by the location of beneficiary area (R=0.898), the intake water for another purposes

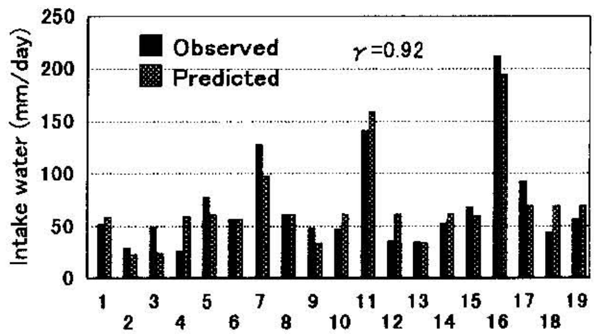

Fig. 5. Observed and predicted of intake water for Case 3.

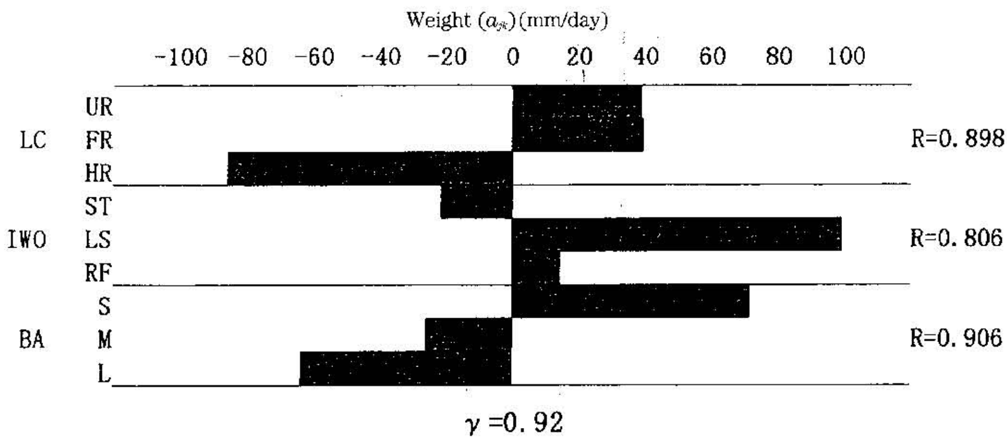

Fig. 6. Category–weight of intake water for Case 3.

(R=0.806) and the beneficiary area (R=0.906). Fig. 6 shows that intake water tended to increase due to both of the location of beneficiary area in the urban area (UA) and in the flat rural area (FR). But intake water did not tend to increase due to the location of beneficiary area in the hilled rural area (HR). The actual condition of operation intake water in this area is conducted with deeply consideration, in which irrigation water and drainage water are usually separated for beneficiary area in the hilled rural area. Because the over flow from drainage canal through the inclined land causes to damage on the surrounding area.

In the case of the irrigation water for another purposes as shown in Fig. 6, the intake water tended to decrease due to the settlement (ST). On the contrary, the intake water tended to increase due to both the rise of fish (RF) and the landscape (LS). However, it is important to increase the case samples for finding the reasonable results.

Fig. 6 depicts that the intake water tended to increase due to the small size (S) of the beneficiary area. Furthermore, the intake water tended to decrease due to both of the middle size (M) and the large size (L) of the beneficiary area. It means that the intake water tended to decrease as increasing in scale of beneficiary area. This phenomenon was considered as the return flow effects in the system.

Case 4

In this study, ratio between the length of irrigation canal and beneficiary area (LI/BA) was considered as an item for increasing the quality of analysis. Furthermore, Case 4 consisted of 3 items i.e., LC, IWO and LI/BA.

Fig. 7 depicts that relationship between observed intake water (y_i) and predicted intake water (Y_i) for Case 4 was slightly significant in F test (α=0.05) due to the smaller of multiple correlation coefficient γ=0.72. Furthermore, Fig. 8 shows that the intake water was not affected by the location of beneficiary area (R=0.434), the intake water for another purposes (R=0.434) and the ratio between the length of canal irrigation and the size of beneficiary area (R=0.635). The former obtained results in Case 2 depicts that there was not directly relationship between the intake water and length of canal irrigation.

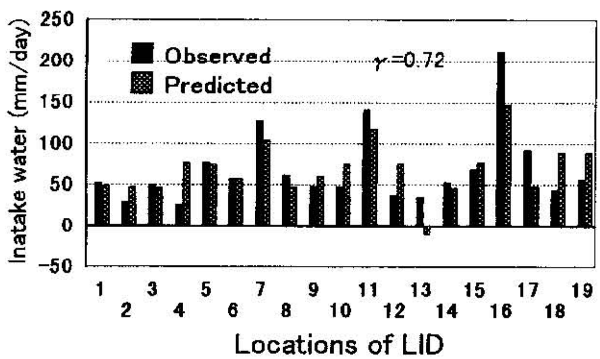

Fig. 7. Observed and predicted of intake water for Case 4.

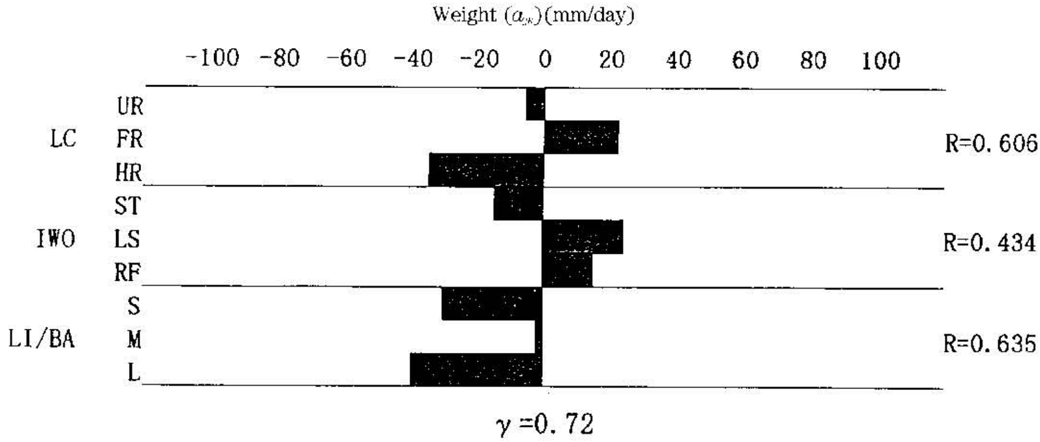

Fig. 8. Category–weight of intake water for Case 4.

CONCLUSIONS AND RECOMMENDATION

The intake water of agricultural water use was affected by the location of beneficiary area, the intake water for another purposes, the size of beneficiary area and there was a little affect of river management. On the contrary, the intake water of agricultural water use was not affected the length of canal irrigation canal and the ratio between the length of canal irrigation and the size of beneficiary area. The intake water varied to concerning Land Improvement District operated under traditional water right. The observed intake water ranged from 26.10 mm/day to 212.10 mm/day and amount of predicted intake water ranged from 24.53 mm/day to 210.53 mm/day (Case 1, γ=0.96). The obtained results were reasonable to explain the characteristics of factors affecting the actual intake water of agricultural water use in those areas.

Results showed that intake water of agricultural water use from concerning water facility were ranged widely. Therefore, it is important to clarify the actual factors in the field affecting the intake water for special water facility. It is recommended to increase the amount of samples and to decrease the amount of categories for increasing the validity of analyze.

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