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**Conference Paper**

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# A Policy of Demand-driven Management for Agricultural Water Use in Japan

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**Abstract:** To this day in Japan, the water supply service for agricultural use has been formed as the supply-driven system. In fact, the farmers can use the utilization volume of agricultural water and they have to pay the price of agricultural water fee decided by water supplier side. However, diverse functions are being desired to irrigation facilities in recent years, not only conventional water supply. Those include reflection of the farmers' various needs and provision of hydrophilic environment as typical examples. Thus agricultural water supply should be regarded as irrigation services and it is needed to consider requirements for providing desired services as well as efficient water distribution. Therefore, we made case study at Aichi-Yosui (Aichi Waterworks, Japan) by following processes: investigate the demands and potential needs of farmers about irrigation services, on it, grasp the agricultural conditions quantitatively from an economic viewpoint by such as estimation of the demand function. From the interview survey, it is observed that the rice farmers of Japan have diversity in management structure and sense of values. Besides, the model analysis based on the interview survey, there is a possibility to respond each farmer having own sense of values by introducing price fluctuation policy. That means, in the scenario of price fluctuation policy satisfied two different demands concurrently, increase of profit in profit seeking farmers and decrease of the cost in balanced and cost-containment farmers. Furthermore, it is notable that agricultural production costs and profit of the entire region were also increased in addition to the immediate benefits. It is suggested as the factors of them that the most efficient planting time were selected for each farmers since this system is a measure based on market principles compared to conventional systems. In addition, this system also expected to play the role that help small-scale farmers' farming activities that may go out of business due to constraints of capital and human resources. For future works, we believe that following two points are important, (1) To clarify the current situation and issues in agricultural water services via field studies, (2) To derive concrete measures and their effectiveness via simulation analysis such as Multi Agent System.

**Keywords:** *agricultural water management, rice cultivation demand-driven system*

**JEL Code:** Q18

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## 1. Introduction

The use of water in socio-economic activities can be mainly classified into three sections, which are the water for agricultural water, industrial water, and domestic and commercial water. In Japan, the agricultural water has the most amounts of use in socio-economic activities, and occupies about 2/3 of the total amount of all water use [1]. The modernistic agricultural water facilities in Japan have been improved by public-works project for wet-paddy rice agriculture for over 50 years. As of 2009 in Japan, the length of agricultural waterway is about 400,000 km, infrastructures of public water system such as dams are about 7,000, and irrigation land area is 2/3 of all the agricultural land [2].

To this day in Japan, the water supply service for agricultural use has been formed as the supply-driven system. In fact, the farmers can use the utilization volume of agricultural water and they have to pay the price of agricultural water fee decided by water supplier side.

On the other hand, recent years with the rise of an international interest and the development of service science approach to a water-resources problem, the demand-driven systems of agricultural water management is expected to lead to efficient use of water for agricultural use, or reflection of a farmer's various needs in water use [3]. Furthermore, the multiple functions of the irrigated area, such as a role of a habitat of wildlife, recreation area, etc., give importance more than ever [4].

However, there is little empirical research and information analysis about the demand-driven systems of agricultural water

management. First, the grasp of the actual demand and potential needs of agricultural water use by farmers is the most important subject to discuss the desirable system of the agricultural water management.

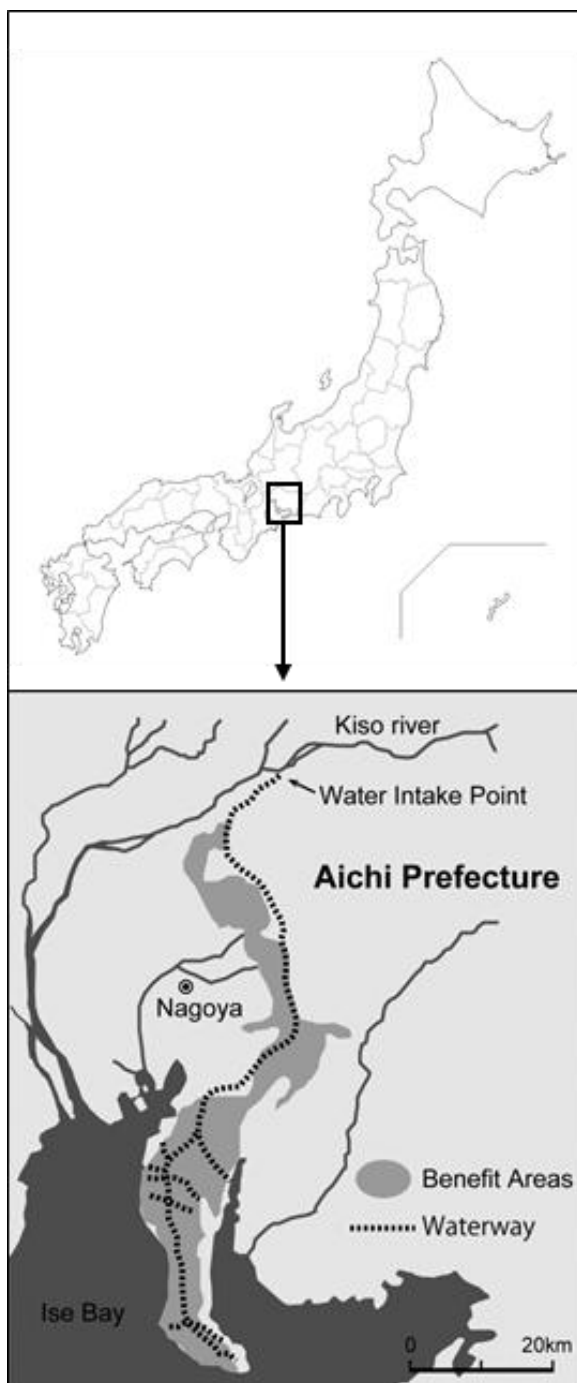
## 2. Purpose

The purpose of this study is to clarify the present condition and consciousness of rice farmers about water use by interview survey, and to analyze the agricultural water management system from an economic viewpoint. Second, we propose the evaluation concept and simulation method for construct of the desirable water service system as a regional policy.

## 3. Target area

The Aichi irrigation area (green area in Figure 1) and the Aichi-yosui irrigation waterway (red line in Figure 1) are located in Aichi prefecture, which is the central part of Japan. The Aichi-yosui irrigation waterway was built for the purpose of resolution of a water shortage in 1961. The length of major waterway is 112km, and that of branch waterway is about 1,012km [5]. The main sources of water are Makio dam, Misogawa dam, and Agigawa dam, which are in the water system of Kisogawa river. The irrigation area is about 13,584ha, in which the rice paddy irrigation area is 8,536ha, the dry field is 4,113ha, and the orchard is 935ha. Now the water supplied by Aichi-yosui irrigation waterway is mainly utilized for industrial use and agricultural use.

In this study, the target water area is an anonymous part of the Aichi irrigation area, which has an area of 2,500a.



**Figure 1.** Target area map.

## 4. Interview survey

### 4-1. Method

In order to obtain the data and information of current state of farmers regarding agricultural activity and water use, the hearing survey is conducted. The information and data about farming and water use will be quantified from the results

of the hearing survey into the farmers. Main question items for farmers are: (1) basic attribute, (2) scale of farming (including revenue and cost of agricultural production), (3) present state and consciousness of water use.

### 4-2. Results of survey and data analysis

The hearing survey was conducted with the farmers engaged in the target area on 29 March 2012. The total farmland area of respondents is about 1,660a, which is about 66.4% of the target area in this survey.

The results of the hearing survey are shown in Table 1, in which the basic attribute and the farming scale of 6 respondents are described. The relation between the cost of agricultural production (1,000JPY) and the farmland area (a) is shown in Figure 2. Also, Figure 3 shows the relation between the revenue (1,000JPY) of agricultural production and the farmland area (a). Therefore the cost of agricultural production in this area changes logarithmically with the farmland area, and the revenue of agricultural production in this area increases in almost direct proportion to the farmland area. The profit function of the farmers in target area is shown in Figure 4, which is derived by the cost function and revenue function. In cases where the scale of farmland area is around 2,000a, the farmer can gain the maximum profit in this area. Figure 5 shows the marginal profit function, and the farmer's profit is maximized at 1,000a of farmland area.

According to analysis of hearing survey data, the marginal profit function of the farmers is estimated as shown in Figure 5.

Figure 6 provides an example of an economic policy to decrease the agricultural water use. In case that the additional fee of 10,000 JPY per 1a for water use is charged to the farmers, the optimal scale of farmland area is 1,750ha in the area. On the other hand, in case that the farmland is less than 250a, the farmer benefits from abandoning the farming.

## 6. Simulation analysis

### 6-1 Model

#### 1) Prerequisite

An irrigation waterway and three beneficiary areas were defined as vertical target area. These beneficiary areas are located in series in the order of A, B, and C from upstream to downstream (Figure 7). Farmers belong to each area shown as Table 2. Each farmer act to maximize their benefit on the basis of their sense of value. Cultivation conditions are not uniform but there are deviations temporally and spatially. Concretely, there are two tendency as follows, (1) The earlier planting period is, the higher transaction prices is, (2) The more downstream is, the more yield is per unit. Each exogenous variable is based on interview survey and existing statistical surveys.

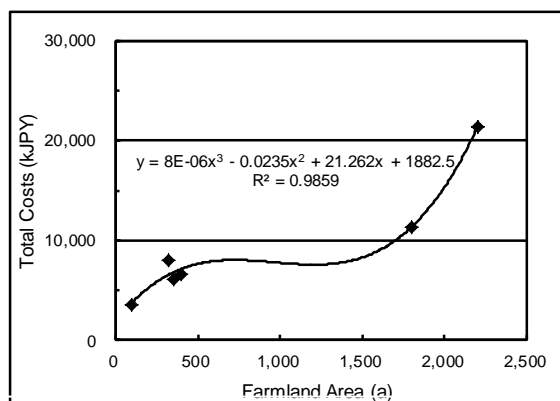


Figure 2. The Relation between Cost of Agricultural Production and Farmland Area.

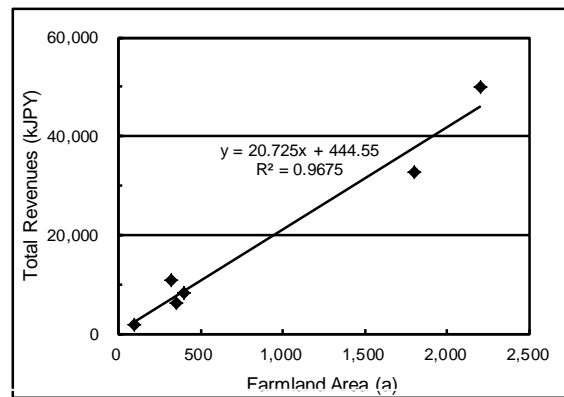


Figure 3. The Results of the Hearing Survey.

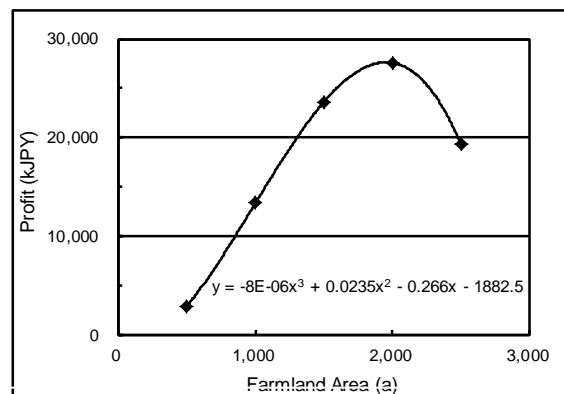


Figure 4. The Profit Function of the Farmers.

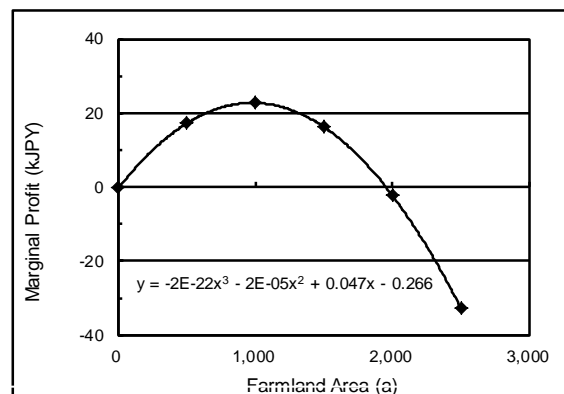


Figure 5. The Marginal Profit Functions of the Farmers.

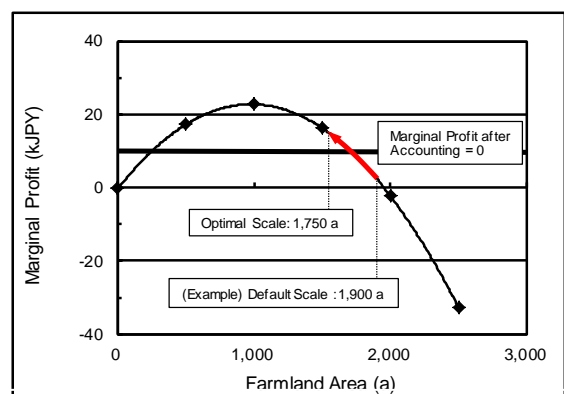
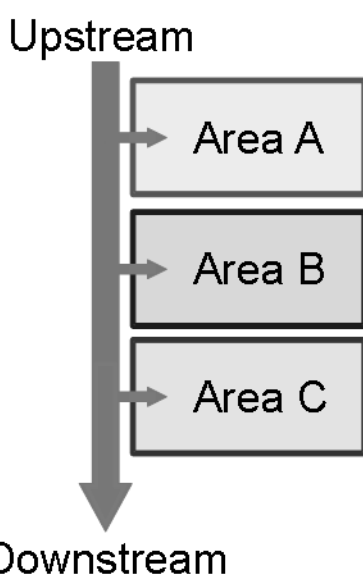


Figure 6. Estimated Marginal Profit Function of Farmers after Collecting Additional Fee.

**Table 1.** The Results of the Hearing Survey

Category	Item	Respondents						Unit
		A	B	C	D	E	F	
Basical Property	Full-time or Part-time	Full-time	Full-time	Full-time	Part-time	Full-time	Full-time	-
	Farming Income Ratio	100.0	100.0	100.0	50.0	100.0	100.0	%
	Total Farmland Area	2200.0	320.0	400.0	350.0	100.0	1800.0	a
	Owned Ratio	30.0	28.1	50.0	71.4	30.0	11.1	%
	Leasehold Ratio	70.0	71.9	50.0	28.6	70.0	88.9	%
	Farmlands Placed Target Area	500.0	320.0	400.0	350.0	90.0	0.0	a
Farm Accounting	Costs	21319.0	7958.4	6656.7	6055.1	3580.5	11373.3	kJPY
	Property Expenditure	4234.0	788.9	876.7	690.1	285.0	2733.3	kJPY
	Labour Expenditure	16600.0	6150.0	4650.0	4500.0	3000.0	6000.0	kJPY
	Capital Interest	100.0	64.0	80.0	70.0	18.0	0.0	kJPY
	Ground Rent Expenditure	385.0	379.5	330.0	165.0	115.5	2640.0	kJPY
	Other Rent Expenditure	0.0	0.0	0.0	0.0	0.0	0.0	kJPY
	Commission Expenditure	0.0	576.0	720.0	630.0	162.0	0.0	kJPY
	Expenditure for Water Use	624.2	257.7	328.4	360.6	219.1	328.4	kJPY
	Revenues	50000.0	10808.0	8167.5	6352.5	1815.0	32670.0	kJPY
	Other Revenues	10000.0	5000.0	907.5	0.0	0.0	0.0	kJPY

Irrigation waterway



**Figure 7.** A conceptual diagram of the virtual target area

**Table 2.** Summary of the virtual target area.

Areas	Farmers	Cult. Areas (10a)	Sense of values
A	A1	5	Type 3
	A2	10	Type 3
	A3	15	Type 3
	A4	20	Type 3
	A5	25	Type 3
	A6	30	Type 3
	A7	35	Type 3
	A8	50	Type 3
	A9	100	Type 3
	A10	150	Type 2
B	B1	50	Type 3
	B2	60	Type 3
	B3	100	Type 2
	B4	150	Type 2
	B5	200	Type 1
C	C1	50	Type 2
	C2	100	Type 1
	C3	500	Type 1

\* See (6) for the detail of each type.

## 2) Model formula

(1) Profit

Profit of farmers is obtained by subtracting total cost from cropping income.

$$\pi = R - TC \quad (1)$$

$\pi$  ; Profit,

$R$ ; cropping income,

$TC$ ; Total cost,

(2) Cost

Cropping cost is obtained by summing water cost and the other cost that proportional to the cultivation area.

$$TC = WC + OC \quad (2)$$

$$OC = \emptyset \cdot L \quad (3)$$

$WC$ ; Water cost,

$OC$ ; Costs excluding the water fee

$\emptyset$ ; Cost coefficient (Exogenous),

$L$  ; Cultivation area (Exogenous)

Water cost is obtained by multiply water fee per unit and cultivating area. Water fee per unit is depends on planting period. They are uniform on the scenario I and II.

$$WC = \gamma(t) \cdot L \quad (4)$$

$\gamma(t)$  ; Water fee per unit in each planting period (Exogenous)

(3) Cropping income

Cropping income is obtained by multiply unit selling price per period, yield per unit per period, and cultivating area. Unit selling price per period and yield per unit per period are depends on planting period.

$$R = p t \cdot Y(t) \cdot L \quad (5)$$

$p(t)$  ; Unit selling price per period (Exogenous),

$Y(t)$  ; Yield per unit per period (Exogenous)

(4) Management of waterway

Waterway is managed by the management

association and its cost is fixed.

$$\Sigma WC = TB \quad (6)$$

$TB$ ; Management cost by the association (Exogenous)

(5) Water supply

Amount of water supply in each period is limited.

$$WA(t) \leq LWA(t) \quad (7)$$

$WA(t)$ ; Amount of water supply in each period,

$LWA(t)$ ; Limitation of water supply in each period (Exogenous)

(6) Activity of each farmer

Each farmer act to maximize one's benefit. Farmers' senses of value are categorized to three types. They do not make activities if surplus is not expected, in all types.

**Type 1.** Profit Seeking: This type of farmer acts to maximize the profit.

$$\max \pi \quad \text{s.t. } (1) \sim (7), \pi > 0$$

**Type 2.** Balanced: This type of farmer acts to maximize the profit within one's limitation of management scale.

$$\max \pi \quad \text{s.t. } (1) \sim (7), TC \leq LTC,$$

$$\pi > 0$$

$LTC$  ; Limitation of cropping cost (Exogenous)

**Type 3.** Cost-containment: This type of farmer acts to maximize the profit within one's limitation of management scale.

$$\min TC \quad \text{s.t. } (1) \sim (7), \pi > 0$$

### 3) Scenario

Following three scenarios were set.

**I. Default operation:** Farmers try to take water in own benefit basis in order from the upstream side. This means downstream farmers are able to take water only when upstream farmers exhaust water of the period.

**II. Social Optimization Policy:** The water association manages to distribute each period of water evenly proportional to farmers' cultivation area.

**III. Price Fluctuation Policy:** The supply and demand are balanced by fluctuating water fee of each period depending on the water demand, based on the strategy shown in Figure 8. This process converges endogenously via farmers economic activities.

### 6-2 Results

Figure 9 shows each type of farmer's agricultural income, cost and profit in three scenarios. On the entire region, price fluctuation policy took highest value in both income and profit, followed by social optimization policy and default operation in descending order. Price fluctuation policy was also the highest profit scenario for all types of farmers, 6.9 to 24.7% higher than

default operation. It is also the lowest production cost scenario for balanced and cost-containment farmers, 5.2 and 7.3 % lower than default operation. In addition, from the point of view of relationship between cultivation areas and water costs (Figure 10), on price fluctuation policy, the smaller the farming scale, fewer cost burden such as water fees is required. Conversely on the other two scenarios, the smaller the farming scale, more cost burden such as water fees is required.

### 6-4 Discussion

As a result of interview survey, following three points were shown for characteristics of the target area, (1) There is a large difference in the scale cultivation between the farmers, (2) On account of the system, smaller the farming scale, more cost burden such as water fees is required, (3) Along with above, farmers have various management structures and sense of values, especially there is a tendency in large-scale farmers to pursue profit, in contrast most of small-scale farmers try to reduce the costs and risks with it. However this is the one case study instead of events that can be generalized, these results consist with existing theoretical studies that suggest there is a problem in the existing system to provide uniform irrigation service for all farmers.

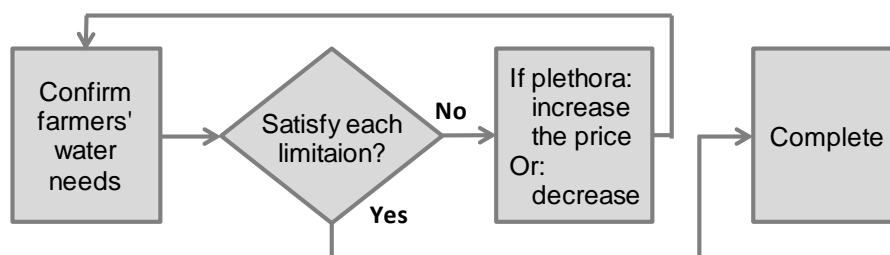


Figure 8. A conceptual diagram of the virtual target area.

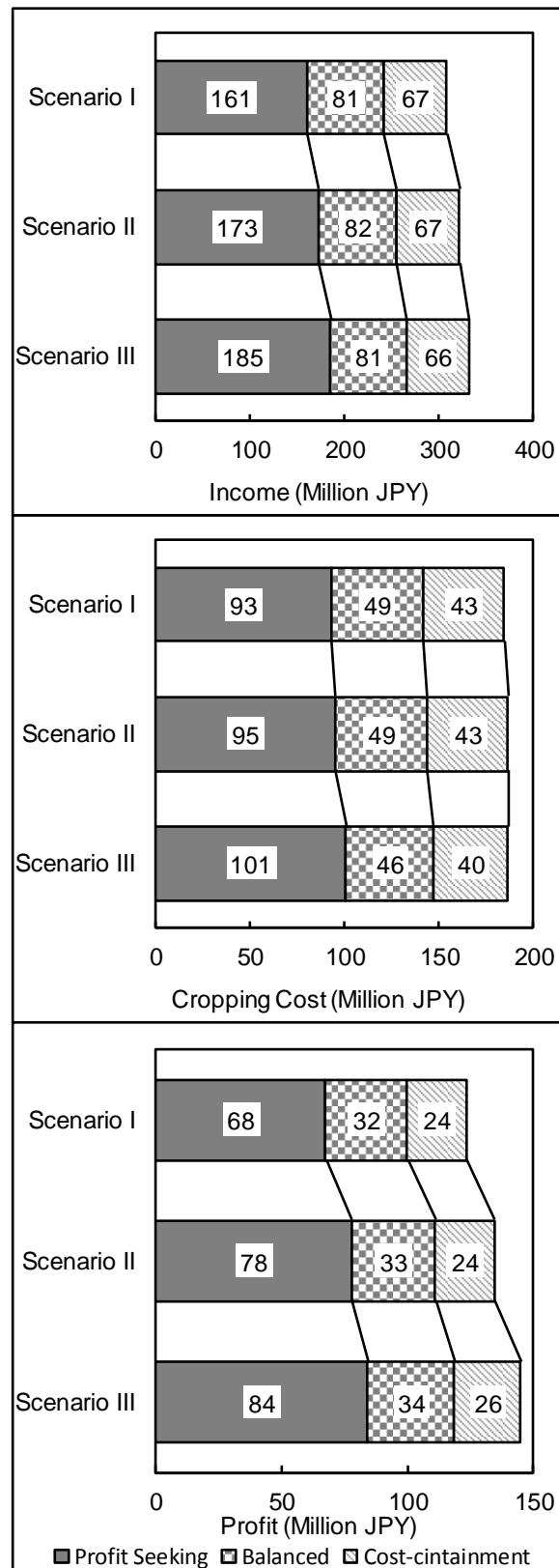


Model analysis based on interview survey, there is a possibility to respond each farmer having own sense of values by introducing price fluctuation policy. That means, in the scenario of price fluctuation policy satisfied two different demands concurrently, increase of profit in profit seeking farmers and decrease of the cost in balanced and cost-containment farmers. Furthermore, it is notable that agricultural production costs and profit of the entire region were also increased in addition to the immediate benefits. It is suggested as the factors of them that the most efficient planting time were selected for each farmers since this system is a measure based on market principles compared to conventional systems. In addition, this system also expected to play the role that help small-scale farmers' farming activities that may go out of business due to constraints of capital and human resources.

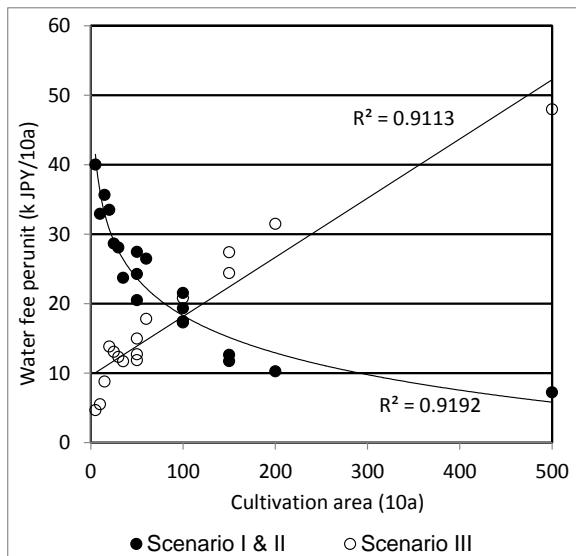
### 7. Concluding remarks

From the interview survey, it is observed that the rice farmers of Japan have diversity in management structure and sense of values. Meanwhile, it is suggested that demand-driven systems of agricultural water is not only be able to respond to wide needs of farmers but also raise productivity the whole region from the model analysis.

For future works, we believe that following two points are important, (1) To clarify the current situation and issues in agricultural water services via field studies, (2) To derive concrete measures and their effectiveness via simulation analysis such as Multi Agent System.



**Figure 9.** Result of the simulation analysis: Each type of farmer's agricultural income, cost and profit in three scenarios.



**Figure 10.** Correlation of cultivation areas and water costs.

## References

- [1] Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan (2011): *White Paper on Water Resources 2011*. Mitsuba Total Printing, 307 pp.
- [2] Rural Development Bureau, Ministry of Agriculture, Forestry and Fisheries, Japan (2010): *Basic Research of Information about Agriculture*. publicized as digital spreadsheet file.
- [3] Ariel Dinar and Dirgha Tiwari (2003): Prospects for irrigated agriculture: whether irrigated area and irrigation water must increase to meet food needs in the future. World Bank, 111 pp.
- [4] Jean-Marc Faurès, Jippe Hoogeveen, Jelle Bruinsma (2002): The FAO Irrigated Area Forecast for 2030. Food and Agriculture Organization.
- [5] Kenshu Osawa and Isao Tatematsu (2005): History and Features of Aichi Canal. *Journal of the Japanese Society of Irrigation, Drainage and Reclamation Engineering* 73(2), pp.87-90.