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Water Service Valuation in Tidal Lowland Agriculture

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ABSTRACT

Water service is a key factor in tidal lowland agriculture where water supply fluctuates following the tidal cycle. Under controlled situations, water can be properly supplied to farmland based on crop water requirements through proper operation and maintenance of the tidal irrigation system. This study aimed at estimating the value of water service in order to support the implementation of a water service fee. The benefit from water service is compared to a water service fee estimated from the cost of water distribution. To achieve the objective, the study employed production function estimation with rice as the main crop. Data were collected through a field survey on randomly selected farmers at Telang Delta, the rice production centre for tidal lowlands of South Sumatra, Indonesia. The result indicates that the value of water service in rice production is higher than any estimates of a water service fee. Proven to be a significant determinant of rice production, it has been suggested that water service should obtain financial support from farmers who benefited from available water service.

Keywords: Water service, valuation, tidal lowland

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INTRODUCTION

Water in tidal lowlands is "plenty, but scarce". It is plenty since by nature lowlands are frequently flooded according to the hydro-topographic characteristics of lowlands (Schultz, 2007). Nevertheless, it is also considered scarce as a result of nature's tidal cycles by which under uncontrolled systems water levels cannot be maintained properly in accordance with the need of a particular crop.

Water scarcity in tidal lowlands is particularly experienced by farmers at the beginning of the second crop (March) when rainfall decreases and tidal water cannot be adequately retained under an open system. Thus water scarcity increases as the plant grows (Zilberman & Lipper, 1999). Crop water needs can only be fulfilled when water structures (gates and canals) can retain tidal water as much and as long as possible (Ali *et al*., 2002). This is possible only if water service functions well.

Water service is categorised as a non-market good (Tietenberg, 2006). It increases the value of water as a resource to the extent that water becomes available to fulfil the amount needed to water the crop. In order to function properly, water service requires not only good water structures (canals and gates), but also proper operation and maintenance and a well managed institution. Therefore, besides providing benefits, water service incurs cost to carry out these tasks that should be borne by the users benefitting from it. However, benefit from a water service is expected to be greater than the cost that water users are willing to pay. For this reason, water service, as an environmental good, needs to be valued to estimate its benefit.

This research aimed to value water service in tidal lowlands, which are mainly based on agriculture with the intent to benefit crop production. The value of water service can further be used as a measure in the assessment of a water service fee.

Water service is valued for several different purposes. At least three were mentioned in water management literature, including water distribution improvement and pollution control (Cornish *et al*., 2004), cost recovery (Molle *et al*., 2008; Cornish *et al*., 2004) and water use optimisation and efficiency (Singh, 2007; Bar-Shira *et al*., 2006; Gonzalez-Alvarez *et al*., 2006).

Several methods have been used to value water service according to the above objectives. These methods vary from fixed and variable cost estimation (Gonzalez-Alvarez *et al*., 2006; Tarimo *et al*.,1998), marginal (social) cost of water delivery (Bar-Shira *et al*., 2006), environmental cost internalisation (Esteban *et al*., 2008) and block tariff application to water market instrumentation (Goetza *et al*., 2008), linear programme modeling (Latinopoulos, 2005), price elasticity prediction (Schoengold *et al*., 2006) and production function (Pagiola *et al*., 2004; Suthirathai, 1997). The choice of proper methods depends on the objectives of water service valuation.

In crop production, water service can be considered as an input since it contributes to providing water at a controllable level according to crop water requirements, without which optimum conditions cannot be achieved. Therefore, the value of water service in crop production can be reliably assessed using production function. Production function has been used in resource valuation through measurement of its impact on produced goods. In the previous work of Suthirathai (1997), for example, the value of mangrove as a resource was successfully revealed through fish production function estimation. The benefit of Haiti's forest remnants protection has been estimated using irrigated agricultural production function (World Bank, 1996). Later, the production function was adopted as one of the main economic valuation techniques (Pagiola *et al*., 2004). It is termed as "change in productivity" and categorised as one of the preference methods.

The value of water service as a resource as well as an input can be observed through the production function of a particular crop. Its value can be estimated as the change in crop productivity that occurs due to the existence of water service in the crop production process.

METHODS

As a non-market good water service can be reliably assessed using non-market valuation techniques (Tietenberg, 2006). In this study, production function as a non-market valuation technique estimated the economic value of water service in tidal lowland rice production. Water service was considered as an input that directly affected rice production as other conventional inputs did.

Production function was applied through three consecutive steps. The first step was to specify the production function for tidal lowland rice. This was a functional relationship between farm inputs (seed, chemicals, fertilizers, labour and water service) and output (rice). The Cobb-Douglas production function stated below was used to specify this functional relationship.

$$\ln Y_i = \beta_0 + \beta_1 \ln SEED + \beta_2 \ln CHEM + \beta_3 \ln FERT + \beta_4 \ln LABOR + \beta_5 D_{WS} + \varepsilon_i \quad [1]$$

where

Y_i = total rice production in tonnes

SEED = seed used in kg

CHEM = chemical used in Rupiah

FERT = fertilisers used in Rupiah

LABOR = labour used in man days

D_{ws} = dummy variable water service with
  0 = without water service and
  1 = with water service

The second step was to estimate the change in output (rice production) for every unit change in the input using the production function specified in the first step. Regression was used to estimate the magnitude and direction of these changes. Both individual and overall effects of the inputs on the output were assessed.

The third step was to calculate the value of water service in rice production. The value of water service was the difference in rice production between rice produced with water service and without water service. Since water service was a dummy variable (1 = with water service; 0 = without), rice production with and without water service could be estimated as follows:

The production function for farm without water service:

$$E(\ln Y_i | D_{WS} = 0) = \beta_0 \quad [2]$$

The production function for farm with water service:

$$E(\ln Y_i | D_{WS} = 1) = \beta_0 + \beta_1 \quad [3]$$

The intercept β_0 was the mean log production and the slope coefficient (β_1) was the difference in mean log production of farm with water service and without.

This research was carried out in the deltaic area of Telang I, South Sumatra, Indonesia. This area was selected since it was among the most productive reclaimed tidal lowland areas supported by a relatively better water management system. Some parts of the area have been equipped with water management structures at secondary and tertiary blocks. Water users associations (WUAs) have been established to manage the operation and maintenance of the system. Similarly, on-farm water management has been applied by individual farmers. Cropping patterns that determine the operation of the system have been planned and implemented by farmer groups. However, a water service fee (WSF) has not been implemented yet due to the absence of objective measures of WSF.

Data were collected through a sample survey due to the fact that tidal lowland areas reclaimed for agriculture was quite large and the farmers shared rather similar characteristics in terms of land ownership and cropping patterns. A stratified random sample of 500 farmers was drawn from the research population in the designated secondary blocks, covering farmers whose farmland had water service and whose farmland did not have water service.

RESULTS AND DISCUSSION

Production Costs, Production and Productivity of Rice

As a primary production process, rice production employs several primary inputs such as seed, fertilizers of several kinds, some types of pesticide, labour and some sorts of equipment. Three kinds of fertilizer were used for rice cultivation, namely nitrogen, phosphorous and potassium fertilizers. The uses of the first two kinds were recommended, whereas the third was used according to particular need. Pesticide consisted of three types, namely herbicides, insecticides and fungicides. The use of these inputs followed the type of crop and the area cultivated. The costs of these inputs are presented in Table 1. These costs were estimated based on per hectare rice cultivation in the first planting season. The cost for each input was derived from the whole research sample based on its average value (mean).

Production is the output of farming activities as the result of employing inputs. The amount of production depends on the land under cultivation such that it varies among farmers with different land holdings. In order to measure a standard output of farming activities, a measure of productivity is employed. Besides its independency on the use of inputs, measure of productivity uses cultivation acreage as a reference. Therefore, productivity refers to the output per unit land cultivated.

Analysis of the data on rice production among respondents of this research indicated that rice production varied from as low as 1.5 tonnes to as high as 79.2 tonnes on-farm dried paddy due to the variation in area cultivated from as low as 0.25 hectare to as high as 12 hectares. The average production was 9.75 tonnes (standard deviation = 5.70 tonnes) and the average cultivation area was 1.84 hectares (standard deviation = 0.99 hectare). Analysis of rice productivity indicated that among all of the respondents, the average productivity was 5.35 tonnes per hectare on-farm dried paddy (standard deviation = 0.88 tonne).

The Value of Water Service in Rice Cultivation

Valuation of water service in rice cultivation was carried out using the production function in which water service was one of the inputs. Rice production is a function of a set of input factors such as seed, chemicals, fertilizers and labour for various activities within the whole process of rice cultivation starting from land preparation, planting, fertilizer application, pests and disease control until harvesting. In order to estimate the effect of these variables, a multiple regression analysis was performed. Water service is one of the variables entered into the model to measure its contribution on rice production to imply the value of water service.

TABLE 1
Costs of Rice Cultivation Per Hectare in the Study Area

Inputs	Types of Input	Unit	Volume	Unit Cost (Rp)	Total Cost (Rp)
Seed	Rice seed	Kg	63.5	6,000	381,000
Pesticides	Herbicides[1]	n.a	n.a	n.a	344,770
	Insecticides[1]	n.a	n.a	n.a	72,480
	Fungicides[1]	n.a	n.a	n.a	107,000
Fertilizers	Nitrogen	Kg	220	1,300	286,000
	Phosphorus	Kg	121	2,300	278,300
	Potassium[2]	Kg	n.a	n.a	13,910
Labor	Land preparation	Man day	10	50,000	500,000
	Planting	Man day	4.5	50,000	225,000
	Fertilising	Man day	2	50,000	100,000
	Controlling	Man day	2	50,000	100,000
	Harvesting[3]	Man day	51	50,000	2,550,000
Total					4,958,460

Notes:
[1]Various types with various unit (L, ml, kg, gram, etc) such that only total cost is applied.
[2]Only few samples used this type of fertiliser such that average volume was not relevant.
[3] Consists of harvesting and threshing; harvesting cost is in shared product with the ratio 1:7 (12.5% for labour, 87.5% for owner). Threshing cost is Rp50 per kg output. All of these expenses are made equivalent to man day.)
n. a: Not applicable

Multiple regression analysis was conducted using the Cobb-Douglas production function and the results are presented in Table 2. The R Square value indicated that 93.6% of variation in rice production was explained by the independent variables. The analysis of variance (F-test) proved that the overall model was statistically significant at 95% confidence interval. Analysis on the effect of each of the independent variable was performed using the t-test. Among all of the independent variables considered to have an effect on rice production, all but seed had a significant effect on the dependent variable.

The coefficient of thedummy variable water service was positive and significant. Considering ‘0’ for ‘without water service’ and ‘1’ for ‘with water service’, the positive value of this coefficient could be interpreted as that rice production of the farmland with water service was 4% higher than that without water service (exponentiated 0,040 is 1.0408, subtracting 1 from this gives 0.04, multiplying this by 100 gives 4%). Taking the mean rice productivity of the farmland without water service as the basis (5.3180 tonnes per hectare), this productivity is expected to increase to 5.5350 tonnes per hectare when the respondents employ water service on their farmland.

Taking productivity as the basis for calculation, the change from a farm without water service to one with water service in rice production will increase the productivity by 0.217 tonne per hectare (the difference between productivity with water service as opposed to that without water service). In monetary terms, this increase in productivity was equal to Rp455,700 per hectare, assuming the price of on-farm dried paddy at local market was Rp2,100 per kg. This amount can be considered as the average value of water service in rice cultivation. In other words, this is the benefit of water service in rice production.

In comparison, the ‘cost’ of water service (as a proxy of a water service fee) estimated using the cost of water distribution varied from as low as Rp315,000 per hectare

TABLE 2
Regression Coefficients and the Value of t-test Statistics

Variables	Coefficients	Std. Error	*t*	Sig.
(Constant)	-3.910	.212	-18.449	.000
Seed	.023	.026	.901	.368
Chemicals	.034	.018	1.828	.068*
Fertiliser	.128	.026	5.030	.000***
Labour	.782	.028	28.374	.000***
Water Service (Dummy)	.040	.013	3.026	.003***

Note:
Dependent variable is total rice production
All variables are in logarithm except for water service
R Square = .936; F-test = 57.083; Sig. of F-test = .000
*Significant at 10%; **Significant at 5%; ***Significant at 1%

TABLE 3
Costs of Water Service (Per Year) and WSF Estimates (Per ha Per Year)

Type of Cost	Cost Components	Block Area Applies		Total (Rp)	WSF (Rp/ha/year)
		Tertiary	Secondary		
Supply Cost	OM cost	1,600,000		80,580,000 (per 256 ha)	WSF_1 = 315,000
	Capital depreciation and replacement cost	3,180,000			
	WUA management cost		4,100,000		
Economic Cost	Opportunity cost	31,500 (per ha)		88,644,000 (per 256 ha)	WSF_2 = 346,500
Full Cost	Avoidance cost of not consuming contaminated canal water	45,000 (per ha)		100,164,000 (per 256 ha)	WSF_3 = 391,500

per year (the supply cost) to Rp346,500 per hectare per year (the economic cost) and to Rp391,500 per hectare per year (the full cost) (Table 3). In comparison, the ‘benefit’ of water service as an input in rice production (as proxy of water service fee) is Rp455,700 per hectare per year (assuming only one crop per year). Therefore, it is valid to say that the ‘benefit’ of water service was sufficient enough to cover its highest ‘cost’ (the full cost).

CONCLUSION

Water service is an environmental good. It contributes to crop production through fulfilling crop water requirements that are needed for optimum crop yield. Therefore, its value can be measured through the production function estimation.

In agricultural tidal lowlands where water management is a key factor, water service has been proven to be a statistically significant variable in rice production. The presence of water service in rice cultivation has significantly increased rice production. This increase is considered to be the financial value of water service upon which a water service fee can be reliably imposed.

The financial value of water service is higher than any estimates of a water service fee. Therefore, it can be used to cover the highest cost (the full cost) of agricultural water management in tidal lowlands. With this available fund, operation and maintenance of tidal irrigation system can be achieved and current agricultural water management in tidal lowlands can be sustained.

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