WATER SCARCITY, MOUNTAIN DEFORESTATION AND THE ECONOMIC VALUE OF WATER IN A SMALL-SCALE IRRIGATION SYSTEM: A CASE STUDY IN EAST JAVA, INDONESIA

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Manuscript received: October 24, 2020
Revised version: March 30, 2021

Budiman S.A., Rondhi M., Khasan A.F., Peratama B., Rokhani, Suwandari A., Ridjal J.A., Soemarno, Prijono S., Soedarto, 2021. Water scarcity, mountain deforestation and the economic value of water in a small-scale irrigation system: A case study in East Java, Indonesia. *Quaestiones Geographicae* 40(2), Bogucki Wydawnictwo Naukowe, Poznań, pp. 153–166. 5 tables, 6 figs.

Abstract: The purpose of this study was to identify the willingness of farmers to pay for small-scale irrigation (SSI) and its determinants. Additionally, this study analysed the physical water availability in the study area using 16 years' (2004-2019) historical data of streamflow, rainfall and forest cover change. A structured questionnaire was used to collect the data from 100 farmers. A contingent valuation method was employed to elicit farmers' willingness to pay (WTP) for irrigation water. The results show that the average WTP of farmers is US$ 215.84/ha/year. It accounts for 20% of farm revenue and is almost 20 times the water fee in large-scale irrigation systems. The study area experienced significant deforestation in the last two decades suffering a decrease of 11.72% of forest cover. It decreases the amount of stored rainwater and decreases the streamflow causing water scarcity during the dry season. Farm size, farmer income, distance to a small dam and usage of water-pump are the significant determinants. The results indicate that water scarcity caused by poor infrastructure increases the economic value of water in a SSI system.

Keywords: water scarcity, small-scale irrigation system, contingent valuation method, economic value of water, willingness to pay

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Introduction

Water scarcity for agriculture is one of the primary threats to agricultural production. It can be divided into two broad categories: physical water scarcity and economic water scarcity. The former refers to a condition where the amount of water withdrawal exceeds the available water (FAO 2017). The latter goes further to describe water scarcity as a condition where economic barriers (lack of infrastructure and financial resources) and institutional barriers (lack of appropriate water management institutions and capability in managing water resources) prohibit a

https://doi.org/10.2478/quageo-2021-0015
ISSN 2082-2103, eISSN 2081-6383

farmer from accessing or managing existing water resources (Molden 2013). Both of these conditions decrease agricultural productivity and farmer income, and increase farmer food insecurity. Several studies reported that water scarcity severely affects farmers in developing countries (Giordano et al. 2019). More severe impacts of water scarcity are experienced by small-scale irrigation (SSI) areas where both physical and economic water scarcities exists.

SSI is vulnerable to both physical and economic water scarcities. The physical water scarcity is caused by climate change that decreases the frequency and intensity of rainfall. The decrease in frequency and intensity of rainfall is the primary threat to a farmer in SSI since most of the farmers depend primarily on rainfed agriculture (de Sousa et al. 2017; Ducrot 2017; Lopus et al. 2017; Mdemu et al. 2017; Moyo et al. 2017; Akrofi et al. 2019). The other threat to water availability in SSI is deforestation. As most SSI is located in river basins, deforestation in the catchment areas reduces groundwater availability (Chervier, Costedoat 2017; FAO 2017). It further diminishes water supply to SSI that utilises spring water (Aberra 2004; Zeweld et al. 2015; Woodhouse et al. 2017; de Bont et al. 2019). On the other hand, inadequate infrastructure and weak water management institutions cause inequitable water allocation (Lopus et al. 2017). Poor infrastructure promotes water loss during distribution. Additionally, the weak managerial capability of water institutions decreases water allocation efficiency and lessens the institution's adaptive capacity (Ducrot 2017). As SSI constitutes a considerable amount of agricultural land in poor and developing countries, improving SSI performance is crucial to increase agricultural production and achieve food security.

Much effort in terms of development has been put in to improve SSI performance by improving the irrigation infrastructure (II). II is the primary requisite to achieve an efficient and equitable allocation of scarce water resources. There are various types of II established to improve the performance of an SSI, such as pipeline network (Lopus et al. 2017; Akrofi et al. 2019; de Bont et al. 2019), motor pumps (Kamwamba-Mtethiwa et al. 2016) and concrete irrigation canals (de Sousa et al. 2017; Delos et al. 2017). The purposes of the II establishment are to limit the water loss (Aberra 2004; Mdemu et al. 2017; Moyo et al. 2017) and extend the irrigation network (Molden 2013; Kamwamba-Mtethiwa et al. 2016; Lopus et al. 2017). Improved II lays a strong foundation for collective action (CA) among farmers in an SSI. Since the degree of CA and water scarcity has an inverted U-shape, CA cannot exist when the water availability is severely scarce or abundant (Agrawal 2001; Fujiie et al. 2005; Araral 2009; Takayama et al. 2018). Thus, improved II decreases the severity of water scarcity to a condition where CA is favourable. This favourable condition is the primary requisite for the second stage of achieving an efficient and equitable allocation of scarce water resources: improving the capability of water institutions in the SSI. The CA in irrigation management can be expanded into CA in forest and nature conservation (Dash, Behera 2015, 2018; Persson, Prowse 2017). This CA will improve the quantity and quality of ground and spring water.

Based on the framework above, the establishment of II is a crucial part of developing an SSI. Several studies have demonstrated that improved II in the SSI enhances water access for the farmer and increases cultivation frequency (Mengistie, Kidane 2016), increases agricultural production and household food security (Tesfaye et al. 2008), increases agricultural income (Zeweld et al. 2015; Mango et al. 2018) and reduces poverty (Tesfaye et al. 2008). Generally, the establishment of II in SSI is financed by the farmer or the government. However, leaving the II establishment to the farmer alone will give rise to private irrigation, initiated mostly by wealthy farmers, limiting the inclusion of irrigation access for lower-income farmers and increasing irrigation cost (de Fraiture, Giordano 2014; Giordano, de Fraiture 2014; Ducrot 2017). On the other hand, government-built II usually lacks planning and ergonomic design; consequently, farmer participation in water management is limited (Luo et al. 2017). Hence, an appropriate framework that facilitates efficient water allocation and promotes the participation of farmers in water management is required.

Improving II at the farm level of SSI requires a large number of resources. Moreover, the turnover program implemented in the 1980s reduced the government funds allocated for its establishment. Thus, it is crucial to find alternative sources of funds, especially those coming from the farming. Utilising the farmers' resources to improve II in SSI has two merits: first, a farmer in the area of interest is likely accustomed to managing irrigation independently. Thus, it is more likely that they are willing to provide funding to establish II. Second, using their funds will increase ownership and participation in and the sustainability of irrigation. However, mobilising farmer resources is not an easy task when farmers perceive that the benefits they will receive are not higher than the funding they are expected to provide. Hence, it is essential first to assess the economic value of irrigation water, which can be derived from the perceived benefit of irrigation.

The economic value of irrigation can be determined by measuring farmers' willingness to pay (WTP). The economic benefit of irrigation, which is typically high, is revealed through WTP. Another essential characteristic of WTP is that it can be used as an instrument to allocate water under conditions of reduced water supplies and water rights (Colby et al. 1993). This study focused on SSI in the eastern region of East Java, Indonesia. The irrigation system in the study area is categorised as a non-technical irrigation system. The primary water source for the studied SSI is mountain spring water. Currently, the area experienced a significant mountain deforestation, which decreases the quantity of spring water for irrigation. Thus, the two types of water scarcity currently exist in the study area. Based on that reasoning, we argue that mobilising farmers resources to improve II in the study area will improve both water availability and farmers' CA in managing the irrigation system. Thus, the primary purpose of this study is to measure farmers' WTP for non-technical irrigation and to identify its determinants. The study also analyses the physical water availability of the study area using 16 years (2004–2019) of historical data on rainfall, streamflow and forest cover change. We are the first to identify farmers' WTP for irrigation water in the study area and to analyse the water availability in the study area. The primary contribution of this study is that it shows that farmers in an area with severe water scarcity have the potential to fund and manage the irrigation system in a sustainable manner. In addition, this study is crucial in the effort to achieve food security since half of the agricultural land in Indonesia is categorised as SSI.

Method

Study area

This study was conducted at Curahtakir village, in the Sanenrejo sub-watershed. It is located in the eastern region of East Java, in the sub-district of Tempurejo in the district of Jember. Figure 1 shows the location of the study area relative to Indonesia. Like a typical Indonesian village, Curahtakir is dominated by agriculture. Agriculture in the study area strongly depends on rainfall in the first season and water supplied by the irrigation in the second and third seasons. The average annual rainfall in the study area is 2,404 mm. The seasonal distribution of rainfall in the study area is 1,378 mm in the rainy season (November 2015–February 2016), 529 mm in the first dry season (March–June 2016) and 497 mm in the second dry season (July–October 2016). Agricultural irrigation was provided and managed by farmers utilising water coming from a spring.[1] We studied one irrigation system serving an area of 144 ha managed by 276 farmers. The main reason for selecting Curahtakir was its distinct irrigation characteristics. Curahtakir irrigation is categorised as non-technical/simple irrigation. In Indonesia, approximately 40.5% of agricultural land is irrigated by non-technical irrigation (Supriyatna et al. 2014). Accounting for such a significant proportion plays an essential role in the Indonesian national plan to achieve food (rice, maize and soybean) self-sufficiency in production.

The altitude of the studied irrigation system is 200 metres above sea level. The studied irrigation system consists of three sections: an upper, middle and lower area. There are three cropping seasons annually in this area with relatively similar cropping patterns in each section: paddy in the first and second seasons and mostly maize in the last season.[2] The distinguishing characteristics among the sections are water availability and

[1] Irrigation in the study area can be defined as gravity-flow hill irrigation; for detailed discussion on the technical and management aspects of this irrigation see Hill (2013, 2017).

[2] Actually, the cropping season is divided based on the two main seasons in Indonesia, the rainy and dry seasons. The first cropping season is called the rainy season, while the second and the third season are called dry season 1 and dry season 2 respectively.

water provider, which vary between cropping seasons. In the first season, water is sufficient in all areas since most water comes from rainfall. In the second season, spring water is the main supplier of irrigation water but can only provide water for the upper area and some parts of the middle and lower areas. In the third season, irrigation water is available only in the upper area and water is provided by a water pump to the middle and lower areas. Irrigation from a spring is provided by the water user association (WUA) and operated by a WUA official called *ulu-ulu*.[3] However, when water is not sufficient in the second and third seasons in the lower and middle areas, irrigation is provided by a private water pump.

A full illustration of the studied irrigation area is shown in Figure 2. Water coming from a spring in the forest is stored in four dams: the Agung and Punco dams in the upper area and the Bloksadeng and Asmoya dams in the middle and lower areas. There are two other water sources in the middle and lower areas: two dug wells and eleven water pumps. Both middle and lower areas have one dug well, but only three water pumps are located in the middle area while the rest are located in the lower area. Many water

[3] There are three *ulu-ulu* in the study area, one person for each section.

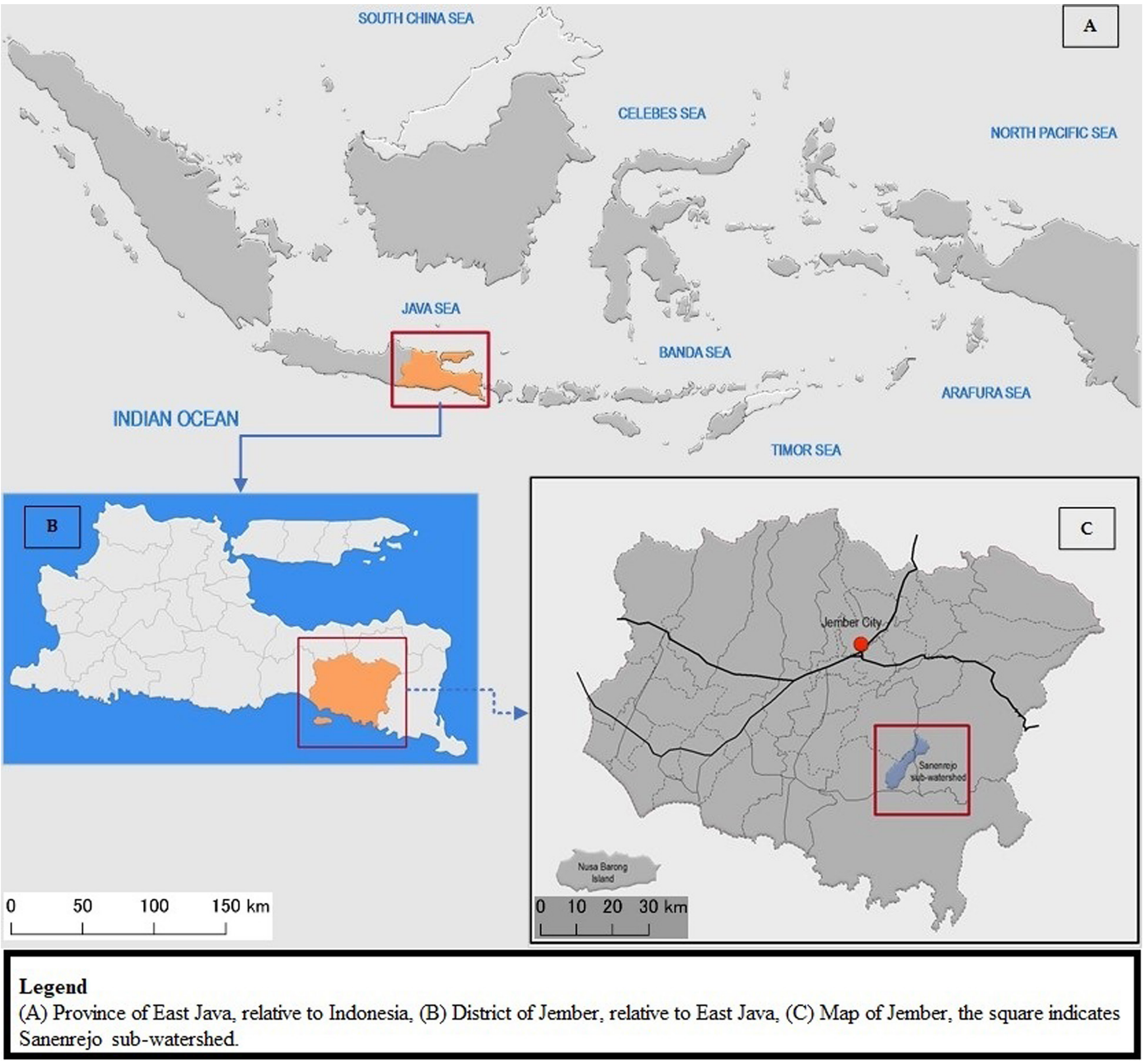
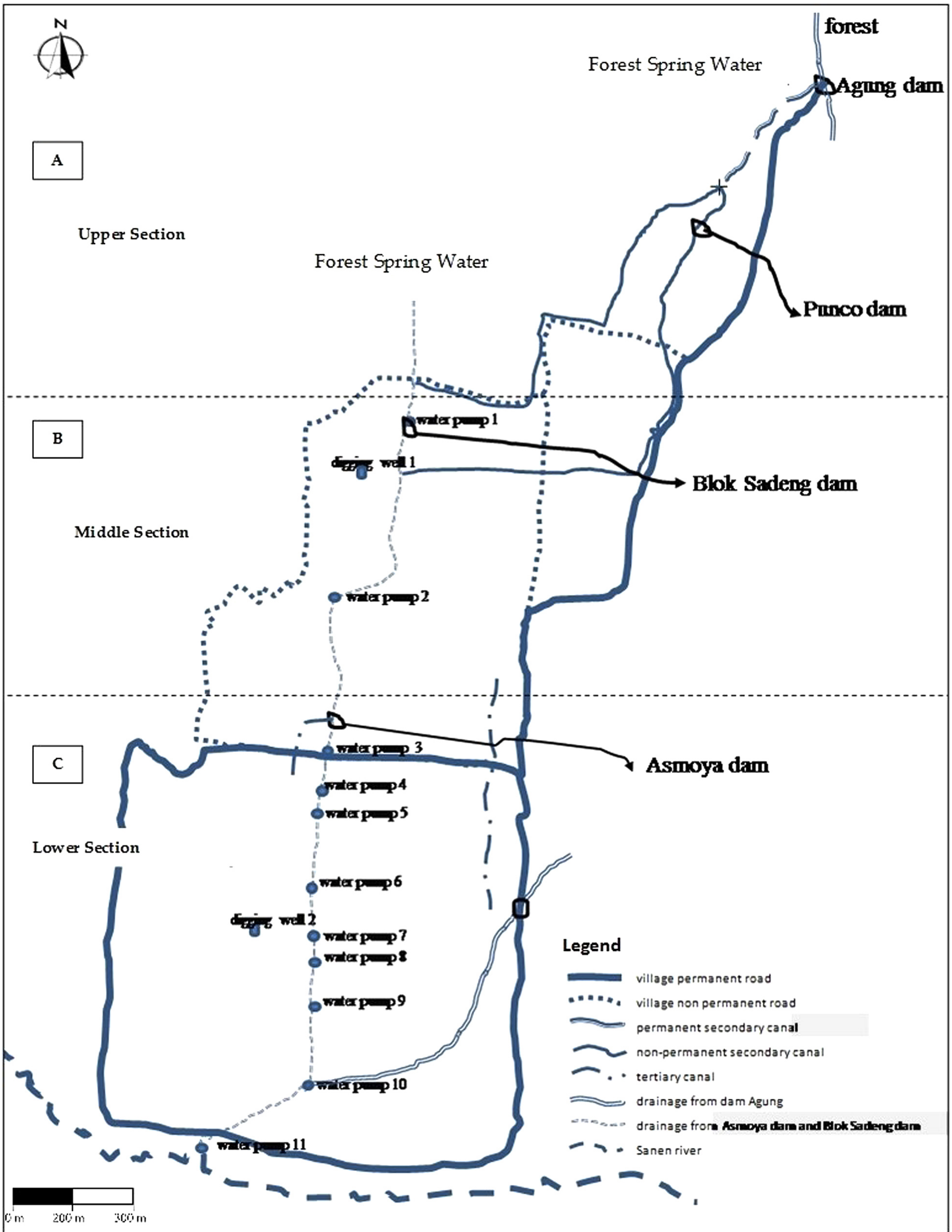


Fig. 1. Map of the study area.
Source: own compilation.



Legend

(A) The upper section of the irrigation system (IS) consists of two spring water from the forest and two dams.
(B) The middle section consists of two water pumps, a digging well and a dam.
(C) The lower section consists of nine water pumps, a digging well and a dam.

Fig. 2. The scheme of the studied irrigation system.
Source: own compilation.

pumps are required in the lower area since the water scarcity is high in the second and third seasons.

Figure 3 illustrates the actual condition of each II. Figure 3A shows the Agung dam located in the upper area, which stores water from the spring. Figure 3B shows one of the water pumps (water pump 7) that pumps water from the drainage canal from the Asmoya and Bloksadeng dams (Figure 3C). Figure 3D shows one of the wells

Legend
(A) Agung dam, the main water reservoir; (B) Private water pump; (C) Irrigation and drainage canal; (D) Farmer digging well; (E) Spring water from mountain forest; (F) Deforestation in the mountain forest.

Fig. 3. Irrigation system in the studied area.
Source: photos taken by the authors.

owned by a farmer (digging well 2). Figure 3E shows spring water from the forest in the mountain. Figure 3F shows substantial deforestation in the mountain forest, which causes a decrease in spring water quantity that leads to water scarcity.

Data

We collected data that represent both physical and economic water scarcities. The physical water scarcity is represented by the rainfall, streamflow and forest cover change data. These data are crucial because the primary water source in the studied SSI is rainfall and forest spring water. We used daily rainfall data from 2010 to 2015 from a rainfall station in Sanenrejo (the nearest station to Curahtakir). Additionally, we collected daily streamflow data from 2010 to 2015. Recently, the quantity of spring water started decreasing due to deforestation. The spatial data of land-use change in the Sanenrejo sub-watershed between 2011 and 2019 represent the most current land use in the studied area. The perceived economic value of water represents the economic water scarcity. We used the contingency value method (CVM) to calculate the economic value of water. Interviews with a sample set of farmers were used to collect information on the economic value of water and socio-economic characteristics of the farmer.

The research sample was determined using simple random sampling (SRS). SRS was used because the population of the study was identified. In the initial sampling stage, the farmer population was determined with the help of *ulu-ulu*.[4] The research sample was n = 100 farmers who were interviewed from a total of 276 farmers. The following formula determined the sampling number:

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

where n is the sample size, N is the population size and e is the sample's error tolerance. With a sample size of 100 farmers, the error tolerance is 7.9%, meaning there is a 7.9% range of tolerated errors in the data. The farmer's WTP of the sample was approximately 7.9% higher or lower than the population WTP.

A structured questionnaire was used to gather data by interviewing sample farmers from Curahtakir village. The main characteristic of Curahtakir agriculture is that it is irrigated by water from a spring utilising non-technical II. However, spring water can only serve the upper area in the dry season, forcing the middle and lower areas to use an irrigation water pump. Thus, the sample farmers used in this study were dispersed across all three areas. The questionnaire consisted of three sections. The first section focused on the social and economic characteristics of the farmer. This section was divided into four parts. The first part dealt with farmer identity. In this part, farmer age (X_2), education (X_3) and income (X_4) were identified. The remainder of the first section was structured as follows: the second part dealt with general farming conditions, the third part dealt with cultivation land status and size (X_1) and the final part dealt with the annual cropping calendar.

The second section focused on irrigation management in each cropping season. This section was divided into irrigation management in the rainy season, the first dry season and the second dry season. The focus was on the technical aspect of irrigation, such as water source, distance of farmed plots to a water source (X_5), information on who provides irrigation services and the service fees, the irrigation schedule and irrigation management in the dry season (D). In the dry season, irrigation management was a dummy variable used to categorise farmers who use the water pump and those who do not irrigate their land in the dry season. The last section of the questionnaire focused on eliciting farmers' WTP for irrigation. This section consisted of 12 questions to explore how a farmer perceives the current irrigation price and the highest price. In this section, the farmer was also asked about what they would do if the irrigation price was beyond their ability to pay. Finally, this section also inquired about the role of *ulu-ulu* as a current irrigation provider.

Analytical procedure

The first step of the analysis was to determine the farmer's WTP. In determining WTP, we used

[4] Responsible for irrigation operation, *ulu-ulu* knows exactly how many farmers he is responsible for and where their plots are located.

the CVM. There are two ways to measure WTP: revealed preference and stated preference methods. The revealed preference method utilises the actual payment data to measure WTP, while the stated preference method measures WTP using direct surveys and is utilised when there is no adequate information about historical payments (Breidert 2006). CVM is the most commonly used method to measure WTP for non-marketed goods. This method has two main advantages: (1) its ability to evaluate proposed goods or services and (2) its usefulness in addressing values that cannot be dealt with any other way (Young 2005; Tang et al. 2013).

The second step of the analysis was to determine factors affecting farmers' WTP. To do so, we used multiple linear regression with WTP as the dependent variable and the variables are shown in Table 1.

The multiple linear regression method estimates the nominal value of the farmer's WTP from the identified social, economic and technical characteristics. Our predicted variable is the WTP value obtained from the contingent valuation method, while X_1–X_5 and D are the explanatory variables. The multiple linear regression method was based on the least squares estimation and estimation performed with SPSS software (version 25; SPSS Inc., Chicago, IL, USA). The empirical model is shown in Eq. (2).

$$WTP = b_0 + \sum_{i=1}^{5} b_i x_i + b_6 D + e \tag{2}$$

The empirical model contains a dummy variable representing two groups: 1 for those who use the water pump in the dry season and 0 for those who do not use. The final model consists of two Eqs (3) and (4).

$$WTP_1 = b_0 + \sum_{i=1}^{5} b_i x_i + b_6 + e \tag{3}$$

$$WTP_0 = b_0 + \sum_{i=1}^{5} b_i x_i + e \qquad (4),$$

where WTP_1 is the WTP of a farmer who uses a water pump to irrigate their crop during the dry season while WTP_0 is the WTP of a farmer who does not use the water pump in the dry season, b_0 is the regression intercept, and the other b(s) are the regression coefficients of the variables.

Results and discussions

Long-term changes in rainfall, streamflow and forest cover

For eight years, the land-use pattern was relatively constant (Table 2). The most extensive land type in the Sanenrejo sub-watershed was forest (close to 50%) followed by plantations (>35%), and then Tegal, rice fields, open land and settlements covered an area <20%. In the same period, the spatial analysis results show that certain types of land use decreased there, and conversely, several types of land use increased. Forest land use was reduced by 1,550 ha, followed by plantations and paddy fields (by 194 ha and 50 ha respectively); on the other hand, there was an increase in land use in Tegal, open land and settlements (1,521 ha, 170 ha, and 102 ha respectively).

The forest ecosystem contains various types of plants with a multilevel canopy that functions as the main rainwater catchment area in the watershed area. Thus, reduced forest land cover can impact the amount of rainwater that can be stored in the soil. Table 2 shows a decrease

Table 1. Variables in the model.

Variables	Code	Description
Farm size	X_1	Size of farmer's land (ha)
Age	X_2	Farmer's age (years)
Education	X_3	Farmer's formal education (years)
Income	X_4	Farmer's income in one cropping season (US$/ha)
Distance to small dam	X_5	Distance of farmer's land to small dam (m)
Management in dry season	D	Dummy variable representing type of irrigation used in the dry season: (1) private water pump and (0) irrigation from WUA.

WUA – water user association.
Source: own compilation.

in average discharge during the rainy and dry seasons, even though the rainfall in the same period showed an upward trend of 184 mm/year and 64 mm/year in the rainy and dry seasons (Table 3).

The volume of stored water shows the amount of rainwater that can be stored in the soil. Table 3 shows that in the wet season, water is stored at a rate of 576 mm/year. In dry season 1, the volume of stored water showed a negative trend. This trend has implications for the lack of water availability in dry season 1. On the other hand, Table 4 shows a decreasing trend in rainfall (natural water input) of −1.082 in the 2011–2019 period compared with the 1993–2010 period. Therefore, in several micro watersheds in the Sanenrejo sub-watershed, farmers have used a water pump to meet plant water needs.

Figure 4 shows that land use changed in the study area. Forest cover has long been a significant factor for water resources. Forests act as 'sponges' that retain water through soil infiltration. Deforestation reduces soil infiltration, increases overland water flow and reduces groundwater recharge and baseflow (Peña-Arancibia et al. 2019). The increasing overland water flow is reflected by the increasing streamflow during a period with heavy rainfall. The declining vegetation cover is also responsible for the declining streamflow and shares an equal role with climate

Table 2. Changes in land use in the Sanenrejo sub-watershed for the period 2011–2019.

No.	Land use	2011		2019		Land use	
		(ha)	(%)	(ha)	(%)	Change	(%)
1.	Forest	13,227.23	47.71	11,676.97	42.12	−1550.26	−11.72
2.	Plantation	10,679.91	38.52	10,486.21	37.83	−193.70	−1.81
3.	Dryland	2,480.25	8.95	4,001.91	14.44	1,521.67	61.35
4.	Rice field	748.43	2.70	698.20	2.52	−50.24	−6.71
5.	Open field	266.76	0.96	437.16	1.58	170.41	63.88
6.	Residential	320.20	1.15	422.32	1.52	102.12	31.89
	Total	27,722.77		27,722.77			

Source: own compilation.

Table 3. Trends of changes in mean discharge, peak discharge, discharge ratio and water volume in the Sanenrejo sub-watershed (2011–2019).

Month	Average discharge (lt/s)	Peak discharge (lt/s)	Peak discharge/average discharge ratio	Vol. stored water (mm/year)
Wet season	29.768**	40.171**	1.97**	576**
Dry season 1	−48.778**	−140.492**	−0.78**	−84**
Dry season 2	−13.864**	−14.194**	−1.83**	325**
Wet season	−54.590**	−89.750**	−2.59**	166**
Dry season	−59.549**	−83.395**	0.86**	583**
Annual	−47.175**	−8.969**	0.23**	4,200**

Source: own calculation based on data from the Sanenrejo climate station.
Notes: ***p < 0.01, **p < 0.05, *p < 0.10.

Table 4. Trends of changes in rainfall, number of rainy days and rain intensity in the Sanenrejo sub-watershed (2011–2019).

Month	Rainfall (mm/year)			Number of rainy days (day)			Rain intensity		
	1993–2010	2011–2019	D	1993–2010	2011–2019	D	1993–2010	2011–2019	D
Wet season	−140**	1.269**	1.409	−4	73**	77	−2.50**	−0.39**	2.10
Dry season 1	27**	−1.055**	−1.082	2	2**	0	−0.39**	−34.17**	−33.78
Dry season 2	−10**	224**	234	−1	56**	56	−2.02**	3.39**	5.41
Wet season	−64**	120**	184	−1	91**	92	−0.75**	−18.17**	−17.42
Dry season	11**	74**	64	0	51**	51	−0.16**	−29.96**	−29.80
Annual	−54**	323**	377	−2	−152**	154	−1.38**	−26.41**	−25.04

Source: own calculation based on data from the Sanenrejo climate station.
Notes: ***p < 0.01, **p < 0.05, *p < 0.10.

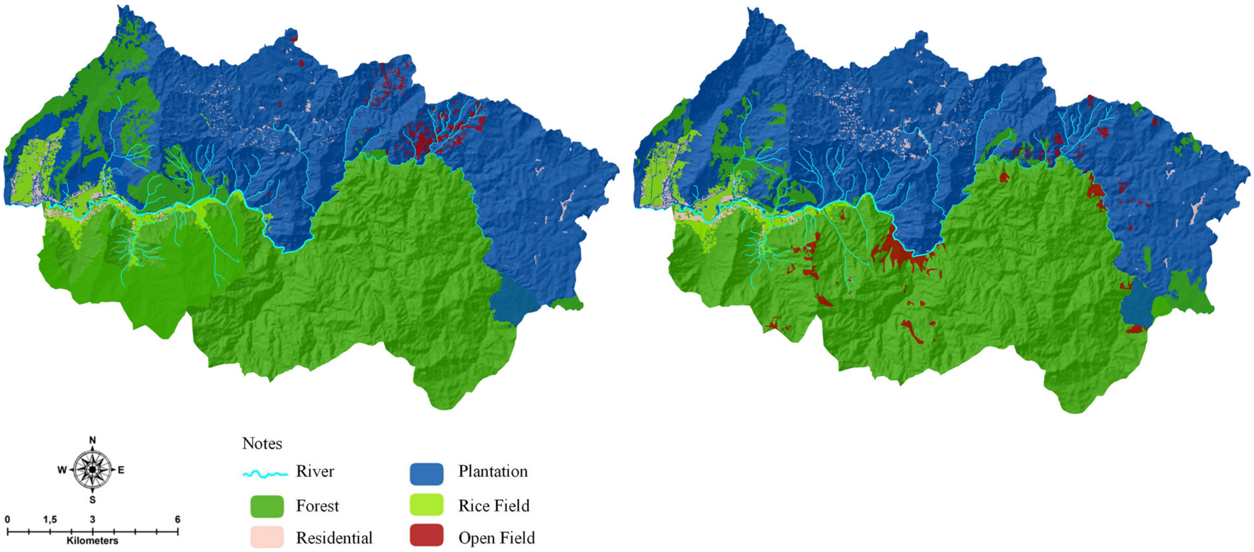


Fig. 4. Land-use change in the Sanenrejo sub-watershed between 2011 (left) and 2019 (right).
Source: own compilation.

change in transforming a catchment area into a water-limited area (Cecílio et al. 2019; Liu et al. 2019). Thus, the data indicate that the studied SSI faced physical water scarcity due to deforestation in the mountain area, which reduced soil infiltration and increased overland water flow.

WTP for irrigation water

WTP for irrigation varies by location and season and is mostly attributed to water scarcity and difficulties in providing water to farmer plots. As water scarcity increased during the second and third seasons, the WTP increased. In the first season, when water was sufficiently available, the average WTP was the lowest. The average WTP for the upper, middle and lower areas were US$ 19.62/ha, US$ 27.44/ha and US$ 23.57/ha respectively. In contrast, the average WTP for the second season was US$ 31.03/ha, US$ 158.68/ha and US$ 108.16/ha for the upper, middle and lower areas respectively. This value is significantly higher than the irrigation water fees charged in an area with technical irrigation, as Syaukat et al. (2014) identified that the water fees paid by a farmer in Bogor and Kudus were US$ 5.29/ha and US$ 10.59/ha annually[5].

These results demonstrate that water is as an 'economic good' during water scarcity. Although this study focused on irrigation from spring water, the same condition was identified for almost all kinds of water sources, such as groundwater (Knapp et al. 2018), surface water (Chandrasekaran et al. 2009) and even for the demand of recycled water for irrigation (Bakopoulou et al. 2010). Moreover, the cost of irrigation for farmers accounts for 20% of their revenue[6]. However, the identified WTP is the highest value the farmer is willing to pay. When asked what they will do when water price goes higher than the current level, they prefer to plant another crop that requires less water[7].

In total, the average irrigation cost for an entire plot (144 ha) was US$ 31,080.95. Furthermore, there was a significant WTP increase of 578% and 458% in the middle and lower areas, while WTP in the upper area was only 192%. This number further increases in the third season with 260%, 799% and 684% rises for the upper, middle and lower areas respectively. This figure indicates that the economic value of water for the farmer is high. Thus, they are likely to invest in building II, which lessens the irrigation cost and increases its efficiency. Although water scarcity grows in land

5 Bogor and Kudus are two districts located in the Province of West and Central Java.

6 Total WTP for the sampled farmers was US$ 5,897.65 and total revenue was US$ 31,692.47.

7 Similar results were found by Bozorg-Haddad et al. (2016) according to which farmers employ irrigation systems with high efficiency to reduce the use and cost of irrigation water. They also change the cropping pattern to cultivate crops with low water requirements.

altitudes, the middle area had the highest WTP in all seasons, showing that the value of water is not affected by water availability alone. Hence, it is crucial to investigate the determinants of WTP further.

Determinants of WTP

The determinants of farmers' WTP were identified by multiple linear regression method. The F-test for the overall fit of the model is shown in Table 5. It tests the null hypothesis that all coefficients in the model are 0. Since the F-test *p*-value is $p < 0.05$; $p = 0.00$, the null hypothesis that all variables coefficients are 0 is rejected. Thus, it can be concluded that the model is better at estimating farmers' WTP for irrigation water. The explained variance of the dependent variable can be measured with the R^2 value. The R^2 value of 0.83 indicates that the model can explain 83% of the WTP variation. This percentage is satisfactory since the model does not violate the normality, multicollinearity, homoscedasticity and linearity assumptions.

The *t*-test in Table 5 measures the significance of each independent variable. If the *p*-value is <0.05, then the variable has a significant contribution to the model. The *t*-test shows that farm size, income, distance to a small dam and management in the dry season are significant. Each of these variables has a *p*-value <0.05. The effects of each independent variable are reflected by the value of the coefficients. A negative coefficient indicates that the corresponding variable reduces farmers' WTP. Conversely, a positive coefficient indicates that the corresponding variable increases farmers' WTP. The value of coefficients reflects a multitude of effects. The estimation results show that social variables—age and education—do not significantly affect farmers' WTP. The farmer's age and education had a *t*-test value of −3.012 and −0.027 with *p*-value >0.05: $p = 0.98$ and $p = 0.11$ respectively. This result shows that social characteristics do not affect the value of farmers' WTP. Identical results were found by Jaghdani and Brümmer (2016), who identified WTP determinants for Iran's groundwater. Their study found that social characteristics do not significantly affect farmers' WTP.

Table 5. Estimation results of the model.

Variable	Coefficients	*t*-test (*p*-value)
Constants	1,283,795	1.520 (0.13)^{ns}
Farm size	−1,702,240	−3.012 (0.00)***
Age	−301,349	−0.027 (0.98)^{ns}
Education	−46,701	−1.607 (0.11)^{ns}
Income	0.146	7.549 (0.00)***
Distance to small dam	−750,874	−2.410 (0.02)**
Management in dry season	2,144,361	9.369 (0.00)***
n	100	
R^2	0.83	
F-test	84.18	
p-value	0.000	

Source: own calculation.
Notes: ***p < 0.01, **p < 0.05, *p < 0.10.
ns – non-significant.

Both economic and technical variables affect WTP significantly. Farm size has a negative effect, while income has a positive one. The results show that larger farms tend to be less willing to pay higher irrigation prices. Conversely, farmers with higher incomes tend to be more willing to pay higher irrigation price. Larger farms require a larger volume of water, thus increasing the overall cost of farming. Hence, farmers with larger farms tend to be unwilling to pay higher irrigation prices. A similar result was found by Jaghdani and Brümmer (2016). Larger land endowment reduces farmers' WTP although farmers with higher incomes can pay higher irrigation prices.

Both economic and technical variables had *p*-value <0.05. Distance to the small dam had a negative coefficient, while management in the dry season had a positive coefficient. This means that farmers with plots located far away from a water source (a small dam) have a higher WTP since it is increasingly costly to provide water to their farm. This factor explains why the WTP in the middle area is higher than in other areas, especially in the dry season. Out of the eleven water pumps in the studied region, only two are located in the middle area. Consequently, the cost to provide water to the middle area is higher. The last variable—management in the dry season—had a positive coefficient and showed that farmers who use water pumps are willing to pay higher irrigation prices.

Conclusions and policy implications

This study assessed water scarcity in a SSI system and measured the economic value of irrigation water in the studied area. The results showed that the studied SSI faces both physical and economic water scarcities. Physical water scarcity is caused by deforestation in the mountain area that reduces the quantity of spring water, which is the primary water source in this area. Deforestation decreases groundwater recharge by decreasing soil infiltration. It also reduces streamflow in the dry season and increases overland water flow during the rainy season. Economic water scarcity is caused by poor II which increases the economic value of water, especially in the dry season and areas far from the water source (the middle and lower areas).

The irrigation system in the study area can be improved in two ways: improving II and strengthening the role of WUA. Improved IIs will extend the coverage of spring water and extend land served by WUA. As shown in Figure 5, the mature rice plants in the upper area receive high volumes of water as the irrigation canal cannot be utilised to stop the water flow. On the other hand, the rice field in the lower area does not receive the water it needs. Thus, an improved irrigation canal could deliver the water to the lower area and make irrigation more efficient.

The establishment of IIs can be funded by mobilising farmer resources. High farmers' WTP indicates that farmers are likely to be willing to participate in that process. The establishment of II will increase irrigation efficiency, increase water availability and lower the irrigation costs. As stated by Sheikh et al. (2016), water canal availability strengthens the social capital among water users and makes WUA more dynamic.

Employing a development strategy that requires farmer participation to improve irrigation efficiency was proven to be favourable in the long-term. Limiting farmer participation in the establishment of II will reduce their incentives to contribute to infrastructure maintenance, and their collective inaction will lead to low-level irrigation performance (Lam 1996). Furthermore, when farmers perceive the benefits they will receive for improved IIs, they are willing to pay more fees. As shown in Iran, farmers are willing to pay an additional fee to fund the operations of WUA, which reduces their transaction costs associated with irrigation (Hassan et al. 2007). Apart from the fact that it is challenging to mobilise farmers, we believe that this option is the most appropriate way to achieve equity, efficiency and sustainability of irrigation. The practical lesson from this study both in local and international cases is that farmers have the potential to fund and manage the irrigation system. Realising this

Fig. 5. Over-watered mature rice plant in the upper area.
Source: photo taken by the authors.

potential is a viable solution to improve the irrigation system that is facing severe water scarcity compared to intervention by outside actors.

Finally, future research needs to address the following issues:

1. The likelihood of farmers participating in the II establishment and their WTP to establish those infrastructures.
   The current study provides information regarding the economic value of water in the studied area. However, to proceed with the infrastructure establishment, the likelihood of farmer participation and their WTP must be measured.
2. Identification of the method to coordinate farmers to mobilise their resources.
   It is critical to identify who has influence in the farmer community. Identifying this person will give an essential insight into how to mobilise farmer communities.
3. The appropriate type of infrastructures.
   It is critical to identify the type of infrastructure required by farmers and its ease of operation.

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