Economic Value of Water Yields on Critical Land Conservation in Kuranji Watershed

E G Ekaputra¹, Yonariza², D Wardiman³

¹ Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology, Andalas University
² Department of Environmental Science, Postgraduate Program, Andalas University
³ Department of Environmental Science, Postgraduate Program, Andalas University

Corresponding author’s e-mail address: dokwardimann@gmail.com

Abstract. The Kuranji watershed has a complex problem which cannot be studied with a single scientific approach. In addition to an ecological approach it is also necessary to consider social and economic influences. Conserving areas that have a negative impact on watersheds, such as critical lands, is one of the efforts made to conserve watersheds will reducing costs and speeding up the recovery. The aim of this research is to estimate the economic value of the water yield of the Kuranji watershed on land conservation efforts. To get the economic value of water yield in the watershed, the non-market price approach method is used with the Contingent Valuation Method (CVM). The results showed that there were 356.10 ha of critical land in the Kuranji watershed that could be conserved. The value of water yield in existing land use conditions is greater than water yield in land use conditions influenced by conservation efforts. In this study, it was determined that the estimated economic value of water yield in the Kuranji watershed is 272 IDR/m³ of water. This is supported with a conservation value of 80% of critical land.

Keywords: Kuranji Watershed, Water Yield, Economic Value, Critical Land.

1. Introduction

Water is one of the natural resources that fulfills human needs and serves as a source of life; in other words, without water, humans cannot live. Nearly 1 billion people in the world depend on water resources which are currently threatened in terms of both access and security. This is especially true when it comes to drinking water [1]. In general, problems in water resource management are related to the fact that there is too much water when it rains and too little when the weather is dry. Furthermore, there are high levels of pollution. Natural disasters that occur in the area of the watershed are an indication that the hydrological function of the watershed is disturbed. In such conditions the watershed cannot support an optimal water system. In addition, climate change and land use change have a major impact on the water balance of the watershed and sub-watershed, affecting various parameters such as water yield, surface runoff, evapotranspiration (ET) etc. [2]. Changes in land use and vegetation types on a large and permanent scale can affect the amount of water yield [3]. Water utilization activities in the upstream area will also have an effect on the downstream watershed in the form of changes in water retention capacity. Control of water release in the downstream area in the form of changes in water quantity and water quality [4].
There are 6 watersheds in the city of Padang which meet community water needs, including the Air Dingin Watershed, the Air Timbalun Watershed, the Batang Arau Watershed, the Batang Kandis Watershed, the Kuranji Watershed and the Sungai Pisang Watershed. However, the Kuranji Watershed is one of 2 watersheds with the status of being flood-prone areas in Padang (Regional Environmental Status (SLHD) of West Sumatra Province, 2014). The high level of activity in the Kuranji watershed has had an impact on the social and economic conditions of the community. This was proven in July 2012 when flash floods hit the city of Padang. The Kuranji watershed has a complex problem which cannot be studied with a single scientific approach. In addition to an ecological approach it is also necessary to consider social and economic influences.

Conserving areas that have a negative impact on watersheds, such as critical lands, is one of the efforts made to conserve watersheds. Conservation that is right on target will succeed in reducing costs and speeding up the recovery of the watershed. Individual preferences in terms of the value of environmental damage, inconvenience, increase or decrease in the level of welfare on the use and management of a resource differ from one another. Willingness to pay (WTP), for example, will reflect people's perceptions of the availability and importance of water for society [5]. The approach for analyzing the economic value of water yields will generate an economic value in an effort to improve the Kuranji watershed environment. The aim of this research is to estimate the economic value of the water yield of the Kuranji watershed on land conservation efforts.

2. Materials and Methods

This research was conducted from October to December 2019 in the Kuranji watershed area, Padang City, West Sumatra Province - Indonesia. The conservation area of the Kuranji watershed was analyzed based on the output of a SWAT analysis, e.g. the level of land criticality, based on the Ministry of Forestry Regulation No P.32 / Menhut-II / 2009 concerning Procedures for Preparing Technical Plans for Forest and Watershed Land Rehabilitation (RTkRHL-DAS) [6].

To get the economic value of water yield in the watershed, the non-market price approach method is used. The economic value obtained from the respondents will determine the community's perception of the sustainability of the Kuranji watershed. The non-market price approach is carried out using the Contingent Valuation Method (CVM). The survey is limited by the definition of a sample survey, which is information collected from a segment of the population meant to represent the entire population [7]. The number of samples was calculated using the Slovin formula, with an error rate of 10%. Based on the results of preliminary observations, the total number of people who use water resources in the Kuranji watershed is 286,147; these live in 34 villages in the city of Padang. The Slovin formula for determining the number of samples is as follows:

\[
n = \frac{N}{1 + Ne^2}
\]

with \(n\) is number of samples, \(N\) is total population, and \(e\) is Error. When using a percentage error of 10%, the number of samples studied is 100 people.

There are four techniques for collecting data and information on WTP, i.e.:

1. Desk study: This technique consists of collecting and studying secondary data from related agencies in the Kuranji watershed.
2. In-depth interview: This technique is used to obtain data and information from the community, users and managers of the Kuranji watershed.
3. Observation: This technique is used to see the real existing conditions of the Kuranji watershed.
4. Questionnaire, This technique is used by giving questionnaires to respondents who are drawn based on samples to obtain information on the benefits and willingness to pay of the Kuranji watershed.
The value of the WTP is both qualitative and quantitative in nature, including the condition of the area, the history of natural resource utilization and management. The respondents' personal data covers age, gender, education, income, number of dependents, status of population and residence, perceptions of the importance of conservation, and perceptions of the level of need for water. The questions mentioned are variables that might affect the WTP of the Kuranji watershed.

The Contingent Valuation method is used in several developing countries to determine individual preferences regarding non-use products such as clean water and sanitation services [8]. The community’s desire and ability to earn environmental benefits is obtained by directly interviewing respondents. The stages of CVM research are as follows:

a. Making a hypothetical market
b. Getting bids value
An analysis of the estimated auction value is obtained based on the area of conservation and the amount of water produced. The water price offered is a conservation price which refers to several conservation activities, in accordance with the Regulation of the Director General of Conservation of Natural Resources and Ecosystems Number: P.8/KSDAE/SET/REN.2/10/2017 Concerning Standard Activities and Costs in the Sector of Natural Resources and Ecosystem Conservation in 2018. Conservation will be carried out biologically, namely, in the form of forest rehabilitation, with plants that have an economic value, such as durian, mangosteen, and other types of plants that the local community is familiar with. This effort can reduce water yield by increasing groundwater, and can improve the quality of surface water and especially groundwater [3]. Therefore, the land cover of the conservation area will turn into a mixed forest. Conservation areas for simulation activities are made into 3 scenarios, e.g. 100% conservation, 80% conservation and 50% conservation. This scenario is carried out to see the differences in the results of water yield, runoff, and groundwater from the simulation results of the SWAT model.

The bids value in this study is obtained by means of the referendum model technique or discrete choice (dichotomous choice). This model consists of offering respondents a certain amount of money and asking whether they are willing to pay that amount of money to obtain environmental quality improvements. This method makes it easier to classify respondents who have a tendency to pay for environmental improvements and those who do not have the desire to do so. To determine community water needs, an analysis is carried out based on SNI 19-6728.1-2002 and SNI T-01-2003. So, the auction bids value is therefore obtained as shown in table 1.

c. Calculating the Average WTP
The techniques for calculating the average value of WTP are as follows:

$$\Sigma WTP = \Sigma_{i=1}^{n} W_i. P_f i$$  \hspace{1cm} (2)

With WTP is estimated average of WTP, $W_i$ is the lower limit of the WTP class, $P_f i$ is the relative frequency of a particular class, $n$ is number of classes, and $i$ is Class $i$.

d. Calculating the Aggregate of WTP

$$TWTP = \Sigma_{i=1}^{n} WTP. \left(\frac{n_i}{N}\right) P$$  \hspace{1cm} (3)

| Activities          | Luas (ha) | Price of Conservation | Price of Water       |
|---------------------|-----------|-----------------------|----------------------|
| 100 % Conservation  | 356,10    | Rp 33,679.581.900,00  | Rp/m³ 395,02 ≈ Rp/m³ 400 |
| 80 % Conservation   | 284,68    | Rp 26,924.749.720,00  | Rp/m³ 315,78 ≈ Rp/m³ 300 |
| 50 % Conservation   | 178,14    | Rp 16,848.303.060,00  | Rp/m³ 197,60 ≈ Rp/m³ 200 |

Source: SNI 19-6728.1-2002 and SNI T-01-2003
with TWTP is the willingness of the population to pay, WTP is the willingness of respondents (sample) to pay, n is the number of samples willing to pay in WTP amount, n is Number of classes; P is total population; and i is Sample i.

3. Result and Discussion

Water yield is one of the outputs of the SWAT model. Besides generating water yield, the SWAT model also unravels all hydrological processes that take place in an area. The water yield of the watershed is influenced by several parameters such as runoff and groundwater. Consequently, the offer given to respondents is not only related to water yields but also to runoff and groundwater.

The value of water yield in existing land use conditions is greater than water yield in land use conditions influenced by conservation efforts. Judging from the water needs of the people of this area, there is a high yield of water that has not been used and thus has the potential to cause runoff. The value of water yield has decreased since the conservation of critical land began in the Kuranji watershed (Table 2). This decrement of water yield does not indicate bad conditions of critical land conservation. One of the causes of reduced water yield can be higher evaporation due to increased forest area but this decrease has little impact as long as the temporal flow is evenly distributed throughout the year [9].

Change in forest land use almost certainly follows a pattern as urban areas develop, moving from forest to agricultural, plantation, and residential use types. Such changes clearly have a profound effect on the regional water balance and the relevant watershed hydrological regime [10]. The scenarios developed in this model can be used as a direction in planning future watershed management with due regard to economic value. The simulation results in the four scenarios show that the 100%-conservation scenario results is better hydrological conditions. This is because the area of land cover in the form of forest increases more than in other scenarios, which prevents direct rainwater from falling to the soil surface, thereby reducing erosion and surface runoff (Table 3). In addition, if land is conserved, this increases groundwater (Table 4). The resulting groundwater will become a stock if a water crisis occurs in the Kuranji watershed. The increase in groundwater is caused by a decrease in surface runoff due to changes in land use. Therefore, a lot of water will be absorbed by the soil. This condition is of course very beneficial when it comes to the water in the Kuranji watershed area meeting community needs.

| Months  | 50 % Conservation | 80 % Conservation | 100 % Conservation |
|---------|--------------------|--------------------|--------------------|
| January | 249,534            | 249,652            | 249,665            | 250,001 |
| February| 396,502            | 396,309            | 396,186            | 396,150 |
| March   | 359,171            | 358,829            | 358,675            | 358,415 |
| April   | 321,867            | 321,909            | 321,937            | 321,996 |
| May     | 318,329            | 318,315            | 318,334            | 318,293 |
| June    | 230,518            | 230,981            | 231,196            | 231,670 |
| July    | 274,214            | 274,444            | 274,562            | 274,740 |
| August  | 182,393            | 182,840            | 183,076            | 183,402 |
| September| 289,179          | 289,218            | 289,273            | 289,195 |
| October | 465,043            | 464,572            | 464,401            | 463,842 |
| November| 534,081            | 533,544            | 533,317            | 532,765 |
| December| 573,513            | 573,364            | 573,265            | 573,235 |
| Total   | 4,194,344          | 4,193,977          | 4,193,887          | 4,193,704 |
Table 3. Runoff Simulations on Land Conservation of Kuranji Watershed

| Months  | Existing | 50% Conservation | 80% Conservation | 100% Conservation |
|---------|----------|------------------|------------------|-------------------|
| January | 65,991   | 65,473           | 65,256           | 64,789            |
| February| 237,610  | 236,848          | 236,522          | 235,802           |
| March   | 147,562  | 146,438          | 145,982          | 144,907           |
| April   | 117,552  | 116,734          | 116,405          | 115,644           |
| May     | 103,444  | 102,465          | 102,071          | 101,157           |
| June    | 55,456   | 55,079           | 54,925           | 54,606            |
| July    | 94,385   | 93,780           | 93,542           | 92,945            |
| August  | 32,030   | 31,668           | 31,543           | 31,163            |
| September| 122,636  | 121,827         | 121,494          | 120,746           |
| October | 255,798  | 254,369          | 253,771          | 252,457           |
| November| 275,758  | 274,156          | 273,475          | 272,025           |
| December| 301,474  | 300,205          | 299,636          | 298,557           |
| Total   | 1,809,696| 1,799,042        | 1,794,622        | 1,784,798         |

Table 4. Ground water Simulations on Land Conservation of Kuranji Watershed

| Months  | Existing | 50% Conservation | 80% Conservation | 100% Conservation |
|---------|----------|------------------|------------------|-------------------|
| January | 141,273  | 141,802          | 141,998          | 142,716           |
| February| 118,858  | 119,301          | 119,465          | 120,062           |
| March   | 132,700  | 133,296          | 133,541          | 134,230           |
| April   | 136,911  | 137,622          | 137,934          | 138,650           |
| May     | 147,400  | 148,207          | 148,571          | 149,333           |
| June    | 142,798  | 143,566          | 143,912          | 144,638           |
| July    | 132,756  | 133,448          | 133,756          | 134,438           |
| August  | 119,000  | 119,686          | 120,003          | 120,634           |
| September| 104,077  | 104,778          | 105,117          | 105,691           |
| October | 119,923  | 120,693          | 121,064          | 121,694           |
| November| 150,631  | 151,461          | 151,845          | 152,589           |
| December| 189,795  | 190,716          | 191,124          | 192,034           |
| Total   | 1,636,122| 1,644,576        | 1,648,330        | 1,656,709         |

The environmental conditions in the Kuranji watershed are quite alarming. Almost every year floods occur in the Kuranji watershed. The high activity in the upstream part of the Kuranji watershed is one of the causes of the decline in the function of the watershed. The general characteristics of respondents who use water in the Kuranji watershed are obtained based on a survey conducted on 100 respondents. The general characteristics of these respondents are explained by several criteria, as described below (Figure 1.).
A total of 83 respondents affirmed their willingness to participate in the conservation efforts directed at the Kuranji watershed. Respondents who are willing to conserve the Kuranji watershed also expressed a desire to secure water availability and a better environment (Figure 2).

Respondents who were unwilling to pay thought that conservation efforts would affect their income. As the survey results show, the respondents who are not willing to pay are low-income
farmers. Apart from that, this category of respondents also believed that conservation efforts had no significant effect on water availability.

| No | Bids Value (Rp/m³) | Frequency (Responden) | Relative Frequency (Pfi) | WTP (Rp/m³) |
|----|-------------------|-----------------------|--------------------------|-------------|
| 1  | 400               | 44                    | 0.44                     | 176         |
| 2  | 300               | 18                    | 0.18                     | 54          |
| 3  | 200               | 21                    | 0.21                     | 42          |
| 4  | Tidak Bersedia    | 17                    | 0.17                     | -           |
| Total | 100                  | 1                    | 272                      |

A total of 44 respondents were willing to pay for environmental services at a water price of 400 IDR/m³, while 17 respondents were not willing to pay for or participate in the conservation efforts aimed at the Kuranji watershed. Therefore, the average value of WTP obtained in this study is 272 IDR/ m³ of water (Table 5). If it is assumed that the average use of the community is 22 m³/month (data from PDAM Kota Padang), the WTP value obtained is 5,984 IDR per month. This value is smaller when compared to the WTP value obtained by other researchers, which is 33,601.93 IDR in a month (RM 10.13) [11], as well as the WTP value that appears in several related studies carried out previously.

The difference in WTP value is due to the difference in the bids value offered. Previous researchers determined the auction value based on the applicable water bill in that country. Meanwhile, in this study, the determination of the bids value offered is based on the price of water that emerges from the land conservation simulation model. The price of water is therefore the result of calculating the cost of planning activities that will be carried out for watershed restoration according to the Regulation of the Director General of Natural Resources and Ecosystem Conservation No. P.8/KSDAE/SET/REN.2/10/2017 Regarding the Standard Activities and Costs for the Conservation of Natural Resources and Ecosystems in 2018. Based on this calculation, the total WTP (TWTP) value is 27,464,389.06 IDR/m³ (Table 6). This means that the emerging economic value is only 80%, or 284.68 ha, sufficient for conservation activities directed at critical land.

| No | WTP (Rp/m³) | Respondents who are willing to pay (n) | TWTP (Rp/m³) |
|----|-------------|----------------------------------------|-------------|
| 1  | 176         | 44                                     | 22,159,223,68 |
| 2  | 54          | 18                                     | 2,781,348,84   |
| 3  | 42          | 21                                     | 2,523,816,54   |
| 4  | Unwilling to pay | 17                              | -            |
| Total | 100                  | 27,464,389,06                       |

Based on the results of the observations made, the majority of people who want to pay the highest price are in the downstream area of the watershed. The downstream communities of the watershed are users of the Drinking Water Company (PDAM) in the Central Region of Padang City, who directly benefit from the Kuranji watershed and experience the consequences of floods every year. With efforts to improve the condition of the upstream area of the Kuranji watershed, people in the downstream areas hope that the sustainability of water resources can be improved, and the potential for flood disasters can be gradually reduced.
4. Conclusion

In this study, it was determined that the estimated economic value of water yield in the Kuranji watershed is 272 IDR/m$^3$ of water. This is supported by the fairly high desire of the community to pay for water resources in the Kuranji watershed, with a conservation value of 80% of critical land.

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