Cost of water acquisition from forested watershed

Zufarzaana Zulkeflee\textsuperscript{a,}\textsuperscript{*}, Jinan Mohamad Pauzi\textsuperscript{b}, Mohd Kamil Yusoff\textsuperscript{c}, Nor Rohaizah Jamila

\textsuperscript{a}Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia
\textsuperscript{b}Department of Environmental Management, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia
\textsuperscript{c}UPM Consultancy and Services Sdn. Bhd., Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia

Abstract

Estimation of the cost of water acquisition from two watersheds, namely Sungai Teranum catchment area and Sungai Sia catchment area in Raub, Pahang, from the overall cost of managing the watershed by the Pahang State Forestry Department was conducted. Field measurements of river flow velocity and cross-sectional area of the rivers were conducted and the average flow rates (m\textsuperscript{3}/s) were determined using the formula $Q=VA$. It is estimated that the cost of 1 m\textsuperscript{3} of water generated from the Sungai Teranum catchment with an average water yield of 13868498.29 m\textsuperscript{3}/yr is RM 0.0019 and RM 0.00069 from the Sungai Sia catchment with an average water yield of 113345052.96 m\textsuperscript{3}/yr.

\begin{itemize}
  \item \textsuperscript{*} Corresponding author. Tel.: +603-89468076; Fax: +603-89438109
  \item E-mail address: zufarzaana@upm.edu.my
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1. Introduction

Water generation by a catchment area is a dynamic process that changes with time and circumstances. Natural external factors such as climate change and anthropogenic factors such as changes in land use pattern in the watershed or in the surrounding forested area, will affect the components of the hydrological cycle which will then influence the increase or decrease of the rate of water yield. Precipitation rates and high surface water runoff will
In Malaysia, 97% of the country’s water supply required for domestic, industrial and other purposes is derived from surface water namely rivers [2], with naturally defined forested watershed. The drastic rise in the demand for water due to growth in population, urban development, industrialisation and the increase of irrigated agriculture has placed additional pressure on the water resources of the country [3]. Annually, water demand is increasing at the rate of at 4% and is estimated to reach 20 billion m$^3$ by the year 2020 [4]. In order to ensure the water supplied from forested catchments is continuously in good quality to meet the demand, proper management of the catchment area is crucial [2, 5].

Good watershed management practices can minimize the impact of anthropogenic disturbances on the reduction of the baseflow rate as to guarantee sustainable water generation [6, 7]. In Malaysia’s effort to ensure better governance of water resources, the National Water Policy was designed to manage the quantity, quality and reliability of the nation’s water resources, with the view of achieving optimum, long-term, environmentally sustainable, social and economic benefits to society from their use. Aside from policy, there are also various pieces of legislation that are water related, containing provisions on good watershed management. Among them are The Water Act 1920 (only applies to Federated Malay States); the Environmental Quality Act 1974 (focuses on environmental protection and pollution control); Land Conservation Act 1960; Street, Drainage and Building Act 1974; National Forestry Act 1984; Local Government Act 1976; various other State enactments and regulations, Ministerial Directives and cabinet decisions under the Ministerial Functions Act 1969. Under the Federal Constitution, water is essentially a State matter [8]. Nevertheless, when it comes to water resources development, utilization and management, both the Federal and State Governments are involved. This is because the responsibility for water resource administration is fragmented and is shared among a number of Federal and State agencies, each of them having their own specific involvement in water related issues [9]. The Legislative Lists, which comprises of the Federal List, State List and Concurrent List, determine the jurisdiction and legislative powers relating to water management. Watershed management comes under the state jurisdiction which involves multiple agencies including the Forestry Department, Water Supply Department, Drainage and Irrigation Department, Department of Environment, local authorities and others [3].

The management of forested catchments seeks to effectively protect the source of raw water through integrative cooperation from all relevant parties, taking into account not only the entire watershed area, but also the immediate vicinities. The cost of managing the catchment area involves operational, maintenance and also emolument costs of manpower. Considering the total cost of managing the watershed in producing high quality water supply, questions arise on how to put a monetary value on the water generated from the catchment. Therefore, an estimation of the cost of acquiring water from a watershed can be relatively determined based on the cost of managing the watershed.

This study was conducted with the objectives of estimating average total water yield from two forested water catchment area in Raub, Pahang namely, the Sungai Teranum catchment area and Sungai Sia catchment area and to relatively estimate the value of water generated based on the management costs of both catchments. This research will benefit the Forestry Department and other relevant bodies and stakeholders by giving a direct, tangible value of the raw water supplied by the forested catchments. This will be an indirect incentive to relevant bodies to sustainably manage the forested catchment as to produce an abundant amount of good and clean quality water to meet the future demand.

2. Methodology

2.1. Study area

Sungai Teranum catchment area and Sungai Sia catchment area are both located in a permanent forest reserve, 10 km to the south and about 20 km to the north respectively, of Pekan Raub in the district of Raub, Pahang (Fig. 1). Sungai Teranum Forest Reserve was gazetted on 25th October 1938 with a total land area of 2701 ha while Sungai Sia Forest Reserve with a total land area of 8126 ha was gazetted on 28th August 1932. The site chosen at Sungai Teranum catchment is located between the latitude of 03° 42.77’ N and longitude of 101° 46.29’ E with an elevation of 483 m above sea level, has an open area used for recreational activities. The site chosen at Sungai Sia catchment,
located between the latitude of 03° 58.21’ N and longitude of 101° 44.80’ E is more secluded with the only activity nearby is a fish cultivation farm called Agro Harvest Sdn. Bhd. that breeds Kelah fish. Both areas experienced an average temperature of 22°C and rainfall of more than 2500 mm annually.

2.2. River water flow measurement and total water yield

River water discharge or flow rate measurement (m³/s) is calculated as the product of velocity (m/s) of the river flow and the cross-sectional area (m²) of the water column made perpendicular to the flow direction as stated in Equation (1) [10]:

![Fig. 1. Sungai Teranum and Sungai Sia sampling stations](image-url)
where:

\[ Q = VA \]  

\( Q \) – flow rate (m\(^3\)/s)  
\( V \) – velocity of river flow (m/s)  
\( A \) – cross-sectional area (m\(^2\))

The flow rate measurement of a river depends greatly on the river width [11]. Sub-compartments were constructed accordingly along the river width. The measurements of the velocity of the river flow for each compartment were measured using a current meter depending on the water depth. For the depth \( \leq 1.0 \) m, the velocity was measured at 60% of the total depth and for the depth \( > 1.0 \) m; two depths were measured at 20% and 80% of the total depth. Cross-sectional area of each sub-compartments were calculated and the discharge data represent the whole river was achieved through the summation of the data from the sub-compartments.

The total discharge value in cubic meter per second calculated was then extrapolated to achieve the estimated value of total water yield from the catchment area in cubic meter per year.

2.3. Estimation of the cost of water acquisition

The cost of water generated from the catchment area was estimated based on the management cost of the watershed [12]. The management cost data for both catchment areas were obtained from the Pahang State Forestry Department. The Pahang State Forestry Department has no specific management budget for every catchment area in its domain. Rather the budget allocated was for the management of the whole forest reserve. Therefore, to relatively calculate the cost of water generated from a specific watershed, the total budget allocated was divided by the total land area of the forest reserve and multiplied by the total land area of the watershed. Estimation of the water cost was then obtained by dividing the cost of managing the catchment with the total water yield achieved.

3. Results and discussion

3.1. Hydrological characteristics and total water yield

Hydrological characteristics of Sungai Teranum and Sungai Sia Catchment area are depicted in Table 1. Soil surface pressure, determines how penetrable the soils in the area are, as to allow water to infiltrate, while the infiltration rate determines how fast the water can infiltrate into the soil. The shear stress is the measure of the erodibility of the soil in the area. All parameters contributes to the increase or decrease of total water yield in the catchment area.

| Catchment area | Soil surface pressure (kg/m\(^2\)) | Shear stress (kg/m\(^2\)) | Infiltration rate (mL/s) | Flow rate (m\(^3\)/s) |
|---------------|-----------------------------------|--------------------------|-------------------------|------------------------|
| Sungai Teranum| 1.07                              | 2.45                     | 0.01-0.02               | 0.440                  |
| Sungai Sia    | 1.25                              | 2.70                     | 0.002-0.003            | 3.594                  |

The average total water yield estimated from Sungai Teranum and Sungai Sia catchment area is at the rate of 13868498.29 m\(^3\)/yr and 113345052.96 m\(^3\)/yr respectively, making the total water yield of Sungai Sia catchment about 88% higher than Sungai Teranum. This could be the result of many hydrological factors [1]. The characteristics of Sungai Sia catchment that have higher soil surface pressure and shear stress with lower infiltration rate as compared to Sungai Teranum, contribute to the higher total water yield derived from the watershed. However, the amount estimated from both watershed can be an underestimation or overestimation as no direct correlation were made with the rainfall input. Nevertheless, the results portrayed the baseflow rate; the minimum amount of water yield, which are assumed to be available all throughout the year [1] in the respective watershed.
According to Hinrichsen and Tacio [13], fresh water scarcity is being experienced globally due to the increasing demand from population growth and urbanization, especially in developing countries and more apparent during the dry season. As water exhibit properties of both renewable and non-renewable resources, they are both rate and stock limited whereby the rate of replenishment and the stock saved can be inadequate due to the high demand imposed [14]. Focusing on Malaysia, the water demand in 1996 was 28,183 m$^3$ per capita [13] and is extrapolated to be around 49,602 m$^3$ per capita in year 2015 at the increasing rate of 4% per year. To meet this growing demand, it is crucial to protect and conserve the watershed as to ensure sustainable water production and supply can be achieved. Hence, cooperation of all relevant bodies is important to manage and maintain the catchment area.

3.2. Cost of water acquired from the forested watershed

Raub, Pahang has an overall forest reserve area of about 130735 ha, whereby Sungai Teranum and Sungai Sia catchment occupies 2701 ha and 8126 ha of the area, respectively. The overall budget allocated to the management of the forest reserve is about RM 1,249,000, thus the estimated management cost for 1 hectare of land area is RM9.55/ha. The estimated cost for each catchment area and the estimated cost of water acquisition from each watershed is detailed out in Table 2. The huge 64% difference between the costs of water acquisition from both catchments could simply be explained based on the total land area of the catchment and the budget allocated for managing the catchment. As Sungai Sia catchment has a bigger total land area, with a higher rate of total water yield, thus the cost of acquiring 1 m$^3$ from Sungai Sia is much cheaper.

| Catchment area | Total land area (ha) | Management Cost (RM) | Cost of water acquisition (RM/m$^3$) |
|----------------|----------------------|----------------------|-------------------------------------|
| Sungai Teranum | 2701                 | 25,804.48            | 0.0019                              |
| Sungai Sia     | 8126                 | 77,633.18            | 0.00069                             |

Therefore, estimating roughly the cost of water demand based on the average per capita water demand of the country in 2015, the cost of water demand from Sungai Teranum and Sungai Sia catchment would be at the rate of RM94.00 and RM34.00, respectively.

In 2012 the government had started the Pahang-Selangor Interstate Raw Water Transfer project as an initiative to solve water shortage issues in the state of Selangor, Kuala Lumpur and Putrajaya [15]. Relevant stakeholders are still doubtful on the aspect of the project in solving the water shortage issue as a comprehensive water conservation policy is still lacking [16]. Therefore, giving a tangible monetary value to the raw water supply from forested catchment can be an indirect indicator and incentive in developing a comprehensive policy for watershed management and protection as well as water conservation and distribution, especially in the state of Pahang which has the most abundant forest cover and watershed in Malaysia.

4. Conclusion

The average total water yield estimated from Sungai Teranum and Sungai Sia catchment area is 13868498.29 m$^3$/yr and 113345052.96 m$^3$/yr and the overall cost of water acquired were estimated to be RM0.0019/m$^3$ and RM0.00069/m$^3$, respectively. Though the figure seem negligible, the impact of putting a monetary value on raw water acquisition could help in water policy development and benefit all relevant parties in tackling the inevitable water shortages in the future.

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