BorneoScience
The Journal of Science & Technology
Volume 45 Issue 2 : Sept 2024
Online ISSN : 2231-9085 | ISSN : 1394-4339

FOREST FOR DOMESTIC WATER CATCHMENT OF GUNUNG TEBU FOREST RESERVES, TERENGGANU

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Received 24th April 2024; Accepted 28th Nov 2024
Available online: 31st December 2024
Doi: https://doi.org/10.51200/bsj.v45i2.5877

ABSTRACT. *Forests play an important role as water catchments for all downstream demands, such as domestic, industrial, and agricultural use. They provide not only quantity of water but also good-quality clean water. Forests help prevent impurities from entering streams, lakes, and groundwater in several ways. This process is called water purification but occurs naturally. The objective of this paper is to evaluate the importance of forest reserves, specifically the Gunung Tebu Forest Reserve (FR) in Besut, Terengganu, as a water catchment, especially for domestic use. Data on Bukit Bunga Water Treatment Plants (WTP) intakes, cost information, and forest land uses from the National Forest Inventory V (NFI V) are the main inputs for the analysis. Results show that the overall average marginal value for Gunung Tebu FR is RM297.24/ha/year. This value can be used to consider the operational cost implications of WTPs for the water purification services provided by the FR. A comparative analysis of the water catchment for Bukit Bunga WTP covers an area of 6,456.4 ha, of which approximately 88.6% is the Gunung Tebu FR. Therefore, the conservation of forest reserves as water catchment areas is important to ensure the availability of clean water, especially for domestic use.*

KEYWORDS. Watershed, domestic water used, ecosystem services

INTRODUCTION

Forests are recognized as an important source of water supply for industry, agriculture, households, and recreational purposes. Most of the clean water supply comes from rain that is filtered through forests and ends up in rivers. Forests help prevent contaminants from entering rivers, lakes, and groundwater in a number of ways. This process is called water purification. Forested areas and landscapes with trees also act as natural filters, reducing soil erosion and water sedimentation, thus providing high-quality water for human consumption and industry (Unasylva, 2019). The benefit is that clear water from forests in water catchment areas tends to reduce the cost of water treatment. Water purification ecosystem services are one of the natural services provided by ecosystems, especially forest ecosystems. It is categorized as a regulating service. The Millennium Ecosystem

Assessment (2005) also explains the role and function of this ecosystem for life. This service has a strong connection to the balance of human well-being, especially concerning issues of safety (the safety of clean water), disasters, sufficient resources, and life and health needs.

Among the earliest economic studies in the 1980s confirmed that the operating costs of water treatment plants are low when the water source is clean (Foster ***et al***., 1987; Moore and McCarl, 1987). Other studies show that improving the quality of the water source allows the utility to use a simpler treatment process to avoid large costs (Spiller *et al*., 2013). A prime example is the City of New York, which states that the utility can save multi-billion costs for a new treatment plant by utilizing the Catskills basin ecosystem (Chichilnisky and Heal, 1998). A study conducted in tropical regions, which considered the environmental impact and changes in forests related to water treatment costs, was carried out in Thailand (Sthiannopkao *et al*. 2007) and focused on samples from just one treatment plant. Another study by Abdul Rahim and Mohd Shahwahid (2011) examined the effects on six water treatment facilities in Kelantan. Furthermore, Vincent *et al*. (2015) analyzed panel data from 21 plants in Perak, with a follow-up study in Pahang in 2016.

The essential contribution of these services, along with other primary ecosystem services, lies in the continuous provision of clean water resources. Therefore, the aim of this paper is to evaluate the role of Gunung Tebu Forest Reserve (FR) as a water catchment area for domestic use.

MATERIALS AND METHODS

Data

The data utilized for the analysis were obtained from various agencies. Coordinates for the Water Treatment Plant (WTP) and the intake points, along with information on raw water sources, were sourced from the local water operator in Terengganu. Only one Water Treatment Plant, the Bukit Bunga WTP, was selected from the Gunung Tebu watershed. A Digitized Elevation Model (DEM) with a spatial resolution of 90 meters was employed, which is available for free download from https://earthexplorer.usgs.gov. The DEM data serves as a representation of the earth's surface elevation. Additionally, data from the National Forest Inventory V (NFI V) were used as the foundational information on forest land use types within the study area. This NFI V data was published by the Forestry Department of Peninsular Malaysia as part of its fifth series. Information regarding Terengganu's forest land use, specifically the gazetted forests for water catchment, was obtained from the Terengganu Forestry Department.

Methodology

Data from the relevant plant were sourced from the state water supply management agency, Syarikat Air Terengganu Sdn Bhd (SATU). The information collected included the coordinates of the WTP intake points, the monthly total volume of treated water produced, and the monthly operational costs incurred by the WTP. Catchment boundaries for the WTP intakes were created using DEM data and the intake point coordinates, processed through the ArcSWAT module within ArcGIS software. This

module utilizes a specialized Soil and Water Assessment Tool (SWAT) model integrated with ArcGIS. The ArcSWAT module has gained global usage and is continuously updated to accommodate user analysis needs. The ArcSWAT extension and additional SWAT modules are available for free download at https://swat.tamu.edu/.

A GIS analysis was performed to determine the percentage of forest land use within the water catchment area, utilizing data from the National Forest Inventory V (NFI V). To evaluate the area designated for water catchment in relation to the WTP catchment, data layers were overlaid to calculate the total matched area. The assessment of the economic benefits provided by Gunung Tebu Forest Reserve for water purification services is based on the benefit transfer approach to economic models developed in Perak (Vincent et al., 2015). The econometric analysis of water treatment costs in Perak utilizes a comprehensive panel dataset alongside an examination of forest changes. This analysis is informed by theories regarding cost functions for assessing environmental input values (McConnell and Bockstael, 2005; Vincent, 2011; Freeman et al., 2014), as follows:

$$\ln(C_{it}) = \mathbf{L}_{iy}\boldsymbol{\beta} + \alpha \ln(q_{it}) + c_i + \theta_y + \theta_m + u_{it}$$

(Equation 1)

Where;

i :WTP, t :Time (years), y :Year, m :Month, C :Operating cost (RM) or chemical quantity (kg), L :Land use (% of WTP basin), q :Volume of treated water (m3), c, θ :Fixed effects, μ :Error term. Issues: heteroskedasticity, spatial and serial correlation, Moulton problem, endogeneity of q

RESULTS AND DISCUSSION

To identify the river basin that drains into the Bukit Bunga WTP intake, a GIS analysis was conducted to establish the basin boundaries. The analysis revealed that the total area of the WTP intake basin is 9,062.91 hectares, of which 7,286.01 hectares fall within the Gunung Tebu Forest Reserve area (Figure 1). Sungai Angga, located within the Gunung Tebu FR, flows into Sungai Besut and subsequently reaches the Bukit Bunga WTP intake.

The water treatment process necessitates the use of various chemicals, each serving a specific function to achieve the desired water quality prior to distribution for domestic use. These chemicals include lime, liquid chlorine, sodium fluoride, liquid alum, and other reagents. Typically, the treatment process begins with filtering raw water at the intake to remove initial solid impurities. The water then moves to an aeration tank (aerator) to increase oxygen levels and eliminate any undesirable odors and flavors before the appropriate dose of liquid alum is added to aid in subsequent treatment steps. After filtration, liquid chlorine and sodium fluoride are introduced to adjust the pH to acceptable levels. Overall, the operating costs encompass four main components: chemical expenses,

electricity, maintenance costs, and employee salaries. The average operating cost for the Bukit Bunga WTP was 14.86 sen/m^3 in 2019 and 14.53 sen/m^3 in 2020.

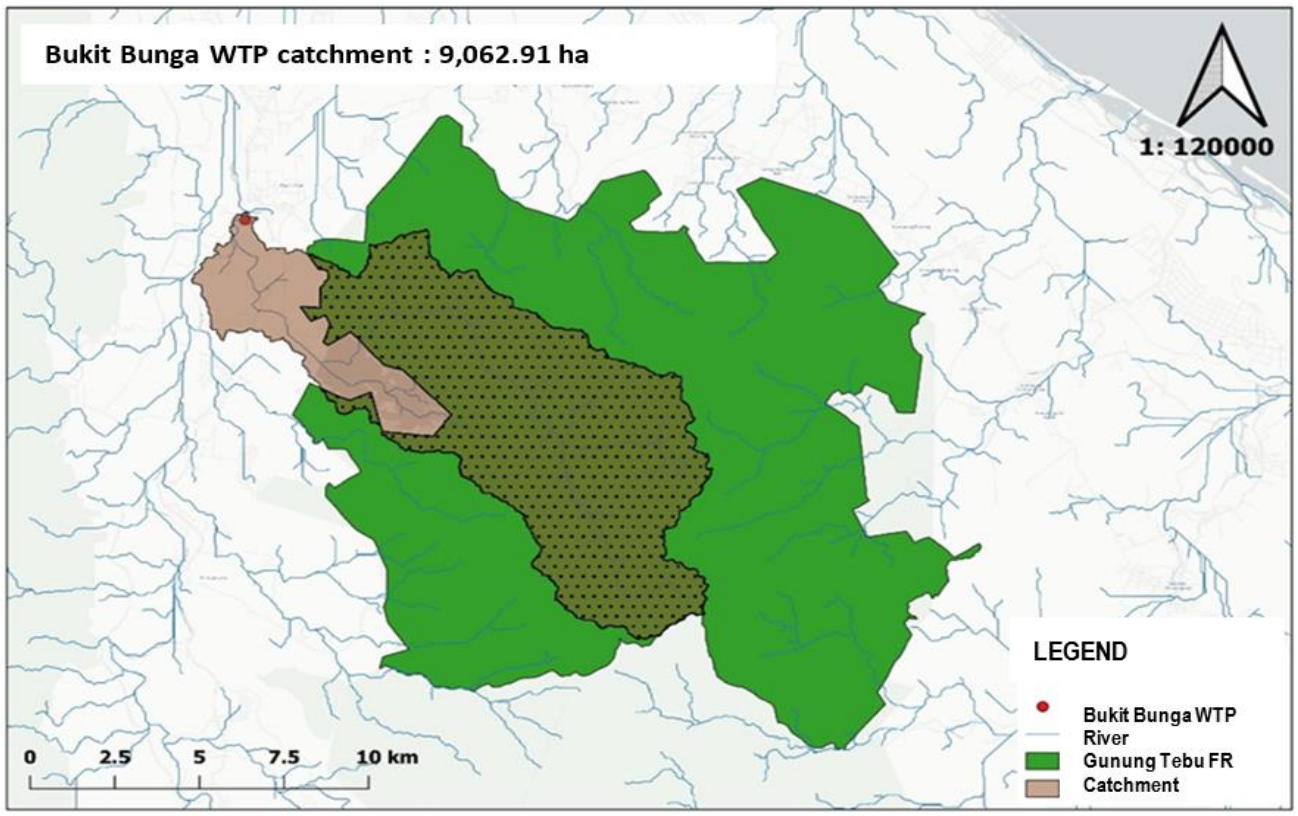

Figure 1. Delineation of the Bukit Bunga WTP catchment area within the Gunung Tebu Forest Reserve

Forest land use data from the NFI V was evaluated for the Bukit Bunga WTP catchment. This assessment is crucial as it demonstrates how forest land uses within the catchment area affect water treatment costs at the WTP. The catchment size, percentage of forest land use, and treatment costs were utilized to calculate the marginal value of water purification services. In terms of forest composition, the virgin forest occupies 3,793.33 hectares (52.5%), while logged forest covers 2,878.83 hectares (39.8%) (Table 1). Additionally, other areas, including water bodies and non-forest regions, total 560.58 hectares (7.75%).

Table 1. NFI V strata at Gunung Tebu FR

Forest Strata	Area (ha)	Percent (%)
Virgin forest	3,793.33	52.45
Logged forest	2,878.83	39.80
Others	560.58	7.75
Total	7,232.73	100.00

A comparative analysis of the water catchment area designated for Gunung Tebu FR and that for Bukit Bunga WTP indicates that the total area is 6,456.4 hectares, comprising 88.6% of the coverage (Figure 2). This demonstrates that the designated catchment zone for Gunung Tebu FR accurately encompasses the actual catchment area used for water supply. Figure 2 illustrates the water catchment area for WTP within the delineated river catchment area.

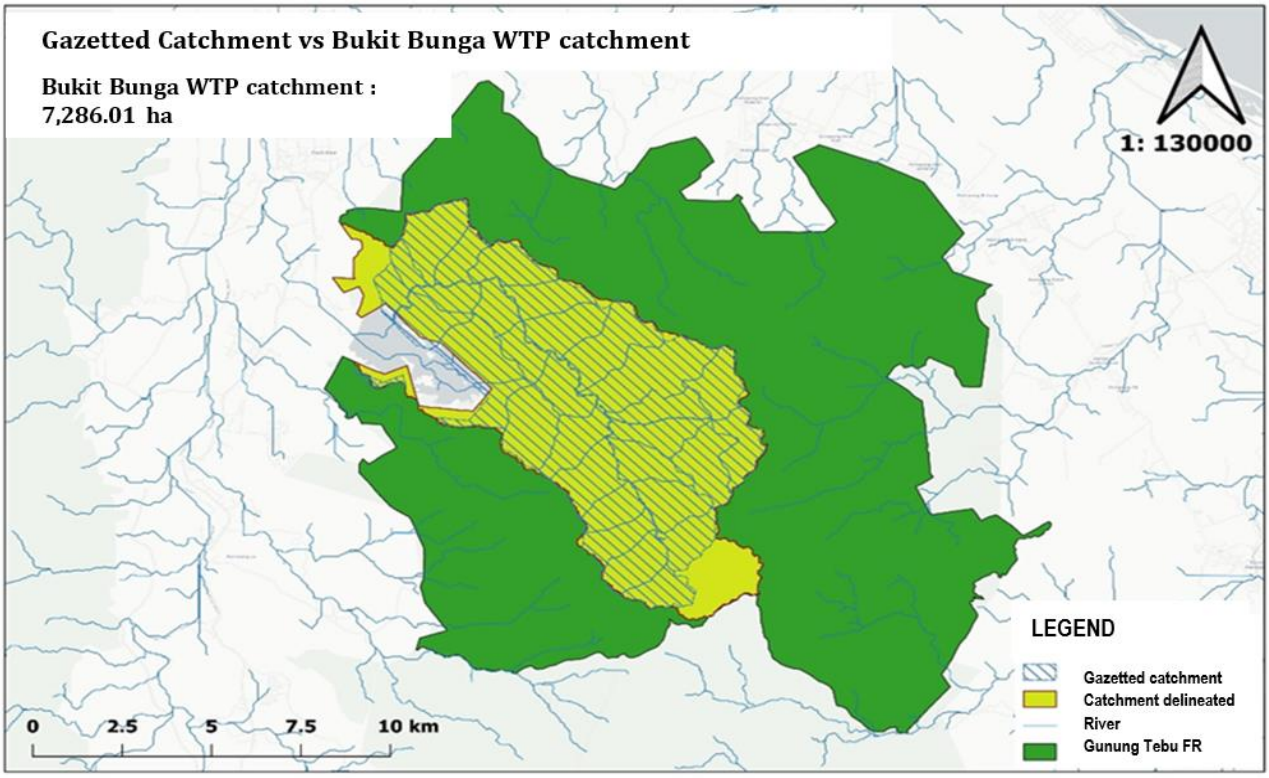

Figure 2. The catchment area for Bukit Bunga WTP within the delineated catchment zone

The analysis reveals the marginal value of water purification services provided by the forest to the Bukit Bunga WTP. Marginal value is defined as the annual benefit derived from forest reserve services in relation to the decrease in treatment costs achieved by preventing the conversion of 1 hectare of virgin forest to alternative land uses. Overall, the average marginal value for Gunung Tebu FR is RM 2,702,652 per year, which equates to approximately RM 297.24 per hectare per year. This value can be utilized to assess the operational cost implications for the WTP in financing water treatment services offered by forest reserves, similar to how other operational expenses (such as chemicals, electricity, and labor) are covered by the WTP. The findings indicate that the marginal value of forest reserve services for domestic water purification is relatively high compared to previous studies. This discrepancy may be due to the fact that this assessment focuses on a single watershed for one WTP, while earlier studies in Perak, Pahang, and Kelantan evaluated entire states or landscapes.

CONCLUSION

A comparative analysis of the water catchment area for Bukit Bunga WTP reveals that it encompasses approximately 6,456.4 hectares, with around 88.6% of this area attributed to Gunung Tebu Forest Reserve. This significant overlap indicates that the gazetted water catchment zones are closely aligned with the forest reserve areas, highlighting the importance of these zones in safeguarding water resources. To effectively protect these vital resources, it is essential to implement appropriate surveillance and enforcement measures. Such actions will ensure that the integrity of the catchment areas is maintained and that they continue to provide clean water for domestic use. Ultimately, conserving forest reserves as designated water catchment areas is crucial for securing a sustainable supply of clean water, particularly for community needs. This not only contributes to public health but also supports ecosystem balance and resilience in the face of environmental changes. The preservation of these areas will play a significant role in safeguarding water quality and availability for future generations.

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