Water Security In Tunda Island, Banten Indonesia: Potency & Threat

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Abstract

Water availability and management for water security on small islands are critical. The purpose of this research is to uncover the water resources issue at a small island community level as well as discourse on the potential threats and sustainable management for water security. Tunda Island, located in the Java Sea, is one of 81 small islands in Banten Province, Indonesia. Data were collected through focus group discussions, open interviews with key persons, direct field observations, and secondary data gathering. Moreover, we analyzed time series climate data, particularly rainfall and population growth projections, based on data from official Indonesian government sites. The monthly mean precipitation is ranging from a low of 48 mm/month in August to a high of 292 mm/month in January. A “surplus of water” occurs from November to May, while months with a “deficit of water” occur from June to October. The majority of

the community is unaware of the water security issue due to a lack of information and knowledge in the community. Some threats to the sustainability of water resources would be caused by two factors, both anthropogenical and natural: rising water demand, diminishing groundwater reserves due to population growth and tourism activities on the island, drought, sea level rise, and seawater intrusion as climate-related impacts due to increasing population growth and tourism activities on the island and drought, sea level rise and seawater intrusion as climate-related impacts. Developing community knowledge and awareness of water security is the main issue that should be handled first, coinciding with sustainable management practices that consider water use efficiency, the use of alternative water sources (e.g., rainwater harvesting), and protecting and restoring coastal ecosystems, especially for the future tourist destination.

Keywords

Water security, Small island, Community awareness, Water management, Tunda Island

Introduction

Water is an essential natural resource for human beings and other living things. People depend on groundwater and rainfall on small islands as their main water sources (Liu et al. 2006). Rainwater percolates into the soil and is stored in the lenses underground, where it will become groundwater or overflow as surface water if fully charged. However, the storage capacity of water lenses is usually limited and depends on many factors, such as the size of the island, its geological setting, and rainfall intensity. As a result, water input on small islands is highly seasonal and subject to climatic events (van der Velde et al. 2007; Post et al. 2018). In the meantime, the sustainability of this natural resource on small islands could be threatened by a growing population, uncontrolled development, changing weather, pollution, and massive tourism.

Moreover, small islands are vulnerable to the impacts of changing climate, which may considerably affect the rainfall pattern, escalate the storm event, and increase the wave height, seawater temperature, and sea level (Zikra et al. 2015; Tallar and Dhian 2021). Climate change may directly impact water recharge and storage. Still, the human response to these impacts, such as the increased groundwater abstraction due to more frequent droughts, may exacerbate the impact (Green et al. 2011; Taylor and Tindimugaya 2011). Another problem is that when rainy season occurs, excess water is not used or conserved for future use and is just wasted on the sea increasing the vulnerability of the island during drought season. Accordingly, managing freshwater on small islands is a crucial factor, along with the underlying community perception.

Tunda Island is categorized as one of 81 small islands in Banten Province, Indonesia, following Dijon (Dijon R 1984) and Falkland (Falkland and Custodio 1991), who define a small island as having an area of no more than 100 km2 (equal to 10,000 ha). The island has an area of 260 ha (Central Bureau of Statistics 2022; Ministry of Marine Affairs and Fisheries 2023). Tunda Island is surrounded by coral reefs, mangroves, and seagrass. It has been set aside for several things, such as aquaculture, fishing, and marine ecotourism. The island has also been designated as a conservation area based on the Regional Regulation of Serang Regency No. 2 for the Year 2013 regarding the Zonation Plan for Coastal and Small Islands in Serang Regency 2013–2033. This condition allows the community to develop new livelihoods as tour operators, guides, and homestay service providers to accommodate the increased tourism activities in line with its unique identity as a tropical small island (Graham and Campbell 2021). The tourism industries are an instant way of creating more opportunities, especially from an economic perspective, inspite of some possible drawbacks such as

environmental degradation (Katircioglu et al. 2020) and extra pressure and load on the island's carrying capacity (Gössling et al. 2012; Hampton and Jeyacheya 2020).

Water resource management research has been conducted in a number of locations, including the Pacific Small Island Developing States (SOPAC 2007; Bouchet et al. 2019), Kinmen Island, Taiwan (Liu et al. 2006), and the Caribbean. Yet only a small number of them are from Indonesia, including Manez et al. (2012), Sinulingga et al. (2015), and Hantoro et al. (2009). Despite the fact that Indonesia has 16,771 islands and most of them are classified as small or extremely small islands (Geospatial Information Agency 2022), studies related to water resources and management on small islands are still very limited. Manez et al. (2012) describes public perceptions of water shortages in the Spermonde Islands, South Sulawesi, as a result of a growing population in the past and present and highlight the threat posed by climate change impacts that could exacerbate water shortages in the future. Sinulingga et al. (2015) demonstrated the groundwater potency on the Seribu Islands, DKI Jakarta, including its quality and quantity, and projected the future water demand based on population growth. More recently, Hantoro et al. (2009) highlighted the challenges faced by small islands in the Derawan Archipelago, East Kalimantan, in terms of limited water resources and potential threats from climate change-related impacts, which could pose a serious threat in the future. Apart from the topics previously studied, in this study we discuss the possible impact of tourism activities, along with population growth and climate change, community awareness and advocating to the future water security.

Observing the intensifying activities and future projections on Tunda Island would influence the water balance and increase the likelihood of contamination. Therefore, fundamental questions have been raised regarding how the community manages its water resources and whether they have any plans to address this issue if the island's development increases, particularly in relation to the tourism industries, which may require additional water resources (Gössling et al. 2012; Hadjikakou et al. 2014; Ramazanova 2020). Tourists typically consume more water while on vacation than they do at home; they also prefer dry season to avoid rain during their trip. In contrast, water scarcity exists in the destination region. In reality, additional water is required to maintain the quality of the hotel, homestay, and other facilities (Gössling 2005; Lootvoet and Roddier-Quefelec 2009; Gössling et al. 2012). Additionally, direct information from the community based on their prior experience must be comprehended in order to improve the quality of water management for sustainability purposes. Therefore, the purpose of this paper is to review the water management practices of the community on the small island, specifically Tunda Island, based on their perceptions and daily activities. Furthermore, the paper discusses potential threats to water security on small islands due to population growth, increased tourism, and climate-related impacts as well as the possible solutions to cope with these challenges.

Method

Study Site

The study was conducted on Tunda Island, Serang Regency, Banten Province. The island is geographically situated in the northern part of Banten Bay at 5° 48' 43.000" S and 106° 16' 47.000" E, approximately 20 km from the mainland (Figure 1). The island is close to the Seribu archipelago — Jakarta, which is famous for tourist attractions. Since many tourists nearby have explored the entire archipelago, Tunda Island has become a new tourist destination. In addition, some island in the Seribu Archipelago, such as Panggang and Payung Island, are already experiencing a freshwater shortage; even Panjang Island, the island closest to Tunda Island in Banten Province, is currently facing a freshwater crisis.

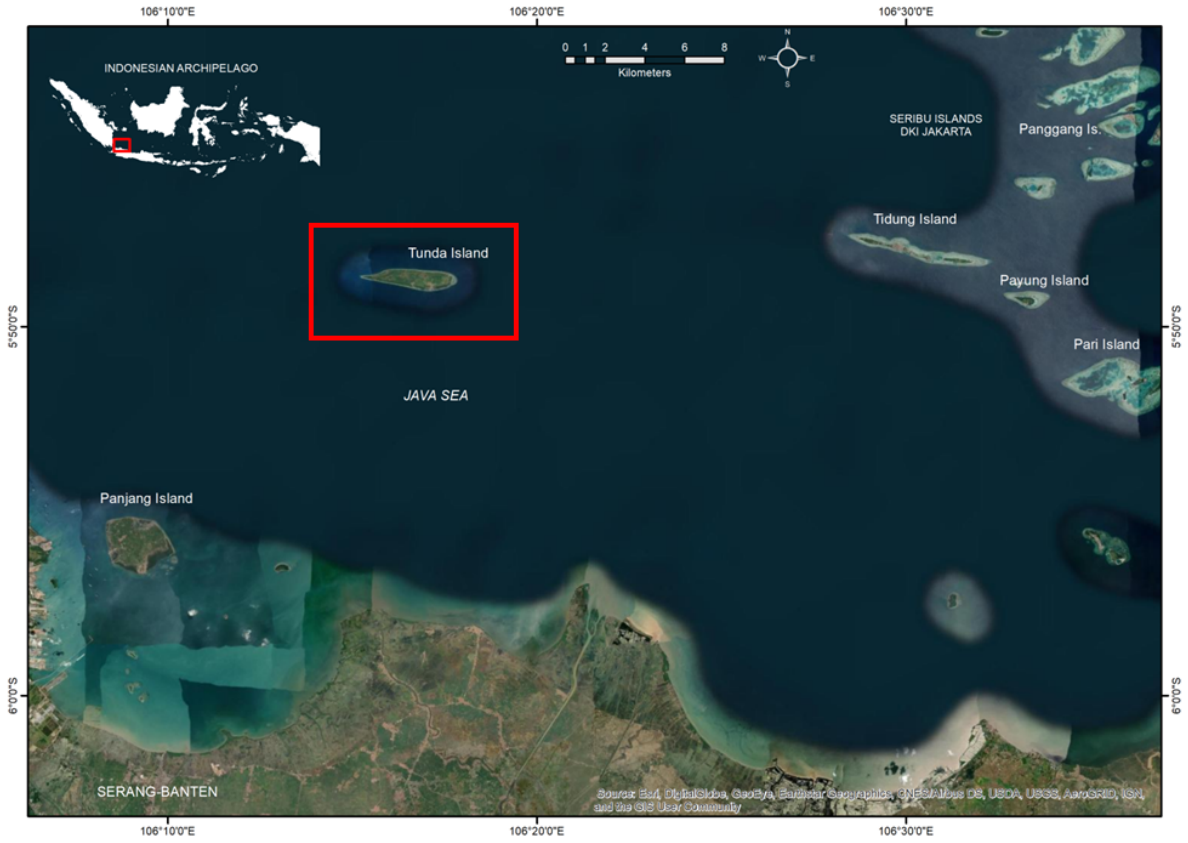

Fig 1. The study site, Tunda Island (marked with the red rectangle).
(Source: Google Earth)

This island is named Tunda, which means "postpone" or "delay", because in the past it served as a stopover for ships avoiding bad weather or transiting goods. With approximately 276 hectares of land, the inhabitants of Tunda Island are divided into two sub-villages (kampung) (west and east) under a village named Wargasara. The population density is 543.5 people per km2. Fishing and aquaculture are the primary sources of the island community's income. Tunda Island is morphologically classified as a reef island with an elevation between 0 and 12 meters according to the digital elevation model (DEM) data. Geologically, Tunda Island is composed of Quaternary reef limestone (Rusmana et al. 1991). The hydrogeological features of Tunda Island consist of an aquifer system formed by fissures, fractures, and dissolution with low productivity, low-to-high transmissivity, and a debit discharge greater than 10 L/s (Soetrisno 1993). The landuse and landcover of Tunda Island, based on data processing in 2022, consist of vegetation (86.16 percent), settlements (4.39%), open land (9.01 percent), and agriculture (0.44%).

Data Collection and Analysis

a. Rainfall Data

Climate data, especially the rainfall data, for tropical studies is an important parameter, to provide more information and an in-depth interpretation of the historical fresh water availability of the study site. Climate data for Serang Regency was extracted from the Agency of Meteorology, Climatology, and Geophysics of the Republic of Indonesia (BMKG) website in 2015. The climate data is composed of total daily rainfall and temperature from 1979 to 2012. The data was then further processed to obtain the annual average rainfall intensity, normal monthly rainfall, evapotranspiration, and annual average

air temperature. The average rainfall intensity is the amount of rain that falls in a certain area over a certain amount of time. It is typically expressed in units of millimeters per hour. It is calculated by dividing the total amount of rainfall over a specific period of time by the duration of that period. Evapotranspiration (ET) refers to the combined process of water evaporation from the surface of soil, water bodies, and plants, as well as transpiration from the plants' leaves. The amount of evapotranspiration depends on a number of things, such as the temperature, the humidity, the wind, the amount of sunlight, and how much water is available. The annual average air temperature refers to the average temperature of the air over the course of a year. It is calculated by adding together the daily high and low temperatures for each day of the year and dividing by the total number of days. Based on these data, a "water deficit and surplus month" is then calculated. A water surplus occurs when there is more water available than is required for that area or region, while a water deficit occurs when there is not enough water available to meet the needs of that area or region.

b. Focus Group Discussion (FGD) and Interview

Data was collected from a series of FGD, open interviews with key persons, direct field observations, and secondary data analysis. The method of purposive sampling was applied in this investigation. Fifteen respondents were selected from three existing community groups: one representing gender representation, another representing conservation, tourism, and natural resources surveillance, and the third representing local authorities.

The FGD was conducted three times consecutively in January-March 2022.

- The first FGD was aimed to gather information about community knowledge of water resources, capacity, and future consequences on ground water over extraction. Ten questions were first asked in a multiple-choice format, and then participants were introduced to simple scientific information regarding the topic. The questions include, understanding of water resources, their characteristics and availability on small islands, and what would happen to uncontrolled water resources utilization.
- The second FGD was to disseminate scientific knowledge that had been collected during the first visit to the island as part of data gathering process. The information was shared with the community in order to increase their awareness of the state of the island's water condition and the consequences that would result if the resources were not managed appropriately. Subsequent to the FGD, the key persons from the village government and the leader of the community groups were asked a series of questions. The questions were designed to ascertain whether the interviewees comprehended the scientific information presented, whether the had considered the potential hazards to the water resources and their plans for addressing them, and finally, whether they were willing to contribute financially to the creation of a rainwater harvesting system for future sustainable water management.
- The third FGD was a collaborative discussion where a larger group of participants, including representatives from various sectors such as the local government, private companies, non-governmental organizations, scholars, and universities, as well as members of the Tunda and Panjang Island communities, were involved. Panjang Island, located nearby, has already faced issues with water scarcity and seawater intrusion. The main objective of the FGD is to build a common concern for the sustainability of water management.

c. Population Growth and Projection

To determine the population of Tunda Island, data from 2012 and 2020 provided by the Central Bureau of Statistics (BPS) of Serang Regency were utilized. The analysis enabled the calculation of the percentage increase in population (r), which

can be expressed as the percentage ratio between the increase of the population (2012 and 2020) and the population in 2012. The objective of this calculation was to project population growth and anticipate the island's future water usage conditions.

Furthermore, the growth projection were calculated using the following formula (Adioetomo and Samosir 2010):

$$Pt = Po\,(1 + r)^t \qquad \text{(Equation 1)}$$

Pt = total population on t-year; Po = total population on initial year; r = percentage of population growth; t = time interval (total year).

A descriptive analysis technique was applied to this study based on collected data and processed data.

Results and Discussion

The Existing Condition

a. Climate

As part of a small tropical island adjacent to Java Island, the climate in Tunda Island is mainly influenced by the Asian monsoon (Purwanto et al. 2021). The air temperature ranges from 21–36 Celsius and the mean annual air temperatures is 26.67 degree celcius, where the lowest occurs in July and the highest in October. The annual average of precipitation intensity is 1.622 mm/year. The monthly mean precipitation ranges from the lowest of around 48 mm/month in August to the highest of around 292 mm/month in January (Figure 2). The annual evapotranspiration rate is 1.156 mm. Based on annual data on rainfall and evapotranspiration, months of water surplus occur from November to May with the total rate is 466 mm. Meanwhile, from June to October, there are water deficit months with a total rate is 225 mm (Figure 3).

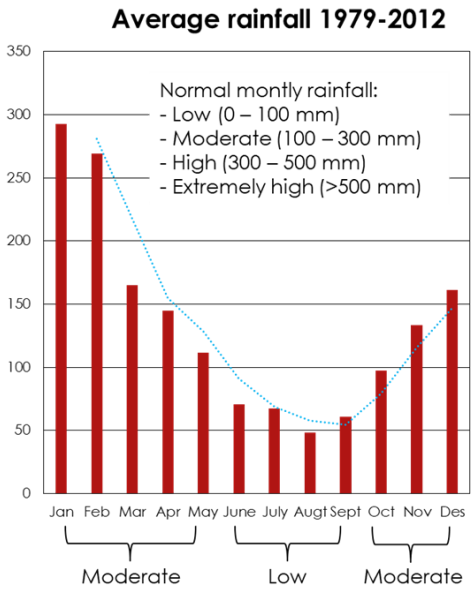

Fig 2. Mean precipitation in Serang area during 1979–2012
(Data sources: BMKG website, taken 2015)

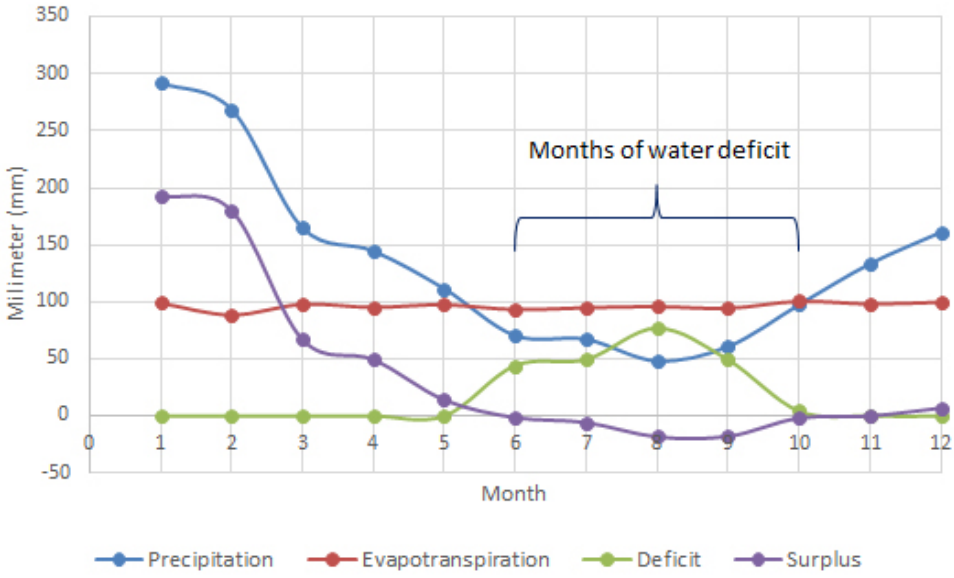

Fig 3. Months of water deficit and surplus based on rainfall in Banten Area during 1992–2012 (Data sources: BMKG Website, taken 2015)

The meteorological water availability indicates overall water surplus in Tunda Island under zero anthropogenic disturbance. This is evident by comparing the total amount and duration of water surplus and deficit, which reveal a greater value, namely 466 mm of water surplus compared to 225 mm of water deficit, and 7 months of water surplus compared to 5 months of deficit.

The duration of a water surplus or deficit, including in Tunda Island, depends on several factors, including the amount of precipitation, evaporation rates, and human water use. In some cases, the cycle over time of water surpluses-deficit could be high, while in other cases, a water deficit can persist for months or even years (Anna et al. 2016; Dara et al. 2021). Hence it is important to carefully and effectively manage water resources to ensure water resource is available all the year around. Several approaches could be taken to achieve this, including but not limited to, water conservation, water recycling, and the exploration of alternative sources of water to accommodate increasing demands (World Bank 2022)

b. Community Knowledge and Awareness

According to the analysis of the questionnaire data in the first FGD, only 30% of the community was aware of the importance of water resources and their management, while the remaining 70% were still unaware of these issues. We suggested this condition was due to the adequacy of water resource in the island. Accordingly, the participants thought that ground water was “renewable” and would still be available to support their daily lives in the upcoming years. This habit was reflected on their daily activities where limited knowledge of water resource capacity leads them to use fresh water without considering its availability.

The dissemination of the water quality surveys of dug-wells of Tunda Island has enlightened the local community toa broader perception of the water management problem across the island. The sign was clear when, in the second FGD, the head of the village realized that the island's water resource was important and needed to be conserved for an improved management and long-term sustainability. He added that since the early beginning, he has grown and lived on

the island without thinking about the sustainability of water resources and their management. But now he realizes the impending threat, especially when more people are coming and visiting the island. The participants in the deep interview section also strengthened this statement. The other key outcomes of the second FGD were a significant increase in the awareness and the understanding of the targeted communities on the importance of managing and conserving their island's water resources. However, intensive public awareness campaigns involving all stakeholders should be carried out on a regular basis.

In contrast to that of the Tunda Island, the third FGD exhibited the residents and the local government on Panjang Island, the other small island nearby, were already aware of water resources and management issues. Recently, there are seven sub-villages (*kampung*) on the island, in which four of them have experienced seawater intrusion affecting their groundwater. Several households in Panjang Island have also implemented the concept of rainwater harvesting as a reserve of water for drinking and cooking due to the saline dug-well water. The seawater intrusion that occurred in four villages on Panjang Island has forced the residents to seek alternative freshwater sources, such as channeling water from the other villages that have not been contaminated by seawater intrusion or relocating their housing to the center of the island, where the groundwater is still uncontaminated by seawater.

The other problem facing the local communities on both Tunda and Panjang Islands is the sanitary issue. The laboratory test ascertained that total coliform and *E. coli* were positive in one of the collected dug-well water samples. We suspected the issue came from the inadequate distance between the dug-well and the septic tank. Moreover, some of the wells are kept without lids that increase the probability of contamination. From the third FGD implementation, we learned that many stakeholders, especially the local government, which has worked closely with the community, have different goals for community development and resilience through sustainable water resource programs. The wise use of water resources on both the Tunda and Panjang Islands to keep them alive is another important part of the third FGD. Although the groundwater resources on Tunda Island are still sufficient.

c. Water Resources Management

The water management in Tunda Island was once assisted by the PAMSIMAS (the community-based water supply and sanitation program) through collaboration between the Central Government, Local Government, World Bank, and the Australian Government (Ministry of Public Works and Housing 2021). The national budget funds this program through The Ministry of Public Works to increase the number of facilities for underserved members of society, including low-income communities in rural and peri-urban areas. The PAMSIMAS program was implemented with the “Community Based” approach, using the “Direct Assistance Community (BLM)” fund, which creates assets that are built automatically and become the property of the community. For reasons of sustainability and improving service, the community is allowed to work with other groups through the citizen deliberation mechanism, whose motto is "planned by the community, implemented by the community and managed by the community".

The PAMSIMAS constructed one well in 2008, and the community appointed a group of locals to manage it. As of 2020, the village-owned enterprises (BUMDES) started to manage the well. The residents who are experiencing difficulties getting drinking water can buy it from the well's administrator. The price is Rp 5,000 (about 33 cents) per jerrycan of 20 liters, or about Rp 75.000 (US$ 5) per month to fulfill their needs. The price is comparable to the purchase price on the mainland, but cheaper than what is sold in local shops. Occasionally, there are arrears in these water payments. In the future, BUMDES plans to construct a new dug well.

Another existing water management facility on Tunda Island is a rainwater harvesting tank (Figure 3). There are installed in front of the building. This facility is built in the area of the Ministry of Transportation. It seems that the facility is restricted to the assigned people. We also found this system in the two houses, which use rainwater for washing and cleaning. This condition implies that Integrated Rainwater Harvesting and artificial groundwater Recharge Systems (IRAHARS) can be implemented in public places such as mosques, and that everybody agrees with the idea. On the other hand, some people in the community thought that the system didn't need to be put into private homes right away, except for those on the coast. If the system is installed in a public place, residents are willing to participate in maintaining the system so it works properly. However, the community finds it challenging to construct IRAHARS independently due to economic factors. Therefore, the community hopes the government or private company will help build IRAHARS in the village.

Fig 4. Rainwater harvesting facility on Tunda Island

Potential Impending Problems

a. Population Growth and Tourism Activities

In recent years, the beauty of Tunda Island has caught the attention of many stakeholders due to its stunning coral reefs. According to data from local authorities and one of the island's tourist managers, the number of visitors to the island is increasing over time. They visit Tunda Island for diving, snorkeling, and fishing. Visitors come to Tunda Island for more than just a vacation; they also come for research on coral reefs and mangroves. One of the local universities in Banten Province routinely conducts research activities related to the mangrove and coral reef ecosystems on this island. In 2019, there were 1,301 visitors from nearby cities such as Serang, Jakarta, and Bogor, as well as from foreign countries such as Japan, Germany, and Australia. Surprisingly, in 2020, after the pandemic outbreak in Indonesia, the number of tourists still reached 1,134 by the end of the year. No tourist visits only occur when the lock-down policy is enforced from March to May 2020. Social media campaigns by local tourism operators also boost tourism activity. In terms of accommodations, the first homestay was established by local residents in 2014, and there are currently 16 homestays.

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All the homestays are built in a traditional way. In other words, there has been no big investment from capital-intensive entrepreneurs on this island.

Based on 2019–2020 data, the number of visits per month is different throughout the year. The peak of tourist visits occurs during the dry season or June to August and the beginning of the rainy season between June to September. This is most likely due to the weather condition. A high wind speed and the significant wave height happen in December to February or northwest monsoon (Purwanto et al. 2021). On the other hand, during the transition season between June and September, the wave energy is not that high and the weather is predominantly bright throughout the day, making it very suitable for tourists going on vacation to Tunda Island.

Despite the fact that tourism on Tunda Island has not had a substantial influence on the preservation of natural resources, notably water resources, the increasing number of visitors in the coming years will undoubtedly disrupt the island's water reserve. As an illustration, the daily water requirement per person according to UNESCO criteria is 60 liters (Mashuri et al. 2015). If 1,000 tourists visit Tunda Island each year, the island will require an additional 60,000 liters, or 60 cubic meters, of water per year. The increasing number of tourists and tourism-related activities on Tunda Island may threaten not only water supplies but also coastal ecosystems such as coral reefs and mangroves, as well as waste management (Hannak et al. 2011; Lukman et al. 2022).

On small islands, tourism activities can have a significant impact on the groundwater reserve (Hantoro et al. 2009; Sinulingga et al. 2015). Small islands frequently rely on groundwater as their primary source of potable water, and tourism can put additional pressure on the island's limited water resources (Gössling 2001). Tourism-related activities such as hotel construction, homestays, and population growth can increase water demand, resulting in a decline in groundwater levels. Waste disposal, sewage, and other pollutants related to tourism activities may also contaminate groundwater reserves and environment degradation (Katircioglu et al. 2020). In addition, climate change can exacerbate the effects of tourism on groundwater reserves by increasing the frequency and intensity of droughts and storms, which can decrease groundwater recharge (Meixner et al. 2016; Atay and Saladié 2022).

During the in-depth interview, the participants agreed that a growing population, a rise in tourism, and climate-related impacts increase water use and lead to a lack of water. From 2012 to 2021, the Central Bureau of Statistics of Serang Regency estimates that the population of Tunda Island will grow by between 3.6% and 4.2% per year. This rate tends to go up as the local government works to improve the tourism industry. More research was done to figure out what the population will be like in the next 5 to 10 years, which led to more people moving to the islands.

Years	2024	2027	2030
Population (people)	1,687	1,898	2,135
Water needs (m^3 yrs^{-1})*	36,945	41,566	46,757

*Water need 60 l/person/day

At a rate of 3.6% per year of increasing population, Tunda Island would most likely be inhabited by around 2,100 people in ten years and require an additional 36,000 liters or 36 m3 of water per day from current use to meet the water needs of the people on the island. This means in ten years, each person would have access to water resources 30% less than now, assuming the same status of water availability. Increased population also means increasing house or road activities. Land use changes reduce rainfall absorption into the soil, reducing the groundwater recharge. Some small islands in Indonesia are suffering from water scarcity as a result of the growing population (Máñez et al. 2012).

b. Seawater Intrusion and Climate Impacts

Despite the good water condition in most parts of Tunda Island, there is a need to be aware of seawater intrusion, especially in dug-wells near the coast. The condition does not only happen in Panjang Island as explained earlier but also in several small islands in Indonesia such as Karimunjawa — Central Java (Prihantono et al., 2021), Panggang Cay — Seribu Islands Jakarta (Cahyadi et al. 2018) and Ternate Island — North Maluku (Nagu et al. 2018). Seawater intrusion is the process by which saltwater gets into freshwater aquifers, contaminating the groundwater supply (Kayode et al. 2017). Many factors are associated with this phenomenon, one of them is over-extraction of groundwater (Holding et al. 2016; Jakeman et al. 2016). This can have significant impacts on small island communities that rely on groundwater for their freshwater needs.

Groundwater in small islands is highly dependent on climate where rainfall is the only source (Welsh and Bowleg 2022). A changing climate would change the availability of water. The monsoon will have an impact on Tunda Island's dry season from June to August, with rainfall as low as 4 mm per day (Koropitan and Siregar 2021). Climate change may exacerbate seawater intrusion in several ways. For example, rising sea levels can cause saltwater to penetrate further inland, increasing the risk of saltwater intrusion into groundwater supplies. Changes in precipitation patterns may also affect the amount of freshwater that recharges aquifers, potentially leading to a decline in freshwater availability.

Another threat arises from climate phenomena such as El Niño-Southern Oscillation (ENSO) which mainly affect countries along the equator. This phenomenon created a variability of precipitation between two occasions, where during the warm phase of El Niño there will be a deficit of rainfall, vice versa with the condition in the cold phase La Nina with an excess of rainfall (Phillips et al. 2005; van der Velde et al. 2007).

Future Task

Sustainable water resources and tourism practices that prioritize water conservation and management are necessary to mitigate the impact of tourism activities on groundwater reserves. These practices may include promoting water conservation through education, implementing water-efficient technologies, and encouraging the use of alternative water sources, such as rainwater harvesting and artificial recharge (Badiger et al. 2002; Samdani and Arora 2011; Holding and Allen 2016; Alataway and el Alfy 2019; Atay and Saladié 2022). Moreover, regulations and monitoring of groundwater resources are essential for ensuring sustainable tourism development and preserving the island's natural resources for future generations (Geissen et al. 2015; Lamari et al. 2016; Castilla-Rho et al. 2019; Closas and Villholth 2020).

Small island communities are especially at risk because they have few sources of fresh water and depend on groundwater for drinking water and farming (Post et al. 2018; Huq and Bahauddin 2019). Seawater intrusion can also have broader ecological and economic impacts, such as damage to coastal ecosystems and reduced agricultural productivity (Roson and Sartori 2014; Tosi et al. 2022). To address these challenges, communities may need to implement a range of adaptation strategies, such as developing alternative water sources (e.g., desalination or rainwater harvesting), improving water-use efficiency, and protecting and restoring coastal ecosystems to help mitigate the impacts of sea level rise. Also, reducing greenhouse gas emissions to lessen the effects of climate change is important for making sure that these effects aren't too bad in the long run.

Considering the importance of water availability on Tunda Island within its plan to be a tourist destination, it is necessary to conserve water in the area by using appropriate technology such as IRAHARS, which is designed with simple

techniques and is easy to implement, but some financial issues might come up and require assistance from other parties such as the local government or private sector so that the construction can be carried out. Based on the interview sessions with the local community, they have an awareness of the importance of water conservation in their area to maintain water availability. Local government support, in this regard, can be carried out by coordinating stakeholders such as the private sector to solve the financial problems.

Besides that, community empowerment can be carried out by educating the community to apply technology to water conservation. In practice, the local government might act as a coordinator to support the clean water supply and water resources management implementation plan by inviting many stakeholders to work together. Scientific knowledge and proper community perception are the prominent aspects of applying water resources management in a small island community. The contribution of the local government and other stakeholders, such as private companies and NGOs, to support water supply and water resources management is needed to solve the financial issues and empower the community.

The Indonesian government has several policies related with water resources management as stated in Law No. 7 of 2004 concerning Water Resources, which regulates water resources management including efforts to plan, implement, monitor and evaluate the implementation of water resources conservation, water resources utilization, and control the destructive power of water. Meanwhile, in Presidential Regulation No 33 of 2011 concerning The National Policy on Water Resources Management (Jaknas SDA), through this regulation, a strategic direction of national water resources management for a period of 20 years (2011–2030) has been established. One of the purposes of creating Jaknas SDA is to serve as a reference in formulating water resources management policies at the provincial level. So, Banten Province Water Resources Management Policy was appointed by the Banten Governor within his regulation No. 63 of 2014.

Conclusions

This study describes the characteristics and public perceptions of water resources and their management on Tunda Island, Serang Banten. In addition, this study examines the potential threat to the sustainability of water resources on small islands, particularly Tunda Island, caused by both human factors such as population growth and tourism activities and natural factors such as climate change-related impacts and seawater intrusion. Based on average data from 1979 to 2012, the normal monthly rainfall on Tunda Island can be classified as low (0–100 mm) to moderate (100–300 mm). The former occurs from June to September, whereas the latter takes place from October to May. According to climate data, months with an excess of water occur from November to May, while months with a deficit of water occur from June to October. In terms of public perception, the level of awareness of Tunda Island communities towards the sustainability of water resources and their management is 30% aware vs. 70% unaware. The low awareness level of the Tunda Island communities is due to a lack of information and knowledge in the community on this issue. The threats to the sustainability of water resources on Tunda Island and other small islands are typically caused by two factors: anthropogenic and natural. Anthropogenic factors are directly related to rising water demand and diminishing groundwater reserves, while natural factors include climate-related impacts such as drought, sea level rise, and seawater intrusion. The government and many other stakeholders such as scholars, private sectors, NGO’s, public figures, and communities at large should play a role in enhancing the community's knowledge and understanding of sustainable water resources and their management. These practices may include promoting water conservation through education, improving water-use efficiency, implementing water-efficient technologies, encouraging the use of alternative water

sources (e.g. rainwater harvesting and desalination), as well as protecting and restoring coastal ecosystems to help mitigate the impacts of sea level rise.

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