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Civil Engineering – Research Article

Sabu Raijua: Hydraulic Mission and Evaporation Threat

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A B S T R A C T

In Sabu Raijua, the more than 200-year-old hydraulic mission just began to demonstrate its dynamics in 2011. This study, which employs the literature review method and field survey, discusses the hydraulic mission and examines the challenges associated with evaporation for farm pond, also known as embung (in Indonesia), in Sabu Raijua. According to the data search findings, the government constructed large and small embungs in 230 locations between 2011 and 2018 with funding assistance from the district and the central governments. The presence of a large number ponds—nearly four times as many as kelurahans or villages—seems to be a blessing of aridity for this region. However, the mission still has to deal with socioeconomic issues like a petition against the construction of the Guriola reservoir, a series of droughts, and the threat of evaporation. All of Sabu Raijua's reservoirs had a loss of water of more than 50% in the fifth year of drought since 2015. Low rainfall is a contributing factor, although it is not the only one. According to the analysis of climate data, Sabu Raijua has evaporation risks from April through November, peaking in August, during both normal and below normal rainy periods.

INTRODUCTION

The current map of the embung distribution on the island of Sabu makes it look like we are in the 1930s in the US. Tennessee Valley Authority (TVA) was in charge of developing new technologies for water supplies in the US (Molle, Peter P. Mollinga, and Philippus Wester 2009). President Roosevelt gave TVA a mandate to construct massive dams and weirs for a variety of uses, including flood control, irrigation, and power generation. As a result of this obligation, enormous water resource infrastructure has been built along the Tennessee River, ranging from upstream to downstream. One hydraulic project that has been evolving since the 1800s is the US's TVA (Wester, Edwin Rap, and Sergio Vargas-Velázquez 2009).

The phrase "hydraulic mission" refers to the idea that every drop of water that enters the ocean is a waste of water, hence the nation must construct infrastructure for water resources in order to gather as much raw water as possible and use it for human purposes (Wester 2009). This concept makes it clear that the state is the primary player in the development of water resources. Irrigation is not profitable; hence the private sector is not interested in investment. The Madras Irrigation and Canal Company in India in the 1860s, the Chaffey Brothers in Australia in 1894, and numerous private investors in the western United States in the 1870s are a few instances of private sector failures in investment on water resources infrastructure (Molle, Peter P. Mollinga, and Philippus Wester 2009).

The fact that the mission began in the nineteenth century does not imply that water harvesting technology was invented at that time. Rainwater harvesting (RWH) technique has been used for thousands of years in arid and semi-arid areas. Some examples include the 4,000-year-old PAH technology in the Middle East and Mediterranean Region (Hashemi, Berndtsson, and Persson 2015), and the 9000-year-old technology in Jordan (Ammar et al. 2016). In semi-arid Indonesia, a popular RWH technique is the embung. The development of this technology has been largely influenced by international donors since the 1980s (Pradhan et al. 2009). At the moment, the (state) government, including the central government as well as districts and villages, is in charge of building embungs. The Jokowi administration intends to construct 4,500 embungs around Indonesia by 2024 (Aditya 2022).

There were 1,086 embungs in the province of East Nusa Tenggara (NTT) as of 2018 (BPS NTT 2022). This figure seems to be a blessing of aridity for this region. This advantage is accompanied with the risk of sedimentation, which reduces the reservoir's storage capacity. According to a number of studies conducted in mainland Timor, heavy sedimentation was causing reservoirs in West Timor to lose storage capacity by 3–6% year (Pradhan et al. 2009; Widiyono 2011; Dethan and Marthen Roby Pelokilla 2014).

Evaporation poses a serious risk to the storage capacity of reservoirs, dams, and other water infrastructure in arid regions (Alazard et al. 2015). Evaporation is the process by which water in lakes, rivers, reservoirs, and seas changes into gas as a result of wind speed, air temperature, humidity, and solar radiation (Triatmodjo 2016). However, the evaporation effect has not been taken into account in the planning and execution of reservoir development in Indonesia, particularly in semi-arid regions. Thus, the purpose of this literature-based and field-based study is to examine how evaporation affects reservoir capacity in the Sabu Raijua region in the NTT province of Indonesia. This site was selected because the government constructs an extensive number of embungs each year, although many of them suffer from dryness in the summer.

Sabu Raijua Overview

Located in the province of East Nusa Tenggara (NTT), Sabu Raijua has been an autonomous area since 2008. Two of its four islands, Sabu and Raijua, are home to 90,837 inhabitants (BPS Sabu Raijua 2021). Administratively, there are 6 sub-districts, 58 villages, and 5 kelurahan in Sabu Raijua. West Sabu sub-district has the largest population distribution (37%), followed by Hawu Mehara (20%) and the remaining four sub-districts (10–12%) (BPS Sabu Raijua 2022b).

Fisheries, forestry, and agriculture are the primary sources of income in this region. Nearly two-thirds (61.7%) of Sabu Raijua's population are farmers, according to data from 2016 (Pemkab Sabu Raijua 2022). The main source of income is dryland farming, with a small proportion as wetland farmers, plantations, palm sugar production, seaweed, salt ponds, and weaving crafts. Construction services absorb about 22% of the workforce and the rest are small traders, transportation services, finance, and civil servants (BPS Sabu Raijua 2022a).

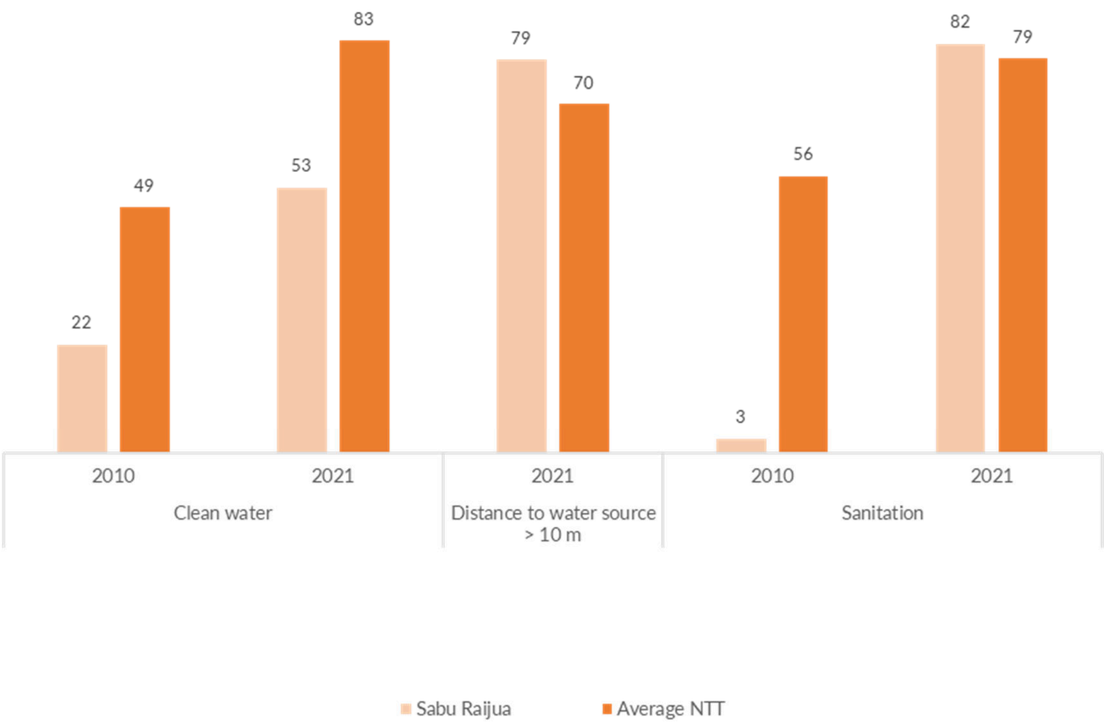

Figure 1. Access to clean water and sanitation in Sabu Raijua
Source: Compilation from (POKJA AMPL NTT 2012; BPS NTT 2021)

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Figure 1 shows access to sanitary facilities and drinking water. According to data, barely 2 out of 10 homes (21%) had access to a source of safe drinking water in 2010, which is much less than the 50% provincial average (POKJA AMPL NTT 2012). In 2021, ten years later, there was a significant increase. Although it is still below the provincial average of 83%, 53% of families have access to safe drinking water (BPS Sabu Raijua 2021). Access to clean water in Sabu Raijua is 80%, but distance to water source is above 10 meters.(BPS Sabu Raijua 2021). By 2021, 82% of families had proper sanitation, up from 3% in 2010.

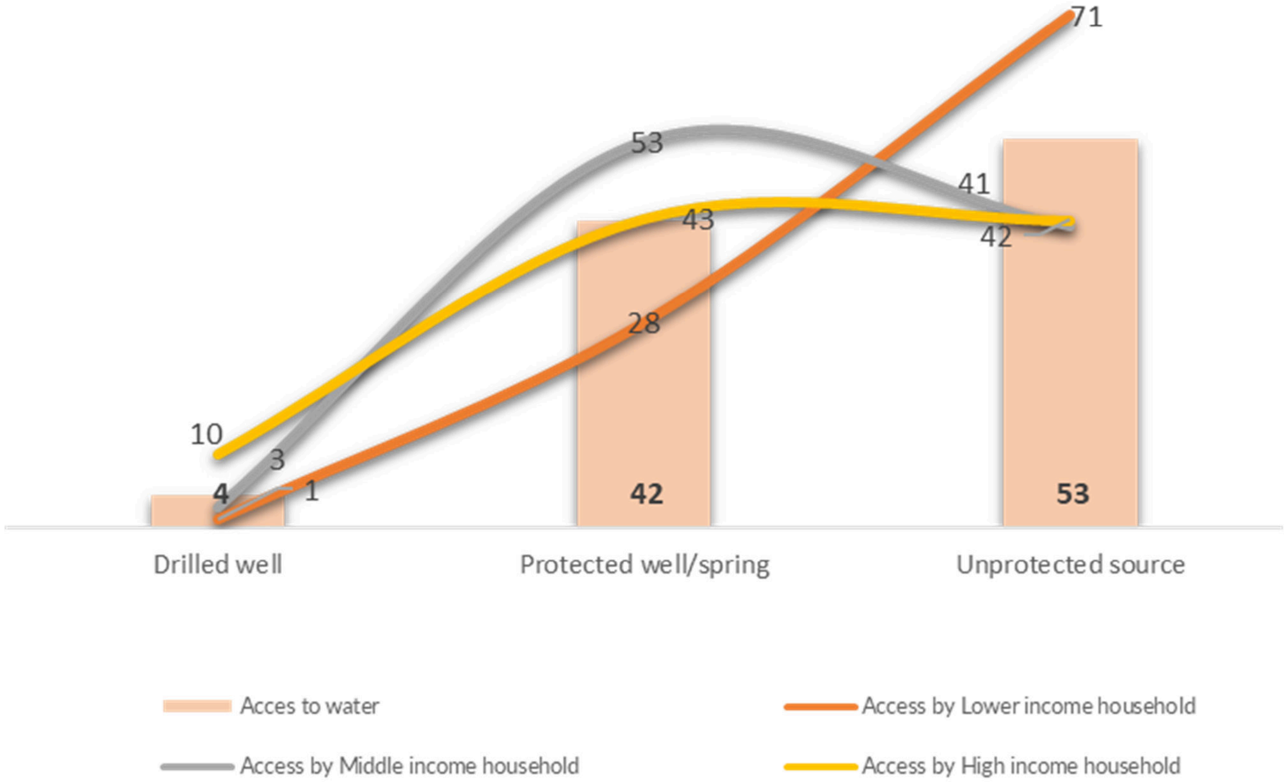

Figure 2. Access to clean water based on family income
Source: Compilation from (BPS Sabu Raijua 2021)

A further overview of access to safe drinking water by family income level is shown in Figure 2. In general, most families in Sabu Raijua (53%) access drinking water from unprotected sources, such as open wells, ponds, rivers, springs, and others. Based on income level, 71% of poor families access water from unprotected sources, one of which is from embungs (see Figure 3).

Figure 3. Children fetching water from embungs for domestic use
Source: (Benge 2022)

Families are further burdened by the task of transporting water in addition to the hygienic considerations of the water source. 92% of families carried water over challenging terrain, according to a survey done in the Hawu Mehara subdistrict by the Institute of Resource Governance and Social Change (IRGSC). Children's involvement in getting water varies in frequency. While families who collected water by carrying it had a daily frequency of twice (40%), three times (48%), and four times (10%), those that used carts only carried water once a day (2%).

RESULTS AND DISCUSSION

Water Resource Management

In Sabu Raijua, the government has constructed at least 230 embung units in six subdistricts since 2011 (Dinas PUPR Sabu Raijua 2020). Figure 4 shows the distribution of big embungs that have a capacity of above 3,000 m3. It is evident from the figure that nearly all of the area's rivers now have embungs, and the main rivers now have 23 dam units.

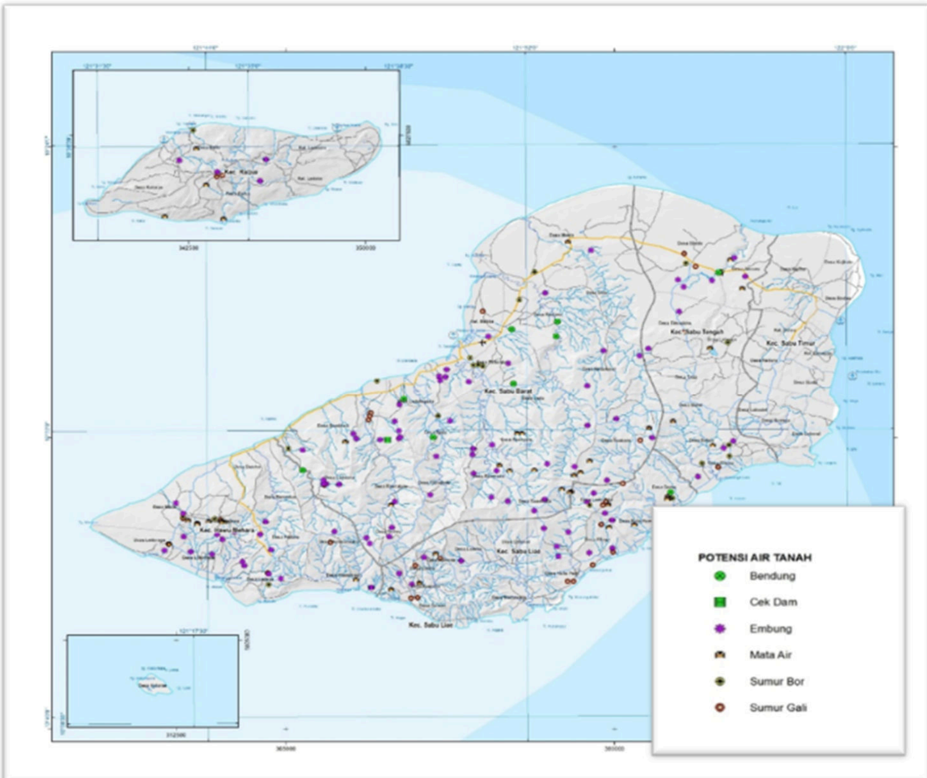

Figure 4. Water source type distribution in Sabu Raijua
Source: (Dinas PUPR Sabu Raijua 2022)

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Both the state budget (APBN) and the regional budget (APBD) funded the construction of all embung units, as Table 1 demonstrates. 113 units were constructed by the national government, compared to 97 by the Sabu Raijua government. This indicates the face of the hydraulic mission and demonstrates the government's role as the primary water supply actor.

Table 1. Embungs and source of funding

Year	*Embung*	Funding source	
		Local government	National government
2011	4	4	
2012	1	1	
2013	120	3	117
2014	35	32	3
2015	60	51	9
2016	3	3	
2017	1		1
2018	6	3	3
Total	**230**	**97**	**133**

In order to support agriculture, the district administration especially initiated the construction of water supply systems, such as reservoirs, between 2011 and 2016, as per the Regional Medium-Term Development Plan (RPJMD) (Bappeda Sabu Raijua 2011). Unfortunately, everything did not go as planned for the government's mission.

A group of villages petitioned against the Guriola reservoir's construction in 2014, claiming that the government was abusing its authority to evict people and take their land without providing any compensation (change.org 2022). This demonstrates how crucial socioeconomic factors are when developing water supply systems. The 350,000 m3 reservoir was eventually constructed with financial assistance from the federal government despite objections.

Climate Challenges

Geographically, Sabu Raijua experiences semi-arid climate with 1,100–1,500 mm of yearly precipitation. There are only four months of the rainy season (December to March), six dry months (May to October), and humid months (typically April and November). According to Schmidt-Ferguson climate research, Sabu Raiua's climate pattern falls between climate E (quite dry) and F (dry), which is defined by savanna woodland vegetation, which is frequently the predominant vegetation (BPBD Sabu Raijua 2020).

Figure 5 illustrates the temporal scale and intensity variations of rainfall as a climatic indicator. In some years, November marks the start of the rainy season. In other years, December and October mark the beginning of the rainy season.

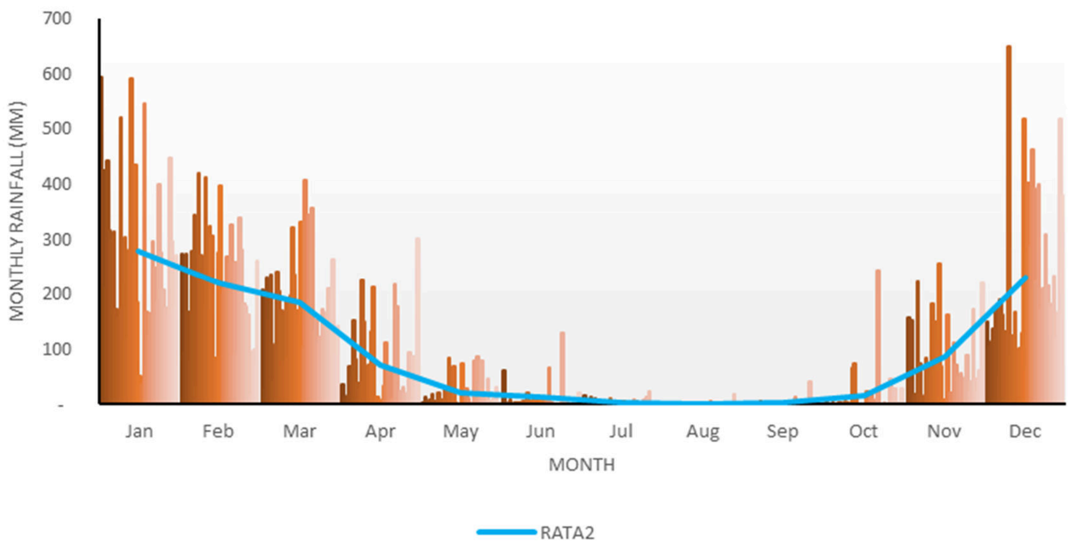

Figure 5. Rainfall variability in Sabu Raijua 1986-2021
Source: Compilation from (BMKG Sabu Raijua 2021)

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The amount of rainfall that falls in the same month every year varies as well. In the months of November through March, the difference between the minimum and average rainfall is between 79 and 243 mm/month. In the same time frame, the monthly average rainfall and the monthly maximum rainfall vary by 169 to 419 mm/month.

This area also experiences periods of moderate to extreme drought almost every year. Analysis using the Standardized Precipitation Index (SPI) method for the period 1986-2021 shows that there have been at least 16 drought episodes in the last 36 years (see Figure 6). Indices with values below zero indicate periods of drought, especially in the wet months (November - March). Drought periods occurred in 1987, 1990, 1991, 1993, 1996, 1998, 2001, 2003, 2005, 2012, 2015, 2016, 2017, 2018, 2019 and 2020. The form of adaptation to such climatic conditions is to rely on palm sugar as one of the family's food sources. However, there are currently no climate-smart agricultural improvements in place for irrigation techniques, crop selection, or land conservation strategies.

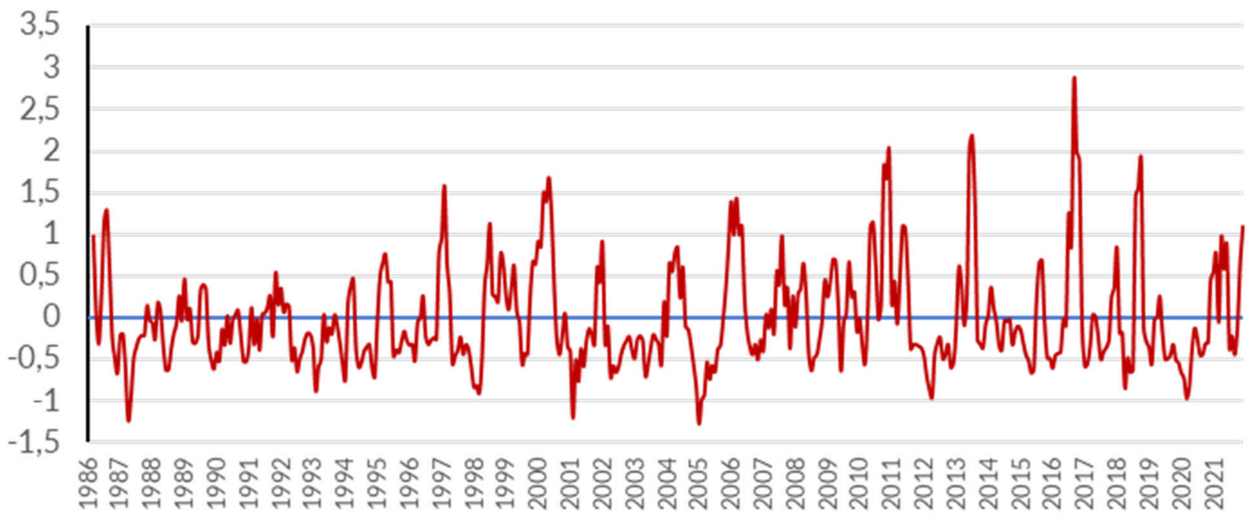

Figure 6 Standardized Precipitation Index in Sabu Raijua 1986-2021
Source: Compilation from (BMKG Sabu Raijua 2021)

Evaporation Threat

In 2019 the government reported a 53% reduction in raw water in all reservoirs in Sabu Raijua due to drought (Dinas PUPR Sabu Raijua 2020). If the sedimentation factor is also considered, this number ought to be significantly greater. However, the threat of diminished capacity due to evaporation is the only one addressed in this paper. Notably, the government grouped small reservoirs (indicated in blue on the graph in Figure 7) into three groups according to the year of completion, resulting in 58 units: 100 units in 2013, 25 units in 2014, and 50 units in 2015. According to the data, five big reservoirs remained at optimum capacity (0%), while six reservoirs faced complete drought (100%). The decline in other reservoirs was between 10 and 83 percent. Reservoirs with a capacity of less than 3,000 m3 in particular saw a drop of 43–83%. The reduction was attributed to insufficient rainfall or drought, the authorities said. Given that this region saw consecutive droughts from 2015 to 2020, this justification is reasonable (see Figure 6). Evaporation is another element contributing to the decline, in addition to the lack of rainfall.

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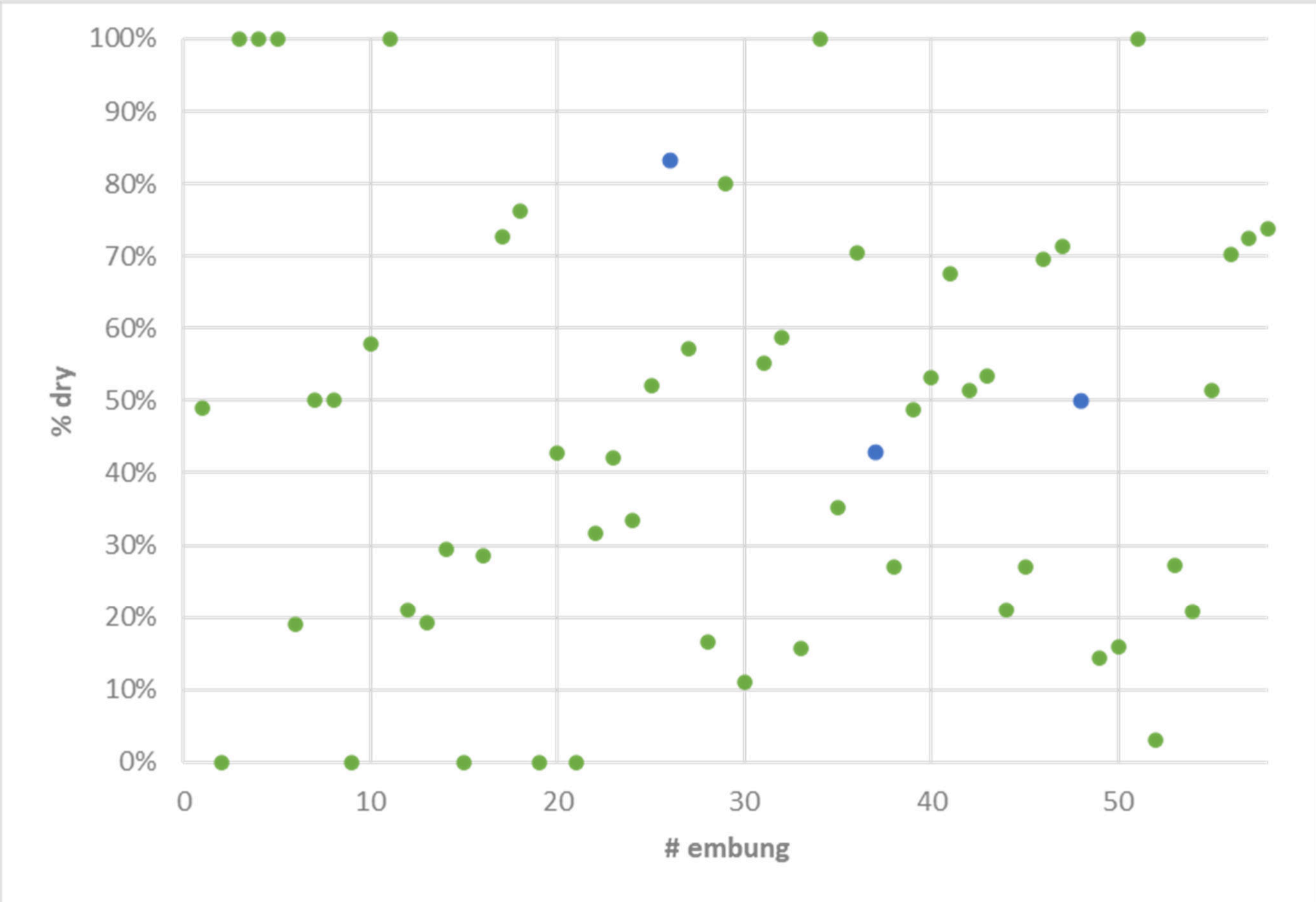

Figure 7 Percentage of embung capacity reduction in 2019
Source: Compilation from (Dinas PUPR Sabu Raijua 2020)

Figure 8 shows the evaporation calculation using the Harbeck equation (Triatmodjo 2016) in conjunction with the average monthly rainfall. The Muli reservoir in Nadawawi village, West Sabu sub-district, is used as an example in the analysis. According to this graph, the reservoir is at risk of evaporation for eight months, from April to November, with August being the peak. This demonstrates that the reservoir is still vulnerable to water loss due to evaporation even during normal rainfall periods. According to an IRGSC survey, just sixteen percent of wells dried up between May and November, compared to wells where the water body is not immediately exposed to wind and sunlight. Evaporation in water structures in this region has not yet been addressed by any measures at all.

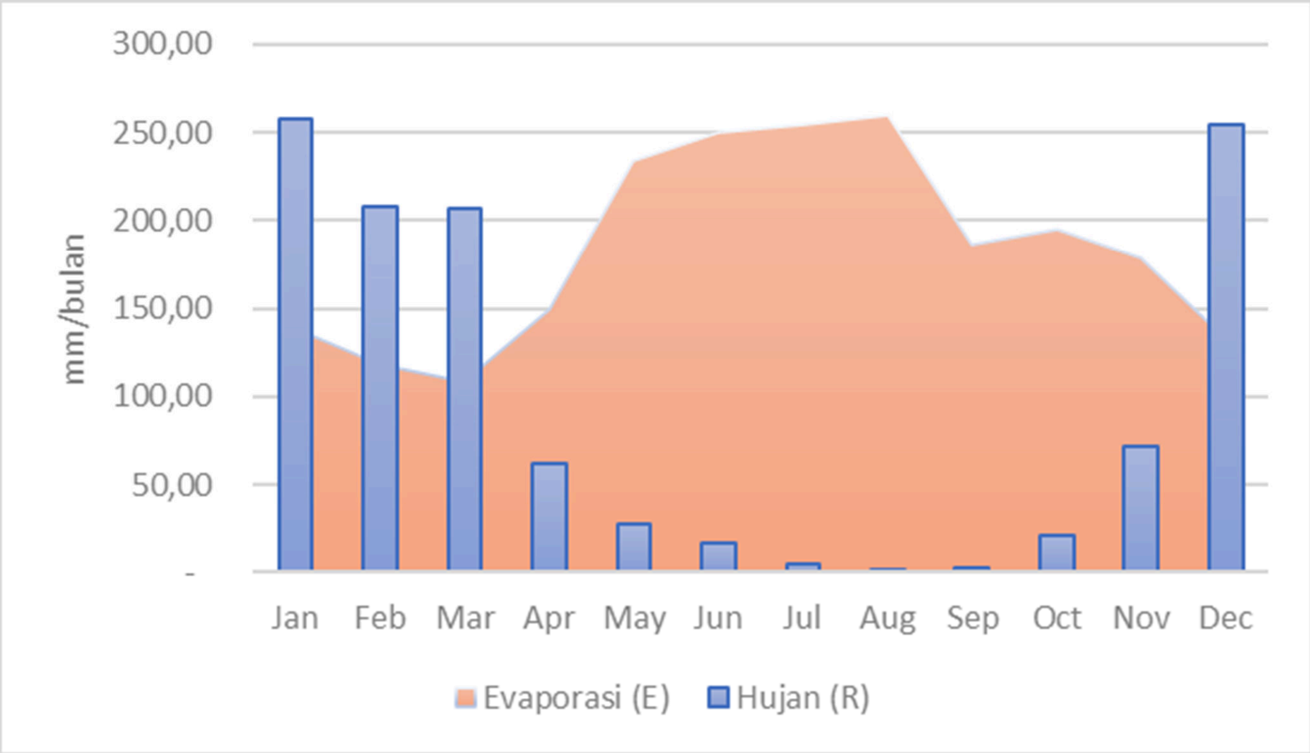

Figure 8 Evaporation and rainfall comparison

Some methods to lessen evaporation-related water loss include covering water bodies with a double layer of polyethylene (PE) (Gallego-Elvira et al. 2011), building underground dams (Widjaja et al. 2004) and sand dams (Yifru et al. 2021)], and installing floating solar photovoltaic (PV) panels on embassies' and weirs' water bodies (Agrawal et al. 2022). The use of polyethylene (PE) double layers in Spain can reduce annual evaporation by up to 85% (Gallego-Elvira et al. 2011). These evaporation reduction technologies offer varying degrees of performance, but all have the benefit of avoiding direct exposure of surface water to evaporation-inducing factors.

CONCLUSION

This paper describes the challenges of evaporation that impact the operation of water resources structures and discusses the state's passion for delivering water (hydraulic mission) through embungs technology for communities in semi-arid locations. According to the literature study, 230 large and small embungs units were built by the central and local governments in Sabu Raijua between 2011 and 2018. However, since 2015, a series of droughts have caused the storage capacity to drop by more than 50%. In addition to the risk of drought, evaporation in both normal and below-average rainfall scenarios also lowers the embung's capacity. According to the study's data, the risk of evaporation occurs annually between April and November. Therefore, as the only actor involved in reservoir construction, the government needs to consider methods to reduce evaporation using a variety of alternatives, including installing floating solar panels, covering the water body with PE layer, and other options that are both financially viable and appropriate for the local climate. Other runoff water harvesting technologies, such as sand dams and underground dams, are also advised in addition to massive embungs construction.

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