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SOLUTION TO WATER SCARCITY IN THE EASTERN INDONESIA: A CASE STUDY OF THE LEMBATA REGENCY

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ABSTRACT: The Lembata Regency, which is located on Lembata Island in eastern Indonesia, is a region with high water scarcity. Appropriate efforts should be made to ensure the drinking water supply in the area. A water supply-demand analysis is needed to determine the condition of water sources (surplus or deficit). Water supply is determined based on rainfall data, while water demand is calculated based on domestic, non-domestic and irrigation needs, including evapotranspiration. Evapotranspiration is calculated using the Thornthwaite method. The results showed that a water deficit would exist in the Lembata Regency in 2033 for seven months per year (May to November), although the amount of accumulated water in one year would still be surplus. Therefore, it is recommended to store water in a raw water reservoir during the rainy season for use during the dry season. The minimal total reservoir capacity is 95,000,000 m^3, and the reservoir should be spread among watersheds in Lembata. The raw water reservoirs need to be lined with a geomembrane to prevent lost water from seeping into the soil.

Keywords: Lembata Regency, Reservoir, Supply-demand analysis, Water scarcity

1. INTRODUCTION

Water is a human right [1], but many people in Indonesia do not have access to safe and healthy water. The Indonesia Central Agency of Statistics noted that in 2017, as much as 80.82% of the urban population and 62.10% of the rural population in Indonesia had access to feasible and sustainable water services [2]. Some regions in eastern Indonesia have water vulnerability. Hydrologically, these areas have small annual rainfall amounts, and geologically, the soil is composed of soil that is less able to store water. Climate change may also affect water availability [3,4,5,6]. One region in which drought often occurs is Lembata Regency, East Nusa Tenggara Province (see map in Fig. 1). In 2018, a drought occurred in several areas of the Lembata Regency, mainly including Ile Ape, Ile Ape Timur, Nubatuan, Omesuri, Buyasuri, Atadei, Nagawutun, and Wulandoni [7].

The Water Supply Company (called PDAM in Indonesia) has not been able to meet the drinking water needs of the community in terms of quantity, quality, and continuity, especially during peak hours. The need for drinking water will always increase with rapid population growth [8,9]. Increasing populations will increase water demand for households and commercial services, including hospitality, industry, and tourism. Therefore, the optimization of drinking water services must always be accomplished through the construction of drinking water infrastructure to improve services to the community [10].

In the framework of water supply infrastructure development planning, the condition of water sources and water demand (supply-demand analysis) must be studied in the Lembata Regency. Water supply-demand analysis can determine the condition of water availability (i.e., surplus or deficit) [11]. Furthermore, a decision can be made regarding a strategy to meet water needs by optimizing the use of available water resources [10].

A water supply-demand analysis is a study conducted to assess water availability compared to future water demand [12,13]. This analysis is part of supply management, which especially aims to increase water availability. Joshi [14] stated that the driving force of water scarcity was the imbalance between water supply and demand.

Some actions must be taken to improve water supply systems, such as modernization of equipment, expansion of catchment structures, development of water distribution, and changes in operational procedures [15]. Additionally, demand management refers to solutions to meet the quantity of water needed for certain activities. This strategy involves the efficiency of water use by users (i.e., the community or economic sector), including reducing and reusing water resources if possible [16].

Many studies have investigated water supply-demand. Hossain *et al.* [17] conducted a gap analysis between supply and demand in Pourashava, Bangladesh, with a focus group discussion, interview, and questionnaire technique to assess growing water demand and the deterioration of surface and groundwater quality.

Wang *et al*. [18] reviewed the effect of evapotranspiration on the water balance in the Yellow River Basin. Liu *et al*. [19] analyzed the supply-demand balance in the Yellow River Basin using statistical techniques. This analysis makes conclusions about the reliability of water resources based on normal future demands for living, production, and ecological maintenance. Cambrainha and Fontana [20] used a multi-criteria decision-making approach to balance the water supply-demand strategy with the water supply system. The proposed model was able to generate a balance between water supply and demand strategies through the selection of alternatives for supply and demand.

Numerical simulation has provided trends in the demand and supply of water resources. Recent science and technology developments have been used for supply-demand analysis, such as remote sensing and geographic information systems [21], the continuous deep belief echo state network (CDBESN) [22], system dynamics [23,24,25,26], and others.

Okungu *et al*. [11] analyzed water supply and demand using the WEAP Model in the Yala Catchment, Kenya. He recommended that measurement of supply and demand must be related to the aim of regulating activity levels, consumption, and losses. The water supply-demand analysis used the RIBASIM (RIver BAsin SIMulation) model conducted by Omar [27] in Fayoum, Egypt. This model produced actions that were classified as inventory management and demand management.

Manoli *et al*. [28] used a spatial decision support system to evaluate water supply schemes and demand management. This system integrates a spatial database and study area infrastructure and tools for network assumptions that affect supply-demand. It also includes a model to analyze demand, water allocation, and components and to manage and present information. Ayivi and Jha [29] estimated water balance and water yield using the Soil and Water Assessment Tool (SWAT) in the Reedy Fork-Buffalo Creek Watershed. They recommended that the SWAT model could be used for the prediction of water balance and water yield for sustainable water management of water resources in other watersheds.

Therefore, this paper aims to illustrate the availability of water sources as raw water for water supply in the Lembata Regency. The availability of raw water is the key to the success of water supply systems, including raw water, production, distribution, and service units.

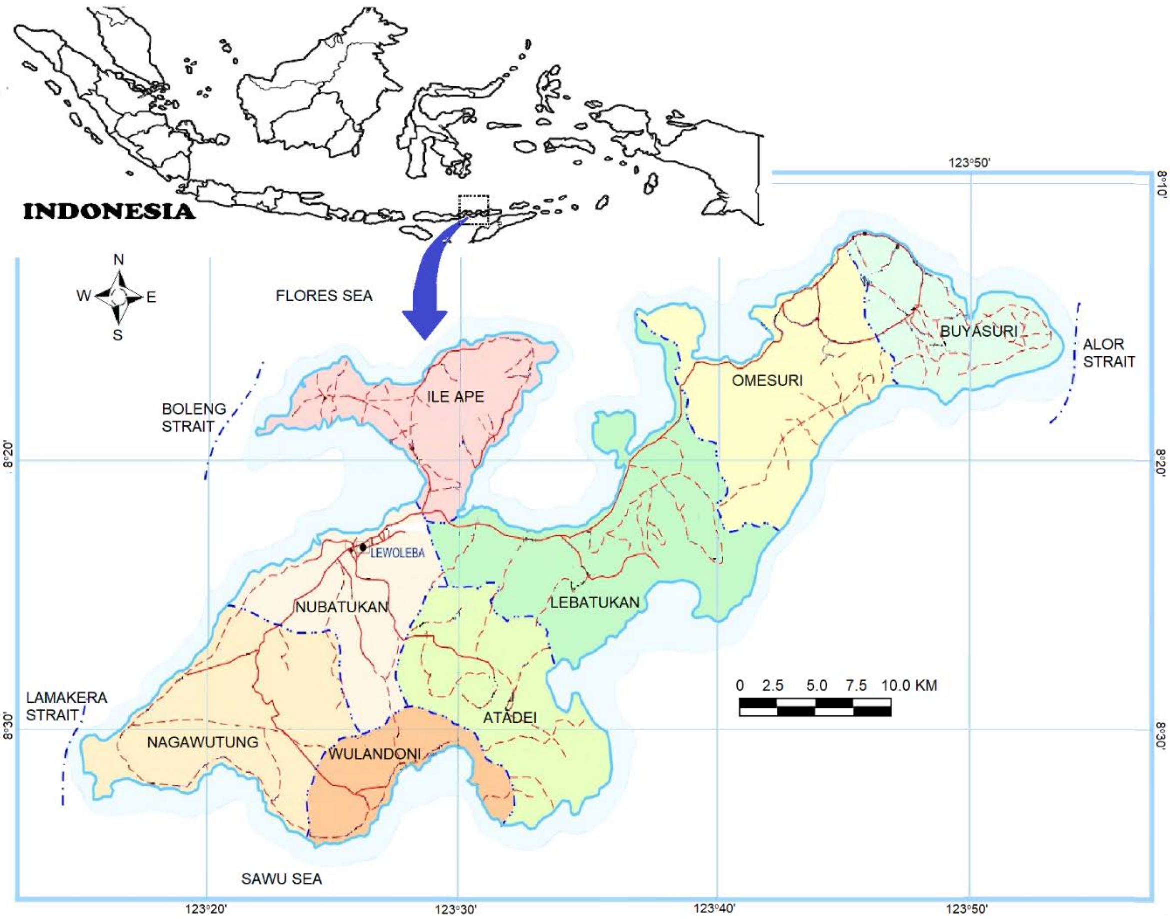

Fig. 1 Map showing the Lembata Regency location

2. METHODS

The method used in this study is supply-demand analysis, which compares the availability of water sources with water demand [14]. Water availability is calculated based on rainfall data in an area, which then is converted to the volume of water received each month for one year. Water demand includes water needs for the domestic sectors, nondomestic sectors, irrigation sectors, and evapotranspiration. The water demand of the domestic and nondomestic sectors is calculated based on applicable regulations in Indonesia with the following assumptions.

1. The water demand per capita for house connections (HCs) is determined as follows:
   a. The first five years (up to 2023)
      - For a population <10,000 people: 85 liters/cap.day
      - For a population ≥ 10,000 people: 100 liters/cap.day
   b. The second five years (2024-2028)
      - For a population <10,000 people: 90 liters/cap.day
      - For a population ≥ 10,000 people: 105 liters/cap.day
   c. Final year projection (2033)
      - For a population <10,000 people: 100 liters/cap.day
      - For a population ≥ 10,000 people: 110 liters/cap.day
2. The water demand for public hydrants (PHs) is determined to be 30 liters/cap.day, and we estimate that 1 PH serves 100 people.
3. The HC:PH ratio is adjusted to the condition of the Lembata Regency, which is 90:10.
4. The water demand for nondomestic purposes is assumed to be 15% of the total domestic water demand.
5. Water loss is estimated to be 20% of the water demand of one zone.

The water consumption needs for each plant are assumed to be 4 mm/day. The evapotranspiration rate is calculated using the Thornthwaite method [30] with the following formulas:

$$ET_0 = 16\,(10t/J)^a \qquad (1)$$

J = total j for 12 months

$$j = (t_n/5)^{1.514} \qquad (2)$$

$$a = (675\times10^{-9})J^3 - (771\times10^{-7})J^2 + (179\times10^{-4})J + 0.492 \qquad (3)$$

with:

j = monthly heat index

t_n = average temperature at the n-month

Furthermore, the water balance (WB) analysis is carried out with the following formula:

$$\text{WB} = \text{Supply} - \text{Demand} \qquad (4)$$

A positive WB is called a "surplus", and a negative WB is called a "deficit" [13].

3. RESULTS AND DISCUSSION

3.1 Water Supply

The Lembata Regency is a dry area. The average annual rainfall is 1022 mm/year, and the area has a total of 72 rainy days (Table 1). The Lembata Regency area is 1266.40 km^2. The rainfall data and region area can be used to obtain the amount of water supply that enters the Lembata Regency.

Table 1 Average rainfall in Lembata Regency

Month	Rainfall (mm)	Rainy days (day)
January	186	16
February	163	14
March	177	12
April	128	10
May	0	0
June	5	1
July	0	0
August	0	0
September	0	0
October	0	0
November	3	4
December	360	15
Total	1022	72

Source: BPS [2]

3.2 Water Demand Projection

The United Nations [12] stated that the growing water demand and deterioration of surface and groundwater quality affected the availability of conventional water resources. In 2018, the population of the Lembata Regency was 140,390 people [2]. With a growth rate of 1.94% per year (calculated based on population data for 2010 - 2018), the population in the next 15 years projected using the geometric method is 187286 people. The population projection for each district is shown in Table 2. The projected population is used to project the water demand for the next 15 years.

Based on the provisions described in the Methods, water demands were calculated for nine districts in the Lembata Regency for the years 2019-2033. The water demand calculation results are presented per 5 years in Table 3. Overall, the water demands for the domestic and nondomestic sectors of the Lembata Regency are 21800 m^3/day or 252 L/sec in 2033.

Other water demands include water for irrigation and evapotranspiration. The land areas that require irrigation water are agricultural land and protected areas. The other lands are for annual crops, seasonal wet season crops, and seasonal dry season crops. The evapotranspiration rate is calculated using the Thornthwaite Method, Eq. (1), (2), and (3). The heat index j and J calculations are shown in Table 4.

Table 2 Calculation Results of Population Projection

n	Year	Amount of population projection, in District:								
		Naga-wutun	Wulandoni	Atadei	Ile Ape	Ile Ape Timur	Leba-tukan	Nuba-tukan	Ome-suri	Buya-suri	Lembata Regency
0	2018	9655	8480	7151	12421	5075	9012	54126	15508	18962	140390
5	2023	10629	9335	7872	13674	5587	9921	59584	17072	20874	154547
10	2028	11700	10276	8666	15052	6150	10921	65592	18793	22979	170131
15	2033	12880	11313	9540	16570	6770	12022	72206	20688	25296	187286

Table 3 Water Demand per District in Lembata Regency

District	Water Demand per District (m^3/day)					
	2023		2028		2033	
	Domestic	Non-Domestic	Domestic	Non-Domestic	Domestic	Non-Domestic
Nagawutung	988.50	148.27	1140.75	171.11	1313.76	197.06
Wulandoni	742.13	111.32	1001.91	150.29	1153.93	173.09
Atadei	625.82	93.87	727.94	109.19	887.22	133.08
Ile Ape	1271.68	190.753	1467.57	220.14	1690.14	253.52
Ile Ape Timur	444.17	66.62	516.60	77.49	629.61	94.44
Lebatukan	788.72	118.31	1064.80	159.72	1226.24	183.94
Nubatukan	5541.31	831.20	6395.22	959.28	7365.01	1104.75
Omesuri	1587.70	238.15	1832.32	274.85	2110.18	316.53
Buyasuri	1941.28	291.19	2240.45	336.07	2580.19	387.03
Total Water Demand	13931.31	2089.70	16387.56	2458.13	18956.28	2843.44

Table 4 Calculation Results of Heat Index Numbers

Month	Temperature (°C)			j
	Min.	Max.	Avg.	
January	21.1	30.8	25.95	12.1
February	17.8	27.0	22.40	9.68
March	17.6	28.7	23.15	10.18
April	20.1	31.6	25.85	12.03
May	20.9	31.3	26.10	12.21
June	19.0	31.4	25.20	11.57
July	20.3	31.4	25.85	12.03
August	18.7	32.2	25.45	11.75
September	16.1	32.7	24.40	11.02
October	17.5	33.7	25.60	11.85
November	21.0	33.9	27.45	13.17
December	21.2	33.7	27.45	13.17
			J=Σj=	140.77

Then, the evapotranspiration rate calculation refers to the number of J, as follows.

- Calculation of the value of a (Eq. 3):
  $a = (675\times10^{-9})140.77^3 - (771\times10^{-7})140.77^2 +(179\times10^{-4})140.77+0.492$
  $a = 3.37$
- Calculation of the evapotranspiration rate per month using the following formula (Eq. 1):
  $ET_0 = 16\ (10t_n/140.77)^{3.37}$
  ET_0 = 129,88 mm/month (for January with t_n = 26°C)
  ET_0 = 4,19 mm/day

The monthly evapotranspiration rate result is shown in Table 5. The evapotranspiration rate values in Table 6 have been adjusted for the number of days in each month.

The following is an example of the calculation for irrigation water demand and evapotranspiration for January:

= ($ET_{January}$ + water consumption by plants) × total day in one-month × land area
= (4,19 mm/day + 4 mm/day) × 31 days × 57.84 km^2
= 8.19 mm/day × 31 days × 57840000 m^2
= 14684521 m^3

Table 5 Monthly Evapotranspiration

Month	Average Temperature	ET (mm/month)
January	26.0	129.88
February	22.4	71.45
March	23.2	88.40
April	25.9	124.07
May	26.1	132.43
June	25.2	113.86
July	25.9	128.20
August	25.5	121.64
September	24.4	102.13
October	25.6	124.07
November	27.5	151.90
December	27.5	156.96
Annual	25.40	120.42

3.3 Supply-Demand Analysis

Water balance analysis is intended to evaluate the availability of water and its utilization and to determine whether excess water (surplus) or a lack of water (deficit) will occur. Based on the results of this analysis, plans and development programs for the drinking water supply system can be developed, especially plans for raw water. Water balance analysis is a calculation of the difference between the inflow and outflow of the hydrological system. The inflow is precipitation water, and the outflow consists of water used for drinking water, nondomestic demand, irrigation water, and evapotranspiration (see Table 6). The following formula is used to calculate the water balance (from Eq. 4):

$$WB = Q_{rainfall} - (Q_{domestic\ demand} + Q_{nondomestic\ demand} + Q_{irrigation+ET})$$

The water balance projection for the year 2023, 2028, and 2033 are obtained. Fig. 2 shows the water balance projection for the year 2033. Deficits occur from May to November or during the dry season. Although the monthly calculation is showing a 7-months deficit, yet the rainwater potential is still sufficient to meet the water needs for one year. It is because of the five surplus months would still have 93%-96% of water remained in the balance. The annual water balance for each of those three projected years is at 86%-87% of the total inflow, while the total outflow of a year only takes 13%-14% of the total inflow for each respective year. This result concludes that the projected supply-demand analysis has an annual surplus water balance for 2033.

Table 6 Water Demand of Lembata Regency in 2033

Month	Domestic m^3	Non domestic m^3	Irrigation + ET, m^3
Jan.	587645	88147	14684521
Feb.	530776	79616	10611031
Mar.	587645	88147	12285047
April	568688	85303	14116842
May	587645	88147	14831869
June	568688	85303	13526650
July	587645	88147	14587404
Aug.	587645	88147	14207752
Sep.	568688	85303	12848175
Oct.	587645	88147	14348479
Nov.	568688	85303	15726632
Dec.	587645	88147	16250853
Total	6919042	1037856	168025253

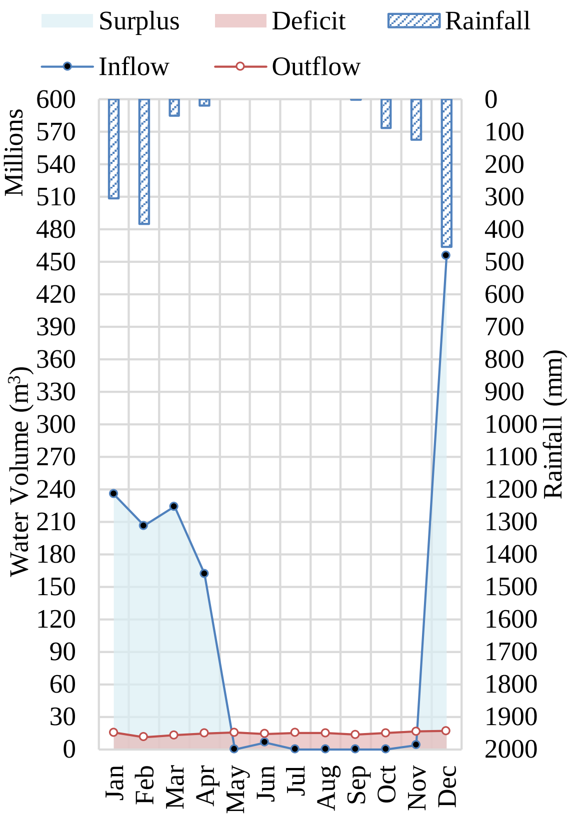

Fig. 2 Water balance graph for the year 2033

3.4 Solution to Water Scarcity

Misuse of water resources in domestic, industrial, or agricultural sectors is a threat to sustainable development [14] and is also a cause of poverty. The proportion of people living in poverty in Lembata has reached 26.48% [31]. The supply-demand analysis result concludes the water availability of the Lembata Regency is surplus. In this case, why does drought still occur? It is the geological condition of the Lembata, which affects the groundwater scarcity. Most of the Lembata region is comprised of hilly groundwater areas with small water potencies. Furthermore, because of the area's climate, the rainfall amount in Lembata is not high [5]. Therefore, a solution is needed to help the community with water scarcity.

The soil condition must be engineered with technology to accommodate rainwater with enough potential (surplus) for use as water reserves during the dry season. The construction of reservoirs needs to be considered in the Lembata area. Water conservation is the most significant way to find solutions for water crowding and scarcity [14]. Based on the calculation results (Table 7), water reservoirs are needed with a total volume exceeding 95,000,000 m^3. Reservoirs can be built in some watersheds spread throughout the Lembata areas.

To block the water from seeping into the ground, a geomembrane needs to be included as a liner at the bottom of the reservoir. Peggs [32] recommended HDPE (high-density polyethylene) as the best liner, followed by LDPE (low-density polyethylene) and then PP (polypropylene). Although a geomembrane has a high lifetime, Rowe *et al*. [33] predicted that the service life of a geomembrane was affected by temperature. Based on these predictions, the service life of the specific geomembrane tested, which was immersed in leachate, is likely to exceed 700 years and probably longer at 20°C, more than 150 years at 35°C and more than 40 years at 50°C. Additionally, Tazi *et al*. [34] studied the mechanical and structural properties of biocomposites made from HDPE reinforced with sawdust, which improves the mechanical properties of biocomposites.

Another type of geomembrane is EPDM (ethylene propylene diene monomer) which has been installed in the El Boquerón reservoir (Spain) [35]. After 18 years of exposure to high temperature and UV rays, it shows that the EPDM geomembrane conditions remain in good mechanical properties and are still very suitable for reservoir liner.

Table 7 Calculation of Raw Water Reservoir Volume

Month	Inflow (m^3)	Outflow (m^3)	Inflow - Outflow	Volume Reservoir
January	235,550,400	15,360,312	220,190,088	
February	206,423,200	11,221,423	195,201,777	
March	224,152,800	12,960,838	211,191,962	
April	162,099,200	14,770,834	147,328,366	
May	0	15,507,660	- 15,507,660	
June	6,332,000	14,180,642	- 7,848,642	Sum of negative value
July	0	15,263,195	- 15,263,195	is 94,610,900 m^3
August	0	14,883,543	- 14,883,543	
September	0	13,502,166	- 13,502,166	
October	0	15,024,270	- 15,024,270	
November	3,799,200	16,380,623	- 12,581,423	
December	455,904,000	16,926,644	438,977,356	
Total	1,294,260,800	175,982,152	1,118,278,648	

4. CONCLUSION

Analysis of water supply-demand can be used to estimate water availability in areas where water scarcity frequently occurs in the dry season, such as Lembata in eastern Indonesia. From the water supply-demand analysis, we found that the Lembata Regency still had a surplus of water resources over one year despite the water deficit during the dry season. The solution suggested overcoming the drought problem in Lembata is the construction of reservoirs with a total capacity exceeding 95,000,000 m^3 spread among some watersheds of Lembata. To prevent lost water from seeping into the soil, a geomembrane is needed that is resistant to local environmental conditions. Alternative geomembrane options are HDPE, LDPE, PP, or EPDM.

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