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Analysis of water carrying capacity in Pulubala sub-watershed, Gorontalo Regency, Gorontalo Province

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Abstract. Government Regulation No. 37 of 2012 mandates that to prevent the decline in the carrying capacity of a watershed, it is necessary to increase the carrying capacity of the watershed. The carrying capacity of a watershed is the ability of a watershed to realize the sustainability and harmony of ecosystems and the increasing use of natural resources for humans and other living things in a sustainable manner. Minister of the Environment Regulation No. 17 of 2009 mandates that in carrying out the calculation of environmental carrying capacity, there are two carrying capacities that must be calculated, namely the carrying capacity of food and carrying capacity of water. Water carrying capacity is the potential contained in water and / or in water sources that can provide benefits or harms to human life and livelihoods and the environment. This study aims to analyze the carrying capacity of water in Pulubala Sub- watershed, Gorontalo District. This research uses the method of calculating the carrying capacity of water through the availability of water and the need for water which is calculated based on the guidelines for the preparation of environmental carrying capacity in the Minister of Environment Regulation No. 17 of 2009, and added with some calculations for the needs of agriculture (rice fields), industry, and animal husbandry. Pulubala watershed covers 4 sub- districts, namely Bongomeme District, Dungaliyo District, Pulubala District and Tibawa District. From the results of the analysis, the carrying capacity of water in Bongomeme District in 2016 was 0.59, in 2017 it was 0.70, in 2018 it was 0.69. Water carrying capacity in Dungaliyo District in 2016 was 0.46, in 2017 it was 0.54, in 2018 it was 0.46. Water carrying capacity in Pulubala District in 2016 amounted to 1.15, in 2017 amounted to 1.34, in 2018 amounted to 1.24. Water carrying capacity in the District of Tibawa in 2016 was 0.51, in 2017 it was 0.62, and in 2018 it was 0.57. The water carrying capacity in the Pulubala Sub-watershed is exceeded (carrying capacity <1) and conditional safety (carrying capacity between 1-2).

1. Introduction

Water resources, is one type of resource that is vital for the survival of life on earth. All living things in this world cannot be separated from their need for water. Clean water is a necessity that is used and utilized in everyday human life. As water for drinking, bathing, washing, and other activities such as agriculture, and plantations. Humans and other living things that are very dependent on water are sometimes not or lacking in managing the sustainability of clean water.

The watershed as one of the providers of clean water from rain, which then holds, stores and flows water plays a very important role in maintaining the management of the distribution of clean water that will be used by the local community and living creatures. However, some human activities can cause disruption of the watershed ecosystem which indirectly also affects the water supply that will be received.



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Clean water needs and population growth affect each other. The more people in an area, the more clean water needed by the area. And, do not rule out the possibility that more types of activities will be carried out by the community that can cause disruption of the watershed ecosystem. The availability of water should ideally be more than the water needed, so that the balance of the ecosystem is maintained, and all activities in the region can run well.

Pulubala sub-watershed is one of the Limboto sub-watersheds located in Gorontalo Regency, Gorontalo Province, which has an important role in the sustainability of all activities in the area. In the Pulubala sub-watershed, there are several types of industrial activities such as tapioca flour factories, seaweed processing, etc. which of course require more water than other activities. In order for the production process of several industrial activities and the daily needs of the population and livestock, it is deemed necessary to find out how much water is needed (water needs) in the Pulubala Sub-watershed, and compare with how much water is available in order to know the status of power support water in the Pulubala Sub-watershed. Departing from these problems, this research is very important to know the status of water carrying capacity (water availability and demand) in the Pulubala Sub-watershed.

2. Literature review

The carrying capacity of the environment is the limit where human activity will lead to undesirable changes to the environment, assuming there are certain limitations that the environment places on development. Therefore environmental carrying capacity has three components: ecological capacity; environmental assimilative capacity; and renewable resource capacity. However, environmental capacity does not only involve natural resources and environmental assimilative capacity. Conversely, the environment also includes natural disasters, geological systems, and other natural phenomena. The concept of environmental carrying capacity must emphasize ecological aspects of the environment (including natural resources, environmental assimilative capacity, and ecosystem services). Here, a more specific definition of environmental carrying capacity is proposed as a combined threshold in the time and space of natural resources, environmental assimilative capacity, ecosystem services, and social environmental support capacity that can carry out socio-economic activities without causing obvious changes or damage on the structure and function of the environment [1].

Water carrying capacity is the potential contained in water and / or in water sources that can provide benefits or harms to human life and livelihoods and the environment. The concept of carrying capacity comes from the field of biology. The concept of carrying capacity was first used by US biologists, Park and Burgess (1921) and is interpreted as the maximum number of a particular species that can be maintained in a particular region [2].

Watershed is defined as a land area that receives rainwater, holds it and flows it through one main river into the sea and / or lake. One watershed, usually separated from other surrounding areas (other watersheds) by topographic natural separators (such as ridges and mountains. A watershed is further subdivided into sub-watersheds which are parts of watersheds that receive rainwater and flow it through tributaries into rivers especially [3].

3. Methodology

The research method used in this study is an analytical method of calculating the availability and demand for water in accordance with the Regulation of the Minister of Environment No. 17 of 2012. This method is used to calculate the amount of water availability in the study area. Then, calculate the ideal amount of water needed in the study area. After getting the amount of water availability and demand in the study area, then the water carrying capacity can be determined. If the amount of availability is greater than the need ($SA > DA$), the water carrying capacity is surplus. However, if the amount of availability is less than the need ($SA < DA$), the water carrying capacity is deficit [4]

3.1. Water Availability Analysis

Analysis of water availability is carried out based on the reference in the Minister of Environment

Regulation No. 17 of 2012. Calculation using the Runoff Coefficient method modified from the rational method with the following equation.

$$C = \frac{\sum (Ci \times Ai)}{\sum Ai} \quad (1)$$

$$R = \frac{\sum Ri}{m} \quad (2)$$

$$S_A = 10 \times C \times R \times A \quad (3)$$

Where:

- SA = water availability (m³/ year)
- C = weighted runoff coefficient
- Ci = coefficient of land use runoff i
- Ai = area of land use i (ha) from BPS or Regional Data in Numbers
- R = algebraic average annual regional rainfall (mm / yearly) from BPS or BMG data
- Ri = annual rainfall at station i
- m = number of rainfall observation stations
- A = area (ha)
- 10 = conversion factor from mm.ha to m³

3.2. Water Needs Analysis

Analysis of water needs is divided into three, namely water needs for humans, water needs for animal husbandry activities and water needs for agricultural activities.

For human water needs, the following equation is used

$$DA = N \times KHLA \quad (4)$$

Where:

- DA = total water demand (m³ / year)
- N = total population (people)
- KHLA = water needs to live properly
= 1600m³ water / capita / year
= 2 x 800 m³ of water / capita / year is water needs for domestic needs and to produce food
= 2 is a correction factor to take into account the needs of a decent life which covers food, domestic and other needs [4]

To determine the water needs for animal husbandry, SNI 2002 is used based on the results of a study of 1992 national water resources. The calculation is seen in the following equation:

$$Q(L) = 365 \text{ days} \times (qskk \times pskk) + (qkd \times pkd) + (qb \times pb) + (qun \times pun) \quad (5)$$

Where:

- Q (L) = the need for livestock water (m³ / year)
- qskk = raw water needs for cattle, horses, buffalo (lt / head / day)
- qkd = raw water needs for goats, sheep (lt / head / day)
- qb = standard needs for pig water (lt / head / day)
- qun = raw water needs for ungags (lt / head / day)
- pskk = number of cows, horses, buffalo
- pkd = number of goats, sheep
- pb = number of pigs
- pun = number of poultry [5]

The amount of water needed for each type of livestock is different. For quality standards for livestock water needs can be seen in following table :

Table 1. Water demand for livestock

No	Type of Livestock	Water needs (lt)
1.	Cattle/horses/buffalo	40
2.	Goats/sheep	5
3.	Pig	6
4.	Fowl	0.6

To calculate the water requirements for industrial activities, obtained from the number of industries in the Pulubala Sub-watershed. Types of industries can be divided into three types of industries, namely small, medium and large industries. For the water needs of each industry can be seen in following table:

Table 2. Water demand for industry

Type of Industry	Number of workers	Water needs
Small industry	100-900	1600-11200
Medium industry	1000-2500	12000-86000
Large industry	>2600	90000-140500

$$Q_{id} = K_{ai} \times \sum id \quad (6)$$

Where:

K_{ai} = Industry water needs

$\sum id$ = Type of industry [6]

4. Result and discussion

4.1. Calculation of water availability

Water availability is the amount of water available in an area in terms of the absorption capacity of each existing land use. The parameters in the calculation of water availability are the type of land use, the area per land use, and rainfall. The following are the extent of land use and the coefficient per land use in the Pulubala sub-watershed:

Table 3. Land use and run off coefficient

Land use	Area (ha)	Run off coefficient
Built land (non- settlement)	83,013	0.4
Settlement	545.30	0.4
Bush	325,228	0.1
Rice field	842.32	0.7
Mixed garden	9154.34	0.3

To calculate the water availability using average rainfall value it needs rainfall data in the nearest station. In Pulubala watershed there are 5 nearest station with total rainfall in 2018 in this following table :

Table 4. Rainfall station

Station name	Rainfall (mm/year)
Jalaludin	1529
Datahu	1490.9
Tabongo Timur	1364.5
Pilolalenga	1474.3
Mootilango	1786

The calculation of the water availability using land use run off coefficient and rainfall data can be seen in this following table :

Table 5. The calculation of the water availability using land use run off coefficient and rainfall data

No	Land Use	Area (Ha) / Ai	Run Off coefficient / Ci	Ci x Ai	C	R	A
1	Builded land (non-settlement)	83.013	0.4	33.2052	0.3305669	1528.94	10950.2
2	Settlement	545.3	0.4	218.12			
3	Bush	325.228	0.1	32.5228			
4	Rice field	842.32	0.7	589.624			
5	Mixed garden	9154.34	0.3	2746.302			
Total		10950.201		3619.774			

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$$Sa = 10 \times C \times R \times A$$

$$Sa = 10 \times 0.3305669 \times 1528.94 \times 10950.2$$

$$Sa = 55344172.6 \text{ m}^3/\text{year}$$

(7)

4.2. Calculation of Water Demand

Water demand is the total amount water that living creatures need and all of the activity in the research location. To calculate the water demand, some parameter that used in this research is for human, livestock, industry and irrigation. In table 67 we can see the human water needs on 2018:

Table 6. Water demand for inhabitant

No	Sub district	Village	Inhabitant amount	Water demand (m ³ /years)
1	Pulubala	Bakti	3088	4940800
2		Bukit Aren	1843	2948800
3		Pongongila	2480	3968000
4		Pulubala	3265	5224000
5		Tridharma	1080	1728000

6		Molalahu	1608	2572800
7		Molamahu	2117	3387200
8	Tibawa	Datahu	4458	7132800
9		Tolotio	2675	4280000
10		Reksonegoro	1200	1920000
11		Iiomata	1571	2513600
12		Molowahu	2516	4025600
13		Dunggala	1830	2928000
14		IsimuSelatan	3263	5220800
15	Bongomeme	Otopade	1025	1640000
16		Batulayar	1136	1817600
17		Bongohulawa	1425	2280000
18		Dulamayo	2132	3411200
19	Dungaliyo	Pangadaa	1912	3059200
Total				64998400

In this following table, we can see the livestock amount and their water demand in 2018 :

Table 7. Water demand for livestock

Type of Livestock	Amount of Livestock	Water demand m ³ /year
Chicken (fowl)	85000	18615
	25000	5475
	14000	3066

There are only 1 industrial activities in the research location, namely tapioca flour factories which require water in the production process for one year, as many as 7500m³ / year. Rice fields as a producer of rice needed by the people also need not less water. In this research area, rice fields have their own watering system in the form of a water reservoir which then drains water to several fields in a day. At the study site, there were 7 water reservoirs with a capacity of 147 m³ of water which were flowed twice a day for 1 group of farmers. If accumulated, in a year irrigation for rice fields in the Pulubala Sub-watershed requires 551880 m³ of water.

The accumulation of water needs in the Pulubala Sub-watershed in terms of the water needs of the population, livestock, industry and rice fields is 65584936 m³ water. (Da = 65584936)

4.3. Calculation of Water Carrying Capacity

Water carrying capacity is a calculation carried out to determine the value of an area's ability to collect water compared to the water requirements for all activities both for living things and other activities.

$$DDA = \frac{Sa}{Da} \quad (8)$$

DDA = Water Carrying capacity

Sa = water availability (m³ / year)

Da = water demand (m³ / year)

Water carrying capacity in the Pulubala Sub-watershed is based on the calculation of water availability and demand as follows:

$$\begin{aligned} DDA &= \frac{5344172.6}{65584936} \\ &= 0.84386 \end{aligned} \quad (9)$$

From the calculation of the carrying capacity, the carrying value of water carrying capacity in the Pulubala Sub-watershed is 0.84386 where the value <1 means it has a **deficit** status. Deficit is a carrying capacity status where the value of water needs is greater than the availability of water.

5. Conclusion

Water carrying capacity is the potential contained in water and / or in water sources that can provide benefits or harms to human life and livelihoods and the environment. Water carrying capacity is classified into 2 classes according to Permen LH No. 17 of 2009, namely surplus and deficit. Surplus if the value of water availability > water demand ($S_a > D_a$). Deficit if the value of water availability < water demand ($S_a < D_a$). In Pulubala Sub-watershed, based on the calculation of carrying capacity, it has a value of 0.84386 or the value of water availability is smaller than the water requirement ($S_a < D_a$).

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