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Study of The Carrying Capacity of The Environment Case Study: The Simanindo Area, Samosir Regency, North Sumatra

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Abstract. *Lake Toba area has been designated a National Strategic Area, which is a priority spatial planning area. The Simanindo Area is a sub-district in Samosir Regency which is an island in the middle of Lake Toba, North Sumatra, Indonesia. Lake Toba's current condition has been polluted by organic contamination and high free chlorine. In addition, the existence of fish farming activities or floating net cages that contribute to the contamination of phosphorus by 0.78 mg/l and free chlorine by 0.84 mg/l into Lake Toba which resulted in the need for studies on the carrying capacity and environmental capacity. Land carrying capacity can be calculated by comparing the availability of land with land requirements. While the carrying capacity of water can be calculated by comparing the availability of water with water requirements or using the Thornwaite Mather Water Balance method. Land Capacity can be calculated by the Land Endurance Unit. While the Capacity of Waters can be calculated by STORET analysis or calculation of domestic waste pollution load. The existence of a massive development plan for Simanindo area and rapid population growth is projected to cause the Land Support Capacity of the Simanindo Priority Zone to be conditionally safe in 2040. Water Carrying Capacity experienced a deficit in the atmosphere in July after being calculated with the Thornwaite Mather Water Balance. In addition, the Capacity of Water Bodies is also in the Status of Severe Pollution according to the STORET Method.*

Keywords: *carrying capacity, free chlorine, Lake Toba, phosphorus, Simanindo*

INTRODUCTION

Simanindo is a sub-district in Samosir Regency which is an island in the middle of Lake Toba, North Sumatra, Indonesia. The capital of this sub-district is in the village of Ambarita. Simanindo sub-district has a strategic plan focused on development in the tourism sector, with an object Simanindo tourism, which has a panoramic view of beauty and the abundance of objects ancient relics of antiquity (Sihombing et al., 2014). The plan to develop the Lake Toba area as world-class tourism was conveyed by the President of the Republic of Indonesia. The Lake Toba area has been designated as a National Strategic Area (Ditjen Bangda, 2020). That policy will increase the number of inhabitants which can lead to the conversion of land from empty or agricultural land to a tourism area. This situation has resulted in increased population pressure on land, which might be experiencing environmental pressures well beyond its current carrying capacity in the country's urban area (Meilasari-Sugiana et al., 2018). People tend to use the remaining space along with the increasing population and the increasing needs of the shelter (Sari et al., 2018). The use of land and water that does not consider the ecosystem structure will tend to cause an imbalance in the environment.

According to research by the (Kementrian Kelautan dan Perikanan, 2018) there is a fairly high load of phosphorus entering the body of Lake Toba, namely 941 tons/year from floating net cage fish culture and 25,334 tons/year originating from the river that empties into the lake. As well as the phosphorus concentration of 0,78 mg / l and free chlorine 0,84 mg / l, where it showed that the concentration of phosphorus and free chlorine in the waters of Lake Toba exceed the quality standards (Kartamihardja et al., 2015). Based on these data, the water quality of Lake Toba has decreased, so it is necessary to study the carrying capacity of the environment in the Lake Toba area.

The country's urban areas are experiencing environmental pressures well beyond their current carrying capacity (Meilasari-Sugiana et al., 2018). Environmental Supporting Capacity is

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the ability of the environment to support the lives of humans, other living things, and the balance between the two. Meanwhile, the purpose of the interaction is to achieve a balance between availability and need. Environmental Capacity is the ability of the environment to absorb substances, energy, and/or other components that enter or are incorporated into it. Meanwhile, the purpose of the interaction is the ability of nature and the environment to accommodate or neutralize waste or excess from an activity without reducing the ability of nature (KLHK, 2019). The study of the carrying capacity of the environmental in Simanindo area become more important because there are no any study regarding it, therefore this study is expected to be an instrument that has an optimal function in the context of the management and utilization of natural resources and the environment especially in the context of environment control instruments process.

METHODS

This research is structured based on problem identification that leads to research on more focused problem topics. This research was conducted in Simanindo Subdistrict and Laboratory of Environmental Service, Samosir Regency, North Sumatra. From December 2019 to February 2020. Identification of the problems found becomes a framework for thinking to find solutions. The main stage in this research is to identify the characteristics of the area which is then evaluated for carrying capacity and determining the status of carrying capacity.

In the survey and observation phase, it involves collecting primary and secondary data. This study uses primary data obtained from direct sampling to the field from several points of the lake scattered in the Simanindo area then checked in the Samosir Environmental Agency laboratory, for secondary data obtained from literature studies and related institutions, some of the data used in this study are land cover data, total population, the data urban facilities, rainfall data, and test results of water quality of Lake Toba in the form of BOD, fecal coli, phosphorus, and chlorine-free. This study uses evaluation of the carrying capacity of the environment aims to determine the status of the carrying capacity of the land and waters of the Simanindo area, whether or not it has been exceeded. The stages of determining the carrying capacity of the environment include determining the status of a surplus or deficit in the Simanindo area of Lake Toba resulting from an evaluation of the carrying capacity of the environment. The research method used is descriptive quantitative, namely determining the status of the carrying capacity based on the calculation results.

1. Population Projections

In calculating the carrying capacity of the environment, one of the most influencing factors is the population projection. The population projections of the Simanindo area are divided into 2 types, namely natural projections and progressive projections. Natural projection is a natural population growth projection that has not been influenced by external factors that will affect population development in the area.

Natural population projection can be carried out by observing the growth rate of the population in the past, so the statistical method is the best method to estimate the population in the future. This study use 10 year data population in the past to determine the growth rate. Several methods can be used to analyze the development of natural population, such as:

1. Least Square Method
   This method is carried out if the amount of data is odd, using the following equation:

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$$y_{(t)} = a + b\,x$$
$$a = \frac{\sum y_i}{n}$$
$$b = \frac{\sum y_i u_i}{\sum u_i^2}$$
…….. (1)

Informations:

- yi = Total population in the year i
- ui = Multiplier variable
- x = he period of year between the projection year and the current year
- ui = 0

2. Arithmetic Method
   This method is used if periodic data shows the number of additions that are relatively the same each year. The formula for this method is:
   $$y_{(t)} = y_n + g.x$$
   …….. (2)

   Informations:
   - yn = Total population in the final data
   - x = The period between the projection year and the data year-end
   - g = verage annual population growth = $\frac{y_{end} - y_{first}}{Total\ Data}$
3. Geometric Method
   This method is used if the population data shows a rapid increase from year to year. The formula for this method is:
   $$y_{(t)} = y_n\,(1 + r)^x$$
   $$r = \left(\frac{y_n}{y_o}\right)^{\frac{1}{n}} - 1$$
   …….. (3)

   Informations:
   - y(t) = Projected population in a given year
   - yn = Total population in the final data
   - x = The period between the projection year and the data year-end
   - r = Population growth rate
   - n = Amount of data
4. Linear Regression Method
   This method is done using the following equation:
   $$y = a + bx$$
   $$a = \frac{\sum y \sum x^2 - \sum x \sum (xy)}{N \sum x^2 - \left(\sum x\right)^2}$$
   $$b = \frac{N \sum (xy) - \sum x \sum y}{N \sum x^2 - \left(\sum x\right)^2}$$
   …….. (4)
5. Exponential Method
   This method is done using the following equation:
   $$y = a\,e^{bx_n}$$
   $$\ln a = \left(\frac{1}{N}\right)\left(\sum \ln y - b \sum x\right)$$
   $$b = \frac{N \sum (x \ln y) - \left(\sum x \sum \ln y\right)}{N\left(\sum x^2\right) - \left(\sum x\right)^2}$$
   …….. (5)
6. Logarithmic Method
   This method is done using the following equation:
   $$y = a + b \ln x$$
   $$a = \frac{1}{N}\left[\sum y - b \sum (\ln x)\right]$$
   $$b = \frac{N \sum (y \ln x) - \sum y \sum \ln x}{N \sum (\ln x)^2 - \left(\sum \ln x\right)^2}$$
   …….. (6)

To determine the most appropriate method to be used in planning, it is necessary to calculate the correction factor, standard deviation, and the state of the city's future developments. The correlation coefficient and standard deviation are obtained from the analysis and calculation of existing population data with population data from the calculation of the projection method

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used. The correlation, r, can be calculated using the formula:

$$R^2 = 1 - \frac{SSE}{SST}$$

$$R^2 = 1 - \frac{\Sigma(P_n - P)^2}{\Sigma(P_n - P_r)^2} \quad \text{........ (7)}$$

Informations:

- R^2 = correlation factor
- P_n = t otal population in the n year
- P_r = average number of population from known data
- P = Projected population-based on regression calculations method performed

The correlation criteria are as follows:

1. $r < 0$, strong correlation, but negative and the relationship between the two variables is inversely proportional.
2. $r = 0$, both data have no relationship.
3. $r > 1$, strong correlation, positive value, and the relationship between the two variables is straight.

The standard deviation can be calculated using the formula:

$$STD = \left[\frac{\Sigma(P_n - P)^2 - \left[\Sigma \frac{(P_n - P)^2}{n} \right]}{n} \right]^{\frac{1}{2}} \quad \text{........ (8)}$$

Informations:

- STD = Standard deviation of known data
- n = Amount of known data

The projection method chosen is the method with the lowest standard deviation value and the largest correlation coefficient. The pattern of urban development by the function of the city in the future is also used as a reference in determining the projection method. In general, the function of a city shows the population growth in the future.

Meanwhile, the progressive projection is a population projection that sees population development if population migration which is expected to support the Simanindo area as an international class tourism area occurs. The calculations carried out are based on the ideal storage capacity, namely preserving the protected zone areas and optimally utilizing the cultivation zone areas according to the potential and limitations of each area for spatial use in the Simanindo area.

2. Land Carrying Capacity

The land carrying capacity is the ratio between the availability of land and land requirement or demand and supply side. Land requirements are obtained by processing the data needs of residential land and land needs of the economy (KLHK, 2019)

Land Requirements (ha) = Land Requirements for Settlements (ha) + Land Requirements for Economic Activities (ha) .... (9)

Calculation of land requirements for settlement is obtained by the formula:

$$\text{Need for residential land (ha)} = 0{,}005 \frac{ha}{people} \text{ X Total population (people)}$$

Calculation of land requirements for economic activity is obtained by the formula:

Land Requirements for Economic Activities (ha) = Number of population (people) X (Land requirement per capita for activities A+B+etc...) .... (10)

Meanwhile, land availability can be calculated based on the area of land available in the area reduced by the area of protected areas.

Land Availability (ha) = Total Area (ha) - Protected Area (ha) .... (11)

After obtaining data on land availability and needs, a comparison is made to determine the status of the land carrying capacity.

- >2 is included in the **Safe category**;

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- 1 - 2 are included in the **conditional safe category**;
- < 1 is included in the **unsafe category** (carrying capacity has been exceeded).

3. Water Carrying Capacity

Water Carrying Capacity, is the ratio between the amount of availability and the need for water. Water availability is obtained by calculating land runoff, a land-use area, and average annual rainfall (Departemen-Kehutanan, 2013). Water carrying capacity is the ability of water resources to meet a need by considering its size availability of water. The water carrying capacity is calculated based on the calculation of water needs and water availability. These variables are compared so that it can be seen that the available water is sufficient for various needs (Santoso, 2015). The calculation of water availability can use the runoff coefficient method which is modified from the rational method, such as:

$$C = \Sigma(C_i \times A_i) / \Sigma A_i$$

$$R = \Sigma R_i / m$$

$$SA = 10 \times C \times R \times A \quad \text{........ (12)}$$

Informations:

- SA = Availability of water (m^3/year)
- C = Weighted runoff coefficient
- Ci = i land use runoff coefficient
- Ai = Area of land-use i (ha)
- R = Average annual rainfall of the region (mm/yearly)
- Ri = Annual rainfall at station i
- M = Number of rainfall observation stations
- A = Area (ha)
- 10 = conversion factor from mm.ha to m^3

4. Land Retention Capacity

The rapid and massive population growth is very much related to land capacity. The value obtained from the calculation of the carrying capacity can be used as a reference to find out which areas are in a condition that can still be utilized.

Analysis of land carrying capacity can be seen from the types of Land Capability Units (SKL) (Kementerian Pekerjaan Umum, 2007) in the planning area, including:

1. Land Capability Unit Morphology (Landscape)
2. Land Capability Unit Easiness to do
3. Land Capability Unit Slope Stability
4. Land Capability Unit Foundation Stability
5. Land Capability Unit Water Availability
6. Land Capability Unit Natural Disasters
7. Land Capability Unit Drainage
8. Land Capability Unit Erosion
9. Land Capability Unit Waste Disposal

Classification of land capability for Simanindo area did by way of seeing each unit of land which has been acquired ability (level of land capability on every SKL) and compared with the criteria of land capability.

- Value 0-5, then the status of Low Land Capacity or Zone E;
- Value 6-15, then the status of Less Land Capacity or Zone D;
- Value 16-25, then the status of Medium Land Capacity or zone C;
- Value 26-35, then the status of Sufficient Land Capacity or Zone B
- Value 26-45, then the status of High Land Capacity or Zone A.

Meanwhile, water needs are calculated as follows:

Water Needs = Domestic Water Needs + Non-Domestic Water Needs

Where domestic water demand is calculated based on the following formula:

Domestic Water Need = Total Population x Water Needs per Capita

Domestic water demand is a necessity of water used for daily necessities is 100

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liters/person/day. Meanwhile, non-domestic water demand is obtained by the formula:

Total Non-Domestic Water Needs = Water Needs for Industry + Water Needs for Trade and Services + Water Needs for Other Economic Activities

The water requirement for each type of activity is the multiplication of the number of units and the water requirement per unit of activity. After obtaining data on land availability and needs, a comparison is made to determine the status of the land carrying capacity.

- >2 is included in the **Safe category**;
- 1 - 2 are included in the **conditional safe category**;
- < 1 is included in the **unsafe category** (carrying capacity has been exceeded).

The second approach in calculating the carrying capacity of water is to use the Thornthwaite Mather Method (Hartanto, 2017). Water balance calculations using the Thornthwaite Mather Method can be done by:

1. Calculate the evaporation potential with the following equation:

$$\mathbf{i = (T/5)^{1,514}}$$
$$\mathbf{I = \Sigma\, i}$$
$$\mathbf{a = (0{,}675.10^{-6}.I^3) - (0{,}77.10^{-4}.I^2) + 0{,}01792.I + 0{,}49239}$$
$$\mathbf{Pex = 16\,(10T/I)^a}$$

   Informations:
   - Pex = uncorrected potential evapotranspiration (mm/month)
   - T = air temperature (°C)
   - i = heat index
   - I = number of heat index in a year
   - a = heat index
2. Calculate the corrected potential evapotranspiration multiplied by the correction factor

$$\mathbf{PE= f.Pex}$$

   Informations:
   - PE = corrected potential evapotranspiration (mm/month)
   - f = correction factor (seen in the thickness of the latitude and time correction)
3. Determining the difference in the value of rainfall (P) with corrected potential evapotranspiration (PE), it can be seen that the month is included in the wet or dry months.
   - (P-PE) > 0, there was a wet month.
   - (P-PE) < 0, there was a dry month.
4. Calculate the accumulated potential groundwater loss by:
   - In the dry months, or (P <PE) is done by way of summing the value of the difference (P-PE) every month with a value (P-PE) the previous month.
   - In the wet months (P> PE), the APWL value is zero.

5. Water Retention Capacity

Water-related environmental carrying capacity has an approach to assess water quality in terms of water quality. The carrying capacity of lake and/or reservoir water pollution loads is the ability of lake water and reservoir water to receive input pollution loads without causing lake and reservoir water to become polluted.

The calculation of the water holding capacity can also be done with STORET Analysis. According to the Minister of Environment Decree (Keputusan Menteri Negara Lingkungan Hidup, 2003) the STORET method is a method to determine the status of water quality. Water quality is assessed based on the STORET system provisions issued by the EPA (Environmental Protection Agency) which classifies water quality into four classes, namely:

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- Class A: Very Good, score = 0 meets the quality standard
- Class B : Good, score = -1 s/d -10 lightly polluted
- Class C : Moderate, score = -11 s/d -30 moderate polluted
- Class D: Poor, score > -31 heavily polluted

Determination of the water quality status using the STORET method is carried out in the following steps:

1. Comparing the measurement result data of each water parameter with the quality standard value by the water class.
2. If the measurement results meet the quality standard value (measurement results <quality standard) then given a score of 0.
3. If the measurement results do not meet the water quality standards (measurement results> quality standards) then a score is given as in Table 1.
4. The negative number of all parameters is calculated and the quality status is determined from the total score obtained using the value system.

Table 1. Determination of value systems for determining water quality status

Number of Sampels[1]	Score	Parameter		
		Physics	Chemist	Biology
< 10 (sampels)	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
≥ 10 (sampels)	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-6	-12	-18

Source : (Keputusan Menteri Negara Lingkungan Hidup, 2003)

Note : [1] the number of parameters used for determining the water quality status.

RESULTS AND DISCUSSION

1. Population

Based on the population projection method that has been described, the best method is the method that has the largest regression correlation and the smallest standard deviation. But in this projection, the highest regression correlation is generated by the Least Square and Arithmetic methods, while the lowest standard deviation is owned by the Arithmetic and Exponential e methods. Validity level is more determined by regression correlation, so the projection of the population for the next 20 years uses the results of using the Arithmetic method.

However, population projections used in the calculation of capability and capacity simanindo environment uses population projections calculations progressive contained in the Detailed Spatial Plan Draft and Control instruments Region Simanindo priority, while the progressive population projections contained in the Table 2.

Table 2. Projection of Simanindo's progressive population

Year	Projected Population (People)	Population Density (People/Ha)
2018	17564	2.59
2019	17654	2.61
2024	33108	4.89
2029	64042	9.46
2034	95003	14.03
2039	126421	18.67

Source : (Kementerian ATR/BPN, 2019)

2. Land Carrying Capacity

In determining the status of land carrying capacity there is 2 (two) calculation steps are carried out, namely: calculating land availability (SL) and load requirements (DL). First, the calculation of land availability is obtained from the variables: total production value, rice price, total rice from lowland and field rice, rice harvested area, and rice productivity. From this calculation, it is obtained the availability of land (Kusmawati et al., 2016). In this research used the standards of requirement of land for

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settlements, land requirement for settlement/capita amounted to 50 units/ha, assuming a family consists of four people. This standard has a purpose to utilizing suitable space for a place to live in the area designation of settlements in rural areas by providing the environment which is healthy and safe from natural disasters and can provide environment that is suitable for community development, with still pay attention to the preservation of environmental functions. Meanwhile, to calculate the land requirement for existing economic activities, it is done by adding up the land area for several activities, namely tourism, commercial, industrial, and public infrastructure. After obtaining data on land needs for the economy and housing, these data can be added together to obtain the area of land requirements. The recapitulation of land requirements in the Table 3.

Table 3. Recapitulation of land requirements in Simanindo areas

Years	Population (people)	Land Requirements		Land Requirements (ha)
		Economic (ha)	Resident (ha)	
2020	17,720	190.81	88.60	279.41
2030	53,774	579.06	268.87	847.93
2040	101,648	1094.58	508.24	1602.82

Source: Calculation Results (2020)

Meanwhile, to find data on land availability, it is done by reducing the total land area with the protected area. So that the availability of land is obtained 3,135.89 ha. Based on data availability and needs that the was calculated, can be used to search for the carrying capacity of the land, by way of comparison as in Table 4.

Based on the data above, the following is the carrying capacity value of the land. Where the Simanindo area has a status that tends to be safe in 2020 and 2030 but is conditional safe in 2040 so there is a need for a zoning division regulation regulating this so as not to exceed the carrying capacity of the land. Spatial planning in the form of policies and rules for the distribution of areas / zoning for lake utilization is an urgent need to be realized immediately. The zoning of lakes based on their utilization in the form of protected areas, cultivation areas, fishing areas, water transportation areas and tourist areas can make lake management easier and more efficient. (Kristanto et al., 2014)

Table 4. Calculation of the land carrying capacity for Simanindo areas

Years	Population (people)	Land Requirements (ha)	Land Availability (ha)	Land Carrying Capacity	Status
2019	17,720	279.41	3135.9	11.22	Safe
2030	53,774	847.93	3135.9	3.70	Safe
2040	101,648	1602.82	3135.9	1.96	Conditional Safe

Source: Calculation Results (2020)

3. Water Carrying Capacity

To calculate water availability in the Simanindo area, it is necessary to know the existing land cover area, and then based on the land cover can be seen the runoff coefficient used. The value of C is the total runoff coefficient value multiplied by the area of land cover divided by the total area of land cover . Water availability is the result of multiplying C with the average rainfall. The calculation of water availability can use the modified runoff coefficient method from the rational method so that the results are in Table 5.

Domestic water needs are water needs used for daily needs, namely 100 liters/person/day. Domestic water needs can also be obtained by comparing the number of residents served by household connections and public taps are 70:30 because Simanindo District is a rural area with an existing population of 17,554 people. Meanwhile, the standard of water consumption in the household connection unit is 100

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L/person/day and for general tap units, it is 30 L/person/day. Calculation of domestic water demand can be seen in Table 6 and Table 7.

Table 5. Calculation of water availability in Simanindo areas

Land Cover	Area (Ha)	Ci (Runoff coefficient)	Ci * Ai	C	R	SA (m3/year)
Building	299	0.7	209.3	**2.53**	**178.5**	**28,866,592**
Forest	2054	0.02	41.08			
Street	54	0.95	51.3			
Pool	83	0.02	1.66			
Empty Land	191	0.2	38.2			
Yard	1	0.2	0.2			
Plantation	1230	0.2	246			
Rice field	389	0.15	58.35			
Shurbs	2091	0.07	146.37			
River		0.02	0			
Total	**6392**	**2.53**	**16,172**			

Source: Calculation Results (2020)

Table 6. Calculation of total population served by HC and PT

Criteria	%	2020	%	2030	%	2040
Population		17,720		53,774		101,648
Household Connection Served	70	12,404	70	37,642	70	71,154
Public Taps Served	30	5,316	30	16,132	30	30,494

Source: Calculation Results (2020)

Table 7. Calculation of domestic

Connection Type	Water Demand Standard (l/p/day)	2020		2030		2040	
		Population (people)	Water Demand (l/day)	Population (people)	Water Demand (l/day)	Population (people)	Water Demand (l/day)
House hold Connection	100	12,404	1,240,400	37,642	3,764,180	71,154	7,115,360
Public Taps	30	5,316	159,480	16,132	483,966	30,494	914,832
Total		**17,720**	**1,399,880**	**53,774**	**4,248,146**	**101,648**	**8,030,192**
		l/s	**16.20**	**l/s**	**49.17**	**l/s**	**92.94**

Source: Calculation Results (2020)

Based on the above calculations, it can be seen that the domestic water demand in the Simanindo area is 16.20 l / s in 2020, 49.17 l / s in 2030, and 92.94 l / s in 2040.

Non-domestic activities in a city usually consist of facilities for education, health, worship, commerce, public, recreation and sports, transportation, and industrial activities (Himan et al., 2018) so that projections of non-domestic water demand are obtained as in Table 8.

Table 8. Recapitulation of non-domestic water needs

Facilities	Tahun					
	2020		2030		2040	
	Number of Facilities (Unit)	Water Demand (L/s)	Number of Facilities (Unit)	Water Demand (L/s)	Number of Facilities (Unit)	Water Demand (L/s)
Education	37	147,600	76	316,800	126	532,800
Health	80	56,690	143	78,870	214	102,670
Religion	64	130,000	81	179,000	101	238,000
Commerce	27	7,430	213	75,120	448	152,170
General recreation and sports	42	720,000	52	1,111,800	57	1,307,700
Industry	0	-	8	80,000	18	180,000
Transportation	0	-	2	3,750,000	3	5,625,000
Total	**L/d**	**1061720.00**	**L/d**	**5591590.00**	**L/d**	**8138340.00**
	L/s	**12.29**	**L/s**	**64.72**	**L/s**	**94.19**

Source: Calculation Results (2020)

Based on the calculation of domestic and non-domestic water needs, the amount of clean water demand in the Simanindo area can be calculated as shown in Table 9.

Based on the calculated availability and demand data, it can be used to find the carrying capacity of water, namely by comparing it as in Table 10.

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Table 9. Recapitulation of clean water Needs in Simanindo areas

Demand	2020	2030	2040
Domestic (L/s)	16.20	49.17	92.94
Nondomestic (L/s)	12.29	64.72	94.19
Total I	**28.49**	**113.89**	**187.14**
Keperluan Umum Kota			
Fire Hydrant (10%) (L/s)	2.85	11.39	18.71
Urban Planning (5%) (L/s)	1.42	5.69	9.36
Total II	**32.76**	**130.97**	**215.21**
Water Loss Rate (%)	17.5	17.5	17.5
Water Loss (L/s)	5.73	22.92	37.66
Total Water Produced (L/s)	**38.50**	**153.89**	**252.87**
Maximum Daily Discharge (fm=1.2)	**46.20**	**184.67**	**303.44**
Peak Hour Discharge (fp=1.8) (L/s)	**69.30**	**277.00**	**455.16**

Source: Calculation Results (2020)

Table 10. Analysis of the water carrying capacity of Simanindo areas

Year	**S/D**	**Status**
2019	1711,91	Safe
2030	428,27	Safe
2040	260,63	Safe

Source: Calculation Results (2020)

Based on the analysis of water availability and demand that has been calculated, it is found that the water carrying capacity in the Simanindo area is still safe until 2040. However, it should be noted that this safe status is the result of water carrying capacity if the water source is taken from Lake Toba. However, to ensure the availability of water in the Simanindo area is still sufficient for the needs of a decent living for the population, it is necessary to carry out strategic studies, especially in the drinking water supply system plan that is adjusted to the calculation of Simanindo area Water Demands, several things that need to be done are:

1. Need a specific studies related to the plan for the dam or reservoir as a future water source on the island of Samosir to meet the demands of the Simanindo area.
2. The water distribution system is attempted to use a gravity system and avoids the pumping system.

Concerning the water carrying capacity can also use the Thornthwaite Mather Method. The Thornthwaite Mather method is a method based on the concept of water balance. This method is a calculation of water availability based on existing climatological and hydrological data, namely rainfall and temperature as an input. The results of water balance calculations using the Thornthwaite method can be seen in Table 11.

Based on the table and Figure 1, it can be concluded that the availability of water for one year has the potential for the use of rainfall with the construction of reservoirs. When there is a deficit in July, the government needs to anticipate water shortages during this July by utilizing Lake Toba as a source of raw water from the Water Treatment Plant in the Simanindo area.

Table 11. Thornthwaite method water balance in Simanindo areas

Bulan	**T**	**I**	**a**	**Pex**	**f**	**PE**	**P**	**ΔS**	**Keterangan**	**APWL**
1	17.96	6.93	0.36	52.44	1.04	54.54	58.95	4.41	surplus	
2	18.42	7.20	0.36	51.33	0.94	48.25	73.82	25.57	surplus	
3	18.88	7.48	0.35	50.25	1.04	52.26	84.82	32.56	surplus	
4	19.36	7.76	0.35	49.14	1.01	49.64	107.51	57.87	surplus	
5	19.66	7.95	0.35	48.47	1.05	50.89	96.6	45.71	surplus	
6	19.00	7.55	0.35	49.97	1.02	50.97	66.87	15.90	surplus	
7	18.20	7.07	0.36	51.86	1.05	54.45	41.61	-12.84	defisit	-12.84
8	18.18	7.06	0.36	51.91	1.04	53.98	68.36	14.38	surplus	
9	20.40	8.41	0.34	46.83	1.01	47.30	80.19	32.89	surplus	
10	18.26	7.11	0.36	51.72	1.04	53.78	97.88	44.10	surplus	
11	18.84	7.45	0.35	50.34	1.01	50.85	124.91	74.06	surplus	
12	18.46	7.22	0.36	51.24	1.04	53.29	122.44	69.15	surplus	

Source: Calculation Results (2020)

Informations :

T = Temperature (^{o}C)

I = The number of heat index in a year

a = Heat index

PEx = Potential evapotranspiration (mm/month)

F = Latitude and time correlation factor

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PE = Corrected potential evapotranspiration (mm/month)
P = Rainfall (mm/month)
ΔS = Water balance

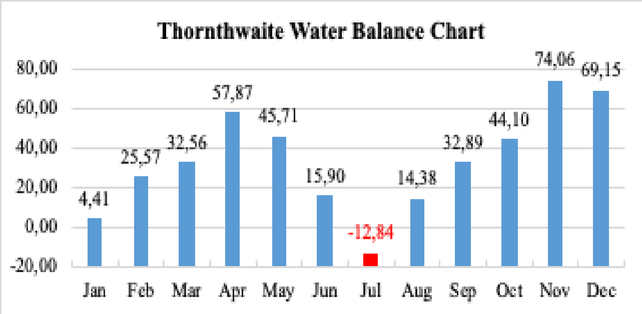

Figure 1. Thornthwaite Water Balance Chart

4. Land Retention Capacity

This analysis of land capacity is prepared based on the type of Land Capability Unit (Satuan Kemampuan Lahan) in the planning area, including:

1. Land Capability Unit Morphology (Landscape)
2. Land Capability Unit Easiness to do
3. Land Capability Unit Slope Stability
4. Land Capability Unit Foundation Stability
5. Land Capability Unit Water Availability
6. Land Capability Unit Natural Disasters
7. Land Capability Unit Drainage
8. Land Capability Unit Erosion
9. Land Capability Unit Waste Disposal

Classification ability of the land to Priority Regions Simanindo did by way of seeing each unit of land which has been acquired ability (level of land capability on every LCU) and compared with the criteria of land capability. So that the scores obtained from the 9 LCU are shown in Table 12.

Based on the table 12, the Simanindo area can be divided into 2 areas, namely protected areas and cultivation areas. Protected areas have moderate land holding capacity status or Zone C with a total score of 17. Meanwhile, cultivated areas have sufficient land capacity status or Zone B with a total score of 29.

Table 12. Scores of land capacity analysis

Informations	Score	
	Protected Area	**Cultivation Area**
Land Capability Unit Morphology (Landscape)	1	
Land Capability Unit Easiness to do	1	4
Land Capability Unit Slope Stability	1	4
Land Capability Unit Foundation Stability	1	4
Land Capability Unit Water Availability	1	4
Land Capability Unit Drainage	5	2
Land Capability Unit Erosion	1	4
Land Capability Unit Waste Disposal	1	4
Land Capability Unit Natural Disaster	5	2
Total	**17**	**29**
Status	**Medium Land Capacity (Zone C)**	**Sufficient Land Capacity (Zone B)**

Source: Calculation Results (2020)

5. Water Retention Capacity

Lake Toba water quality data presented is the value of each parameter taken from several sampling points. The sampling point used is the sampling point commonly used by the Samosir Regency Environmental Agency to check how the water quality conditions in Samosir. The sampling points are listed in Table 13. and Figure 2.

After taking water samples, the water samples were given to the Laboratory of the Environmental Service of Samosir Regency to do the test water pollution parameters. As for these parameters, namely, BOD, Free Chlorine, Phosphate, and Fecal Coli. After obtaining the water quality data that has been tested, the water carrying capacity is calculated. Calculation of water capacity can be done with STORET Analysis. According to the Minister of

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Environment Decree No. 115 of 2003, the STORET method is a method for determining the status of water quality. Water quality is assessed based on the STORET system provisions issued by the EPA. Based on the STORET test results, it was found that the value of turbidity, free chlorine, phosphate, COD, and fecal coli exceeded the quality standard. The comparison between standard and test result in Table 14.

Table 13. Water sampling location

No.	Location	Coordinate	
		North	East
1	Aquafarm Pangambat Beach	2°38'31.94"	98°52'16.63"
2	Sumber Sari Port	2°39'15.29"	98°51'38.79"
3	Silintong Hotel Beach	2°40'17.68"	98°51'43.40"
4	Siallagan Port	2°40'49.95"	98°50'13.75"
5	Vannessa Hotel Beach	2°42'26.92"	98°48'41.13"
6	Simanindo Ferry Port	2°45'14.97"	98°44'44.81"
7	Simarmata Beach	2°44'17.61"	98°42'5.69"

Source: Survey Results (2020)

The high value of this turbidity can be caused by the presence of sediment and erosion, high discharge of domestic waste, agricultural activities, etc. This high turbidity will result in reduced light intensity entering the water, thus inhibiting the growth of flora and fauna in the water. The high COD value can be caused by the presence of waste from the domestic activities of the surrounding community which contains non-biodegradable chemicals that are directly disposed of into the lake, which can be derived from food scraps, or emulsifying oil. This high COD value can result in a decrease in oxygen content in these waters which will disrupt the lake ecosystem. The high value of fecal coli can be caused by the presence of domestic waste that enters water bodies. This can endanger the health of residents because it can lead to diarrhea and other diseases. The high value of free chlorine can be caused by disinfectants that are disposed of directly into water bodies such as disinfectants, etc. The high value of free chlorine can disrupt the aquatic ecosystem and the survival of the biota in it. The increase in phosphate compounds is influenced by nutrient intake from the catchment, activity residents around the lake and fishing activities (Suharto et al., 2016). The high value of this phosphorus can result in algae blooming or the massive growth of algae and other aquatic biotas which can disrupt the balance of the aquatic ecosystem. The conditions of high phosphorus in waters or lakes are also found in Lake Sentani, the phosphate concentration tends to rise with decreased rainfall in May and July as well continues to decline from September to January when the rainfall is high. Phosphate surge in the floating net cage zone on the moon September shows that the rainfall is high and supported by the decomposition that occurs in the sediment increases the concentration of phosphate (Indrayani et al., 2015).

Based on Environmental Protection Agency (Keputusan Menteri Negara Lingkungan Hidup, 2003) the results of the STORET analysis show that Lake Toba in Simanindo areas indicate that the water quality of Lake Toba has been polluted, by category Class D: **Heavily Polluted.** This condition is almost the same with the results of the calculation of the water quality status of Lake Sentani for each location indicates that Lake Sentani has been moderately and heavily polluted. The high and low water quality scores are influenced by several community activities upstream and downstream of the river which empties into the waters of Lake Sentani. Activities that are dominant, among others, settlement, agriculture, C excavation mining, fishing, industry, erosion and natural factors of soil content around the

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lake (Walukow, 2010). Different results were obtained in the results of the STORET analysis in the Riam Kanan dam which produced class B lightly polluted, namely water that can be used for freshwater fish farming, water farming to irrigate plants and / or other uses that require the same water quality as this use (Rahayu, A., Rahman, A., & Dharmadji, 2017).

Figure 2. Map of water sampling location

Table 14. STORET Highest parameters result

No	Parameters	Unit	Standard	Test Result (maks)	Score
	Physics				
1	Turbidity	NTU	5	5.39	-2
2	Free Chlorine	mg/L	0.03	0.84	-16
3	Phospat	mg/L	0.2	0.7824	-4
4	COD	mg/L	25	26.83	-4
	Biology				
5	Fecal coli	jml/100 mL	100	210	-6
	Jumlah				-32

Source: Analysis Results (2020) (Pemerintah Indonesia, 2001)

Calculation of domestic waste contaminant load in Simanindo area can be seen in Table 15. Various sources of water pollutants in Lake Toba include domestic waste, agriculture, livestock, fisheries, water transportation, and mining of classified minerals.

Based on STORET analysis and domestic waste pollution load, it is necessary to handle because the fecal coli content exceeds the quality standard, in some areas such as Lake Tondano, local government try to minimize the impact of pollution wastewater in Lake Tondano, then planned installation development waste water management (IPAL) (Mende et al., 2015). Or it can also use simple technology such as latrines (jamban), the way to overcome the decline in water quality of the Kuin River due to the presence of fecal coliform bacteria can be done by making special latrines for tidal areas (Santy et al., 2017).

Table 15. Calculation of domestic waste contamination load

Demand	2020	2030	2040
Clean Water Discharge (l/s)	46,20	184,67	303,44
Wastewater Discharge (fab=0.8)(l/s)	36,96	147,73	242,75
Average Discharge (m/s)	2,09	2,75	2,39
Equivalent Population (/1000 people)	17,72	53,77	101,65
Q Min (l/s)	13,14	65,56	122,35
Infiltration Discharge (fi = 0.2) (l/s)	7,39	29,55	48,55
Channel Infiltration Discharge	0,01	0,03	0,05
Maximum Daily Discharge (fm=1.2)(l/s)	2,50	3,30	2,87
Q Max (l/s)	124,79	399,50	577,96
Peak Hour Discharge (fp=1.5)(l/s)	9,90	32,87	51,46

Source: Calculation Results (2020)

CONCLUSION

From the discussion above, it can be concluded that the land carrying capacity in the Simanindo area is still in a safe status in 2020 and 2030 with a value of availability compared

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to needs of 11.22 and 3.70 and will have conditional safe status in 2040 with an availability value of 1.96. The water carrying capacity in the Simanindo area is still in a safe status in 2020, 2030, and 2040. Medium value land retention capacity in protected areas in Simanindo areas or zone c.The land retention capacity in protected areas in Simanindo areas is of sufficient value or in zone B. Water Retention Capacity in Simanindo areas using the STORET method has a heavily polluted quality status. Water Retention Capacity in Simanindo area has a domestic waste load of 2.5 l/s in 2020, 3.3 l/s in 2030, and 2.87 l/s in 2040.

Zoning regulations regarding land use in the Simanindo area are in place so that the status of the land carrying capacity is not exceeded. The construction of a dam utilizing rainfall to anticipate water shortages during July. The use of Lake Toba as a source of raw water from the Clean Water Treatment Plant in the Simanindo area to anticipate water shortages during July. The handling of domestic wastewater in the Simanindo area uses an alternative WWTP or use latrines for tidal areas to reduce the burden of water contamination that enters Lake Toba in Simanindo area.

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