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Land and Water Carrying Capacity in Tourism Area of Nusa Penida, Bali

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Abstract
Environmental resources are very important in supporting tourism activities. As a developing tourism area Nusa Penida needs sufficient land and water resources. Increasing population of residents and tourists triggers new activities that affect the patterns of land use and available water, which in turn has a negative impact on the availability of land and water. The carrying capacity of the environment is disrupted due to the utilization of environmental resources that exceed its capacity. This study aims to calculate the availability, needs and status of the carrying capacity of land and water in the Nusa Penida Tourism Area.
The methodology of this study is to calculate the availability of land and water, calculate land and water needs for residents and tourists and calculate the carrying capacity of land and water. This study predicts the availability of land and water, land and water needs and the carrying capacity of land and water in the Nusa Penida Tourism Area until 2023.
From the results of data analysis shows that the availability of land in Nusa Penida amounted to 5,350 hectares. Projected land needs until the year 2028 of 24,640 hectares, the carrying capacity of the land in Nusa Penida deficit. The results of the calculation of land requirements based on the ecological footprint amounted to 17,724.283 hectares, while the availability of land in Nusa Penida was 5,350 hectares. This shows that the carrying capacity of the land in Nusa Penida has a deficit of 12,374,283 hectares.
Availability of water based on rainfall and springs in Nusa Penida is 95,443,402.56 m^3/year. The results of data analysis show that in 2028 water needs for residents and tourists are estimated at 83,398,400 m^3/year. Projection of the carrying capacity of water in Nusa Penida based on rainfall surplus of 901,002.56 m^3/year. Projection of the carrying capacity of water in Nusa Penida based 10% utilization of springs Penida and Guyangan in 2028 surplus of 2,433,865,856.44 m^3/year Projection of the carrying capacity of water in Nusa Penida based on rainfall + 10% utilization of springs Penida and Guyangan in 2023 surplus of 2,529,309,259 m^3/year. Projection of the carrying capacity of water in Nusa Penida based on rainfall + all springs water potencyin Nusa Penida in 2028 surplus of 34,958,390,240 m^3/year.

Keywords: Tourism, Carrying Capacity, Land, Water, Availability, Needs, Status, Nusa Penida

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Introduction

The development of tourism in the last three years in Nusa Penida has increased rapidly. In 2016, the number of tourists coming to Nusa Penida was 350,000 and it is predicted that in 2025 it will reach 1,050,000 (KSPN, 2016). Exceeds tourism increase. In 2016 the total number of 189 and the total number of 1300 and in 2017 the total number increased by 301 and the number of rooms by 2143. Increasing the number of tourists to the environment and increasing carrying capacity the environment supports the carrying capacity of the land and water, so that every growth supports tourism, tourists and population growth need land and water carrying capacity to support the sustainability of tourism.
The increasing population participating in activities related to available water use patterns, which are present at the time associated with negative impacts on related water can also affect the environment that supports the carrying capacity of the environment to protected air (Admadhani et al., 2014).

Tourism industry activities are inseparable from the need for land and water. In the tourism industry activities. Land is used for building activities, green open space and water is used for MCK activities, laundry, kitchen / restaurant activities, and garden activities (hotel landscapes).

The carrying capacity of land and water is calculated by considering the availability and need for water resources for residents and tourists in the study area. To measure the magnitude of environmental degradation, it is necessary to have an inventory of natural resources. Measurement of environmental degradation will give an idea of how much the environment is able to support human life (Wijaya et al., 2017). land carrying capacity is systematic land use and population data (Riyadi and Bratakusumah, 2004). Decreased carrying capacity of land has a negative effect due to the conversion of land into other allotments due to the growth of urbanization (Qian et al., 2015). Analysis of the carrying capacity of agricultural land needs to be done to determine the ability of land to provide food to meet the needs of the population in a certain area and time (Moniaga, 2011). The availability of water for the population shows an indicator of the carrying capacity of water for the environment, especially for the population and all their life activities. Water carrying capacity includes aspects of meeting water needs and availability (Santoso, 2015). Decreased water carrying capacity due to lack of water resources, serious water pollution, and low water use efficiency (Lu et al., 2017). As an economic entity, water resources must be managed as economic goods through the principles of sustainable environmental resource management (Asdak et al., 2006).

This study aims to determine the availability of land, land requirements and carrying capacity of land and determine the availability of water both from rainfall, springs and groundwater reserves, water needs for residents and tourists and determine the status of water carrying capacity in the Nusa Penida Tourism Area.

Experimental Method

1. Land Carrying Capacity

- **Calculation of Land Availability**

Calculation of land availability was done by calculating the availability of land. Analysis of land availability using equations that refer to the Minister of Environment Regulation No. 17 of 2009 as follows:

$$S_L = \frac{\Sigma(Pi \times Hi)}{Hb} \chi \frac{1}{Ptvb}$$

SL is the availability of land, Pi is the actual production of each type of commodity (the unit depends on the type of commodity). Commodities calculated include agriculture, plantation, forestry, animal husbandry and fisheries, Hi is the unit price of each type of commodity (Rp / unit) at the producer level, Hb is the unit price of rice (Rp / kg) at the producer level and Ptvb rice productivity (Kg / Ha). In this calculation, the conversion factor is used to equalize non-rice products is price.

- **Calculation of Land Requirements**

To find out whether there is sufficient land inventory can be done by comparing the amount of available land with the land requirements. The equation used refers to Minister of the Environment Regulation No. 17 of 2009:

DL = N x KHLL

DL is the total land requirement equivalent to rice (Ha), N is the number of residents (people) and KHLL is the area of land needed for the needs of decent living per resident and tourist needs.

- **Determination of Land Carrying Capacity Status**

The carrying capacity of land was obtained by comparing the availability of land (SL) and land requirements (DL) (Minister of Environment Regulation No. 17 of 2009):

If SL> DL, the carrying capacity of the land is declared surplus.

If SL <DL, carrying capacity is declared deficit or exceeded.

2. Capacity of Land based on Ecological Footprint

The ecological footprint calculation in this study adopted using the ecological footprint calculation used by the Global Footprint Network (GFN). The calculation of the ecological footprint considers the six parts of basic necessities products expressed in the form of agricultural, livestock, forest, fishery products, built-up areas, and energy use, where each staple product has global average yields and equivalent factors (Adnyana

et al., 2011). Equations to calculate the ecological footprint for types of agricultural products, livestock, forests, fisheries, and built areas are:

$$JE = \sum\left(\frac{\frac{P}{Y_W} \times EQF}{N}\right)$$

information:

JE = ecological footprint (gha / capita)

P = total consumption of each type of product (tonnes or m3)

Yw = global average yield factor (ton / ha)

EQF = equivalent factor (gha)

N = population

The equation for calculating the ecological footprint of the type of product built area is:

Built Area = Area XB x YW x EQF

information:

JEArea Awakened = ecological footprint (gha / capita)

Size = total area developed (ha)

XB = coefficient value (2,368 x 10-8)

Yw = global average yield factor (ton / ha)

EQF = equivalent factor (gha)

The ecological footprint of energy use is calculated by the equation:

$$JE\ Use\ of\ Energy = C \times \left(\frac{1-faOc}{Yc}\right) \times c$$

information:

JEPeng use of Energy = The ecological footprint of energy use (gha / capita)

C = consumption of fossil fuels and electricity (tons)

faOc = CO absorbed by the sea (0.27 CO2 / gha)

Yc = Sequestration rate (1.35 tons / gha)

c = coefficient value (1.18 x 10-8)

The equivalent factor is a conversion factor from the broad dimension (ha) to the global broad dimension (gha). The equivalent factor is the same for each country and does not change. The equivalent factor values can be seen in Table 1.

Table 1. Equivalent Factor Values

Basic Products	Equivalent Factor (gha)
Agriculture	2.64
Animal Husbandry	0.50
Forest	1.33
Fishery	0.40
Built area	2.64
Used energy	1.00

Calculation of land needs based on guidelines for determining the carrying capacity of land carrying capacity for water (KLH, 2008) at level 3. Calculation of land needs at level 3 includes the influence of JE values in its calculations. The equations for calculating land requirements at level 3 are:

DL = N x JE

information:

DL = total land requirements

N = total population (people)

JE = ecological footprint (gha /capita)

3. Water Supply Capacity

- **Calculation of Water Availability**

Calculation of Weighted Runoff Coefficient. There are 2 types of land use in the study area, namely agricultural land and non-agricultural land. For agricultural land consisting of paddy land with a runoff coefficient range (Ci) around 0.30, non-paddy land with runoff coefficient 0.30, and non-agricultural land with a coefficient of 0.15 - 0.9 (Pramesty et al., 2014). Calculation of the weighted runoff coefficient is presented in Table 2.

Table 2. Calculation of Weighted Runoff Coefficient

No	Surface Description	Runoff Coefficient
gricultural Land		
addy Field		
1	echnical Irrigation	-
2	alf Technical Irrigation	0.3
3	imple Irrigation	0.3
4	illage Irrigation	-
5	ainfed	0.3
6	idal	-
7	ebak	-
8	ther Polder and Rice Field	-
on Rice Field		
1	arden	0.3
2	eld	0.3
3	lantation	0.3
4	ree/Community Forest Planted	0.3
5	ond	-
6	ool/Grass	0.3
7	asture/Grassland	-
8	hile Not Attempted	0.3
9	ther	0.3
on Agriculture Land		
1	he Yard Not Planted	0.15
2	orest State	0.18
3	wamps (Not Planted)	0.2
4	ther	0.9

Source: Premesty *et al*., 2016

Calculation of water availability using the runoff coefficient method is modified by the rational method. The equation for calculating water availability is the runoff coefficient method (Minister of Environment Regulation No. 17 of year 2009) as follows:

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

SA is the availability of water (m3/yr), C is the weighted runoff coefficient, R is the average yearly rainfall (mm / yr), A is the area (ha), and 10 is a conversion factor from mm / ha to m3 Besides that, the availability of water from existing springs, because in Nusa Penida there are 2 springs that have been utilized. C value is the average value of runoff coefficient in an area.

$$C = \frac{\Sigma (Ci \times Ai)}{\Sigma Ai}$$

Ci is the land use runoff coefficient i, while Ai is the land use area i.

$$R = \Sigma \frac{Ri}{m}$$

Average annual rainfall algebra is obtained based on the comparison of annual rainfall (Ri) to the number of rainfall observation stations (m).

• **Population Projection**

In the calculation of population projections that are used to determine the amount of water needs for the next 10 years using calculations with exponential methods. The calculation of the exponential projection method can be done using the equation:

Pn = Po.er.n

information:

Pn = Projection of population in the desired year

Po = Number of population in the last available data

r = Population growth rate

n = time period in years

e = Exponential number = 2.7182818

• **Water needs for tourism**

Water carrying capacity is calculated by considering the availability and need for water resources for residents and tourists in the study area. Water availability is determined using the runoff coefficient method based on land use information and annual rainfall data calculated for 10 years. Meanwhile, water needs are calculated from the results of conversion to the needs of decent living of residents and tourists (Sunarta, 2015). Determination of water carrying capacity is done by comparing the availability and demand of water. Water needs for the Falkenmark indicator population which is the minimum water requirement to be able to live properly based on estimates of domestic, industrial and energy water needs, as well as environmental needs, where for Indonesia the value is set at 1,600 m3 / capita / year (Minister of Environment Regulation No. 17 of 2009) and for tourism in Nusa Penida using the basic needs of decent living tourists and restaurants that have been built in Nusa Penida in the last year. The average amount of water usage per day in accordance with the Planning Criteria of the Directorate General of Human Settlements of the Public Works Department in 1996 was 150 liters per person / bed and 100 liters restaurant per seat.

• **Calculation of Water Demand**

Water demand analysis using equations that refer to the Minister of Environment Regulation No. 17 of Year 2009:

$D_A = N \times KHL_A$

DA is the total water demand (m3 / yr), N is the number of residents (people) and tourists, and KHLA is an Falkenmark indicator which is the minimum water requirement to be able to live properly based on estimates of domestic, industrial and energy water needs, as well as the needs environment, where for Indonesia the value is set at 1,600 m3 / capita / year (Minister of Environment Regulation No. 17 of 2009). Besides that, Nusa Penida also needs water for tourism purposes, assuming per capita consumption per day from the number of tourists who come.

• **Determination of the Water Carrying Capacity Status**

Water carrying capacity is obtained from a comparison between the availability of water (SA) and water demand (DA) with the condition if SA> DA, then the carrying capacity of water is declared surplus, if SA <DA, then the carrying capacity of water is declared deficit or exceeded.

Result And Discussion

1. Land

Land area in Nusa Penida according to land use is mostly non-paddy land area of 14,366 ha. Non-rice fields are mostly tegal / gardens covering an area of 4,970 ha, plantations 3,572 ha. Planted a tree area of 5,361 Ha. Nusa Penida has 1,048 Ha of state forest consisting of 824 Ha of state forest, 244 ha of mangrove forest and 5,333 ha of community forest. Land area according to usage in Nusa Penida is presented in Table 2.

Table 3. Land Area According to Usage in Nusa Penida in 2017 (Ha)

No	Land Use	Land
1	Agricultural Land	14.366
1.1	Rice field land	
a.	Irigation	
b.	Rainfed	-
c.	Tidal Swamp	-
d.	Swamp Lebak	-
1.2	Not Paddy Field	14,366
a.	Tegal / Kebun	4,970
b.	Field / Huma	-
c.	Plantation	3,572
d.	Planted Trees	5,361
f.	Pasture	-
g.	Temporary Land Not Cultivated	-
2.	Land Not Agriculture	6,381
a.	State Forest	824
b.	Mangrove	224
c.	Community Forest	5,333
	Total	**20,284**

Source: Klungkung in Figures 2018

- **Land Capabilty**

Land capability is a systematic land appraisal based on traits that are potential and a barrier to its sustainable use. Land capability analysis, including analysis of soil properties (physical and chemical), topography, drainage, soil depth, and other environmental conditions. Based on the characteristics of the land, a land capability classification with depth of class, sub-class and management unit is carried out. Land capability is closely related to "the level of danger of damage" and "obstacles in managing land". The land capability classification is grouped into 8 classes, from class I to class VIII. In this case, if the level of danger / risk of damage and barriers to use increase, the spectrum of land use decreases. The land capability class is divided into VIII classes. From classes I to IV can be used for agriculture, while from classes V to VII for pasture, class VIII should naturally be protected forest. Each class is further divided into sub-classes, namely the erosion sub-class, waterlogging sub-class, solum sub-class (rooting inhibitor) and climate sub-class. Sub-classes can be divided again into several units of land class classification and their use can be seen in Table 4 and land capability classes and their limiting factors in Nusa Penida can be seen in Table 5.

Table 4 Classification of Land Capabilities in Class Level

Class	Criteria	Usage
I	Does not have or only a few obstacles that limit its use. Suitable for various uses, especially agriculture. Characteristics of the land include: almost flat topography, the threat of small erosion, deep effective depth, good drainage, easy to process, good water holding capacity, fertile, not threatened by flood	Agriculture: Agricultural crops annuals. Grass plants. Forests and nature reserves.
II	Has several obstacles or threats of damage that reduce the choice of use or require moderate conservation action. Management needs to be careful, including conservation measures to prevent damage.	Agriculture: a. Annual crops. b. Grass plants. c. Pasture. d. Production forest. e. Protected forest. f. Nature preserve.
III	Has several obstacles which reduce land use choices and	Agriculture:

	require special conservation measures and both. Has a more severe barrier than class II and if used for plants need soil management and more difficult conservation measures to implement. The obstacles in number I limit the use of annual crops, processing time, choice of plants or combination of these constraints.	Annual crops. Plants that require tillage. Grass plants. Meadow. Production forest. Protected forest and nature reserve.
IV	Obstacles and threats of soil damage are greater than class III, and crop choices are also limited. Careful management of annual crops is needed, conservation measures are more difficult to implement.	1. Agriculture: Annual crops. Plants that require tillage. Grass plants. Meadow. Production forest. Protected forest and nature reserve. 2. Non-Agriculture
V	Not threatened by erosion but has other obstacles that are not easy to remove, thus limiting the choice of use. Has obstacles that limit the choice of use and plants types. Located on a flat topography - almost flat but often affected by flooding, rocky or inadequate climate.	1. Agriculture: Grass plants. . Pasture. Production forest. . Protected forest and natural asylum. 2. Non-agriculture
VI	Has a severe inhibiting factor that causes the land use is very limited because it has the threat of damage that cannot be eliminated. Generally located on steep slopes, so that if used for grazing and production forests must be managed properly to avoid erosion.	1. Agriculture: Grass plants. Pasture. Production forest. Protected forest and nature reserve 2. Non-agriculture
VII	Has inhibiting factors and severe threats that cannot be eliminated, therefore their use must be on a conservation nature. If used for pasture or production forest, heavy erosion prevention must be done.	a. Meadow. b. Production forest
VIII	It should be left naturally. Barriers and threats are very severe and conservation measures are not possible, so they need to be protected	a. Protected forest. b. Nature recreation. c. Nature preserve

Table 5 Land Capability Class and Limitation Factors in Nusa Penida

No	Land Capability Class	Limitation Factors	Area	
			Ha	%
1	I	-	0	0
2	II	Slope 3 - 8%	216	1.06
3	III	Slope 8-15%, soil depth 50-90 cm, texture is rather rough	4,577	22.56
4	IV	Slope 15-30%	4,222	20.81
5	V	Bad drainage	224	1.10
6	VI	Slope rather steep 30-45%, heavy erosion, soil depth <30 cm	6,686	32.96
7	VII	45-65% steep slope, very heavy erosion	1,737	8.56
8	VIII	Very steep slopes> 65%	2,622	12.93
Total			**20,284**	**100**

- **Land Availability**

Calculation of land availability is carried out based on Minister of the Environment Regulation No. 17 in 2009 concerning on The Guidelines for Determination of Environmental Support Capacity in Regional Spatial Planning. Based on this, the data needed in the calculation of land availability are the actual production of each type of commodity (Pi) and the price of rice at the producer level (Hb), the unit price of each commodity at the producer level (Hi), and the productivity of rice in Nusa Penida (Ptvb). The calculation of the total production value of each commodity in Nusa Penida is presented in Table 6 as follows:

Table 6. Results of Calculation of Total Production Value in Nusa Penida in 2017

No	Commodity type	Actual Production(Pi) (Kg)	Unit Price of Commodity (Hi) (Rp/Kg)	Production Value (PixHi) (Rp)
1	Corn	9,334,000	4,600	42,936,400,000
2	Cassava	16,344,000	3,800	62,107,200,000
3	Peanuts	1,103,000	8,000	8,824,000,000
4	Green Beans	43,000	10,000	430,000,000
5	Red Beans	63,000	12,000	756,000,000
6	Undis	38,000	15,000	570,000,000
7	Mango	3,500,000	7,000	24,500,000,000
8	Siam Orange	94,000	8,000	752,000,000
9	Water Guava	3,600	6,500	23,400,000
10	Sapodilla	13,200	12,000	158,400,000
11	Pineapple	500	5,000	2,500,000
12	Silik	4,000	8,000	3,200,000
13	Papaya	16,700	5,000	83,500,000
14	Banana	501,700	10,000	5,017,000,000
15	Guava	6,200	8,000	49,600,000
16	Jackfruit	26,900	5,500	147,950,000
17	Coconut	329,000	4,000	1,316,000,000
18	Cashew nuts	58,950	25,000	1,473,750,000
19	Cow	24,192	9,500,000	229,824,000,000
20	Goat	224	3,000,000	672,000,000
21	Pig	13,283	2,000,000	26,566,000,000
22	Chicken	119,134	80,000	9,530,720,000
Total				**397,029,180,000**

Source: Nusa Penida in Figures 2018 and survey results

Based on data from the Central Statistics Agency combined with the results of the survey unit price of rice at the producer level of Rp9,200 per kilogram and the average rice production per hectare is 7,900 kilograms per hectare, the availability of land in Nusa Penida is 5,462.7 hectares.

- **Land requirements**

Land requirement is minimum living needs. Population pressure on the carrying capacity of land can be determined based on a comparative value between the population and the percentage of farmers with a minimum area of land to live properly (Soermarwoto, 2001). The area of land needed for the needs of decent living per population is the need for a decent living per population divided by the productivity of local rice. According to Minister of the Environment Regulation No. 17 in 2009, it is assumed that 1 ton of rice / capita / year is equivalent to the standard of living needs per population. As is known above, rice productivity in Nusa Penida District is 2,400 kg / ha / year. So the area of land needed for decent living needs per population in Nusa Penida is 0.417 hectares / person.

The calculation of land requirements in Nusa Penida uses the approach of population in Nusa Penida and the number of tourists each year who travel to Nusa Penida. Based on data from the National Tourism Strategic

Area study, the number of tourists coming to Nusa Penida in 2015 was 255,079 people, in 2016 was 293,647 people and in 2017 was338,046 people. Using basic data in 2016, the rate of tourist growth was 15.12%. Projected tourist arrivals can be seen in Table 7.

Table 7. Projection of Tourists Arrival in Nusa Penida

No	Year	Tourists Arrival Projection
1	2018	389,159
2	2019	447,999
3	2020	515,737
4	2021	593,716
5	2022	683,486
6	2023	786,829
7	2024	905,798
8	2025	1,042,754
9	2026	1,200,419
10	2027	1,381,922
11	2028	1,590,869

Source: KSPN Nusa Penida and Projection Results

The average number of tourists staying in the Nusa Penida Tourism Area is 3 days, then the projection of the number of tourists staying for 1 year in the Nusa Penida Tourism Area can be seen in Table 8.

Table 8. Projection of the Number of Tourist Who Stayed for 1 Year in Nusa Penida

No	Year	Projection of Tourists Staying for 1 Year in Nusa Penida
1	2018	3,199
2	2019	3,682
3	2020	4,239
4	2021	4,880
5	2022	5,618
6	2023	6,467
7	2024	7,445
8	2025	8,571
9	2026	9,866
10	2027	11,358
11	2028	13,076

Source: KSPN Nusa Penida and Projection Results

From the projected number of tourists staying for 1 year in Nusa Penida categorized as residents, thus the number of residents in Nusa Penida will be the original population of Nusa Penida plus the number of tourists staying for 1 year in Nusa Penida as presented in Table 9.

Table 9. Projections of Population + Tourists in Nusa Penida

No	Year	Number of Population Projection	Number of Tourists Projection	Total
1	2018	45,510	3,199	48,709
2	2019	45,560	3,682	49,242
3	2020	45,610	4,239	49,849
4	2021	45,660	4,880	50,540
5	2022	45,711	5,618	51,328
6	2023	45,761	6,467	52,228
7	2024	45,811	7,445	53,256

8	2025	45,862	8,571	54,432
9	2026	45,912	9,866	55,778
10	2027	45,963	11,358	57,321
11	2028	46,013	13,076	59,089

Source: BPS Data, KSPN Nusa Penida and Projection Results

Based on the projected population + tourists in Nusa Penida and the area of land needed for decent living needs per resident in Nusa Penida, the land needs in Nusa Penida are presented in Table 10.

Table 10. Land Requirement Projection in Nusa Penida

No	Year	Land Requirement Projection in Nusa Penida (ha)
1	2018	20,311
2	2019	20,534
3	2020	20,787
4	2021	21,075
5	2022	21,404
6	2023	21,779
7	2024	22,208
8	2025	22,698
9	2026	23,260
10	2027	23,903
11	2028	24,640

Source: Projection Calculation Results

• Land carrying capacity status

The carrying capacity of land is obtained from the comparison between land availability (S L) and land needs (DL). Based on Table 11 regarding the projected land requirements and land availability in Nusa Penida, which is 5,462.7 hectares, the carrying capacity of the land in Nusa Penida is deficit or exceeded because the availability of land is less than the land requirement.

2. Land Carrying Capacity based on Ecological Footprint

Calculation of the ecological footprint requires consumption data or the needs of each type of primary product which can be either primary primary products or secondary primary products. Data on consumption or needs of each type of primary product that can be either primary primary products or secondary primary products in Nusa Penida can be seen in Table 11.

Table 11. Consumption Data or Needs of Each Main Type of Product in Nusa Penida

No	Commodity	Consumption (kg/capita/year)	Number of Population	Total Consumption (Ton)
Agriculture				
1	Rice	100.57	47,957	4,823.035
2	Wheat	2.35	47,957	112.699
3	Soybean	4.97	47,957	238.3463
4	Sugar	24.7	47,957	1,184.538
5	Frying Oil	11.78	47,957	564.9335
6	Vegetable	52.33	47,957	2,509.59
Livestock				
10	Beef	0.42	47,957	20.14194
11	Chicken meat	5.37	47,957	257.5291
12	Fork	0.26	47,957	12.46882
13	Egg	9.79	47,957	469.499

14	Milk	6.17	47,957	295.8947
Forest		**Volume ($m^{3)}$**		
15	Wood	0.19481	47,957	9,342.503
Fishery		31.17	47,957	1,494.82
Built Area		**Width (Ha)**		
16	Settlement and Industry	845.721		
17	Transportation	124.665		
Energy Use		**Consumption Net (10^3 t)**		
18	Kerosene	0.000054108	47,957	2,5949
19	Diesel oil	0.000043894	47,957	2,1050
20	Petrol	0.000141600	47,957	6,7907
21	Gas	0.018396741	47,957	882.2525
22	Electricity	0.698210431	47,957	33,484.0777

Average per capita consumption for agricultural, livestock and fishery products uses Ministry of Agriculture Statistics data for 2017. The average wood consumption system uses the timber consumption approach conducted by Siagian in 1992. The built area data comes from the digitization results of Nusa Penida District map. Meanwhile the energy consumption data uses data sources from each of the Bali Province Regional Organization and PLN data. The calculation of the ecological footprint based on the six parts of basic needs products expressed in the form of agricultural, livestock, forest, fishery products, built up areas, and energy use in Nusa Penida can be seen in Table 12.

Table 12. Calculation of the Ecological Footprint in Nusa Penida

Basic Product	Total Consumption	Global yield (t/ha)	Equivalent Factor (gha/ha)	JE (gha/cap)
Agriculture				
Rice	4,823.035	2.80	2.64	0.094823133
Wheat	112.699	4.11	2.64	0.002215715
Soybean	238.3463	47.07	2.64	0.004686000
Sugar	1,184.538	2.83	2.64	0.023288573
Frying Oil	564,9335	2.38	2.64	0.011106858
Vegetable	2,509.59	16.92	2.64	0.049339718
Livestock				
Beef	20.14194	2.23	0.50	0.000075000
Chicken meat	257.5291	2.23	0.50	0.000958929
Egg	12.46882	2.23	0.50	0.000046429
Milk	469.499	2.23	0.50	0.001748214
Forest				
Wood	9,342.503	1.84	1.33	0.092534748
Fishery	1,494.82	19.15	0.40	0.004452858
Built Area				
Settlement and Industry	845.721	1.74	2.64	0.081008069
Transportation	124.665	1.74	2.64	0.002450972
Energy Use				
Kerosene	2,5949	0.27	1.35	0.000165574
Diesel oil	2,1050	0.27	1.35	0.00000053
Petrol	6,7907	0.27	1.35	0.00054706
Gas	882.2525	0.27	1.35	0.00000563

Electricity	33,484.0777	0.27	1.35	0.00013301

The results of the calculation of land requirements based on the ecological footprint amounted to 17,724.283 hectares, while the availability of land in Nusa Penida was 5,350 hectares. This shows that the carrying capacity of the land in Nusa Penida has a deficit of 12.374,283 hectares. With this condition, preventive steps are needed thus the carrying capacity of the land remains sustainable and the environment in Nusa Penida is sustainable.

2. Water resources river

Nusa Penida's topographical characteristics consist of hills and valleys but no perennial rivers are found which are permanent streams. In general, rivers in Nusa Penida only flow during the rainy season, especially when it rains and after rain falls, so that the potency of river water in this area cannot be used for irrigation needs and the provision of clean water for its residents. Based on research by the Regional Office of Public Works in Bali Province (1994), the potential for the flow of rivers on Nusa Penida Island annually is 24 million m3. The rivers on the island of Nusa Penida are included in the river with the category of having less condition, which are always lacking water every year.

- **Water springs**

There are 16 springs in Nusa Penida, mostly near the coast in the southern coastal region. Whereas the concentration of the population on this island is mostly along the north coast, so as to obtain water sources from these springs it experiences obstacles, especially the distance which is quite far and the area is hilly. Although in terms of numbers are quite a lot, but not all springs are potency to be used (Department of Public Works, 2008).

Based on the report from the Department of Public Works, only a part of the springs identified in Nusa Penida could be identified. These springs ranges from 0.5 to 200 l / second (Table 13). Of the eight identified springs potency, there are two springs whose discharge is relatively large, namely Penida springs in Sakti Village with a discharge of 200 litre / second and Peguyangan in Batukandik Village with a discharge of 178.4 litre / second. Meanwhile, in Nusa Lembongan and Nusa Ceningan there are no springs (Department of Public Works, 2008).

Table 13. Water Springs Potency in Nusa Penida

No	Location	Potensi (l/dt)
1	Water Springs Penida –Sakti Village	200
2	Water Springs Seganing – Bungamekar Village	78,8
3	Water Springs Temeling – Batumadeg Village	26,4
4	Water Springs Peguyangan –Batukandik Village	178,4
5	Water Springs Tabuanan – Sekartaji Village	38,5
6	Water Springs Anceng – Sekartaji Village	1,25
7	Water Springs Wates – Tanglad Village	0,75
8	Water Springs Angkal – Suana Village	0,50
	Total	**524,60**

Source: PU Department *(2008).*

Water springs in Nusa Penida region have different potency and the distribution is not the same. The capacity of the spring is very dependent on hydrological conditions, climate, catchment area, vegetation, and geological structure. Currently, of the 9 (nine) springs, there are 2 (two) springs that have been managed (built clean water network) by the PDAM, namely Penida Water Springs (discharge rate = +200 lt / sec) and Guyangan Water Springs (large debit = +178 lt / sec). Both of these springs have been used as drinking water sources by the PDAM of Klungkung Regency, but the utilization of the two springs is currently not optimal due to high operational costs.

- **Groundwater**

Ground water is water that is below the surface of the land. Groundwater potential is very much determined by its lithology conditions. Based on the Bali Island Groundwater Basin Distribution Map (Geological Agency, 2008), in the Klungkung Regency area there are two Groundwater Basins namely the Denpasar-

Tabanan and the Nusa Penida. Nusa Penida Groundwater Basins has a total free ground water recharge of 39 million m^3/year and without the potential for depressed ground water recharge.
In Nusa Penida Island, groundwater drilling has been carried out by the Bali Province Groundwater Development Project (P2AT) and the Bali Tourism Development Corporation (BTDC) with a depth of between 30-108 m. The groundwater potential has been managed by the Nusa Penida PDAM (through a wellbore) in a limited way, in the Village of Kutampi.
Two drill wells in Kutampi Village are located close to each other and the depth of the well reaches 45 m. The installed capacity and drainage of each wellbore are 2.5 lt/sec. The transmission pipe used is galvanized pipe, 100 mm in diameter and accommodated in a reservoir capacity of 200 m^3 before being distributed to the community. Distribution pipes use PVC pipes with diameters between 50 mm - 200 mm with service areas including: Desa Kutampi, Batununggul, Ped, and Toyapakeh. But unfortunately this Kutampi artesian well is not good water quality.
The potential for ground water on Nusa Lembongan Island has been managed by the Nusa Penida PDAM (through bore wells) in a limited manner with sufficiently good water quality so that it can serve and supply the clean water needs of the people on Nusa Ceningan and Nusa Lembongan Islands. Based on an inventory of groundwater potential through a Geoelectric Study using secondary data located in the Village of Jungut Batu (around well-3), it can be concluded that "no indication of a layer containing fresh water" was found.

- **Carrying Capacity of the Environment based on Water Availability**

Water carrying capacity of an area is "the ratio between the availability and demand of water" in the area concerned. The approach used in determining the carrying capacity of water is to use the runoff coefficient method based on land use data, and annual rainfall data. While water needs are calculated from the results of the conversion of the need for a decent living population for water which is determined by the size of the human population in an area. Referring to Minister of Environment Regulation No. 17 of 2009 year concerning the Guidelines for Determination of Environmental Carrying Capacity in Spatial Planning has provided a constant number about the level of water consumption that comes from the level of consumption of water for basic needs such as rice, eggs, and fruit that is synchronized with water needs and also from the utilization of virtual water to produce one unit of product.
The availability (supply) of water, in relation to the carrying capacity of water, is the amount of water reserves available to meet the daily needs of human life (domestic needs) and human needs for water to produce one unit of product within a period of 1 (one) year. The availability of water is sourced from surface water such as river water and underground water, which in principle all come from rain water. The level of water availability in an area is influenced by 3 (three) factors namely; rainfall, weighted runoff coefficient, and area. Whereas the demand for water, in relation to the carrying capacity of water, is an illustration of the amount of water needed for the daily needs of human life (domestic needs) and human needs for water to produce one unit of product within a period of 1 (one) year.

1. Water Availability

The results of runoff coefficient analysis revealed that 4,970 ha (24.5%) of tegal / garden land in Nusa Penida had runoff coefficient value of 0.3, 3,572 ha (17.61%) of plantation land had runoff coefficient of 0.52, covering an area of 5,361 ha (26.4%) planted with trees have a runoff coefficient value of 0.3, an area of 824 ha (4.1%) is a State forest with a runoff coefficient value of 0.18, 224 ha (1.1%) is a mangrove forest with runoff coefficient value of 0.3 and an area of 5,333 is community forest with runoff coefficient value of 0.3.

Table 14. Runoff Coefficient Value for Each Type of Land Use in Nusa Penida

No	Land Use	Land Area (Ai)	Rauoff Coefficient (Ci)	(Ai x Ci)
1	Agricultural Land	14,366		
1.1	Paddy Fields			
a.	Irrigation			
b.	Rainfed	-		
c.	Tidal Swamp	-		

d.	Swamp	-		
1.2	Not Paddy Field	14,366		
a.	Garden	4,970	0.3	1,491
b.	Field	-		
c.	Plantation	3,572	0.52	1,857.44
d.	Planted Trees	5,361	0.3	1,608.3
f.	Pasture	-		
g.	Temporary Land Not Cultivated	-		
2.	Land Not Agriculture	6,381		
a.	State Forest	824	0.18	148.32
b.	Mangrove	224	0.3	67.2
c.	Community Forest	5,333	0.3	1,599.9
	Total	**20,284**		**6,772.16**

Based on the calculations set out in the table above, the weighted runoff coefficient value in Nusa Penida is 0.33. The average annual rainfall in Nusa Penida over the past 10 years is 1428.40 mm. The data was obtained from the results of the Geographic Information System (GIS) analysis using the Kriging Interpolation Method. The availability of water in Nusa Penida is divided into three patterns as follows:

a) The availability of water based on rainfall alone is 95,443,402.56 m3/year.
b) Water availability is based on 10% of Peguyangan and Penida springs usage of 2,528,408,256.44 m^3/year.
c) Availability of water based on rainfall + 10% of Peguyangan and Penida springs usage is 2,623,851,659 m^3 / year.
d) Availability of water based on rainfall is added to all springs in Nusa Penida if used 100%. So the availability of water is 35,052,932,640 m^3/year.

2. Water needs

The level of water demand is determined by the number of population / population in this case the population of Nusa Penida plus tourists in 1 year of stay in Nusa Penida. Projected water needs in Nusa Penida are presented in Table 15.

Table 15. Projection of Water Needs in Nusa Penida

No	Year	Projection of Total Population	Projection of Total Traveler	Total	Projection Water of Needs (m^3/tahun)
1	2018	45,510	3,199	48,709	77,934400
2	2019	45,560	3,682	49,242	78,787200
3	2020	45,610	4,239	49,849	79.758400
4	2021	45,660	4,880	50,540	80,864000
5	2022	45,711	5,618	51,328	82,124800
6	2023	45,761	6,467	52,228	83,564800
7	2024	45,811	7,445	53,256	85,209600
8	2025	45,862	8,571	54,432	87,091200
9	2026	45,912	9,866	55,778	89,244800
10	2027	45,963	11,358	57,321	91,713600
11	2028	46,013	13,076	59,089	94,542400

3. Water carrying capacity status

Water carrying capacity comes from a comparison between the amount of water available and the level of water demand. Water carrying capacity status describes the ability of the environment (hydrosphere) in maintaining its condition due to human activities. Water carrying capacity status in Nusa Penida is surplus until 2023. Comparison of water demand and water availability is presented in Table 16 and water carrying capacity status in Nusa Penida is presented in Table 17.

Table 16. Comparison of Water Needs and water availability in Nusa Penida

No	Year	Projection of Water Needs (m^3/tahun)	Rainfall (m^3/tahun)	10% Water Springs Peguyangan and Penida (m^3/tahun)	Rainfall +10% Water Springs Peguyangan and Penida (m^3/tahun)	rainfal+all water springs (m^3/tahun)
1	2018	77,934400	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
2	2019	78,787200	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
3	2020	79,758400	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
4	2021	80,864000	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
5	2022	82,124800	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
6	2023	83,564800	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
7	2024	85,209600	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
8	2025	87,091200	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
9	2026	89,244800	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
10	2027	91,713600	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640
11	2028	94,542400	95,443,402.56	2,528,408,256.44	2,623,851,659	35,052,932,640

Table 17 Projection of Water Carrying Capacity Status based of Rainfall and 10% Water Springs of Peguyangan and Penida in Nusa Penida

No	Year	Projection of Water Needs (m^3/tahun)	Status Daya Dukung		Status Daya Dukung	
			Rainfall (m^3/tahun)	Surplus	10% Water Springs Peguyangan and Penida (m^3/tahun)	Surplus
1	2018	77,934400	95,443,402.56	17,509,002.56	2,528,408,256.44	2,450,473,856.44
2	2019	78,787200	95,443,402.56	16,656,202.56	2,528,408,256.44	2,449,621,056.44
3	2020	79,758400	95,443,402.56	15,685,002.56	2,528,408,256.44	2,448,649,856.44
4	2021	80,864000	95,443,402.56	14,579,402.56	2,528,408,256.44	2,447,544,256.44
5	2022	82,124800	95,443,402.56	13,318,602.56	2,528,408,256.44	2,446,283,456.44
6	2023	83,564800	95,443,402.56	11,878,602.56	2,528,408,256.44	2,444,843,456.44
7	2024	85,209600	95,443,402.56	10,233,802.56	2,528,408,256.44	2,443,198,656.44
8	2025	87,091200	95,443,402.56	8,352,202.56	2,528,408,256.44	2,441,317,056.44
9	2026	89,244800	95,443,402.56	6,198,602.56	2,528,408,256.44	2,439,163,456.44
10	2027	91,713600	95,443,402.56	3,72,9802.56	2,528,408,256.44	2,436,694,656.44
11	2028	94,542400	95,443,402.56	901,002.56	2,528,408,256.44	2,433,865,856.44

Table 18 Projection of Water Carrying Capacity Status based of Rainfall+ 10% Water Springs of Peguyangan and Penida and Rainfall+all Water Springs in Nusa Penida

No	Year	Projection of Water Needs	Status Daya Dukung		Status Daya Dukung	
			Rainfall+10%	Surplus	Rainfall+all	Surplus

		(m^3/tahun)	Water Springs of Peguyangan and Penida (m^3/tahun)		Water Springs (m^3/tahun)	
1	2018	77,934400	2,623,851,659	2,545,917,259	2,528,408,256.44	34,974,998,240
2	2019	78,787200	2,623,851,659	2,545,064,459	2,528,408,256.44	34,974,145.440
3	2020	79,758400	2,623,851,659	2,544,093,259	2,528,408,256.44	34,973,174,240
4	2021	80,864000	2,623,851,659	2,542,987,659	2,528,408,256.44	34,972,068,640
5	2022	82,124800	2,623,851,659	2,541,726,859	2,528,408,256.44	34,970,807,840
6	2023	83,564800	2,623,851,659	2,540,286,859	2,528,408,256.44	34,969,367,840
7	2024	85,209600	2,623,851,659	2,538,642,059	2,528,408,256.44	34,967,723,040
8	2025	87,091200	2,623,851,659	2,536,7604,59	2,528,408,256.44	34,965,841,440
9	2026	89,244800	2,623,851,659	2,534,606,859	2,528,408,256.44	34,963,687,840
10	2027	91,713600	2,623,851,659	2,532,138,059	2,528,408,256.44	34,961,219,040
11	2028	94,542400	2,623,851,659	2,529,309,259	2,528,408,256.44	34,958,390,240

Even though the carrying capacity of water in Nusa Penida is in a surplus status, in reality most of the villages in this region are experiencing a water crisis. This is because surface water in the form of rainfall is accommodated in a body of water or a water storage facility, as well as existing ground water that is not affordable by residents to be utilized.

Conclusion

Based on the results of the research and discussion above the conclusions are drawn as follows:

1. The carrying capacity status of land in Nusa Penida has a high deficit and has been exceeded, where the ratio of land availability and land requirements is less than 1 or around 0.2. The results of the calculation of land requirements based on the ecological footprint amounted to 17,724.283 hectares, while the availability of land in Nusa Penida was 5,350 hectares. This shows that the carrying capacity of land in Nusa Penida has exceeded the threshold or deficit is 12.374,283hectares.
2. The projected water carrying capacity status in Nusa Penida in 2018 is based on rainfall is surplus 17,509,002.56 m^3/year and in 2028 is surplus 901,002.56 m^3/year and in 2029 a deficit is estimated. The projection of the carrying capacity of water in Nusa Penida based on 10% utilization of springs Penida and Guyangan in 2018 is surplus of 2,450,473,856.44 m^3/ year and in 2028 is surplus of 2,433,865,856.44 m^3/year. The projection of the carrying capacity of water in Nusa Penida based on rainfall+10% utilization of springs Penida and Guyangan in 2018 is surplus of 2,545,917,259 m^3/year and in 2028 is surplus of 2,529,309,259 m^3/year. Projection of the carrying capacity of water in Nusa Penida based on rainfall + all potential springs in Nusa Penida in 2018 is surplus of 34,974,998,240 m^3/year and in 2028 is surplus of 34,958,390,240 m^3/year.

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