CARRYING CAPACITY OF AGRICULTURE LAND RESOURCES AND WATER RESOURCES IN NORTH CENTRAL TIMOR REGENCY OF TIMOR ISLAND

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Abstract
This study aims to: (i) analyse the carrying capacity of agricultural land resources in North Central Timor Regency, (ii) analyse the carrying capacity of water resources in North Central Timor Regency. Data analysis using formula according to Minister of Environmental Regulation No. 17 of 2009. The analysis results show agricultural land resources in North Central Timor Regency surplus of 112,101 ha, and water resources in North Central Timor surplus of 378,235,554 m^3. Water management is needed to ensure continuity of water during the rainy and dry seasons, and regional water distribution is balanced.
Key Words: Carrying Capacity, Agriculture Land Resources, Water Resources

I. INTRODUCTION

Environmental carrying capacity is defined as the ability of the environment to support the growth and development of living things. Similiarly, Tian and Wang (2013) stated the concept of resources and environmental carrying capacity reflects not only scale effect in time and space, but also emphasis on the sustainable development, which means the precondition of carrying capacity must protect the original environment for against deteriorate, or even could turn into the direction that benefit to human through regulating action of human.

The carrying capacity of the environment is mainly related to water resources and land resources. Land is used for protecting areas (i.e. forest) and cultivation areas (agriculture, industry, settlement, etc.). Utilization of space for protecting areas can reduce land for cultivation purposes, so that agricultural production can be reduced. The goal of carrying capacity evaluation is to protect eco-environment and guarantee rational utilization of resources (Tian and Wang, 2013).

Land use of the developed area also reduces land use for agriculture, which affects the declining agricultural production and the fulfilment of food needs. Land use changes in the region are reflection the efforts of human to use and manage land resources, which impact on human and environment (Benu et al, 2013).

In addition, Benu, et al (2013) stated decisions or choices on alternative uses of resources to achieve specific goals in the future is a planning. Spatial planning should take proper account of the carrying capacity of land resources in North Central Timor Regency to reduce conversion of agricultural land to other cultivate land. Similarly, the arrangement of protected areas will affect the sustainability of water resources and agricultural production in the long term.

Land use determines the water to be absorbed into the soil and runoff. Higher water absorption will increase water availability in a region, so that the carrying capacity of water resources can support the lives of humans and other living creatures. Conversely, the more of runoff, the carrying capacity of water resources in a region is lower. It needs design evaluation system of water as Ling, et al (2010) stated the design of evaluation Index system on water ecological carrying capacity would reflect the water pressure level of the number of aquatic ecosystems and quality, also reflect the pressure level of the socio-economic system. In addition, it can reflect the ecological system to the ecological capacity of water, and reflect the level of coordination between water system, social system, economic system and ecological system.

Other constraints related to the carrying capacity of water resources in North Central Timor Regency are rainy season (generally four months of the year) and long dry season (generally eight months in each year). The impact is often water scarcity, especially in the dry season. In the prevention and control of these problems people must do the planning and implementation of programs as well as analysis and evaluation of factors that affect the availability of food, including the type and diversity of food crops (Benu et al, 2013). Land use for extensive agricultural cultivation (food crops & horticulture, plantations, forestry, fisheries, livestock) increases the fulfilment of people's food needs.

Spatial arrangement of North Central Timor Regency is one alternative solution to reduce the risk of drought. Given the importance of water for the survival of humans and other living things. Water is used by humans to meet the needs of households (e.g, eating, drinking, washing), the need in agriculture, industry, and other life spheres. The water is obtained from surface water and ground water or is generally known as water resources. Ahirwar and Shukla (2014) stated carrying capacity of water resources is a basic measurement of water resource security that plays an important role in water resource security system. Therefore, making the use of ecological and water footprint appropriately for resource management & maintain the balance between the available water resource and consumption, so the aims of this study are: (i) analyse the carrying capacity of land resources in North Central Timor Regency, (ii). analyse the carrying capacity of water resources in North Central Timor Regency.

II. RESEARCH METHOD

2.1.Hypothesis

1. Suspected surplus of land carrying capacity in North Central Timor Regency
2. Suspected deficit of water carrying capacity in North Central Timor Regency

2.2. Location and Time of Data Collection

This study is a study area with data base area of North Central Timor Regency, which call TTU (local name is: Timor Tengah Utara) Regency. TTU regency is one Regency of the boundary Regency of Indonesia and Timor Leste in Timor Island. The study was conducted in April until June 2017.

2.3. Research Procedure

This study is a literature study supported by a limited survey. Secondary data used comes from the Central Bureau of Statistics (BPS), the agricultural agency, and other relevant agencies. Secondary data relate to agricultural production and productivity, while the prices of agricultural products are obtained from primary sources using the snowball approach.

2.4. Analysis Method

Analysis of environmental carrying capacity using mathematical equations, as stipulated in Minister Environment Regulation No. 17 of 2009.

2.4.1. Carrying Capacity Analysis of Land Resources

Carrying capacity analysis of land resources used in the following stages:

1. **Criteria Status of Land Capacity**

Carrying capacity of land is derived from the comparison between land availability (supply of land/SL) and land needs (deman of land/DL).

a. When SL > DL , the carrying capacity of land is surplus.

b. When SL < DL, the carrying capacity of land is deficit or exceeded.

2. **The Calculation of Land Avaibility (Supply of Land=SL):**

$S_L = \frac{\sum(Pi \; x \; Hi)}{Hb} x \; \frac{1}{Ptvb}$

Description:

SL: Land availability or Land Supply (ha)

Pi: the actual production of each type of commodities (unit depends on each type of commodities). Commodities calculated include: agriculture, plantations, forestry, animal husbandry and fisheries

Hi: unit price of each type of commodities at producer level (Rp)

Hb: unit price of rice at the procedur level (Rp)

Ptvb: rice productivity (kg / ha)

The conversion factor used to equalize the non-rice product with rice is the price of rice.

3. **The Calculation of Land Needs (Demand for Land=DL):**

DL= N x KHL

Description:

DL : Total land needs equivalent of rice (ha)

N : number of people

KHL : Area of land needed for decent living needs for residents. The Criteria follows: (a) The area of land needed for decent living needs per population is a viable living need per population divided by the productivity of local rice, (b) The need for decent living per population is assumed to be the 1 ton equivalent of rice / capita / year; (c) Areas that do not have local rice productivity data, can use national average rice productivity data of 2,400 kg/ha/year.

2.4.2. Carrying Capacity of Water Resources Analysis

Analysis of the carrying capacity of land resources using the following stages:

1. **Calculation Water Resources Capacity**

   $S_A > D_A$: the carrying capacity of water is surplus

   $S_A < D_A$: the carrying capacity of water is deficit

2. **Calculation of Water Supply (S_A)**

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

   S_A = Water Supply (m^3/year)

   $C = \sum (Ci \times Ai) / \sum Ai$

   Description: Ci: Land Use Coefficient,
   Ai: The area of each land use,
   C : weighted runoff coefficient

   $R = \sum Ri / m$

   Description: R: average rainfall area (mm/year),
   m: number of rain observation stations,
   Ri: annual rainfall at stasion i

   A = total area (ha)

   10 = conversion factor from mm x ha to m^3

3. **Calculation of Water Needs (D_A)**

   $D_A = N \times KHL_A$

   D_A= Water Needs (m^3/tahun)

   N= Number of People

   KHL_A= Water requirement for Decent Living

III. RESULT AND DISCUSSION

3.1. Carrying Capacity of Agricultural Land Resources

The total area of North Central Timor Regency is 266,970 ha which divided for protected area of 59,780 ha (22.39%), and cultivation area of 207,190 ha (81.61%). Land use that counts as a protected area is a forest area, whereas other protected areas such as: local protected areas (river border, springs) have not been taken into account. Land use changes in the region are a reflection of the efforts of human to use and manage land resources (Benu et al, 2013). Details of land use accompanied by its extent in North Central Timor Regency are shown Table 1.

Table 1. Data of Land Use and Coefficient of Water Runoff in North Central Timor Regeny in 2015

No	Description of Land Use	Land Area (ha)	Procentace (%)
1	Settlement	10,789	4.04
2	Paddy Fields	11,366	4.26
3	Moorings	31,266	11.71
4	Fields	24,466	9.16
5	Plantations	30,850	11.56

6	Freshwater fish ponds	57	0.02
7	Forest Groves	59,780	22.39
8	Community Forest	30,459	11.41
9	Fish ponds	414	0.16
10	Savanna	63,241	23.69
11	Swamps and land degraded	4,282	1.60
	Total	**266,970**	**100.00**

Source: BPS, 2016

Land use in protected areas and cultivated areas determines the carrying capacity of land resources. According to Minister Environmental Regulation No. 17 of 2009 is the difference between the availability and the needs of land for the population in a region. The results of the analysis provide an overview of the carrying capacity of a region in a state of surplus or deficit. The surplus situation indicates that the availability of land in a region can still meet the needs of the area's biological production, while the deficit state indicates that the availability of land can not meet the need for biological production of the area.

The availability of land is determined based on the total data of the actual production value of each commodities in a region. The data on the actual production value of agricultural commodities (food crops, horticulture, plantation, livestock, fishery, forestry) in North Central Timor Regency amounted to Rp 3,551,900,040,000, - (Pi x Hi). Details of the value of agricultural commodities in the broad sense are shown in Table 2.

Table 2. Value of Agriculture Products in North Central Timor Regency 2015

No	Type of Comodities	Value (Rp)
1	Foods	500,212,000
2	Vegetables	4,913,300
3	Fruits	82,834,600
4	Plantations Products	37,038,000
5	Livestock Products	1,017,432,010
6	Eggs	352,391,500
7	Terrestrial Fishries	3,557,000
8	Forestry Products	1,553,521,630
	Total (Pi x Hi)	**3,551,900,040**

The value of agricultural commodities as shown in Table 2. then converted to equivalent value of rice. The price of rice (Hb) at the producer level is Rp 8,000. - /kg and the rice productivity in TTU is 1,760 kg/ha (Ptvb). The result of analysis shows the value of supply of land equal to 252,260 ha. Khanif (2010) stated land degradation occurs when soil loses its quality, productivity and utility. The degraded land lost its ability to support crop production. The important physical processes, resulting in land degradation are erosion, desertification and destruction of soil structure.

Furthermore the demand of land is calculated based on the needs of decent living. The area of land needed for decent living needs per resident, according to Minister Environment Regulation No. 17 is the need for decent living per population (assumed to be the 1 ton equivalent of rice/capita/year), which equivalent of rice. The population in North Central Timor Regency 2015 is 246,685 inhabitants. The result of analysis shows that the value of demand for land for a decent living in North Central Timor Regency is 140,159 ha.

The difference between the availability (supply) of land and the demand of land is the carrying capacity of a region's land. The analysis shows that land carrying capacity in North Central Timor Regency surplus is 112,101 ha. The obstacles of agricultural productivity compared to the national average productivity are still low (1,760 kg/ha compared to 2,400 kg/ha). Land use in accordance with spatial planning and other technical efforts can be made to improve agricultural productivity. Productivity of agriculture also caused by local and regional climate as stated by Weather (2014). In addition in needs management of water which involves the management of a complex human-natural system, and (b) potential impacts of the human footprint on land and water systems can influence water quantity and quality.

3.2. Carrying Capacity of Water

Water resources consists of surface water and groundwater. Surface water is sourced from rainwater which subsequently seeps into the soil, while some water flows through the surface and fills rivers, lakes and other surface waters (Kodoatie and Sjarief, 2004).

BPS (2016) show that surface water sourced from rain water recorded at 8 rain stations in North Central Timor Regency with total rainfall in North Central Timor Regency is 8,270 mm/year, with an average rainfall of 1,034 mm/year. The highest rainfall is at the Eban station (2,447 mm), while the lowest is at the Oenenu station (568 mm). Details of annual rainfall per station in North Central Timor Regency are shown in Table 3; Meanwhile, monthly rainfall distribution at 8 (eight) stations in North Central Timor Regency is shown in Table 4.

Table 3. Distribution Rainfall Per Stasion on North Central Timor Regency in 2015

No	Stasion Name	Annual Rainfall (mm)	Average Rainfall (mm)
1	Eban	2,447	203.92
2	Noemuti	969	80.75
3	Oenenu	568	47.33
4	Oel ni’naat	1,051	87.58
5	Sap’an	870	72.50
6	Wini	903	75.25
7	Kaubele	677	72.25
8	Lurasik	785	65.42
	Total	**8,270**	**1,034**

Source: BPS, 2016

Tabel 4. Monthly Rainfall per Stasion in TTU Regency 2015

No	Stasion	Month												Total
		1	2	3	4	5	6	7	8	9	10	11	12	
1	Eban	723	559	554	0	0	382	0	0	0	0	0	229	2,447
2	Noemuti	285	106	175	114	56	37	0	0	0	0	18	178	969
3	Oenenu	405	0	42	80	14	27	0	0	0	0	0	0	568
4	Oelnina'at	192	144	259	140	90	75	0	0	0	0	0	151	1,051
5	Sap'an	266	206	191	56	10	59	0	0	0	0	0	82	870
6	Wini	305	235	128	89	12	0	0	0	0	0	0	134	903
7	Kaubele	374	120	74	0	2	0	0	0	0	0	0	107	677
8	Lurasik	425	108	82	92	0	4	0	0	0	0	7	67	785
	Total	**2,975**	**1,478**	**1,505**	**571**	**184**	**584**	**0**	**0**	**0**	**0**	**25**	**948**	**8,270**

Source: BPS, 2016

Rainfall, rainfall intensity and land use determine the amount of surface water and ground water. Mugabe, et al (2017) stated the variability of the rainfall and runoff of the catchment is considered both temporary and spatially, and its implications on surface water resources. The use of more conservation land has a lower coefficient than cultivated land. This condition indicates runoff from higher cultivation area than conservation land. Details of land use coefficients and calculations of weighted runoff coefficients are shown in Table 5.

Table 5. Data of Land Use and Coefficient Runoff in North Central Timor Regency in 2015

No	Description of Land Use	Runoff Coefficient (Ci)	Land Use Area (Ai): ha	Ci x Ai
1	Settlement	0.5	10,789	5,394.50
2	Paddy Fields	0.3	11,366	3,409.80
3	Moorings	0.3	31,266	9,379.80
4	Fields	0.3	24,466	7,339.80
5	Plantations	0.3	30,850	9,255.00
6	Freshwater Fish Ponds	0.1	57	5.70
7	Forest Groves	0.18	59,780	10,760.40
8	Community Forest	0.18	30,459	5,482.62
9	Fish Ponds	0.1	414	41.40
10	Savanna	0.35	63,241	22,134.35
11	Swamps, land degrades	0.4	4,282	1,712.80
	Total		266,970	74,916.00
	C (Weighted Runoff Coefficient)			**0.2806**

The next step calculates water supply using weighted coefficient of runoff, average annual rainfall, and total land area in North Central Timor Regency. Ahirwar and Shukla (2014) show forest require relatively low water resources, compare with agriculture and industry. The results

show that the water supply in TTU is 772,931,544 m^3. Calculation using formula according to Minister Environment regulation No. 17 of 2009 as follows:

S_A = 10 x C x R x A
= 10 x 0,28 x 1.034 x 266.970
= 772,931,544 m^3

Description:

A : Total Populatin of North Central Timor Regency
R : Annual rainfall in North Central Timor Regency
C : Weighted Runoff Coeffisients
10 : Conversion factor from mm x ha to m^3

Then compared water supply with the demand of water for residents in North Central Timor Regency. The number of residents in North Central Timor Regency in 2015 was 246,685 (BPS, 2016). Each residents needs water to meet minimum living needs. Eligible minimum standard of living requirement of each resident for water according to Minister of Environment Regulation No. 17 of 2009 is 1,600 m^3/person/year. Similarly concept is used by Qin et al (2016) to designed carrying capacity water resources; the population size that the local water resources can support is calculated based on the balance of water supply and water consumption, under the design water supply and design socio-economic development mode.

The result of calculation with formula according to Environment Regulation No. 17 of 2009 shows the total demand of water for the entire population of TTU Regency in 2015 was 394,696,000 m^3. The calculation is as follows:

D_A = N x KHL_A
= 246,685 x 1,600
= 394,696,000 m^3

Description:

N : the population of TTU Regency in 2015 is 246,685 inhabitants
KHL_A : 1,600 m^3/person/year

The difference between water supply and water demand indicates the carrying capacity of water resources in a region. The difference between water supply and demand is 378,235,554 m^3, which means a surplus of water in North Central Timor Regency.

The opposite is true in North Central Timor Regency because the excess water generally occurs in: (i) the rainy season, whereas the dry season is generally the lack of water; (ii) certain locations have water resources, while other areas in North Central Timor Regency have limited water resources. It requires proper water management so that the continuity of water during the rainy and dry seasons can be maintained. Distribution of water from over-water areas to water-deprived areas are also required in water resources management. Vos, et al (2010) stated water management through enlarged the carrying capacity by either enlarging the size of natural areas.

The implications of spatial planning in North Central Timor Regency are relate to spatial pattern (protected area and cultivation area). This is concerned about enforcement acts like environmental protection act, biodiversity conservation act as well as zoning regulations, building

permits, land-use ordinances, etc., which provide standards to control the haphazard development (Taiwo and Feyisara, 2017).

IV. CONCLUSION

1. The carrying capacity of land resources is sufficient to meet the needs of community life. The analysis shows a surplus of 112,101 ha of land, but agricultural productivity is still low so it needs efforts to increase agricultural productivity.
2. The carrying capacity of water resources in TTU Regency is still sufficient to meet the needs of human life and other living things in TTU Regency. A surplus of water resources in TTU Regency is 378,235,554 m^3. Nevertheless, based on the season, there is a surplus in the rainy season, while the dry season lack of water, so it takes good management so that the water needs are met throughout the year.

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