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Ecological footprint in Mijen District, Semarang Municipality

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Abstract: ***As a fast growing district, Mijen has been undergoing changes in carrying capacity. This study aimed at finding out bio-ecological carrying capacity of the district based on 2016 ecological footprint and creating projection using projected population in 2031. The study performed field observation, image interpretation, questioner dissemination, and documentation to collect the research data, including the secondary data. Research findings were as follows: ecological footprint rate in 2016 of 0.456 gha/capita, or approximately 28,026.89 gha; biocapacity rate of 0.104 gha/capita, or approximately 6,146.752 gha of bioproductivity; and ecological footprint deficit of 0.352 (Minor Region category). Furthermore, Mijen District obtained a bio-ecological carrying capacity rate of 0.23, indicating that the ecosystem of the district had a low capacity, therefore, unable to fulfill the population need for resources, , and projected ecological footprint in 2031 rate of 43,331.48 gha.***

Keywords: biocapacity, bio-ecological carrying capacity, ecological footprint

1. Introduction

Mijen District, situated in the southern outskirt of Semarang Municipality, has become one of the districts to undergo development. Unlike other districts under Semarang Municipal administration, Mijen is characterised by large agricultural area. As the development continues, potential problems may arise to affect the agriculture. The development in Mijen District has led to the change the agricultural land into other functions, such as infrastucture facilities and settlements.

Ecological footprint calculation in a particular area helps determine bio-ecological carrying capacity. Carlton in Sudanti (2013: 38) defines bio-ecological carrying capacity as the maximum burden an environment is capable to carry. The calculation of the bio-ecological carrying capacity of Mijen District helps us find out its capacity to fulfill the local population need and environmental quality. The ecological footprint calculation in this study was expected to predict the future natural resource demand of Mijen local community using projected population growth in 2025. In other words, the projection included the change in population ten years after the existing environmental condition. Whereas, the definition environmental carrying capacity in this study is a comparison between ecological footprint (demand-side) and bio-capacity (supply-side) in resources exploitation. The different from formula by Wackernagel is approach to indentification landuse by satelit image (Quickbird), so the data more actual dan acurat

This study aimed at calculating the bio-ecological carrying capacity of Mijen District by assessing the ecological footprint and bio-capacity and using the projected ecological footprint and bio-capacity of the area in 2025.

2. Research Methodology

This study applied a quantitative research methodology using a descriptive technique of analysis. A survey took place in Mijen District, Semarang Municipality, on 100 households across the area to finding out, among others, consumption of food and energy resources. In addition to the household survey, data necessary for the research analysis were collected by field observation, sattelite image interpretation, and secondary data documentation.

The study performed a purposive sampling technique and determined the research population by using the 2012 WorldView sattelite image interpretation. This effort resulted in 30% of the total population to be included in the further analysis. The respondents, i.e. the households in Mijen District, were asked for giving information about land necessity value of each land use product according to their consumption. The information collected was then calculated by Slovin equation as follow:

$$n = \frac{N}{1 + Nc^2}$$

where,
n : sample size
N : population size
c : standard errors (10%)

A proportional random sampling technique managed to collect 100 respondents representing 14 different villages.

The following equation applied to the calculation of the ecological footprint demand:

$$EF = N.ef = N.rj.\sum(AAI) = N.rj.\sum\frac{ci}{pi}$$

where,
EF : total ecological footprint
N : population
ef : ecological footprint per capita
ci : consumption quantity per capita for i product
pi : average product per i product
AAI : bio-physical area per capita for i product
rj : equivalence factor
j : productive land ecology

The total ecological footprint per capita was calculated using the following equation:

$$JEi = Ki \times EFi$$

$$JEt = \sum_{i=1}^{k} JEi$$

where,
JEi : ecological footprint for 1 ha/capita land use
Ki : necessity value i for fulfilling the population consumption per capita (ha/capita)
EFi : equivalence factor (cf. WWF, ZSL, and GFN, 2006)
JEt : total ecological footprint

Below is the equation used for calculating the bio-capacity as the supply-side:

$$BKi = (0{,}88 \times LPLi \times FPi)/JP$$

$$BKt = \sum_{i=1}^{k} BKi$$

where,
BKi : biocapacity of land use i (gha/capita)
LPLi: land use coverage (ha)
0.88 :constant (12% of the total value used for securing biodiversity sustainability) (WCED, 1987; WWF, ZSL and GFN, 2006; Habert, Wackernagel et al., 1997)
Fpi : production factor (Ferguson, 1998)
JP : population size (individual)

Table 1: Equivalence Factor and Production Factor of Each Bioproductive Area

No.	Land Use	Equivalence Factor (gha/ha)	Yield Factor (gha/ha)
1.	Wet Rrice field	2,2	0,36
2	Unirrigated agricultural field	1,8	0,07
3	Forest	1.4	1.4
4	Grass land/Field/Farm land	0,5	0,5
5	Waters	0,4	0,4
6	Settlements areas	2,2	1.71

Source: WWF, SL and GFN (2006); Ferguson (1998), modified in Muta'ali (2015)

3. Results and Discussion

Mijen District is situated from 110 16 20 to 110 21 50 East and from 7 0 40 to 7 6 30 South. The district is under two slope classifications, i.e. class I (0-2% slope) and class III (15-40% slope, Wonoplumbon). The district is composed of reddish dark brown latosol and grey grumosol hydromorphic alluvial soils, therefore, suitable for perennial plants, horticulture, and paddy.

Ecological footprint

Ecological footprint value is obtained from primary data collected by questioner dissemination. The calculation begins with land necessity as the result of the comparison between consumption quantity and productivity (Table 2).

Table 2: Land Necessity in Mijen District 2016

No.	Consumption	Annual Consumption Rate	Annual Productivity Rate	Unit	Ki
1.	Food				
	a. Rice	83.455	631.4	kg	
	b. Vegetables	219.56	2.39	kg	
	Total	303.01	633.791	kg/ha	0.478
2.	Animal Product				
	a. Cattle meat	0.957	5,034.79	kg	
	b. Chicken egg	13.66	21,762.8	kg	
	c. Chicken meat	13.44	1,585.00	kg	
	Total	28.057	23,382.59	kg/ha	0.004
3.	Constructed land	0.056	1,202.47	ha	0.00005
4.	Forest	0.3575	2,698.62	ha	0.001

Source: Field observation (2016).

The land necessity rate helped determine the ecological footprint value. In terms of this study, the highest ecological footprint value was 0.478 gha/capita. In other words, 0.478 ha per capita was necessary to fulfill the food resources demand. The lowest value was obtained from the constructed land (0.000051 gha/capita). Overall, the ecological footprint value in Mijen District indicated that the resources consumption, in particular of food, was moderately high.

Once the ecological footprint had been found, the study continued with determining ecological footprint demand (JE-demand) by multiplying the total ecological footprint with the population size. It revealed that the annual consumption rate of Mijen local population resulted in 28,026.89 gha. There are many factors that affected the consumption rate, such as resources consumption, resources accessibility and affordability, and productivity of the products used. Mijen District saw food necessity rate higher than land for settlement necessity rate.

Table 3: Ecological Footprint in Mijen District

No.	Land use	Ki	EF	JE	Ecological Footprint-demand (gha)			
					2016	2021	2026	2031
1.	Rice field	0.478	0.94	0.449	27,590.49	32,482.46	37,237.37	42,688.68
2.	Grazing land	0.004	1.31	0.005	328.268	361.72	414.67	475.38
3.	Built-up area	0.000	1.02	0.0001	3.131	3.69	4.23	4.85
4.	Plantation/forest	0.001	1.71	0.002	105.002	123.71	141.82	162.58
				Total	28,026.89	32,971.57	37,798.08	43,331.48

Source: Indonesia Center for Statistics (BPS) and field observation (2016).

where,
JP : population size
Ki : land necessity rate
EF : equivalence factor
JE : total ecological footprint
Je-demand : ecological footprint-demand

Biocapacity and Ecological Deficit Rate

Biocapacity indicates the supply-side of resources available in Mijen District. It revealed that the biocapacity of the

district (0.104 gha/capita) proved to be lower than its ecological footprint value. In other words, the existing condition (2016) indicated that Mijen District was in resource deficit, therefore, unable to fulfill the local demand. Biocapacity rate closely relates to the coverage of each area in use. In Mijen, most of the areas were dominated by agricultural and foretry land use for food supply. Only few parts that became setlements and bushes.

The land composition by usage in Mijen District during the research observation were as follows: 2,698.62 ha forest; 1,418.25 ha agriculture; 209.43 ha bushes/grass land. In terms of this study, forest area was a combination of plantation and heterogenous plantation assumed having fields.

The land composition by usage in Mijen District during the research observation were as follows: 2,698.62 ha forest; 1,418.25 ha rice field; 209.43 ha bushes/grass land. In terms of this study, forest area was a combination of plantation and mixed plantation assumed having tegakan; constructed land was the land used for industry and settlement; bushes/grass land was the land coverage resulted from the total area of farm land, barren land, yard ground and final waste disposal site. The larger the land use area, the more potential the land availability. Despite, harvest also became an intervening factor that might affect the land use.

In addition to biocapacity that indicated resources availability for per capita unit, the study also found 6,146.52 gha bioproductive land. However, such number was far below the capacity to fulfill the total consumption of Mijen local population.

Table 4: Biocapacity in Mijen District

No.	Land use	Yield Factor (Yi)	Land (ha)	Bioproductive Land (gha)	Biocapacity (gha/capita)			
					2016	2021	2026	2031
1.	Rice field	0.94	1,418.25	1,173.18	0.0191	0.0162	0.0141	0.0123
2.	Bushes/Farm land	1.31	209.43	241.43	0.0039	0.0033	0.0029	0.0025
3.	Constructed land	1.02	1,034.45	928.522	0.0151	0.0128	0.0112	0.0098
4.	Plantation/Forest	1.71	2,698.62	4,060.88	0.0661	0.0561	0.0490	0.0427
5.	Waters	0.81	17.88	12.74	0.0002	0.0002	0.0002	0.0001
	Total			6,146.75	0.104	0.089	0.077	0.055

Source: Indonesia Center for Statistics and field observation (2016).

This study performed ecological deficit rate of the area to obtain a ratio between ecological footprint and biocapacity. The ecological deficit rate obtained during the research was 0.352, indicating that Mijen District suffered from ecological deficit. The ditrict could not fulfill the need of the local population in terms of food and settlement resources. According to CCICED-WWF the current condition put Mijen into Minor Regions criterion due to its lacking capacity of fulfilling the local need, creating a crisis among the surrounding ecosystems, including human population. In terms of area development, such condition indicated the need for policy on preventing the ongoing deficit. This is due to the fact that environmental condition affects the sustainability of human population. Mijen District needed for an environmental quality improvement, e.g. by improving productivity of each land use coverage and population growth control towards a more reliable future environment.

The calculation of the ecological deficit did not take place in the projected year because estimated area need in the projected year was unknown. Therefore, this study calculated the deficit rate only in the existing condition.

Bio-ecological carrying capacity

Bio-ecological carrying capacity is a comparison between total ecological footprint value and biocapacity rate. It compares the demand on resources to the supply of resources in a particular area. The study found that the bi-ecological carrying capacity in Mijen District was 0.23. This value was less than 1 (<1), therefore, it was considered to have an overshoot condition. The overshoot condition occurred where ecosystems in the area could no longer support the population (ecological deficit). By population, the ecological footprint value of Mijen District higher consumption, i.e. food necessity, than its bioproductive land availability. Furthermore, the environmental carrying capacity of the district indicated the need for environmental improvement, thereby, strengthening the bioproductivity.

Projected Ecological Footprint and Biocapacity

Beside the existing condition, the study on ecological footprint shall be more valuable when it also deals with projected environment. Therefore, a projected ecological footprint-demand based on the projected population might help the future demands on resourcers. The observation found that the 2016 ecological footprint-demand was 28,026.89 gha. Such condition occurred when the population growth in Mijen District at the beginning of the projected year, 2015, remained 61,405. The projected calculation for 2031 revealed that the ecological footprint-demand in the district might become 43,331.48 gha. It was estimated that the total number of population in Mijen District would have been 95,075 by 2031. The rising number of population means the rising consumption rate.

In terms of biocapacity, the projected 2031 rate revealed a decrease in biocapacity in Mijen District due to the projected number of population, in which the population boom would cause the decrease in resource capacity and supply. By 2031, the biocapacity would have been at 0.055 gha/capita. the prediction assumed the similar area to the existing condition. Therefore, the biocapacity in the research location needed for improvement towards sustainable ecosystem and preventing larger environmental deficit.

4. Conclusion

The field observation revealed the following conclusion remarks: (1) total ecological footprint of Mijen District in 2016 of 0.456 gha/capita; (2) ecological footprint-demand in 2016 of 28,026.89 gha; (3) biocapacity rate in 2016 of 0.104 gha/capita, in which there was a decreasing trend due to the increasing number of population; (4) ecological deficit of 0.352, therefore the supply-side was less than the demand-side; (5) bioecological carrying capacity was on the overshoot condition (0.23), therefore, unable to fulfill the resources need of the local dwellers; and (5) projected ecological footprint of Mijen District by 2031 revealed an increase in the ecological footprint-demand with the average population growth of 0.0277.

5. Recommendation

This study recommended the following efforts towards preventing even worse conditons: (1) conservation to improve the environmental condition in Mijen District for better ecosystems by restricting the change in land function; (2) increasing food resources to fulfill the local people consumption; (3) increasing local consumption, in particular cattle meats by improving the local purchase power; and (4) increasing capacity of each bio-productive land use by increasing its productivity.

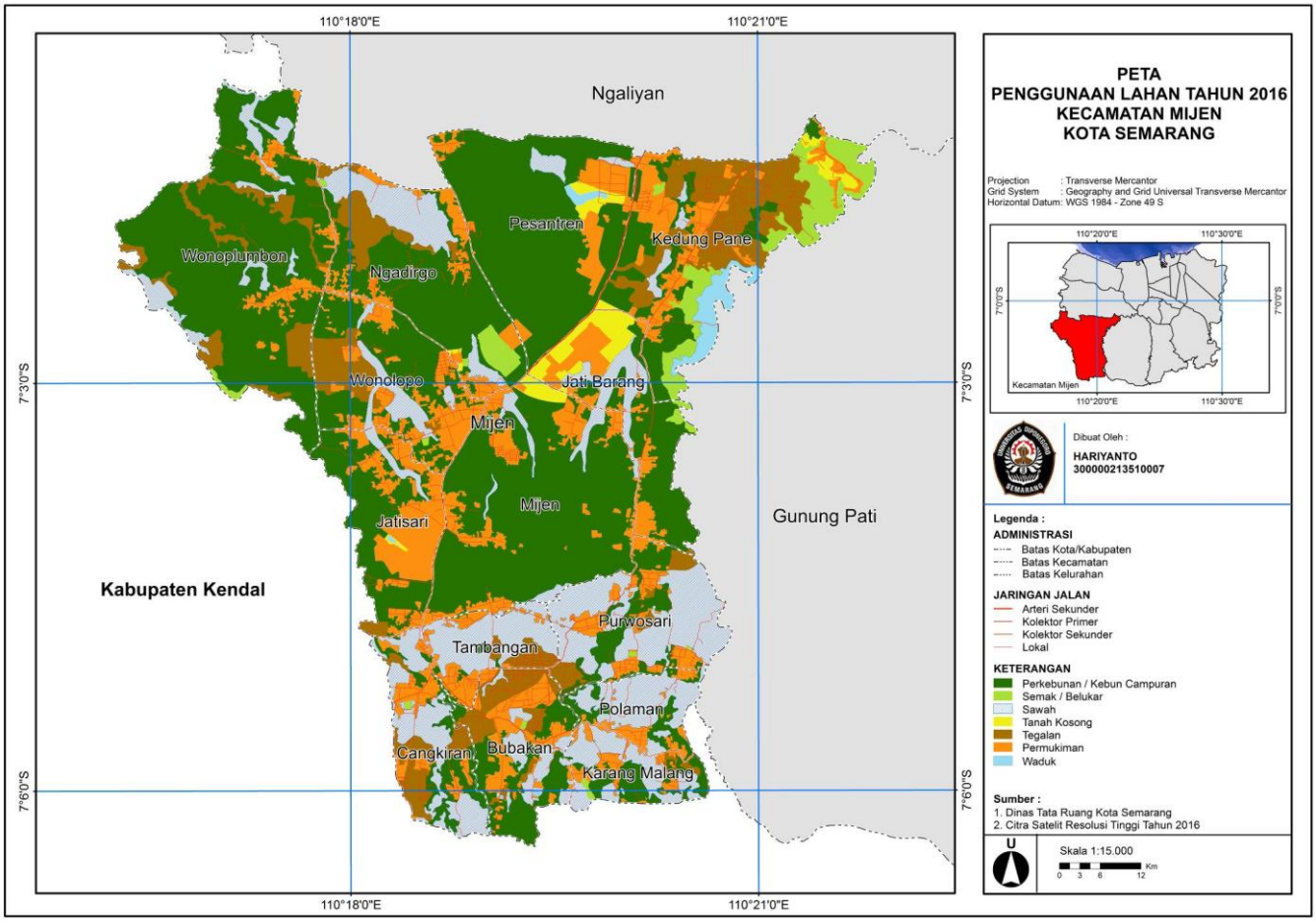

Figure 1: Landuse of Mijen sub-District

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