CHAPTER 7

Land Conversion and Decrease in Environmental Carrying Capacity of Kreo Sub-Watershed in Semarang City, Indonesia

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Introduction

The land is part of the environment as a natural resource that plays a vital role in various human interests. The land is used as housing, agriculture, farm, mining, roads, and social and economic facilities building, and so on. The problem is that the land area is not increasing, whereas land demand will continue to increase. Consequently, increasingly high competition in land utilization has occurred and less productive land will be converted into other utilizations such as housing, industry, infrastructure, and so on (Dewi & Rudiarto, 2013). Data from Agricultural Census in 2003 shows that from 2000 to 2002 rice field land conversion in Indonesia reaches 187.7 thousand ha per year, whereas new rice field development is only 46.4 thousand ha per year (Irawan, 2005). It means that there is a decrease in the rice field area of 141.3 thousand ha per year. The worst yet come since the rice field conversion in Java Island is still massively and accumulatively increasing, whereas soil fertility in Java Island is four-time of soil outside Java Island (Sutomo, 2004). Head of the Agricultural Department of Semarang City, Rusdiana (2014) states that agricultural area in Semarang region is decreasing every year due to land conversion. The rice field of agricultural land area in the region decreases by 5 - 10 percent. Based on data from the Agricultural Department of Semarang City, the rice field area left in Semarang City is only 3,700 ha spread in Mijen sub-district area, Gunungpati, which is a Kreo sub-watershed. He explains that the decrease is related to many new lands clearing for housing and industry that is also occurred in other areas (Office of Agriculture, Semarang, 2016). The agricultural land conversion has a direct implication on the decrease in food production in Semarang City and indirectly on the decrease in environmental quality or environmental carrying capacity.

Agricultural land conversion will influence resource production, especially agricultural products. Consequently, it will reduce the food resource supply. According to Rees (1996), an ecological footprint is a tool for planning toward sustainability. It is an instrument for calculation (accounting tool) that allows us to estimate the human need for resource consumption and waste assimilation on several human populations. The ecological footprint is thus a weight/ load measure of several certain populations on the natural environment. It reflects the area needed to support resource consumption levels and waste disposal conducted by the population. Agricultural land conversion in Semarang City will impact agricultural land area and further, the decrease in environmental carrying capacity, particularly food supply. The decrease in agricultural land means a decrease in green open space and water habitat. In the economic aspect, it will reduce food security for agricultural production. As regards farmer community they will lose their job if they could not shift to other professions and their purchasing power reduces. Based on the economic, social, and environmental aspects, agricultural land conversion equal to the loss of water pockets (rice fields, fishpond, and ponds) that have the potential to reduce flood and groundwater reserves. Particularly, the loss of water pockets located in the upstream part could produce a flood in the rainy season and drought in the dry season in the downstream part. Furthermore, agricultural land serves to reduce pollutants and absorb CO_2 in the air. Agricultural land conversion will thus influence environmental carrying capacity, especially bio-capacity. Based on the problem, research in the "Effect of Agricultural Land Conversion on Ecological Footprint and Bio-capacity of Semarang City Suburbs" is crucial to be conducted.

The change in agricultural land utilization in the Semarang City suburbs because of development has resulted in changes in land resources quality and quantity. An intensive land utilization change pattern occurs from agricultural to non-agricultural land (housing, industry, infrastructure, and so on). Agricultural land, in this case, is vegetation land cover consists of rice fields, moorland, yard, pastures, and forests. According to Law No. 32/ 2009 on Environment Protection and Management, environmental carrying capacity is defined as the ability of the environment to support human life as well as other organisms. Environmental carrying capacity comprises two aspects: carrying capacity as resources ability (bio-capacity) and capacity, which is environment ability to manage waste resulted from human activities. This research focuses only on carrying capacity as a supplier (bio-capacity). The ecological footprint indicates the number of natural resources used by a population in an area. The ecological footprint concept firstly introduces by Rees and Wackernagel in the 1990s (Sudanti, 2013). According to Wackernagel (1997), natural resource consumption of 80 percent of the world population in 1996 has exceeded one-third of the ability of nature to restore it, whereas it was only a quarter in 1992 (Hadi, 2012). The natural environment can restore itself from pollutant damages. However, the natural destruction (pollution) is more intensive; therefore before nature has a chance to restore the pollution weight has increased.

According to data, Indonesian ecological footprint value in 2012 is 1.6 global hectare per people (gha/ people) and its bio-capacity is 1.3 gha/ people. The value indicates that every individual in Indonesia, on average, needs a productive land of 1.6 hectares, which is a deficit of 0.3 gha/ people. American people have an ecological footprint of 9.7 gha/ people, European of 4.7 gha/ people, Chinese of 1.6 gha/people, Indian of 0.8 gha/ people, and Japanese of 4.8 gha/ people (Ewing, 2010). It also suggests human behaviour patterns in Indonesia in terms of food, residence, carbon emission, energy used and renewed energy, and behaviour pattern towards goods in the environment. Competition between sectors will create the most economically profitable land utilization. In other words, the highest land value will replace land utilization with the lowest land value. As a result of changes in land resource quality and quantity, in this case, land area and land utilization type, food supply availability produced by the land will be affected. How is the influence of changes in land utilization on bio-capacity and environmental carrying capacity? How is the ecological footprint in the Semarang City suburbs that experiences substantial agricultural land conversion? How much land area needed to fulfil the population's resources requirement? These are questions to be answered in this research. Purposes to be achieved include (1) spatially, statistically, and descriptively analyse the dynamics of land change in Semarang City suburbs (urban fringe) in the period of 2002 - 2016; (2) analyse the relationship between land conversion trend and agricultural bio-capacity that is used to predict environmental carrying capacity (ecology) of Semarang City in the future in the suburbs area that consists of Mijen, Gunungpati and Ngaliyan sub-district.

The scope of the chapter comprised regional scope, material scope, and time scope. The scopes aimed to limit problems in a certain area, namely suburb areas of Semarang City with a sample of Mijen, Gunungpati, and Ngaliyan sub-districts. The time scope was from 2002 - 2016 as Kreo sub-watershed. The chapter material scope related to the first scope was a spatial pattern that consisted of land utilization type, changes in land utilization, area, distribution, change pattern (modus), and agricultural land conversion intensity (Yunus, 2010). The Bio-capacity of each sub-district could be calculated based on data of each land utilization area. According to the result of the household consumption survey, the ecological footprint per capita could be identified, and then the total ecological footprint. The environmental carrying capacity could be calculated using a ratio between bio-capacity and total ecological footprint. The analysis method of land conversion spatial pattern was conducted using analytic descriptive to identify whether the pattern is spread, cluster, swarm, and so on. To calculate the ecological footprint and bio-capacity, the following formula was used.

$$EF = (P \times YF \times EQF) / YN$$

where;
EF = ecological footprint (TE).
P = number of products harvested or waste produced.
YN = average national productivity for plant P.
YF = yield factor.
EQF = equivalence factor (for given land category).

For ecological footprint calculation, yield factor of GFN was used.

Following is the bio-capacity formula:

$$BK = A \times YF \times EqF$$

Where;
BK = Bio-capacity (BC).
A = Land area of each land category.
YF = Yield factor.
EqF = Equivalence Factor (for land category).

To calculate environmental carrying capacity, Vitousek *et al.* (1986) brings out a concept of appropriated carrying capacity (ACC). Appropriated carrying capacity is defined as land needed to provide natural resources and absorb disposed waste. This new concept of environmental carrying capacity could calculate the number of bio-productivity of a country, area, community, and even household. Environmental carrying capacity is conceptually a comparison between bio-capacity and ecological footprint. The formula is:

DDL = BKcpt – Jecpt

Where;
DDL = Environmental carrying capacity
BKcpt = Bio-capacity per capita
JEcpt = Ecological footprint per capita

If DDL is positive means a surplus condition,
If DDL = 0, means a threshold condition,
If DDL is negative, means a deficit condition (*overshot*) or the carrying capacity is exceeded (Muta'ali, 2012).

Changes in the Ecological Footprint

Agricultural land conversion level was different from one sub-district to another depending on the physical, demographic, and socioeconomic condition of each area. The analysis unit used a sub-district analysis unit. Based on the land utilization type, Mijen sub-district had the most number (7 types) due to the use of plantation land and waters (Jatibarang Reservoir). The highest or fastest change of the three sub-districts (Mijen, Gunungpati, & Ngaliyan) could be identified. Changes in land utilization could be seen in Table 7.1. The three sub-districts have different land utilization change patterns. The largest land conversion in Mijen Sub-district was from rubber plantation to housing. Gunungpati sub-district experienced the largest conversion from rice fields to housing or moorland. The largest land conversion in Ngaliyan sub-district was from moorland and shrubs to housing. There were also common conversion patterns of wetlands (rice-fields) to drylands (moorland, yard, shrubs) and then to housing, industry, and infrastructures (built lands).

Table 7.1: Changes in land utilization in Mijen, Gunungpati, and Ngaliyan sub-districts

No	Land Use	Mijen Sub-District				Gunungpati Sub-District				Ngaliyan Sub-District			
		Year 2002	Year 2016	Change (ha)	Change (percent)	Year 2002	Year 2016	Change (ha)	Change (percent)	Year 2002	Year 2016	Change (ha)	Change (percent)
1	Forest Plantation	1925.82	1459.01	-466.81	-24.24	0	0	0	0	0	0	0	0
2	Mixed Plantation	1289.77	1239.63	-5014	-3.89	3769.20	3451.91	-317.29	-8.4	1196.78	1189.72	-7.07	0.5
3	Shrubs	216.98	197.07	-19.91	-9.18	13.14	53.04	39.9	300	330.19	298.78	-31.42	14.7
4	Settlement	923.68	1017.87	94.19	38.13	966.02	1445.54	479.52	49.6	1602.16	1921.05	318.89	19.9
5	Rice Field	102504	1016.73	-8.31	-0.81	1192.43	783.76	-408.67	-34.3	203.601	195.5	-8.1	4
6	Moor	409.64	401.52	-8.12	22.43	208.27	414.54	206.28	99	1121.62	869.3	-252.32	22.5
7	Water area	7024	17.88	10.86	154.56	0	0	0	0	0	0	0	0
	Total	5797.95	5797.95	-	-	6149.05	6149.05	-	-	4474.35	4474.35		

The ecological footprint in a population estimates the number of land and water needed for the population to produce all consumer goods and absorb waste produced by the population (Wackernagel, 1996). The level of ecological footprint influences by the total population and its economy. The higher the economic level of a population, the larger is its ecological footprint (Table 7.2).

Table 7.2: Changes in total ecological footprint in 2002 and 2016

No	Sub-district	Year 2002 Total EF (gha)	Year 2016 Total EF (gha)	Changes in Total EF (gha)	(%)
1	Mijen	9.606,95	14.530,27	4.923,32	51,25
2	Gunungpati	8.170,93	12.245,50	4.074,57	49,87
3	Ngaliyan	18.340,93	22.800,09	4.459,16	24,31

The total ecological footprint is the result of the estimation between ecological footprints per capita and the total population. The total ecological footprint (total EF) of the three sub-districts experienced an increase. The highest increase was experienced by Mijen sub-district (51.25 percent) due to its high population growth. The largest total ecological footprint was Ngaliyan Sub-district because it has the largest population (Figure 7.1).

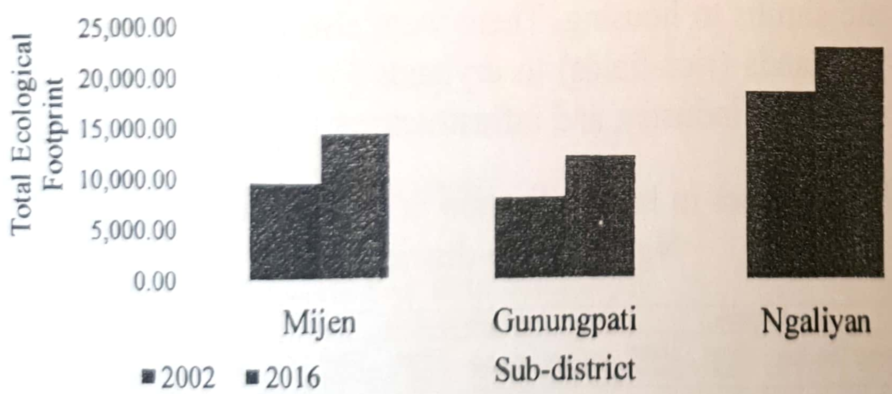

Figure 7.1: Changes in ecological footprint in 2002-2016

Changes in Bio-Capacity

The bio-capacity level is determined by the type of land utilization and land utilization area. In the same land area, rice field land utilization has higher bio-capacity than moorland or pasture since the rice field has larger productivity than the other two lands. The change in land utilization will influence bio-capacity ability. The narrowing agricultural land (forest, plantation, rice field, and moorland) will decrease the ability to provide resources. Based on Table 7.3, bio-capacity describes land ability to supply resources needed by a population. Bio-capacity in the three sub-districts showed a decrease. The highest decrease was found in Mijen sub-district that reached 70.5 percent. It is supported by data that Mijen sub-district experienced the largest land conversion (-446.81 ha), especially plantation land conversion. The bio-capacity of Gunungpati decreased by 30 percent, where rice field land conversion mostly occurred in this area.

Table 7.3: Changes in bio-capacity in 2002 and 2016

No	Sub-district	Bio-capacity in 2002 (ha/cpt)	Bio-capacity in 2016 (ha/cpt)	Change (ha/cpt)	(%)
1	Mijen	0,22	0,07	- 0,15	70,5
2	Gunungpati	0,16	0,12	- 0,06	30,0
3	Ngaliyan	0,07	0,07	- 0,00	10,9
	Average	0,19	0,09	-0,07	37,1

The decrease in bio-capacity caused by two factors, an increase in population and a decrease in land area. The main contributor to the decrease of bio-capacity in Mijen sub-district was rice field land conversion (-408.67 ha) where rice field land has the highest productivity (yield factor) compared to other land utilizations. The average decrease in the bio-capacity of the three sub-districts was 37.1 percent. Figure 7.2 illustrates a graph of changes in bio-capacity.

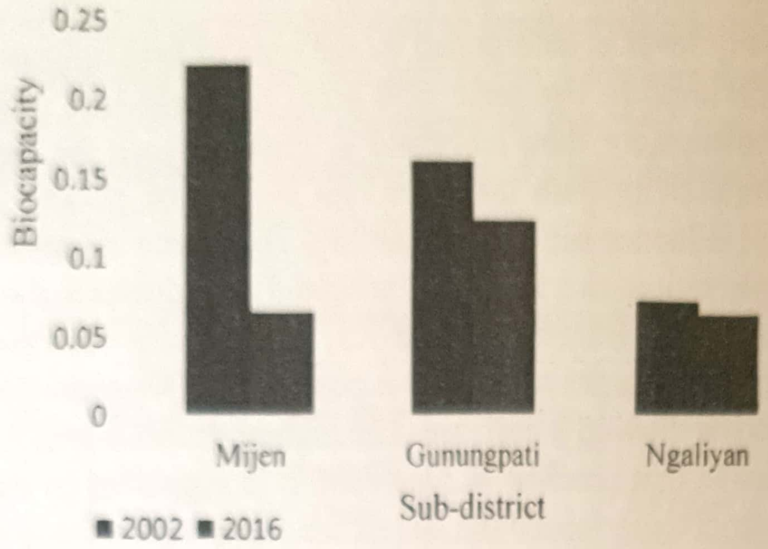

Figure 7.2: Changes in bio-capacity in 2002-2016

Changes in Environmental Carrying Capacity

Environmental carrying capacity is conceptually the difference between ecological footprint (demand) and bio-capacity (supply). If the environmental carrying capacity is positive (+) then the area is surplus. On the contrary if it is negative (-) then the area is deficit (overshoot). Changes in environmental carrying capacity are influenced by demand and supply factors for resource consumption. The demand factor is affected by the total population and population economic level. The supply factor is affected by the productive land area and land productivity (Table 7.4).

Table 7.4: Changes in environmental carrying capacity in 2002 and 2016

No	Sub-district	Environmental carrying capacity in 2002	Environmental carrying capacity in 2016	Changes in capacity
1	Mijen	-0,015	-0,099	-0,084
2	Gunungpati	0,020	-0,034	-0,027
3	Ngaliyan	-0,119	-0,129	-0,010
	Rata-rata	-0,051	-0,087	-0,40

In 2002 only Gunungpati Sub-district had good environmental carrying capacity (ECC positive). It could be interpreted that the environmental carrying capacity at that time was in a condition that was able to support the resources requirement needed by its population. Mijen sub-district experienced a small deficit; however, the three sub-districts were all deficit in 2016. It meant overexploitation on the environment or overshoot where the ecosystem is no longer capable of supporting the population requirement (ecological deficit). There was no doubt that Mijen and Gunungpati sub-districts as a development area of Semarang City had decreased the areas' environmental carrying capacity. Therefore, resources (foods, energies, materials) import from other regions increased. Environmental carrying capacity in 2016 for the three sub-districts experienced a decrease in average of 0.040. The largest decrease was found in Mijen sub-district of 0.084 in the last 14 years. The lowest decrease was in Ngaliyan sub-district because there were no more agricultural lands that could be converted (see Figure 7.3).

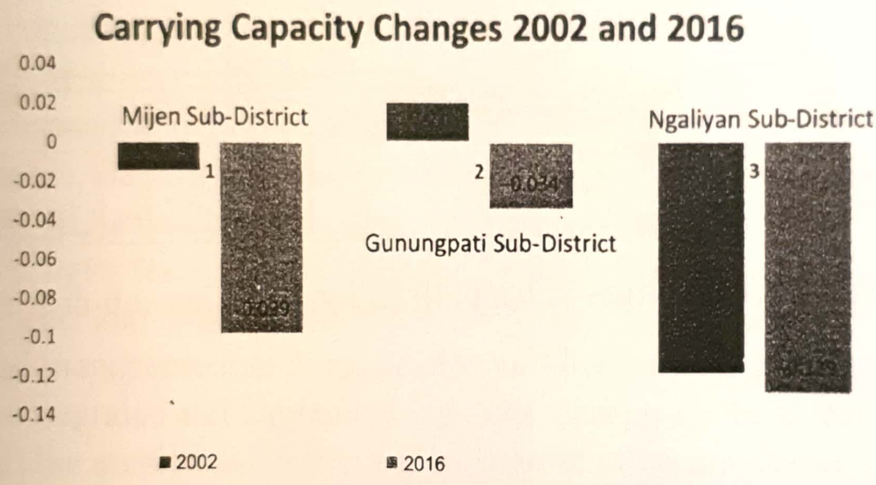

Figure 7.3: Changes in environmental carrying capacity (ECC) in 2002 and 2016

The decreasing environmental carrying capacity will affect quality, which is a decrease in urban open space. Therefore, an increase in local air temperature, runoff and flood and a decrease in groundwater reserves, expansion of critical land, and so on. The socioeconomic impact of agricultural land conversion includes fewer jobs in the agricultural sector and an increase in unemployment or industrial labour. On the other hand, the expansion of the industrial sector to rural areas could trigger a shift in culture from traditional to modern. Figure 7.4 indicates the expansion of moorland and housing in Mijen sub-district. Moorland or dry land is another form of temporary land utilization since it will finally become built land (housing, industry, etc).

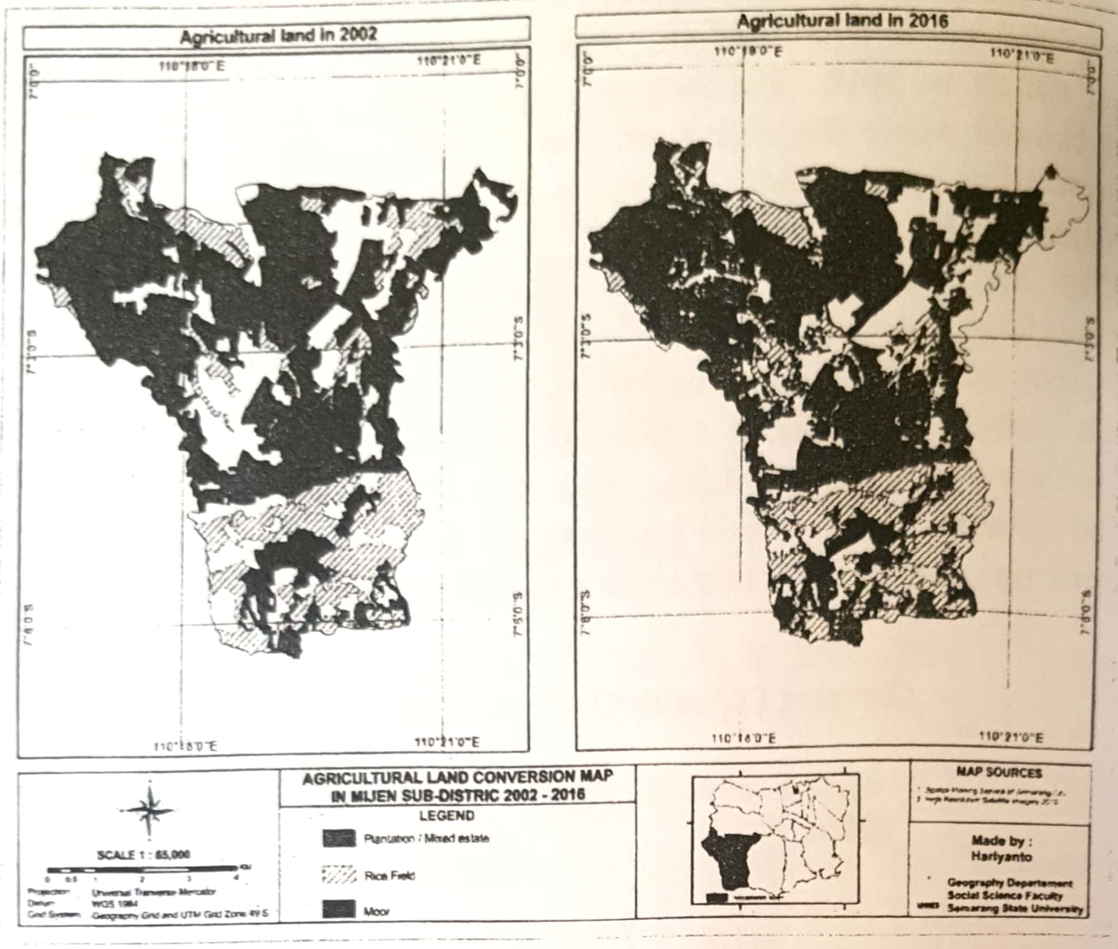

Figure 7.4: Changes in land utilization in Mijen sub-district

Conclusion

The spatial pattern of agricultural land conversion and determinant factors of land conversion is influenced by population growth factors. The largest agricultural land conversion occurred in a rubber plantation in Mijen sub-district of -466.81 ha, whereas the largest converted land in rice field agricultural land occurred in Gunungpati sub-district (-408.67 ha). The highest decreased bio-capacity in 2016 was in Mijen sub-district of 70.5 percent and followed by Gunungpati of 30.0 percent. According to the trend in the decrease in environmental carrying capacity from 2002 to 2016, Mijen sub-district was the fastest (-0.084 gha). The decrease in ECC will have an impact on environmental quality, such as microclimate change, flood, decreasing groundwater level, expansion of critical land and drought, and so on. The changes in land utilization or agricultural land conversion will bring a long impact both physically, environmentally, and socioeconomically. The problem is that the agricultural land conversion phenomenon cannot be avoided due to urban activity development that requires land for various interests.