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Estimation of Ecological Footprint for Sidoarjo Regency and its Implication towards Spatial Development

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Abstract. Sidoarjo Regency is one of buffer zones of Surabaya City in which directly adjacent with Surabaya at the south part of it. The highly economic growth of Surabaya has many direct y for Sidoarjo regency, mainly due to population growth and urban sprawl that bring negative impacts on sustainability. Decreasing of the productivity because of conversion of agricultural land into settlements and air pollution are major issues that occur in Sidoarjo regency. Regional development should be in line by efforts to conserve the environment so that take environmental carrying capacity into account is a must. Ecological footprint is one of approaches in the calculation of sustainability by identifying the components of consumption and emissions resulting from human activities for subsequent comparison with the availability of natural resources (biocapacity). Biocapacity consists of components of land productivity, ie agricultural land, forestry land, terrestrial fisheries, and constructed land that is processed using satellite imagery as resource. The difference between the ecological footprint calculation and the biocapacity indicates the sustainability of the Sidoarjo Regency. In conclusion, Sidoarjo regency has experienced ecological deficit level 1 with biocapacity value of 25,665 and ecological footprint value of 111,962. It is resulted that natural resources in Sidoarjo Regency are only able to accommodate approximately one-fourth of total consumption in Sidoarjo regency. This prediction could be used as consideration on spatial planning as well as spatial policies in terms of sustainability.

Keywords: *Ecological footprint, Spatial Development, Sidoarjo Regency*

1. Introduction

Land consist of natural resources that has limited carrying capacity, based on it's quality, quantity and continuity. The existance of innefactive land use can cause many environmental damages [1], such as pollution, the increasing of social problem and decreasing on productivity. The current resources will be decreased and unable to accommodate the needs of the future generations [2], so the city land use must be organized environmentally friendly. In terms of minimizing the impact of environmental degradation, urban development must be organized with the three main economic, social and environmental pillars as mandated by Act no. 26 Year 2007 on Spatial Planning. In the development of urban areas, environmental aspects tend to be ruled out so as to threaten the needs and consumption of citizen. Ideal development needs to be done with the principle of sustainability by maintaining environmental balance so that natural resources to maintain human survival can also be maintained.



One of the concepts of environmental carrying capacity in supporting sustainable development is by ecological approach. This concept focuses on measures of the balance of population consumption on nature in the provision of resources and emission reducers for future environmental sustainability [3,4]. The carrying capacity of the region is seen through the comparison of consumption and biocapacity called ecological deficit in the Global Hectare unit (GHA) [5]. Thus the size of the equilibrium and the activity of the area can be determined through the calculation of ecological status which can indicate overall and specific type of land use in the calculation area. Ecological status is affected by biocapacity dan ecological footprint per capita. If a region are unable to support the life of certain populations with the ecological defisit signs such as decreased food availability and increased population mortality and declining carrying capacity, this condition is called an excess population that does not reflect environmental sustainability [6].

Sidoarjo Regency is a buffer region that directly adjacent with Surabaya City. The function as a buffer zone is seen from the high demand of settlement for workers in Surabaya. In addition, Sidoarjo Regency itself is one of the strategic districts as industrial areas such as Brebek Industries. This also affects the high demand for public consumption, both primary and tertiary materials. Development and activities that occur in a city must be accommodated by the environment so that human needs who live in the city can be fulfilled. Starting from the need of settlement, basic consumption, and fuel, all these needs must be accommodated by the environment. The question is how much the consumption needs of the population living in Sidoarjo will meet the availability of natural resources? Is the natural resources availability sufficient for the present, and how is the level of ecological sustainability in Sidoarjo regency at this time? Therefore, in this study used measures of environmental carrying with an ecological approach and explaining its implication in spatial development.

2. Data and Methods

2.1 Collecting Data

Data collection in this research using secondary data was obtained from government's data and literature. The data used as illustrated in Table 1

Table 1. Data for Biocapacity and Ecological Footprint Calculation (Analysis, 2017)

Aim	Data Input	Data Collecting Process
Biocapacity Calculation	1. Population of the Regency 2. Productivity of each land use 3. Constructed Area	1. Literature Study 2. Secondary Survey (Government's office) 3. Constructed Land by processing Landsat 8 Imagery
Ecological Footprint Calculation	1. Population of the Regency 2. Consuption of each land use 3. Area of each land use	1. Literature Study 2. Secondary Survey (Government's office) 3. Constructed Land by processing Landsat 8 Imagery
Sustainability Estimation	Result from biocapacity and Ecological Footprint Calculation	

2.2 Analysis Method

2.2.1 Biocapacity Calculation Method

The calculation of Natural Resources availability level was done to know the amount of capability of ecosystem services available for public consumption in Sidoarjo Regency. Land use calculation were processed from *Badan Informasi Geospasial* Satellite Imagery and then classified into specific type of land, namely agricultural land, terrestrial fisheries, forestry and constructed land. For biocapacity calculations all land categories were calculated using the ecological footprint approach. With this approach, the calculation of the quality of the area was converted as a standard bioproductive area.

Based on the method developed by [7] in Guidebook to the National Footprint Accounts 2011 Edition, the biocapacity for all land categories is calculated using the following equation:

$$BC = A.YF.EQF \quad (1)$$

BC : Biocapacity
 A : Land area of each land category
 YF : yield factor
 EQF : Equivalence factor

In the calculation of ecological footprint (EF) and biocapacity calculation (BC), 2 (two) conversion factors are used:

- **Equivalent Factor**
 Equivalent factor is a factor that converts a particular local unit into a universal unit, the global hectare (Gha). Equivalent factors have been determined by the Global Footprint Network for 5 (five) categories of land, namely agricultural land (2.56), forest land (1.28), fishery land (0.35) and constructed land (2.56). This factor is measured from the level of sustainability of land type and population dependence on the land category.
- **Yield Factors**
 Based on the method developed by GFN which also refers to Borucke et al [8], Yield factor is ratio between the productivity of a land category in certain area with the average of productivity of same land category in the world and in the same year. The following equation:

$$YF_L = \frac{YN_{,i}}{YW_{,i}} \quad (2)$$

YFL : Yield Factor for L Land Category
 YNL : Land productivity (yield) of L land category in the calculation area
 YWi : World yield productivity for product i.

2.2.2 Ecological Footprint Calculation Method (Consumption)

The calculation of the amount of land consumption was carried out to determine the needs of the community from the nature that was reflected in the net consumption of categorized products such as agricultural land products, livestock, forestry, buildings, and energy consumption. Based on the ecological footprint approach, the calculation of the formula used is as follows

$$EF = P.YW.EQF \quad (3)$$

EF : Ecological Footprint
 P : Number of products harvested or waste generated (consumption in the area)
 YN : Productivity of land category in the calculation area
 YW : Productivity of the world land category

2.2.3 Ecological Sustainability Calculation

This analysis was done by calculating the condition of land carrying capacity through the calculation of ecological deficits. The ecological deficit can be calculated using the following equation:

$$ED = BC \text{ total} - EF \text{ total}$$

ED : Ecological deficit
 EF total : Total Ecological footprint
 BC total : Total Biocapacity

Ecological deficits occur when the Ecological Footprint of an area exceeds its Biocapacity. Hence, the consumption of the population is greater than the capacity or ability to provide the resources of a particular region. In summary, deficit conditions occur when Ecological Footprint of Land > Biocapacity

of Land. On the other hand, an area will experience a surplus condition if the consumption needs of the population or the ecological foot of the land is no greater than the biocapacity of the land.

3. Result and Discussion

3.1 Biocapacity

In the calculation of biocapacity of Sidoarjo regency needed the harvesting factor and the equalizing factor. The harvesting factor is the ratio between land productivity in a region and the world's productivity of the same type of land at the same time [8]. To obtain the value of harvest factors, then calculated in advance the land use productivity of Sidoarjo regency with the same land productivity in the larger scope of Indonesia. This is done to compare the extent and productivity of land in research areas globally on the same commodity (Table 2)

Table 2. The Harvesting Factors of Each Type of Land Use (Analysis, 2017)

Region	Agricultural Land		Forestry Land		Terrestrial Fisheries	
	Y _w = 25,93		Y _w = 0,82		Y _w = 62,21	
	YNL	YF	YNL	YF	YNL	YF
Sidoarjo Regency	14,10	0,54	0	0	16,04	0,26

The Harvesting factors can be an indication that the productivity of land in a region is better or smaller than the productivity of the world's land in the same year. From the calculation table above harvest factors note that the land productivity of Sidoarjo is small compared to the productivity of land Indonesia. In addition, the forestry value is 0 because in Surabaya there is no forestry land, in this case protected forest and production forest.

The equalizing factor is the factor that converts the unit of land, either hectare or other units, into globalhectare units (gha) (Table 3)

Table 3. Equivalence Factors for Each Type of Land Use [5]

Land Use Type	Equivalence Factors
Agriculture Land	2.56
Forestry Land	1.28
Terrestrial Fisheries	0.35
Constructed Land	2.56

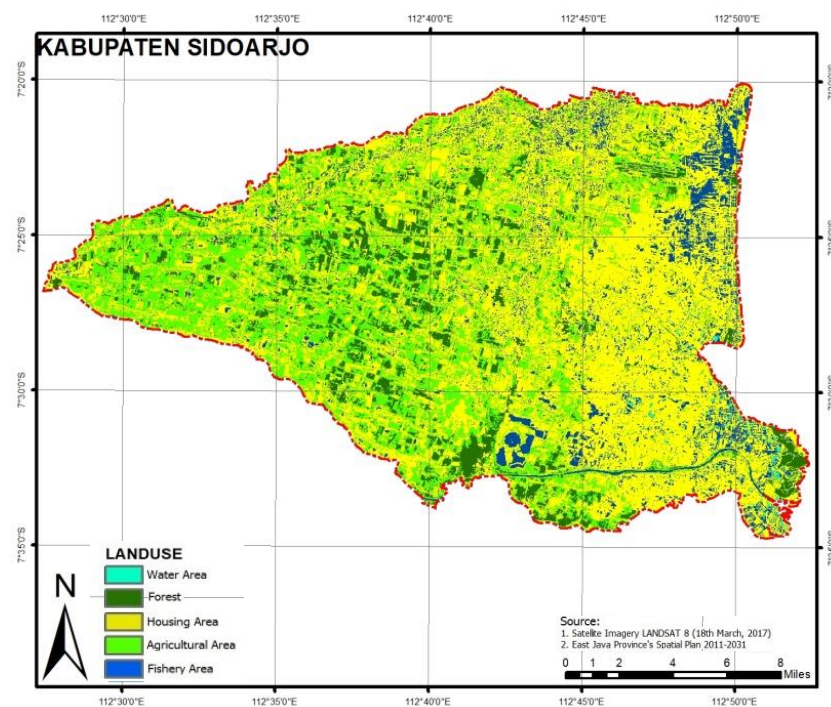


Figure 1. Landsat 8 Imagery Process Result for Each Land Use (Analysis, 2017)

The picture as illustrated in Figure 1 depicts a land use map in Sidoarjo Regency in 2017 covering agricultural land, forestry, terrestrial fisheries, and constructed land. This land use data is used to calculate biocapacity in Sidoarjo regency. In this method of calculation, in accordance with the [5], the biocapacity and ecological footprint of the constructed land is always directly proportional. This is because both illustrate the loss of bio-productivity due to the addition of infrastructure. Therefore, in this study, it is assumed that the biocapacity and ecological footprint of the built land both reduce bioproduction due to infrastructure development so that the number of ecological footprints and biocapacity of the built land will be equal (Table 4)

Table 4. Biocapacity of Each Land Use Types in Sidoarjo Regency (Analysis, 2017)

Region	Biocapacity (Gha)				Biocapacity Total (Gha)
	Agriculture	Forestry	Terrestrial Fisheries	Constructed Land	
Sidoarjo Regency	25,775,01	0	563,59	55,848,72	82,187,32

The table shows that the greatest biocapacity value of Sidoarjo regency is constructed land, Sidoarjo regency plays role as the main support area of Surabaya City regarding the provision of settlement. The rise of population also affects the availability of constructed land. As for other land categories: agriculture 25,775.01 Gha and terrestrial fisheries 563,59 Gha. For forestry land the biocapacity value is 0 because in Sidoarjo there is no protected forest and production forest.

3.2 Ecological Footprint

Ecological Footprint calculation is based on the calculation of natural resource consumption which is the amount of community need for natural resources in fulfilling their life needs. Ecological footprint calculations consist of land cover types such as agricultural land, forestry land, fishery land and constructed land.

The average consumption of agricultural products are rice, corn and soybeans. In 2016 rice consumption was reaching 78.96 kg / capita / year, corn consumption of 5.28 kg / capita / year and 23.76 kg / capita / year. So the total consumption average is 108kg / capita / year or equal to 0.108 ton / capita

/ year. The ecological footprint of agricultural land comes from the total consumption of rice, corn, and soybeans as the main ingredient for meal. Furthermore, the value of consumption is changed to Gha through an ecological footprint formula (Table 5)

Table 5. Ecological Footprint of Agricultural Product (Analysis, 2017)

Region	Consumption (ton)	EQF Agriculture Product = 2.56		EF (Gha)
		YKL	YFL	
Sidoarjo	228.666	14.10	0.37	22,419

Forestry products are used as emissions absorber. The ecological footprint of forest land is obtained by calculating carbon sink demand and wood consumption requirement. The need for carbon sinks is obtained through the carbon footprint of vehicle and the use of electricity that is converted in Gha units by dividing land cover and multiplying by forest land factor. Sidoarjo regency does not have forestry land so it does not have forest products (Table 6).

Table 6. Conversion Value of Fuel Every Unit Vehicle [9]

Types of Fuel	Amount of usage (litre/year/unit)
Gasoline	140,28
Diesel Fuel	3,819,1

Based on the Table 7, the number of vehicles and the conversion of fuel consumption can be seen as total vehicle consumption in Sidoarjo regency as shown by Table 7. In addition, daily activities using electrical energy are also included in emissions-producing consumption. The total electricity used in Sidoarjo is 3,055,215,620 KwH. The total ecological footprint of the Sidoarjo forestry field is 33,643.80 Gha (Table 8 and Table 9).

Table 7. Sidoarjo's Vehicles Fuel Consumption (Analysis, 2017)

Small Vehicles	Conv	Large Vehicles	Conv	Total Consumption (litre/year/unit)	Emission Factor	Total Emission
1,446.358	140,28	46.054	3.819,1	378,779,931,6	2,5	946,949,829,10

Table 8. Total Emission (Analysis, 2017)

Electricity Consumption	Emission Factor	Value	Total Vehicles Emission	Total (ton)
3.055.215.620	0,72	2.199.755.246	946.949.829,10	3.146.705,076

Table 9. Ecological Footprint of Forestry Land (Analysis, 2017)

Carbon Emission (degradation potency of trees: 93,53) EQF= 1,28				EQF= 1,28		Total EF/TE (Gha)
Vehicles Emission	Electricity Emission	EF/TE (Gha)	Consumption (Ton)	YKL	YFL	
946.949.829,10	2.199.755.246	33.643,80	-	-	0	33.643,80

Consumption of fishery products based on Marine and Fishery Data of East Java in 2016 is 11.76 kg/ capita/year which is a combination of consumption of pond and sea fisheries. While in this study,

consumption of fishery products is limited to consumption of terrestrial fisheries products with an average consumption of 0.0034 tons/ capita/year and multiplied by the population of Sidoarjo Regency to obtain total consumption (Table 10).

Table 10. Ecological Footprint of Terrestrial Fisheries Product (Analysis, 2017)

Total Popoulation	EQF Terrestrial Fisheries = 0,35			
	Consumption (ton)	YKL	YFL	EF/TE (Gha)
2.117.279	8.844,06	16,04	0,26	50,18

The calculation of the ecological footprint of the constructed land with EQF 2.56. Total Ecological Footprint of Constructed land in Sidoarjo Regency are 55.848,72 Gha (Table 11 and Table 12).

Table 11. Ecological Footprint of Constructed Land (Analysis, 2017)

EQF Constructed Land = 2,56		
Consumption (Ha)	YFL	EF/TE (Gha)
40.399,83	0,54	55.848,72

Table 12. Total Ecological Footprint of Sidoarjo Regency (Analysis, 2017)

Area	Ecological Footprint (Gha)				Total EF (Gha)
	Agriculture	Folrestry	Terrestrial Fisheries	Constructed Land	
Sidoarjo	22.419	33.643,80	50,18	55.848,72	111.961,71

Sidoarjo regency has a high ecological footprint value as compared to other regencies/cities in GKS metropolitan area. This is because Sidoarjo regency is a buffer zone directly to Surabaya as the second largest city in Indonesia, causing the population growth and the necessity of life mainly on the needs of settlement land. This happens because of the high population due to urbanization, in addition to the high use of motor vehicles exacerbate the ecological footprint conditions in Sidoarjo regency. Of the total ecological footprint value, the highest value is in the constructed land and the lowest is the ecological footprint of the terrestrial fisheries land.

3.3 Ecological Sustainability Condition

The ecological sustainability level is come from calculation's result of biocapacity and ecological footprint of Sidoarjo regency by comparing whether the environmental conditions in Sidoarjo Regency are a deficit (beyond the carrying capacity of the land) or surplus (consumption is still less than the carrying capacity) (Table 13).

Table 13. Total Value of Biocapacity and Ecological Footprint (Analysis, 2017)

	Land Types				Total
	Agriculture	Forestry	Terrestrial Fisheries	Constructed Land	
Biocapacity	25.775,01	0	563,59	55.848,72	82.187,32
Ecological Footprint	22.419	33.643,80	50,18	55.848,72	111.961,71
Condition	Surplus	Deficit	Surplus	Deficit	Deficit

The ecological footprint table above shows that in Sidoarjo Regency has experiencing a deficit due to the existing biocapacity condition cannot accommodate the requirement of high level of consumption. For each category land also experienced deficit except terrestrial fisheries and Agriculture.

3.4 Implication on Spatial Development

A deficit result indicates the implications for future land needs in achieving sustainable regional development. Emissions of vehicles and electricity provide a major contribution to the value of a large

ecological footprint in Sidoarjo regency. Land use change from agricultural area to constructed land also significantly occupied large area due to the needs of settlements that cannot be accommodated by the Surabaya city because of limited land.

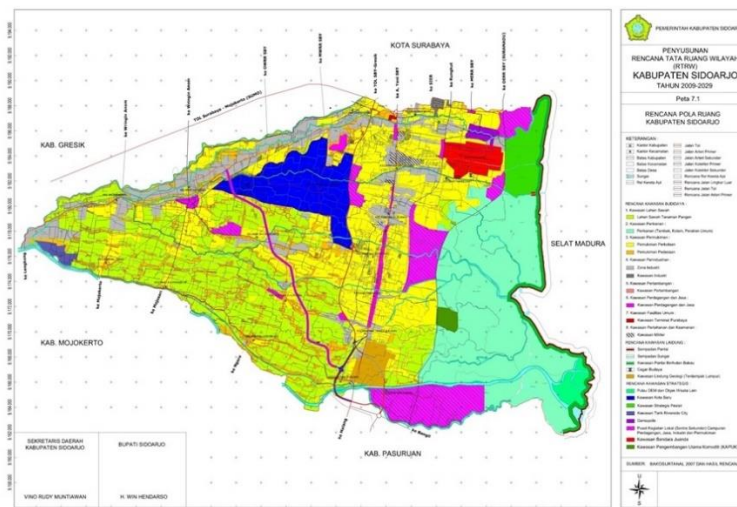


Figure 2. (Sidoarjo Spatial Plan, 2009)

Based on the Sidoarjo Spatial Plan year 2009-2029 (Figure 2), land use is still focused on the provision of settlements, and industries in the northern region of the Regency, while in the southern part is the agricultural area. The conversion of agricultural land into residential areas occurred in the southern part of the "Kota Baru" plan in Sidoarjo to accommodate housing needs.

To achieve ecological sustainability in the district of Sidoarjo, it is necessary to improve the quantity and quality of Green Open Space and Green Pedestrian Way in urban areas. In addition, tree planting can also be done to reduce ecological footprint due to vehicle emissions. In an effort to support ecological sustainability and fulfillment of the needs of Sidoarjo and surrounding areas, urban farming, as well as the involvement of environment-based agricultural technology, can be used as an input for spatial planning and policy to be implemented in Sidoarjo regency. One of the development which can be implemented is SEA (Strategic Environmental Assessment). SEA is an instrument which is developed to manage environmental protection and promoting sustainability by increasing strategic action by focusing in environmental constraints on the plan making [10].

4. Conclusion

Estimation of ecological sustainability level of Sidoarjo regency can be done by calculating biocapacity condition or resource availability level with ecological footprint or consumption level. Based on the calculation, it is concluded that Sidoarjo regency has an ecological deficit where the existing resources have not been able to meet the needs of population consumption in Sidoarjo with Ecological Footprint of 111.961,71 and biocapacity of 82,187.32. Contributors of the largest ecological footprint value of carbon emissions are not absorbed due to the lack of green open space and the absence of forest land to neutralize the carbon emissions. While on agricultural land and terrestrial fisheries, the ecological condition is still surplus, so that Sidoarjo Regency is still able to support the consumption needs of a terrestrial fisheries and agriculture in other areas especially Surabaya city as the main growth center in East Java.

The ecological deficit of the whole calculation shows the need for policies to overcome the negative impacts, such as Strategic Environmental Assessment (SEA) with the addition of green open space and the planting of trees and greenways in minimizing carbon emissions that contribute the largest ecological footprint in Sidoarjo regency.

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