# Ecological Footprint Analysis for Regional Development in Mojokerto Regency, East Java Province - Indonesia

Eko Budi Santoso, Belinda Ulfa Aulia, Vely Kukinul Siswanto and Atina Ilma



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*Sub-Theme 1: Governance*


**Eko Budi Santoso**

Department of Urban and Regional Planning, Faculty of Architecture, Design, and Planning, Sepuluh Nopember Institute of Technology (ITS), Campus ITS Sukolilo, Surabaya 6111, Indonesia

e-mail: eko_budi@urplan.its.ac.id

**Belinda Ulfa Aulia**

Department of Urban and Regional Planning, Faculty of Architecture, Design, and Planning, Sepuluh Nopember Institute of Technology (ITS), Campus ITS Sukolilo, Surabaya 6111, Indonesia

e-mail: b3ltown@gmail.com

**Vely Kukinul Siswanto**

Department of Urban and Regional Planning, Faculty of Architecture, Design, and Planning, Sepuluh Nopember Institute of Technology (ITS), Campus ITS Sukolilo, Surabaya 6111, Indonesia

e-mail: vely.kazu@gmail.com

**Atina Ilma**

Department of Urban and Regional Planning, Faculty of Architecture, Design, and Planning, Sepuluh Nopember Institute of Technology (ITS), Campus ITS Sukolilo, Surabaya 6111, Indonesia

e-mail: atinailma08@gmail.com



## Abstract

*Mojokerto regency has an important ecological function because this region consists of an area of hills, protected forests, national parks, and disaster-prone, also as a buffer area for the Gerbangkertosusila region. Therefore, it is necessary to consider the environmental carrying capacity for the development of the region. This study aims to measure the existing ecological carrying capacity conditions in Mojokerto regency, consisted of bio-capacity, ecological footprint and ecological deficit. The ecological footprint approach is a calculation to determine the level of ecological environmental balance in Mojokerto regency based on the land use patterns and utilization. This approach measures the level of occupational population against the carrying capacity of the land that is using the quantitative model. The research variables using the size of land area according to the type of land use, for example, agricultural land, industrial land, residential land, forest land, and conservation land. This measurement is based on two data sets from 2002 and 2014 to compare and evaluate the regional development based on the ecological deficit condition.*

*The result of the bio-capacity value from entire area is 395,118 Gha in 2014. While in 2002, the value of bio-capacity is 293,628 Gha, which means in 2014 the value has increased up to 35%. The bio-capacity greatest contribution possessed by agricultural land with 46%, followed by husbandry land with 26%, built up land with 16%, land for absorbing carbon emissions by 6% and fishing ponds by 2%. There is a slight change compared to bio-capacity value in 2002, of which 60.3% is agricultural land, built up land by 18.9%, forest land by 12.3%, husbandry land by 8.2%, and fishing ponds by 0.4%. While the ecological footprint on 2002 are 181,166 Gha, and on 2014 are 318,272 Gha, therefore it increased up to 132%. The conditions of ecological deficit showed in 2002 estimated 101,140 Gha while in 2014 estimated 4,866 Gha. So there declined up to 95%. Most of the agricultural* *land and forestry land have surplus by a considerable margin. While the area with the characteristics of high population density such as land settlement shows the high level of deficit.*

Keywords: Ecological Footprint, Environmental Carrying Capacity, Biocapacity, Regional Development.

## Introduction

Mojokerto regency, which is one of districts with the highest density in East Java, experienced land area reduction of 331.1 Ha in protected forest area during 2012 until 2014, and 9 Ha in production forest area in 2013 until 2014. As quoted from the potential problems of Regional Spatial Plan (RTRW Kabupaten Mojokerto), the decrease of forest land area is caused by forest land encroachment. Whereas ecologically, the forest land area is directed as a water catchment area. On the other hand, the direction of Province Spatial Plan (RTRW of East Java Province) establishes this region as the industrial development cluster of Jombang-Mojokerto region. This has led to the widespread development of planned industrial estates in the research area to increase, as shown in the 2011-2012 period. Similarly, the number of land expansions for the built up area has tripled from the previous year. This shows that Mojokerto regency has significant change of environmental function, amidst the population growth and the need for land to fulfill the increase of human activity. Forms of land used in the framework of regional development planning should be done in order to achieve the optimization of existing land resources, so that a better order and environmental sustainability is maintained.

The calculation of environmental balance in terms of the availability (supply) of land area with the needs (demand) of society, due to the development of population activity is urgent to be controlled. The concept of environmental carrying capacity is closely related to the question of how much land area is needed to support human needs (Santoso et al, 2014). Ecological footprint provides a calculation system that tracks how large a region's regenerative capacity is to human needs to produce the ecological resources and services, and compares it with how much regeneration capacity is available from the ecological assets (Galli, 2015). Ecological Footprint is a reflection of the level of utilization of natural resources by the community in the fulfillment its needs, where the comparison between the ecological footprint with biocapacity will show a picture of the sustainability of a region (Ditjen Penataan Ruang, 2010).

Mojokerto's strategic role to GKS region gives the consequences for population increase and consumption of natural resources. This consequence particularly needs to be anticipated in urban areas with population growth rates far exceeding growth rates in rural areas. The Mojokerto region that belongs to the metropolitan area of GKS region is a metropolitan area with a very high concentration of urban activity compared to other urban areas in East Java. In order to achieve the goal of sustainable development, it is necessary to study the level of environmental supporting capacity in Mojokerto regency. Therefore, in this study will be studied the level of sustainability of Mojokerto region through measuring the level of environmental carrying capacity of the region through ecological footprint approach.

The Ecological footprint is an indicator of ecological stability. Theories and methods for measuring sustainable development with ecological footprints have been developed over the last decade (Chambers, et al, 2000). Ecological footprint is a measure of sustainability that illustrates the reality of life in a world with limited resources, and is a synthetic indicator used to estimate the impact of the population on the environment due to population consumption activities (Bala and Hossain, 2012).

The Ecological footprint calculations indicate the ecological status of both overall and the status of each type of land use in a particular area. The ecological status is affected by the biocapacity per capita and the ecological footprint per capita. Thus the population is an important point to measure the ecological footprint. If a certain area of land area is not able to support the life of a certain population with a marked decrease in the food availability and the death of population increases and if the carrying capacity has decreased then this condition is called the population explosion (over population) that does not reflect environmental sustainability. This imbalance is called an overshoot and shows that our consumption exceeds the available natural resources and produced annually on earth (Franchetti and Apul, 2013). Thus an indicator of sustainability is formed by measuring the pressure on the ecosystem and the level of ecological demand by humans on the nature of its life (Franchetti and Apul, 2013).

The Ecological footprint consists of 4 (four) important elements of population, land area, productivity (yield / ha) and land resource consumption (ha / capita), the calculation result will be part in calculation of carrying capacity of a region (Retnowati, 2010). The ecological footprint of a region is lower than its biocapacity indicates that an effort to fulfill its needs, the community of the region has used its natural resources by considering its carrying capacity and ensuring the sustainability of natural resources and environment for the future (Retnowati, 2010).

## Research Methodology

### 1. Ecological Footprint Method

Based on the method developed by *Global Footprint Network (GFN) (2012) in Guidebook to the National Footprint Accounts 2011 Edition*, the biocapacity (BK) for all land categories is calculated using the following equation:

$$BK = A.\ YF.\ EQF \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

BK : Biocapacity
A : Land area of each land category
YF : yield factor
EQF : Equivalence factor (Land category equivalence)

While consumption is calculated from net consumption is actual consumption which is influenced by trading activity (export-import) in the following equation:

$$EF = (P/Y_N).\ YF.\ EQF \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

Since, YF = YN / YW, then the EF formula can be simplified as follows:

$$EF = P.Y_W.\ EQF \quad \text{.........................................} (3)$$

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

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

**a. 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 (2.51), forest land (1.26), farmland (0.46), fishery land (0.37) and constructed land (2.51). This factor is measured from the level of sustainability of land type and population dependence on the land category.

**b. Yield factors**

Based on the method developed by GFN (2012) which also refers to Borucke et al (2012), 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:

$$YF_L = \frac{Y_{N,i}}{Y_{W,i}} \quad \text{.........................................} (4)$$

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

Nevertheless, there are several assumptions used for yield factors calculation for several land categories (Borucke et al, 2012), among others;

1. Built up area has the same yield factor as agricultural land based on assumption that urban land used to convert the agricultural land use.
2. Land of carbon emission has the same yield factor as forest land due to limited data and information on carbon emission for other types of land use.
3. Fishery land has a yield factor value of 1, or productivity of world fishery land equals to calculation area. This is due to limitation of world fishery data, especially on inland country/area. FAO organizations are only able to collect fishery data of 57 countries in the world.

**2. Cluster Method**

Cluster method is used to classify county based on ecological deficit similarity condition. Cluster analysis is an easy method for identifying groups of homogeneous objects called clusters. The magnitude of the ecological deficit rate can be interpreted by referring to a study which is conducted by the 2006 China Council for International Cooperation on Environment and Development-World Wide Fund for nature (CCICED-WWF), in which 6 types of territories are:

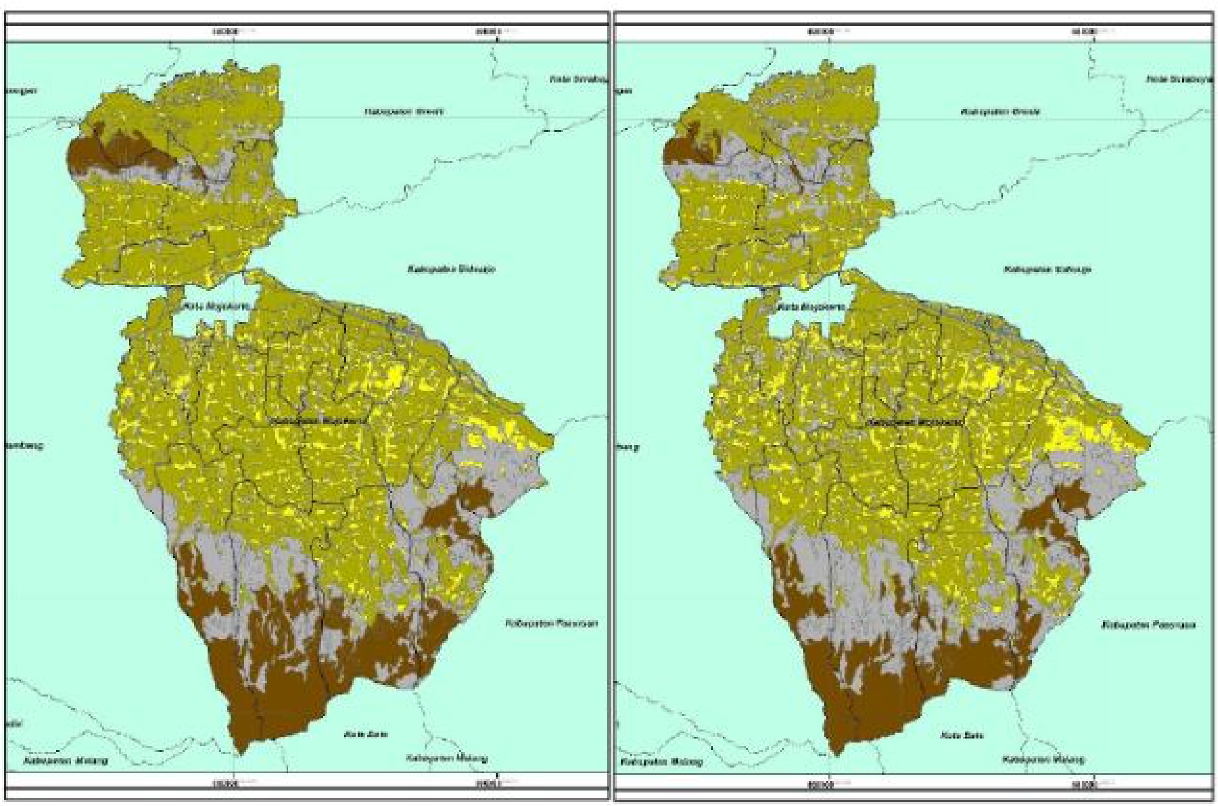
- Very severe deficit (VSD) is region with the carrying capacity is greatly exceeded, if DE> 2
- Severe deficit (SD) if the DE value is at $1 < DE \leq 2$.
- Moderate deficit (MD) if the DE value is at $0.5 < DE \leq 1$.
- Minor deficit (MiD) if the DE value is at $0.1 < DE \leq 0.5$.

• Balanced regions if the DE value is at -0.1 <DE ≤ 0.1.
• Surplus (Reserve regions) if the DE value is in DE ≤ -0.1.

## Results and Discussion

### Land Biocapacity

Biocapacity for agricultural land in Mojokerto Regency in 2002 was 177,066.9 Gha, while in 2014 it was 182,783.74 Gha. In general, compared to the biocapacity of agricultural land in Mojokerto Regency on 2002, it has increased to 3.2%. The value of production and productivity, which increased up to 24% is a major factor in the availability of agricultural land. While the biocapacity of farmland in Mojokerto regency in 2002 amounted to 23,985.5 Gha while in 2014 it was 114,882.78 Gha. To compare with the biocapacity of farmland in 2014, the farmland in 2002 was much smaller. This is related to the productivity level of farms of each sub-district in 2014, which is much greater than the productivity of global cattle fields. As for fishery land, the biocapacity in 2002 was 1,055.7 Gha and in 2014 was 7,589.62 Gha. The biocapacity of fishery land in Mojokerto regency of 2014 has increased significantly in almost all districts, caused by the increase of land productivity, which is quite high. For biocapacity of forest land as carbon emission absorber in 2002 was 36,137.59 Gha, while in 2014 was 25,472.69 Gha. The overall biocapacity of the Mojokerto regency has a greater value in 2002 is compared to 2014.



(a) (b)

**Figure 1. (a) Land use in 2002 and (b) Land use in 2014**

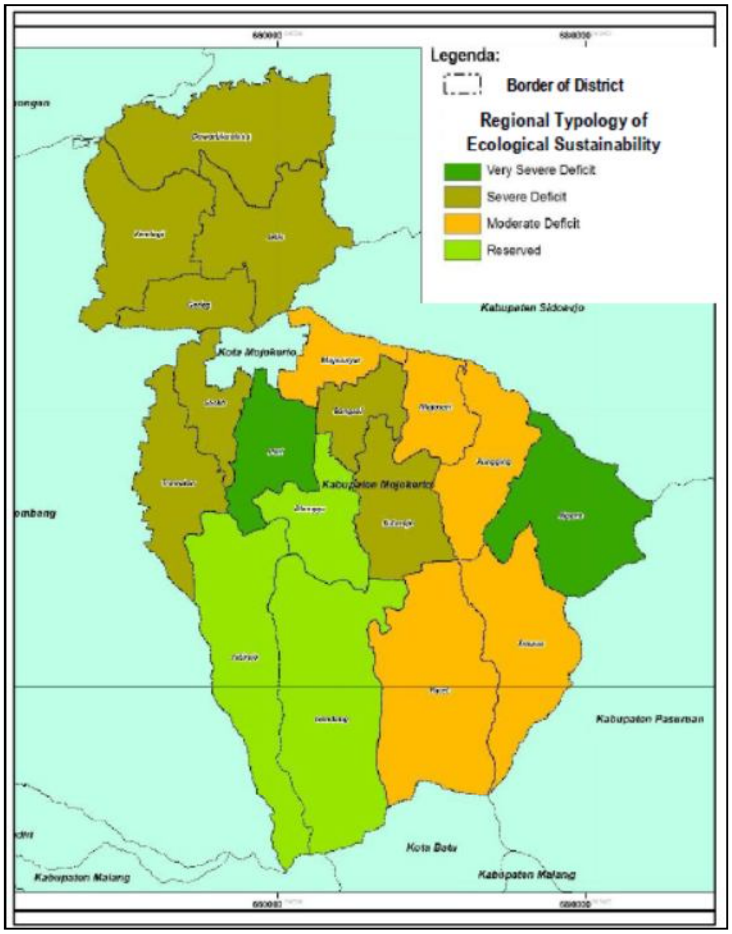
## Ecological Footprint

Ecological footprint of agricultural land in Mojokerto Regency decreased between 2002 and 2014. The consumption was 61,794.46 Gha in 2002 and 40,636.14 Gha in 2014. The amount of purchasing power of Mojokerto Regency decreased up to 41% in 2002 and 2014. So it can be concluded that the level of productivity is inversely proportional to the magnitude of the ecological footprint. This means if land productivity is higher, the ecological footprint is lower. This happens because the land is sufficient to supply food consumption of land products. In the meantime, there was a considerable increase in the ecological footprint of livestock in 2002 by 17,091.7 Gha to 51,110.64 Gha in 2014. The large increase in resource demand was due to population growth and the increasing food needs of the population. The ecological footprint of fishery in 2002 was 13,451.9 Gha which increased to 209,790.79 Gha in 2014. This was due to increased fishery productivity and public purchasing power. Meanwhile, the ecological footprint of carbon emissions released decreased from 2002 to 5,802.17 Gha to 23,668.48 Gha in 2014. As for the ecological footprint of timber production, 2002 was 40,133 Gha and in 2014 10,757.38 Gha.

## Ecological Sustainability Level of Land

The condition of agricultural land measured from the ecological deficit in 2002 increased from 115,273.4 Gha (surplus) to 142,147.6 Gha (surplus) in 2014. For livestock area increased from 6,893.8 Gha (surplus) in 2002 to 63,772.14 Gha (surplus) in 2014. For fishing area decreased in 2002 by 13,451.9 Gha (surplus) to -184,510.28 Gha (deficit). This indicates that the degradation of the land ability in order to meet the needs of the population of Mojokerto regency. While forest land and carbon emissions in 2002 amounted to -9.798.06 Gha (deficit) and in 2014 amounted to -8.953,17 Gha (deficit). In terms for the land of carbon emission absorption, each series of data shows that in each year an ecological deficit occurs. Although in 2002 the biocapacity of carbon emission sinks was much higher, and the release of carbon emissions was much lower when compared to 2014, the high production of timber caused the balance of the environment to deficit. That is, to achieve carbon emission absorption of forestry and production land, the timber production should not exceed 30,335.42 Gha or 19,420.31 $m^3$. While in 2014, the ecological footprint is dominated by the need for carbon emissions absorption by 69% of the total ecological footprint. This means that environmental balance can be achieved if carbon emissions can be reduced to 14,715 Gha or 1,034,829 tons $CO^2$ / year. However, the efforts can be made to increase the green vegetation so that the carbon emission needs can be covered in the future.

**Figure 2 Regional Typology of the Ecological Deficit of Land**




## Regional Typology of Ecology Sustainability

From the results of regional typology, it is found that the Mojokerto regency is divided into four clusters as follows:

• Cluster Reserved Regions (Surplus)
Based on the measurement from its ecological deficits, Jatirejo, Gondang, and Dlanggu districts are classified as surplus districts. The districts of Jatirejo and Gondang have similar characteristics, which are experiencing a surplus on the agricultural land and forestry by a considerable margin, but deficit in other types of land. While Dlanggu District as one of the highest rice producer only experience surplus conditions in agricultural land alone.

• Cluster Moderate Deficit (Fair Deficit)
Some districts such as Pacet, Trawas, Pungging, Mojosari, and Mojoanyar are areas with the fair deficit conditions. Pacet and Trawas districts are areas with deficits on the livestock fields and fishery ponds, as well as on other types of land which still undergoing reserved conditions. In contrast to Pungging, Mojosari and Mojoanyar districts, the type of surplus land is found only on agricultural land. However, the amount of surplus per classification of land in each of these areas is not sufficient to meet the accumulated demand as a whole.

• Cluster Severe Deficit (Very Deficit)
The areas with these ecological deficits (Kutorejo, Bangsal, Trowulan, Sooko, Gedek, Kemlagi, Jetis, and Dawarblandong districts) are regions with similar characteristics with high population density. This has resulted in the absence of sufficient land for forestry, so that any activity of the population that emits carbon emissions can not be reduced well.

• Cluster Very Severe Deficit (Chronic Deficit)
The areas with chronic deficits are found in Puri and Ngoro districts, whose growth despite deficits in farmland, fisheries, and forestry land area. These two areas are among the lowest biocapacity areas, with high demand pressures. This causes a very severe environmental imbalance.
Land use in the Mojokerto regency from year to year has undergone a functional shift, for example agricultural land that has been transformed into residential area, building and industrial area as well as some others are converted into infrastructure. The assessment of environmental suitability follows to particular use at the reasonable level of management and results, while it is maintaining the sustainability of productivity and the environment.
Based on the direction of strategic area plan of Mojokerto Regency according to spatial plan (RTRW of Mojokerto Regency 2012-2032) hence the plan of industrial estate development will be implemented at northern region of Mojokerto regency consist of Dawar Blandong, Jetis, Kemlagi districts. The polluted industrial estate development is directed in Ngoro, Mojoanyar, Jetis, Kemlagi, and Dawar Blandong districts. Based on the results of the assessment of the ecological footprint should be controlled the development of industry on the area because there have been ecological deficits in the area with the category of very and chronic deficit. The development of residential areas on the border of Mojokerto city should also to be controlled because this will increase the population density in Puri, Sooko, Gedeg and Jetis districts.

## Conclusion

Through this Ecological Area Sustainability study, biocapacity or land availability condition, ecological footprint or land consumption, and ecological deficit of the land are known. There are three components that become input to formulate typology according to the characteristics of the sustainability of the land. Total land biocapacity was 395,118 Gha, while in 2002 it was 293,628 Gha or increased by 35%. The largest biocapacity contribution is from agricultural land in the amount of 46%, followed by 26% of livestock farming, 16% of land for built up area, 6% from carbon emission absorption land, and 2% from fishery land. This is slightly changed when compared to the biocapacity of 2002, of which 60.3% is agricultural land, 18.9% of land for built up area, 12.3% of forestry land, 8.2% of farmland, and 0.4% of fishery land.

While the ecological footprint of 2014 was total 318,272 Gha, in 2002 it was 181,166 Gha, or has increased to 132%. The condition of the ecological deficit shows that in 2002 it was 101.140 Gha while in 2014 it was 4,866 Gha. That is, there was a decrease of up to 95% in that time. Based on the measurement from the regional typology of land sustainability, there are 4 groups / cluster which are surplus, fair deficit, very deficit, and chronic deficit. This cluster is divided according to the ecological deficit value of each region. In the surplus area, most experience surpluses in agricultural and forestry areas with considerable margins. While the area is sufficiently deficit, most of it is a type of surplus land only found on agricultural land. On very deficit land, it is a region with similar characteristics, i.e high population density. The area of chronic deficits is the region that belongs to the lowest biocapacity value with high demand pressure. The development of residential and industrial areas in areas whose ecological carrying capacity decreases should begin to be controlled, both in order to reduce the population density and carbon emissions in the region.

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## References

Bala, B.K and Hossain, M. A. (2013). “Modelling of Ecological Footprint and Climate Change Impacts on Food Security of the Hill Tracts of Chittagong in Bangladesh”. *Environment Model Journal* Vol 18. Springer Science.

Chambers, N., Simmons, C., Wackernagel, M. (2000) *Sharing Nature's Interest: Ecological Footprints as an Indicator of Sustainability*, Earthscan Publications Ltd., London.

Franchetti, M. J., & Apul, D. (2013). *Carbon footprint analysis: concepts, methods, implementation, and case studies.* Boca Raton, FL: Taylor & Francis.

Galli, Alessandro (2015). “On the rationale and policy usefulness of Ecological Footprint Accounting: The case of Morocco”, *Environmental Science & Policy*, Volume 48, April 2015, Pages 210-224.

Global Footprint Network, (2016). *Working Guidebook to the National Footprint Accounts, 2016 Edition. Available at* http://www. Footprintnetwork.org

Moore, David (2011), *Ecological Footprint Analysis San Francisco-Oakland-Fremont, CA.* Available at http://www. Footprintnetwork.org

Murray Lane (2010), “The carrying capacity imperative: Assessing regional carrying capacity methodologies for sustainable land-use planning”, *Land Use Policy*, Volume 27, Issue 4, October 2010, Pages 1038–1045.

Robert G. Bailey. (2002), *Ecoregion-based design for sustainability*, Springer-Verlag , New York

Rees, William and Mathis Wackernagel (1996), *Urban Ecological Footprints: Why Cities Cannot Be Sustainable And Why They Are A Key To Sustainability*, Elsevier Science Inc., New York

Retnowati, Inge. (2010). *Kajian Telapak Ekologis: Pertimbangan Untuk Strategi Pembangunan Berkelanjutan*

Santoso et al, (2014). “Concept of Carrying Capacity: Challenges in Spatial Planning”, *Procedia - Social and Behavioral Sciences* 135 (2014), 130 – 135.