Application development of the ecological footprint calculator in support of sustainable development

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Abstract. Sustainable development in Indonesia should take into account the ability of natural resources in every region to meet the growing needs of society. The balance between the availability of natural resources and resident needs can be seen from the analysis of ecological footprint. The scope of the area used in this paper is in Gerbangkertasusila East Java with a focus on the ecological footprint in the food sector. The Ecological Footprint is derived by tracking how much biologically productive area it takes to provide for all the competing demands of people. These demands include space for food growing, fiber production, timber regeneration, absorption of carbon dioxide emissions from fossil fuel burning, and accommodating built infrastructure. The analysis of ecological footprint is a complex calculation to be done because it includes a component of demand and supply in various products in each land use. The development of digital data provision on sustainable development information especially the ecological footprint of the region is required to be more open and understandable. The ecological footprint calculator application is presented to provide calculation information on the conditions of surplus or ecological deficits of a region. The ecological footprint calculator application is used to figure out the balance of the supply side and the demand side of the environment of a region easier based on the android system.

1. Introduction

Earth provides natural resources to support human life where they live and carry out activities, so that people daily consume goods and services derivated from nature with its various impacts (Athira Ravi, 2013). Every consumption of goods and services carried out by humans should be counted as an ecological footprint. An accounting tool is needed to measure how much the productive land is required to produce the goods and services for the consumption by the people and their activities, and also to absorb the waste. The biological capacity is measured to provide the products and services that is needed by the people (Moore et al, 2013). The biological capacity as a supplier of human needs should be greater than the demand for the production of goods and services from natural resources so that the needs of human life are fulfilled.

Ecological footprint is an environmental carrying capacity approach by identifying components of natural resource consumption and waste, and the availability of natural resources in each type of land use (Rees, and Wackernagel, 1996). This can be seen from the biological capacity value and ecological footprint of each region according to the sustainability level of a type of land use. The estimation of The biologically productive land is important part to measure the supply of the renewable resources that the people consume and also to absorb the wastes it generates. The resource-management practices and prevailing technology determine how many people can be supported by the biologically productive land.
The Ecological footprint is important to measure the natural assets that the people require to produce the natural resources it consumes and also to absorb its waste, especially carbon emissions.

The population is increasing but not balanced with the provision of natural resources to challenge a region. If a population’s ecological footprint exceeds the region’s biological capacity, that region runs an ecological deficit. Conversely if a region’s biological capacity exceeds its Ecological Footprint, it has an ecological reserve. Therefore each region must be able to measure the balance of the availability of its natural resources to avoid an ecological deficit. The preparation of a natural resource balance can be carried out by a region through an ecological footprint approach.

Sustainable region should take into account the ability of natural resources in every region to meet the increasing demands of population. The balance between the availability of natural resources and population needs can be seen from the analysis of ecological footprint. The analysis of ecological footprint is a complex calculation to be done because it includes a component of demand and supply in various products in each land use. The development of digital data provision on sustainable development information especially the ecological footprint of the region is required to be more open and understandable.

The application development is presented to provide calculation information on the conditions of ecological surplus or deficits of a region and the ecological footprint calculator application is used to figure out the balance of the carrying capacity and capacity of the environment of a region easier to calculate based on the android system. So that ecological footprint measurements can be carried out effectively and efficiently, there is needed an application that is able to provide real time information and reports related to the supply and demand of natural resource assets, both at the local and regional levels.

2. Methods

**Application Interface**

The Ecological Footprint Calculator is developed in the form of an android mobile using the Kotlin programming language. Besides, Ecological Footprint Calculator also developed in the form of a website.

**Basic build formula for Ecological Footprint Calculator**

The Ecological footprint is obtained by tracking how much biological productive area is needed to meet all the needs of competing people. These demands include space for providing food, producing fiber, replanting wood, absorbing emissions from burning fossil fuels, and accommodating built infrastructure. The consumption of a region is calculated by adding imports to and subtracting exports from the production of the region. The Ecological Footprint uses the results of the main products (from agriculture, forest, grazing land and fisheries) to calculate the area needed to support certain activities. To make biocapacity comparable across time and space, the area is proportional to its biological productivity. This adjusted area is expressed in "global hectares". (www.footprintnetwork.org).

2.1. Yield Factor

The formula for the yield factor calculation for each type of land use is as follows:

\[
YFL = \frac{YKL}{YWL}
\]  
(Eq. 1)

**Description:**

\[YFL = \text{Yield Factor of Land Use L}\]
\[YKL = \text{Productivity of Land Use L in Region K}\]
\[YWL = \text{Productivity of Land Use L World}\]

2.2. Biocapacity

Here the explanation about the research methods

After known yield factor and other factors of the region, the calculation of Biological capacity (supply) in each district/city in the research area. The following are the formula:
$$BC = A \times YF \times EQF$$  \hspace{1cm} (Eq. 2)

**Description:**
- **BC** = Biocapacity
- **A** = Land area
- **YF** = Yield Factor
- **EQF** = Equivalence factor

### 2.3. Ecological Footprint

After knowing biocapacity of the region, the calculation of ecological footprint (demand) in each district/city in the research area. The following are the formula:

$$EF = \frac{P}{YKL \times YFL \times EQF}$$  \hspace{1cm} (Eq. 3)

**Description:**
- **EF** = Ecological footprint
- **P** = Product of land
- **YKL** = Productivity of Land Use L in region K
- **YFL** = Yield Factor of land Use L
- **EQF** = Equivalence factor

### 2.4. Balancing Carrying Capacity

The balance analysis of the carrying capacity is done by calculating the calculation result of ecological palms and the accounting of each district/city.

$$ED = BC \text{ total} - EF \text{ total}$$  \hspace{1cm} (Eq. 4)

**Description:**
- **ED** = Ecological deficit
- **BC total** = Biocapacity total
- **EF total** = Ecological Footprint total (total BK)

### 3. Result and Discussions

Ecological footprint in Gerbangkertosusila (Gresik, Bangkalan, Mojokerto, Surabaya, Sidoarjo and Lamongan) is surplus and deficit in several regions, show the consumption of people not exceeding the threshold of land ability in Gerbangkertosusila. The surplus condition can also be a reference for optimal development at Gerbangkertosusila in the future. However, when a union is reviewed, some region has a deficit condition.

The region that suffered the most severe deficit is Kabupaten Sidoarjo 59% and Gresik 72%, this mean that the ecological footprint condition is greater 50 to 100% of its bioactivity. The deficit condition in these two districts is due to an imbalance between community demand and the supply that the region can provide. Also, the regency of Sidoarjo and Gresik is a regency that is directly adjacent to the provincial capital of Surabaya. The deficit that occurred in Gresik and Sidoarjo is mainly caused by activities that produce high carbon emissions. The high population with industrial activities, large quantities of motor vehicles, electricity use, and LPG gas cause carbon pollution to be not absorbed optimally by the biodegraded carbon-absorbent land. The land of carbon absorbent itself is supported by green land from the forest area, rice field, shrub, and other trees or foliage. Gresik Regency itself has low agricultural land while the Sidoarjo regency is also even experiencing a deficit of agricultural land, it also affects the deficit that occurs in the carbon absorbent land. However, in general, other areas such as Bangkalan, Lamongan, and Mojokerto also suffered from the deficit of carbon emissions disposal activities without the provision of optimal carbon absorbent land. Other areas such as the city of Surabaya and Mojokerto also have a deficit in agricultural land, but it is due to its condition as an urban area. The deficit of carbon absorbent land in Surabaya and the city of Mojokerto in addition to being influenced by the agricultural land deficit, also due to insufficient forestry land.
**App Features**

The following list outlines the features of the Ecological Footprint Calculator:

1. Log In
2. Sign Out
3. View Dashboard/Home
4. Calculate Menu for built up land, carbon footprint, grazing land, forest land, and fishing ground

**Step Using Application**

After the result of balancing of carrying capacity known, this research tries to build the application that makes the calculation easier based on Android system. Here is the step to use the application to calculate the ecological footprint on every district and city:

1. This is the interface of ecology calculator, in this page we can start to add the data such as the name of region by click “+” button
2. On the second page input the area/regional identity such as the name of the region, total population and etc
3. On the third page input the agriculture area with Agricultural land area Agricultural production data of the region
4. Input all the data that needed in all page such as farm area, fisheries area, forestry area and building area data.
5. On the last page we need to make sure if the data is correct, so the application can start to calculate all the data that we input.
Figure 1. Test application with Dummy Data

Table 1. Result of ecological footprint calculator using dummy data

| Main Output | Biocapacity       | Ecological Footprint | Ecological Deficit |
|-------------|-------------------|----------------------|--------------------|
|             | 2207.595483       | 135045.1333          | -132837.5378       |
|             | 5.812817161       | 5.250057758          | 0.562759402        |
|             | 0                 | 0                    | 0                  |
|             | 836.156892        | 562836571.4          | -562835735.2       |
|             | 74316.95348       | 74316.95348          | 0                  |
### Main Output

| Biocapacity | Ecological Footprint | Ecological Deficit |
|-------------|----------------------|--------------------|
| Total       | 563045938.7          | -562968572.2       |

**Ecological Deficit Percentage** 99.00013741

### 4. Conclusions

The balance between the availability of natural resources and resident needs can be seen from the analysis of ecological footprint. Sustainable development in Indonesia should take into account the ability of natural resources in every region to meet the increasing demand of society. The analysis of ecological footprint is a complex calculation to be done because it includes a component of demand and supply in various products in each land use. The existing condition on Gerbangkertosusila region look at the ecological deficit is following Gresik district, Surabaya city, Sidoarjo district, and Mojokerto city. The calculation of ecological footprint of region or city look at the ecological surplus is following Bangkalan district, Mojokerto district, and Lamongan district.

Based on this paper it can be concluded that the application of ecological footprint can facilitate the calculation of ecological footprint a region. This application is more effective than calculating manually for calculating the value of ecological balance by simply entering the available data into the ecological footprint calculator for each district to be counted on its ecological footprint. Besides, it can calculate six types of land use easily and quickly by using an application that has been made. Using this application, it can facilitate researchers and policymakers related to environmental sustainability more practice in determining the policies to be taken.

### References

[1.] Anders Hayden. *Ecolofical Footprint*. https://www.britannica.com/science/ecological-footprint

[2.] David Moore, Joy Larson, Katsunori Iha et.al. (2013). *Methodology for Calculating the Ecological Footprint of California*. Produced for the U.S. Environmental Protection Agency under purchase order EP-11-9-000094

[3.] Ravi Athira, Subha V. (2013). *Ecological Footprint Analysis – An Overview*. American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-1 pp-12-19

[4.] Rees, William, and Wackernagel, Mathis (1996), *Urban Ecological Footprints: Why Cities Cannot be Sustainable and Why They are a Key to Sustainability*, Elsevier Science Inc., New York.

[5.] Wackernagel M., Schulz N.B., Deumling D., Linares A.C., Jenkins M., Kapos V., Monfreda C., Loh J., Myers N. and Norgaard R (2002) *Tracking the ecological overshoot of the human economy* P. Natl. Aal Acad Sci. USA 14 9266-927

[6.] Wackernagel M., Monfreda C., Erb K.H., Habe H. and Schulz N.B. (2004) *Ecological footprint time series of Austria, the Philippines, and South Korea for 1961-1999 comparing the conventional approach to an actual land area approach* Land use policy 21 261-269

[7.] How the Footprint Works. https://www.footprintnetwork.org/our-work/ecological-footprint/

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