Journal of Natural Resources and Environmental Management
12(2): 197-209. http://dx.doi.org/10.29244/jpsl.12.2.197-209
E-ISSN: 2460-5824
http://journal.ipb.ac.id/index.php/jpsl

Ecological footprint and biocapacity analysis of upper Cisadane Watershed

Resti Kharisma[a], Herry Purnomo[ab], Budi Kuncahyo[a]

[a] Faculty of Forestry, IPB University, IPB Dramaga Campus, Bogor, 16680, Indonesia
[b] Center for International Forestry Research, Bogor, 16155, Indonesia

Article Info:
Received: 23 - 06 - 2021
Accepted: 18 - 04 - 2022

Keywords:
Biocapacity, Cisadane Watershed, ecological footprint

Corresponding Author:
Resti Kharisma
Faculty of Forestry, IPB University;
Tel. +6285239578113
Email: restikharisma@gmail.com

***Abstract**. The Ecological footprint (EF) is used as a tool to measure human consumption of the natural resource and compare it with the inhabited environment's ability to recover. EF measures the quantity of bio-productivity (BC) areas that would be appropriate to meet the requirements for sustainable resource production activities to fulfill the population's needs and absorb the generated waste. The event 'overshoot' occurs when the EF is greater than the BC. Overshoot usually occurs for a short term but if happens continuously it could cause various forms of degradation to the environment. Cisadane Watershed was chosen as the study location as it was one of the objective areas of the government program to minimize environmental degradation. This study aimed to determine the condition of the upper Cisadane Watershed and determine whether it is an ecological surplus or deficit. The study results explained that the majority of the upper Cisadane watershed experienced an ecological deficit from 2016-2020.*

How to cite (CSE Style 8th Edition):
Kharisma R, Purnomo H, Kuncahyo B. 2022. Ecological footprint and biocapacity analysis of upper Cisadane Watershed. JPSL **12**(2): 197-209. http://dx.doi.org/10.29244/jpsl.12.2.197-209.

INTRODUCTION

Sustainable development has been a long-standing ambition of countries in almost every corner of the world. It is a commitment to creating harmonious development between nature and humans (Wackernagel *et al.*, 2019; Fu *et al.*, 2015). For that reason, it is obvious for even the smallest administration in spatial planning in the form of districts/urban villages or area-based planning such as agriculture areas, fishery areas and so on to integrate the elements of sustainable development into their objectives.

The phenomena of industrialization and urbanization/population growth are commonly followed by massive exploitation of land resources which could further cost some serious challenges to an area (Chu *et al.*, 2017; Luo *et al.*, 2018; Peng *et al.*, 2018). The land has limited capacity in terms of quantity and continuity (Santoso and Aulia, 2018), and frequently, humans consume the natural resources faster than the ecosystem's capacity to recover (Wackernagel *et al.*, 2019; Fu, 2015; Schaefer *et al.*, 2006). This event is called an "ecological overshoot". On that account, it is important to calculate the carrying and holding capacity of an area so that disadvantageous extreme conditions can be immediately detected. Subekti and Suroso (2018) explained that calculating the carrying and holding capacity could help to better understand the capacity limits of an area to support people's lives.

Based on the Indonesian Law no. 32 of 2009 concerning Environmental Protection and Management, carrying capacity is the ability of the environment to support humans, and other living beings, and the balance between them, while holding capacity shall be the ability of the environment to absorb substances, energy, and/or other components incorporated into it naturally or intentionally (KLH, 2014). The calculation of the carrying and holding capacities of the environment can be done by various approaches. Subekti and Suroso (2018) compared 9 (nine) models in calculating the carrying and holding capacities, and among all the models only the ecological footprint model met all the criteria, namely: 1) Maximum population supported by a sustainable environment; 2) interaction between resources availability and demand by a certain population; 3) the ability to support life; 4) the ability to absorb pollutant load.

The EF analysis consists of two components, which are the ecological footprint (EF) and biocapacity (BC). Schaefer *et al.* (2006) stated that EF calculates the appropriate quantity of biologically productive space to support sustainable resource production to fulfill a person/population's needs and absorb the produced waste. BC is the biological production capacity that can be used for a certain period in a productive area. EF or BC can be calculated at the individual/community, district/city, or even national scale according to the data availability. However, one of the drawbacks of EF is that it is still heavily influenced by the availability of administrative-based secondary data.

Studies related to EF, including Toth and Szigeti (2016), discussed how per capita income could be directly proportionate with EF score, and Holden (2012) compared the value of EF and BC to determine if a situation is considered a deficit or a surplus. Muñiz and Garcia-López (2019) research observed how the formation of cities and the impact of transportation/city structure could lead to a higher EF score (city scale). There is also the study by Guo *et al.* (2016) which took place in a watershed area but used the national scale component instead to determine the yield factor and other components. Looking at some previous studies, it has been common to use the national and provincial productivity data to determine the EF score. The Global Footprint Network (GFN) uses national/country scale data, whilst the Indonesian Ministry of Public Works (2010) uses provincial-scale data. Marwa *et al.* (2020) have done a calculation on a district-scale EF score in West Papua Province.

In the same manner, Rahman *et al.* (2020) conducted their study about environmental carrying capacity in East Kalimantan Province with the EF approach but only on food cropland at the city scale. City and district scale calculations have also been carried out in several regions in Indonesia. One example is research by Marganingrum (2019) which found that the Bandung Regional area, bounded by the upper Citarum-Saguling River Basin, experienced an ecological deficit. Rachmawati (2013) also conducted research on the carrying capacity of the Puncak area of Bogor Regency, focusing on 3 (three) districts, namely Ciawi, Cisarua, and Megamendung, and it was learned that all three districts experienced ecological deficits. Furthermore, Desiana and Santoso (2019) calculated the EF in Sukoharjo Regency using district data, and 3 (three) districts out of a total of 12 (twelve) experienced ecological deficit. Meanwhile, the individual EF scores can be conveniently calculated by using the EF calculator that has been developed by GFN, as was done by Navrátil *et al.* (2012) for EF score calculation in the education sector.

This research is important in order to measure the carrying capacity and holding capacity of the studied location using the ecological footprint and the biocapacity approach. The unique insights gained from this research would be a good reference for planning sustainable natural resources management in the future.

METHODOLOGY

Location and Time of Study

The research was conducted from December 2020 to April 2021 in the upper Cisadane Watershed. The research focused on 15 (fifteen) districts within Bogor Regency, covering 69 969.56 ha of the total area of the watershed, that is 151 808 ha. These 15 (fifteen) districts were chosen because they presented the ideal conditions to carry out calculations for EF and BC.

Data Types and Sources

The types of data used in this study were secondary and primary data. A 5-year (2016-2020) data series as the secondary data was obtained from the districts and region's Central Statistics Agency. Data was also taken from the National Calorie and Protein Intakes Report Document. This research procedure was inspired by several past studies, such as Peng *et al.* (2018); Yue *et al.* (2013); Sun *et al.* (2009). Subsequently, all the data were combined with documents, facts, and other data from the Citarum-Ciliwung Watershed Management Agency (BPDAS) and related agencies such as the Food Crops, Horticulture and Plantation Service (BTPH) of Bogor Regency and the Region I Forestry Service (Dishut) of West Java Province. The data collected were regarding the production of food crops, horticulture and plantations commodities. Whilst, fishery, and livestock production data were acquired from Bogor Regency in Figures reports year 2016-2020 from Statistics Indonesia (BPS).

An initial review was done after all the data were collected, and from there, it was learned that there was a lack of data regarding the area quantity of each land use category. The land use area data is one of the absolute requirements for biocapacity calculation. Therefore to complement the existing data, a primary data collection was carried out with the help of satellite imageries interpretation from the last five years (2016-2020). A series of satellite imageries were downloaded from http://eartheexplorer.usgs.gov/ (Table 1). The data trimming and correction processes were carried out with Erdas Imagine 2014, while ArcGIS 10.3 was used for the satellite imagery analysis. Field data collection was done by taking 10-15 points per land use. These were later used for the accuracy test. Arifasihati and Kaswanto (2016) used 15 points per land use for their accuracy test. Global Positioning System (GPS) device was used to mark the coordinates of each point. Exceptions were made beforehand regarding 2 (two) land use/cover types, namely primary forest and rivers.

Table 1 List of satellite imageries used in this study

Year	Remote Sensing Imagery	Path & Row	Acquisition Date
2019	Landsat 8 Operational Land Imagery	122 and 64	25/07/2019
	(OLI)	122 and 65	11/09/2019
2020	Landsat 8 Operational Land Imagery	122 and 64	22/04/2020
	(OLI)	122 and 65	25/06/2020

Data Analysis Methods

Interpretation of satellite imagery was done by combining two processes, namely on-screen digitization and supervised classification. These two processes were employed based on the fact that this research was meant to only complement the secondary data regarding the 2016-2018 land cover/land use retrieved from the Indonesian Ministry of Environment and Forestry (*Kementerian Lingkungan Hidup dan Kehutanan/*KLHK). A similar thing was done by Afrin *et al.* (2019) using the information from the Government of Alberta to categorize land cover and land use. Afterward, the 2016-2018 land cover and land use data were used to create a land category scheme where 13 (thirteen) categories were generated, namely water body, primary forest, secondary forest, plantation forest, airport, plantations, settlements, mining area, dryland agriculture, mixed-crops dryland agriculture, paddy fields, shrubland, and bare land. Image classification is meant to group pixels into categories according to their brightness levels (Jaya, 2010). With the processed data from the KLHK being the base data, this step was not really necessary.

Then, the Kappa formula was employed to determine the map accuracy. The formula considers all elements/cells within the error matrix and is noted as the most relevant for this matter (Jaya, 2010). In addition, Overall Accuracy, Producer's Accuracy and User's Accuracy were also employed to see a simpler form of the ratio between the number of correctly classified pixels and the total number of pixels used when employing the accuracy (for product of land use categorization with field survey results), while user's accuracy is an error when an area is assigned to an incorrect category (Jaya, 2010). In case of difficulty in interpretation due to the presence of clouds and poor knowledge about the location caused by limited access, the authors assumed the land cover/land use was the same as the previous year.

$$\text{Overall Accuracy } OA = \frac{\sum_{i=1}^{r} Xii}{N} \, 100\% \tag{1}$$

$$\text{Producer's Accuracy} = \frac{Xii}{Xi+} \, 100\% \tag{2}$$

$$\text{User's Accuracy} = \frac{Xii}{Xi+} \, 100\% \tag{3}$$

$$\text{Whilst, the formula for Kappa Coefficient is } K = \frac{N\sum_{i=1}^{r} Xii - \sum_{i=1}^{r} X_{i+}X_{+i}}{N^2 - \sum X_{i+}X_{+i}} \tag{4}$$

Biocapacity Analysis

Biocapacity is the capacity of an ecosystem to produce products from its land for fulfilling individual needs and to absorb waste generated from human activities. There are various types of land use based on bio capacity and EF, namely agriculture land, pastureland, fishery area, forest, and built-up area. The equivalent value (EQF) and harvest factor (Yield Factor) are noted as the ratio of the average production of an area from each land use. The YF and EQF values for Indonesia are as follows Table 2 below:

Table 2 YF and EQF values

Land Use Type	Indonesia Yield	World Yield	Yield Factor	EQF
Agricultural Land	7.32	7.42	0.99	2.49
Pastureland	17.33	6.19	2.80	0.46
Forest	1.12	1.82	0.61	1.28
Freshwater Fisheries	0.00	0.00	1.00	0.37
Built-up Area	0.00	0.00	1.00	2.49

Source: Lin *et al*. (2018).

The formula for calculating biocapacity based on the Global Footprint Network is as follows:

$$\text{BC} = \text{A x YF x EQF} \tag{5}$$

where A is the area quantity of each land use (ha), while YF is the harvesting factor and EQF is the equivalent value. Please refers to Figure 1 for calculating BC and EF.

Ecological Footprint Analysis based on Production Results

EF is the amount of land and water sources needed to support the life and needs of population in a certain area and to absorb the generated waste/emissions for a certain number of years. EF calculation based on Lin *et al.* (2018) is:

$$\text{EF} = \frac{P}{Yw} XEQF \tag{6}$$

Notes: P is the total production or yield of tons per year, Yw is the average productivity of the world/province or district/city (ton/ha/year), while EQF is a fixed equivalent factor.

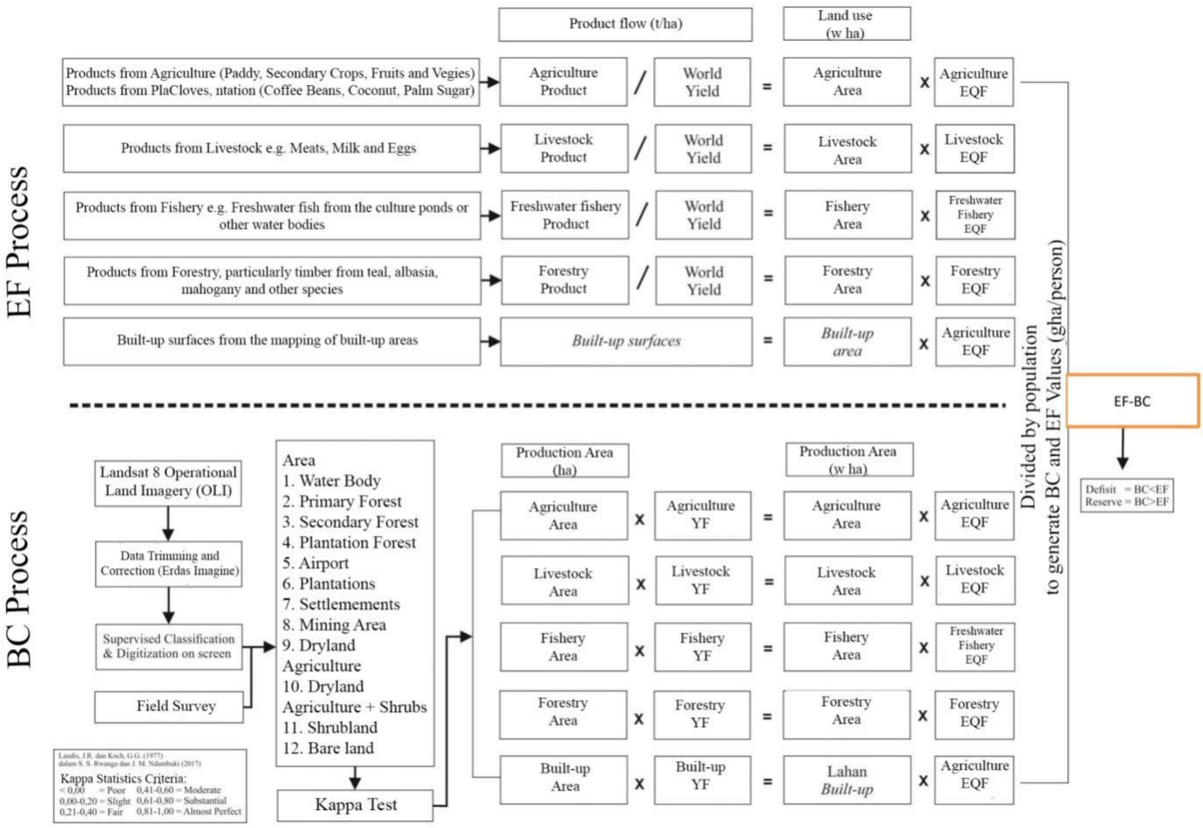

Figure 1 Research flow

RESULTS AND DISCUSSION

Accuracy Test

Accuracy test in remote sensing data processing is very necessary to produce thematic mapping or spatial information on land cover/land use. The term accuracy is used to determine whether the generated map could properly represent the satellite data and the actual ground condition with as little bias (Foody, 2002). In addition, the satellite only captures or scans the earth's surface on a certain date. Hence, for the case when the remote sensing data is acquired in month A, and the research is conducted in month C, it is necessary to do an accuracy test for both the remote sensing data and the field data collection process for each sampling point according to the land cover class classification. This meant to ensure a high level of data relevancy, especially for real-time data.

In the method section (Figure 1), it has been explained that there are 12 (twelve) classes of land cover and land use, but there was 1 (one) class, namely mining area, that data cannot be retrieved during the field survey due to limited access and other reasons. Furthermore, there was 1 (one) other class, primary forest, which has been excluded from the accuracy-test as both the area location and quantity are fixed by legal rules. The accuracy test process was applied to the entire Cisadane Watershed. This was because the EF and BC calculations did not cover the entire watershed area for various reasons also elaborated in the previous chapter. Based on the Table 3, the results of the producer's accuracy were in the range of 64-100%.

This was because of the 22 (twenty-two) points in the field, only 14 (fourteen) points matched both the ground data and the satellite imagery data, with 7 (seven) points were of mixed-crops dryland agriculture class and 1 (one) point was of bare land class. The User's accuracy on secondary forest class resulted the smallest value of 33%, as we were only able to survey 3 (three) points due to limited access. From the 3 (three) points, only 1 (one) matched the ground data and the satellite data, the remaining were mixed-crops dryland agriculture. Even though it was stated in the methodology chapter that each land cover should be sampled 10-15 points (GPS) during the field survey, it does not apply to the secondary forest class due to field accessibility issues. The study of Afrin *et al*. (2019) revealed that the user's accuracy of mixed forest land cover class was as low as 26%, different from Rwanga and Ndambuki (2017) which stated that the lowest user's accuracy value in their study was yielded by the bushland land cover class with 26%.

The Overall Accuracy and the Kappa index yielded 78% and 75%, respectively with the Cisadane Watershed area being 151 808 ha. While the research of Afrin *et al.* (2019) with a research area of 15 025.6 ha resulted in 68% Kappa index and 74.95% Overall Accuracy. The research by Afrin *et al*. (2019) also stated that although the value is below 80% for the Kappa Index, the results were still acceptable considering the quantity of the watershed area and heterogeneity of the land use/land cover classes. Landis and Koch (1997) in Rwanga and Ndambuki (2017) have stated that the Kappa Index of 0.61-0.80 should be interpreted rather as good results (substantial) as values exceeding 0.80 are considered nearly perfect.

Table 3 Accuracy test based on the land cover class in the year 2020

No	Land Cover Class	Producer's Accuracy (%)	User's Accuracy (%)
1	Airport	100	100
2	Dryland Agriculture	81	76
3	Bare Land	80	100
4	Fish Pond	100	50
5	Plantation Forest	100	100
6	Mixed-crop Dryland Agriculture	73	53
7	Plantation	100	75
8	Paddy Field	64	88
9	Secondary Forest	100	33
10	Settlement	83	94
11	Water Body	100	100

Land Use and Land Cover

According to the Decree of the Minister of Forestry No. SK.328/Menhut-II/2009, the Cisadane Watershed is one out of 108 priority watersheds in Indonesia. The upstream is located within two national parks, namely Gede Pangrango National Park and Halimun Salak National Park. The Cisadane Watershed is divided into 10 (ten) sub-watersheds. The districts studied in this research are dominantly situated within the Cianten and Cibeuteung sub-watershed that are part of the upstream area of the Cisadane watershed. This research focused on 15 (fifteen) districts that are situated upstream make it ideal to answer the research question regarding the surplus or deficit position of the upper Cisadane Watershed.

Based on the table below, the dominant land use/land cover class of each studied district was dryland agriculture, with the main commodity being cassava, sweet potato, and taro. The primary forest area tends to remain constant as it is located in the core area of the Halimun Salak and Gede Pangrango National Parks. The Cisadane Watershed Characteristics Report that was retrieved from BPDASHL Citarum Ciliwung (2010) stated a decrease in primary forest coverage by 37.86 ha during the period of 2000-2020, from 735.78 ha in 2002 to 697.92 ha in 2020. Meanwhile, the area of primary forest that is within the scope of the research location was as large as 580.05 ha.

If we look at the Table 4 (illustration on map please refers to Figure 2), we can see that the land cover types that have increased in the area were settlements, paddy fields, and mixed-crops dryland agriculture. Meanwhile, a decline in area was spotted in the secondary forest, dryland agriculture, plantation forest, and plantations classes. The additions to the increased types were from the decreased types that happen to have changed in terms of coverage/functions. Dryland agriculture area had decreased as during the five years there have been a coverage and functions conversions into settlements, secondary dryland agriculture, and paddy fields. The most common phenomenon for agricultural land use was land conversion into settlements.

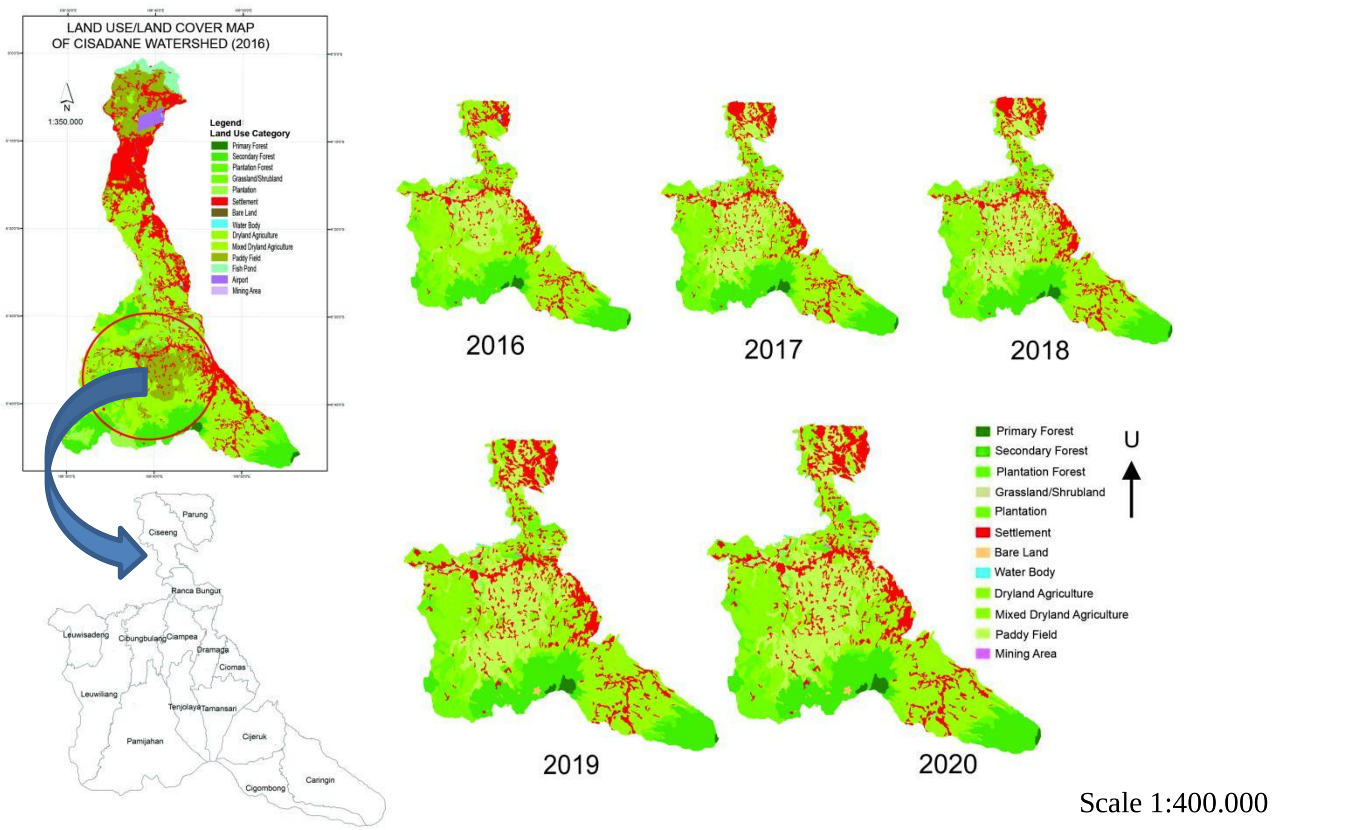

Figure 2 Land cover change during 2016-2020

Table 4 Area of each land cover class (2016-2020)

No	Land Cover Class	Area (ha)				
		2016	2017	2018	2019	2020
1	Primary Forest	580.05	580.05	580.05	580.05	580.05
2	Secondary Forest	10 166.70	10 167.65	10 148.28	9 976.51	9 949.07
3	Plantation Forest	2875.17	2 874.22	2 863.54	2 770.65	2 770.65
4	Grassland/Bushland	34.63	7.02	7.02	7.02	7.02
5	Plantation	2 909.94	2 512.09	2 522.77	2 420.59	2 420.59
6	Settlement	7 631.47	9 658.91	9 671.48	10 015.28	10 015.28
7	Bareland	14.29	39.23	39.23	231.18	402.06
8	Water Body	341.26	322.01	320.52	320.52	320.52
9	Dryland Agriculture	27 355.15	18 476.12	18 458.32	18 448.58	18 325.22
10	Mixed-crop Dryland Agriculture	7 732.27	10 243.00	10 248.39	10 414.66	10 383.60
11	Paddy Field	10 323.25	15 078.75	15 099.46	14 762.34	14 762.34
12	Mining Area	5.37	10.50	10.50	22.16	33.16
	Total	69 969.56	69 969.56	69 969.56	69 969.56	69 969.56

The land cover is then classified into five areas according to the categorization by the Global Footprint Network (2020), which consists of agriculture, livestock, and forestry areas. The area quantity was used to calculate the land supply for community needs by assigning it to the mathematical formula stated in the methodology chapter. The illustration is as below.

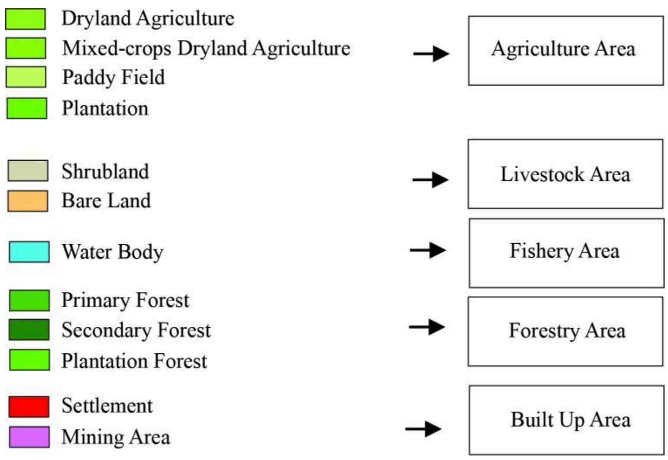

Figure 3 Land covers were classified into 5 classes in accordance with the BC category

In other words, the secondary forests acted as a buffer zone for the core area of the national park area upstream of the Cisadane Watershed. Changes from 2016-2020 that occurred to the secondary forest class were the functions conversion to settlements, paddy field, and bare land (Table 5). Bruenig (1996) in Suhendang (2013) stated that secondary forest in forest classification based on the state of forest plants is a forest that emerged through natural secondary succession on forest land that had experienced severe disturbances in the past from activities like shifting agriculture or permanent agriculture, livestock and mining. Dryland agriculture area had decreased because in the past five years, it had converted in terms of both coverage and functions into settlements, secondary dryland agriculture, and paddy fields. The most common phenomenon for agricultural land use was land conversion into settlements.

Table 5 Land covers based on biocapacity category area

No	Production Area Category	Area (ha)				
		2016	2017	2018	2019	2020
1	Agriculture	48 320.61	46 309.96	46 328.94	46 046.18	45 891.75
2	Fisheries	341.26	322.01	320.52	320.52	320.52
3	Livestock	48.92	46.25	46.25	238.21	409.09
4	Build Up	7 636.84	9 669.41	9 681.98	10 037.44	10 048.44
5	Forest	13 621.92	13 621.92	13 591.87	13 327.21	13 299.77
	Total	69 969.56	69 969.56	69 969.56	69 969.56	69 969.56

The forest area had increased more significantly than the settlements or built-up area, as it was a combination of plantation forest, and primary and secondary forest area, where plantation forest was noted as the primary timber producer. Meanwhile, in several non-forest areas, community forests were usually identified with an area of 1-2 ha, which spread randomly that made them spottable even in the agriculture area, especially in mixed-crops dryland agriculture areas. The fishery area in this study refers to freshwater fisheries as the study area is located upstream. As for the livestock area, it relies on the presence of shrubland and bareland, but on the actual ground, it also depends on agricultural areas as feed sources for both large animals and poultry.

The Biocapacity (BC) of Upper Cisadane Watershed

The production areas that were the focus of the biocapacity analysis in this study were agriculture, settlements/built-up area, and forests (Figure 3). That was because fishery and livestock areas were not really proven to contribute a significant amount of influence on the calculation, as the area for both categories, if compared to the other, were relatively small. The formula used to calculate the biocapacity value only relies on the largest multiplier value. Even if the fishery and livestock areas are omitted and rounded to 3 (three) digits after the comma, the value will stay the same. For instance, in the year 2016, the total value of BC was 0.08741 gha/person (Table 6), and if the fishery and livestock were excluded the value would remain 0.0874 gha/person. The results of the annual calculation of the BC value have decreased by 0.00213 gha/ha during the last period (2016-2020). The units of EF and BC are gha (global hectares), which means that the supply of agriculture area needed for each person per year was 0.06996 ha (in 2016).

Table 6 Biocapacity analysis results of upper Cisadane Watershed

No	Production Area Category	Biocapacity (gha/person)				
		2016	2017	2018	2019	2020
1	Agriculture	0.06996	0.06623	0.06584	0.06480	0.06476
2	Fisheries	0.00007	0.00007	0.00007	0.00007	0.00007
3	Livestock	0.00004	0.00003	0.00003	0.00018	0.00030
4	Build Up	0.01106	0.01383	0.01376	0.01413	0.01418
5	Forestry	0.00628	0.00620	0.00615	0.00597	0.00598
	Total BC	0.08741	0.08636	0.08585	0.08514	0.08528

Changes in land use can affect the value of BC, the research by Guo *et al*. (2016), showed that changes from non-productive land such as bare land or shrubland to agricultural land or forests could increase the BC value. Zhou and Liu (2009) discussed the land use changes in the Loess Plateau-China Watershed that have been adopting the green development agenda, one of which was increasing forest area, the same thing was spotted in research by Sun *et al.* (2009), which revealed that converting a particularly unproductive area into a forest has proven to decrease the EF value and increase the BC value.

The Ecological Footprint of Upper Cisadane Watershed

The ecological footprint is always connected to the needs of the area's inhabitants. The production value of the forest area from year to year was the same because we only managed to obtain the year 2020 data on forest products, particularly wood production in community forest types, from the Region I Forestry Service of West Java. Hence, we assumed the condition in 2016-2020 using only the data from the year 2020. The results in the table below exhibited an increase in the EF value from 2016-2018, more or less up to 0.02 gha/person (Table 7). Then there was a decline in 2019 and 2020.

Table 7 Ecological Footprint analysis results of upper Cisadane watershed

No	Production	Ecological Footprint (gha/person)				
		2016	2017	2018	2019	2020
1	Agriculture	0.08617	0.09211	0.10078	0.07885	0.06984
2	Fisheries	0.01511	0.01569	0.01126	0.01658	0.01482
3	Livestock	0.00294	0.00280	0.00116	0.00346	0.00335
4	Build Up	0.01444	0.01964	0.01949	0.01948	0.01963
5	Forestry	0.00014	0.00014	0.00014	0.00014	0.00014
	Total EF	0.11880	0.13037	0.13283	0.11850	0.10777

The EF value decline that occurred in 2020 was the smallest among the entire data series. Global hectares in EF means that each person in the study location needs 0.08617 hectares of production land in 2016, and so on so forth. EF research that took a case study in a watershed was also conducted by Weijing *et al*. (2018) with the duration of the data series was 15 (fifteen) years, namely from 2000-2015. The results showed that there was an increase in EF in 2015 to double the EF value in 2000, while the BC value was reported to be decreased every year. One of the driving factors that caused the increase in the EF value in the study of Weijing *et al.* (2018) is cultivation land, especially related to the conversion of productive land into built-up areas.

Table 8 Status of the 15 studied districts based on their EF and BC values

District	BC	EF	BC-EF	Interpretation
Leuwiliang	0.16654	0.10749	0.05904	Surplus
Leuwisadeng	0.10549	0.10499	0.00050	Surplus
Cibungbulang	0.05879	0.10563	-0.04684	Deficit
Ciampea	0.04994	0.09335	-0.04341	Deficit
Pamijahan	0.15836	0.16521	-0.00685	Deficit
Tenjolaya	0.11780	0.22808	-0.11028	Deficit
Ciseeng	0.08643	0.11755	-0.03112	Deficit
Parung	0.04446	0.10044	-0.05598	Deficit
Rancabungur	0.09976	0.18029	-0.08053	Deficit
Dramaga	0.05663	0.14047	-0.08384	Deficit
Ciomas	0.02344	0.03476	-0.01132	Deficit
Tamansari	0.07624	0.08481	-0.00857	Deficit
Cijeruk	0.11379	0.0951	0.01867	Surplus
Cigombong	0.08781	0.0801	0.00766	Surplus
Caringin	0.11025	0.11191	-0.00166	Deficit

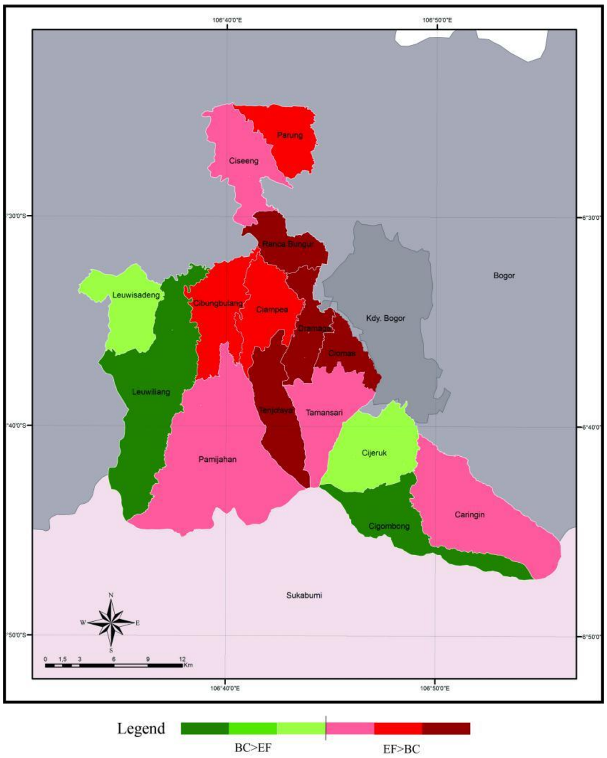

Figure 4 Surplus and Deficit Status by district

This study identified the status of each district in the study area, where it was found that from 15 (fifteen) districts (Table 8), almost all of the study areas experienced an ecological deficit, and only 4 (four) among them experienced surplus. Deficit status means that the district had exceeded its capacity to ideally supply the inhabitant's needs, both for consumption and development, and the interpretation is vice versa if the status was surplus (Figure 4).

Based on the difference of EF and BC values, 2018 had the highest yield, and it declined again in 2019 and 2020. The decline in the EF value in 2019-2020 was suspected to be the result of the decrease in agricultural, fishery, and livestock production. For example, in 2018, production in agricultural areas was 38, 8 285.60 tons and later decreased to 34, 2 905.90 tons in 2020. Production results in agricultural areas had a big influence on the mathematical formula for calculating EF as they were the initial multiplier. Furthermore, the decline in the value of EF in 2019 and 2020 was indicated as a result of a non-natural disaster, the Covid-19 pandemic. The pandemic situation inevitably forced people to limit their mobility and activities. In 2020, there was reportedly a 9.3% decline in the EF value globally due to Covid-19 (GFN, 2020).

CONCLUSIONS

The ecological footprint (EF) and biocapacity (BC) methods can be used to evaluate the condition of the upstream Cisadane watershed in supporting future needs based on the observation of 5 (five) different land use areas. In addition, it is a rather simple method that could help in determining whether the ecology is surplus or deficit. Based on the 5-year trend (2016-2020), the results of the EF and BC calculations showed that the upper Cisadane Watershed was dominantly in an ecological deficit condition. However, among the studied districts, there are four sub-districts that were in an ecological surplus condition. Proceeding this research further in the future is also necessary in order to confirm whether the decline in EF value in 2018-2020 was due to a decrease in agricultural production and the occurrence of a non-natural disaster, Covid-19.

ACKNOWLEDGEMENT

We would like to express our immense gratitude to the Ministry of Research and Technology/National Research and Innovation Agency (RISTEK-BRN) for entrusting the author as one of the awardees of the Master Program of Education Leading to Doctoral Degree for Excellent Graduates (PMDSU) scholarship scheme. Furthermore, the authors would like to thank the Food Crops, Horticulture and Plantations Service (BKTPH) of Bogor Regency, BPDASHL Citarum-Ciliwung, Region I Forestry Service of West Java, and the Central Bureau of Statistics of Bogor Regency for their generous support in providing secondary data to conduct this research.

REFERENCES

[BPDASHL] Badan Pengelolaan Daerah Aliran Sungai dan Hutan Lindung. 2010. *Laporan Karakteristik DAS Cisadane*. Bogor (ID): BPDASHL Citarum-Ciliwung.

[GFN] Global Footprint Network. 2020. *Earth Overshoot Day is August 22, more than three weeks later than last year* [Internet]. [Accessed 2021 Jun 18]. Available at: https://www.footprintnetwork.org/2020/06/05/press-release-june-2020-earth-overshoot-day/.

[KLH] Deputi Bidang Tata Lingkungan Kementerian Lingkungan Hidup. 2014. *Pedoman Penentuan Daya Dukung Lingkungan Hidup*. Jakarta (ID): Kementerian Lingkungan Hidup (KLH).

Afrin S, Gupta A, Farjad B, Ahmed M, Achari G, Hassan QK. 2019. Development of land-use/land-cover maps using Landsat-8 and MODIS data, and Their Integration for Hydro-Ecological Applications. *Sensors*. 19(4891): 1-22. doi: 10.3390/s19224891.

Arifasihati Y, Kaswanto. 2016. Analysis of land use and cover in ciliwung and cisadane watershed in three decades. *Environmental Science*. 33: 465-469. doi: 10.1016/j.proenv.2016.03.098.

Chu X, Deng X, Jin G, Wang Z, Li Z. 2017. Ecological security assessment based on ecological footprint approach in Beijing-Tianjin-Hebei Region, China. *Physics and Chemistry of the Earth*. 101: 43-51. doi: 10.1016/j.pce.2017.05.001.

Desiana TA, EB Santoso. 2019. Optimasi pemanfaatan lahan melalui pendekatan telapak ekologi di Kabupaten Sukoharjo. *Jurnal Teknik ITS*. 8(2): 84-89.

Foody GM. 2002. Status of land cover classification accuracy assessment. *Remote Sensing of Environment*. 80: 185-201.

Fu W, Jonathan CT, Junquan Z, Guozhen D. 2015. Ecological Footprint (EF): An expanded role in calculating resource productivity using china and the G20 member countries as examples. 48: 464-471. doi: http://dx.doi.org/10.1016/j.ecolind.2014.09.023.

Guo J, Yue D, Li K, Hui C. 2017. Biocapacity optimization in regional planning. *Environmental Impact-Sustainability*. 7(no): 1-10. doi: 10.1038/srep41150.

Holden E. 2012. Ecological footprint. *International Encyclopedia of Housing and Home*. 2: 6-11. doi: https://doi.org/10.1016/B978-0-08-047163-1.00581-6.

Jaya INS. 2010. *Analisis Citra Digital: Perspektif Penginderaan Jauh untuk Pengelolaan Sumberdaya Alam*. Bogor (ID): Fakultas Kehutanan IPB.

Lin D, Hanscom L, Murthy A, Galli A, Evans M, Neill E, Mancini MS, Martindill J, Medouar F, Huang S, Wackernagel M. 2018. Ecological footprint accounting for countries: updates and results of the national footprint accounts, 2012–2018. *Resources*. 7(3): 1-22.

Luo W, Bai H, Jing Q, Liu T, Xu H. 2018. Urbanization-induced ecological degradation in Midwestern China: an analysis based on an improved ecological footprint model. *Resources, Conservation and Recycling*. 137: 113-125. doi: https://doi.org/10.1016/j.resconrec.2018.05.015.

Muñiz I, Garcia-López MÀ. 2019. Urban form and spatial structure as determinants of the ecological footprint of commuting. *Transportasi Research*. 67: 334-350.

Marganingrum D. 2019. Jejak ekologi kawasan regional Bandung. *Jurnal Teknologi Linkungan*. 20(2): 159-170.

Marwa J, Silas A, Francine H. 2020. Daya dukung bioekologi hutan dan lahan di Kabupaten Manokwari, Provinsi Papua Barat. *Jurnal Sylva Lestari*. 8(2): 197-206.

Ministry of Public Works. 2010. *Ecological footprint of Indonesia.* Jakarta (ID): Ministry of Public Works.

Navrátil R, Jana S, Marek H. 2012. Internet ecological footprint calculator – successful educational program in Slovakia. *EnviroInfo* [Internet]. [Accessed 2021 Jun 18]. Available at: http://enviroinfo.eu/sites/default/files/pdfs/vol7574/0363.pdf.

Peng B, Li Y, Elahi E, Wei G. 2018. Dynamic evolution of ecological carrying capacity based on the ecological footprint theory: a case study of Jiangsu Province. *Ecological Indicators*. 99: 19-26. doi: https://doi.org/10.1016/j.ecolind.2018.12.009.

Rachmawati T. 2013. Kajian daya dukung bioekologika kawasan puncak Kabupaten Bogor. *Majalah Geografi Indonesia*. 28(2): 180-197.

Rahman MH, Rizky SA, Ariyaningsih, Keumala BC. 2020. Daya dukung lingkungan lahan tanaman pangan berdasarkan pendekatan telapak ekologi di Provinsi Kalimantan Timur. *Jurnal Agroekoteknologi Tropika Lembab*. 2(2): 71-79.

Rwanga SS, Ndambuki JM. 2017. Accuracy assessment of land use/land cover classifica-tion using remote sensing and GIS. *International Journal of Geosciences*. 8: 611-622.

Santoso EB, Aulia BU. 2018. Ecological sustainability level of surabaya city based on ecological footprint approach. *IOP Conf Ser Earth Environ Sci*. 200: 1-9. doi: 10.1088/1755-1315/202/1/012044.

Schaefer F, Luksch U, Steinbach N, Cabeça J, Hanauer J. 2006. *Ecological Footprint and Biocapacity: The World's Ability to Regenerate Resources and Absorb Waste in a Limited Time Period*. Luxembourg (FR): the European Communities.

Subekti RM, Suroso DSA. 2018. Ecological footprint and ecosystem services models: a comparative analysis of environmental carrying capacity calculation approach in Indonesia. *IOP Conf. Ser.: Earth Environ. Sci.* 158: 1-12. doi: 10.1088/1755-1315/158/1/012026.

Suhendang E. 2013. *Pengantar Ilmu Kehutanan Edisi 2 – Kehutanan sebagai Ilmu Pengetahuan, Kegiatan, dan Bidang Pekerjaan*. Bogor (ID): IPB Press.

Sun J, Liu C, Luo B. 2009. Calculation of resources carrying capacity based on ecological footprint in beijing mountainous area. In: Li D, Chunjing Z, editors. *IFIP International Federation for Information Processing*. *Computer and Computing Technologies in Agriculture II*. Boston (US): Springer: 593-602.

Toth G, Szigeti C. 2016. The historical ecological footprint: from over-population to over-consumption. *Ecological Indicators*. 60: 283-291. doi: 10.1016/j.ecolind.2015.06.04.

Wackernagel M, Lin D, Hanscom L, Galli A, Iha K. 2019. Ecological footprint. *Encyclopedia of Ecology*. 4: 270-282. doi: 10.1016/B978-0-12-409548-9.09567-1.

Weijing M, Bin L, Dewei Y, Lingxing X. Qinghai G. 2018. Study on spatio-temporal evolution of watershed ecological capacity using the ecological footprint model. *Journal Environmental Science & Technology*. 41(1): 163-171.

Zhou P, Liu G. 2009. The change in values for ecological footprint indices following land-use change in a Loess Plateau watershed in China. *Environ Earth Sci*. 59(3): 529-536. doi: 10.1007/s12665-009-0050-4.