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Research Paper

Public Works and Housing Infrastructure Planning using Environmental Carrying Capacity Consideration

Case Study on Planning Dam Development in Kalimantan Island, Indonesia

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ABSTRACT

This article aims to explain how the environmental carrying capacity indicators could benefit public works and housing infrastructure planning. Law No. 32/2009 about environmental protection and management stated that the government is obliged to implement the Strategic Environment Assessment (SEA/KLHS) in the preparation of policies, plans, and/or programs that have the potential to cause environmental impacts and/or risks. This research aims to understand the process of using ecosystem services as part of the environmental carrying capacity. This approach would be relevant to the public works and housing infrastructure planning and is related to the National Medium Term Development Plan (RPJMN) goals in considering the environmental carrying capacity. This means that if the development of infrastructure does not meet the criteria of the environmental carrying capacity, it will cause negative impacts that could lead to futile infrastructures. The process of considering the environmental carrying capacity will be explained in quantitative methodology as an analysis process with a matrix as an overlay result. The overlay result will be interpreted as the basic information on whether a building in that location is feasible or not for carrying capacity conditions. The overlay result will be used as a basis for providing suggestions and recommendations.

Keywords: public works and housing infrastructure, strategic environment assessment, environmental carrying capacity, ecosystem services, mitigation and adaptation

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1. Introduction

The United Nations, through the General Assembly held on September 25 2015, constructed the 2030 Agenda for Sustainable Development known as Sustainable Development Goals (SDGs). Seventeen goals should be implemented by all members of the United Nations, including Indonesia. One of the goals is to take urgent action to combat climate change and its impact. A growing body of knowledge and evidence suggests that sustainable development goals cannot be achieved without integrating environmental sustainability goals (Silori, 2015).

One of the priorities within the development agenda, as stipulated in the Presidential Decree No.18/2020 about National Medium Term Development Plan (RPJMN) for 2020-2024, is a regional development that focuses on decreasing inequality and increasing equality (Ministry of National Development Planning/National Development Planning Agency, 2020). This agenda can be achieved by enhancing environmental carrying capacity and developing disaster and climate change resilience.

Under the National Medium Term Development Plan, 2020-2024, and Sustainable Development Goals, the Strategic Environment Assessment (SEA/KLHS) was crucial for infrastructure development. This aspect is also stated in Law No. 32/2009 about environmental protection and management, where the government needs to prepare the SEA/KHLS document, together with the preparation of policies, plans, and/or programs. If the result of SEA shows that the environmental carrying capacity in the area has reached the threshold, the policies, plans, and/or programs should be adapted with the suggestion and recommendation from SEA (Silalahi, 2018). All activities recognized as damaging the environmental carrying capacity should be eliminated. Carrying capacity is an ecological concept that expresses the relationship between a population and the natural environment on which it depends for ongoing sustenance. Carrying capacity assumes limits on the number of individuals that can be supported at a given level of consumption without degrading the environment and, therefore, reducing future carrying capacity. Thus, carrying capacity addresses long-term sustainability (Abernethy, 2001).

Our ecosystem has limitations in supporting all activities. Nonetheless, the carrying capacity concept is clearly of heuristic value given the fundamental truth that no population can grow without limit especially given that many human societies have behaved as if no limits exist (Hixon, 2008). The Ministry of Environmental and Forestry's illustration about overused natural resources as an impact of development in an area affecting the environmental carrying capacity is shown in Environmental Protection and Management Plan Documents (RPPLH) 2015 – 2045. This document showed the scenario for reaching the target of national carrying capacity recovery in Indonesia until 2045. For the year 2015-2025, the condition of using natural resources in Indonesia will reach the maximum of existing carrying capacity. Thus, a scenario must be prepared to recover the carrying capacity, and hopefully, the maximum carrying capacity will decrease by implementing this scenario. The illustration of this scenario can be observed in Figure 1.

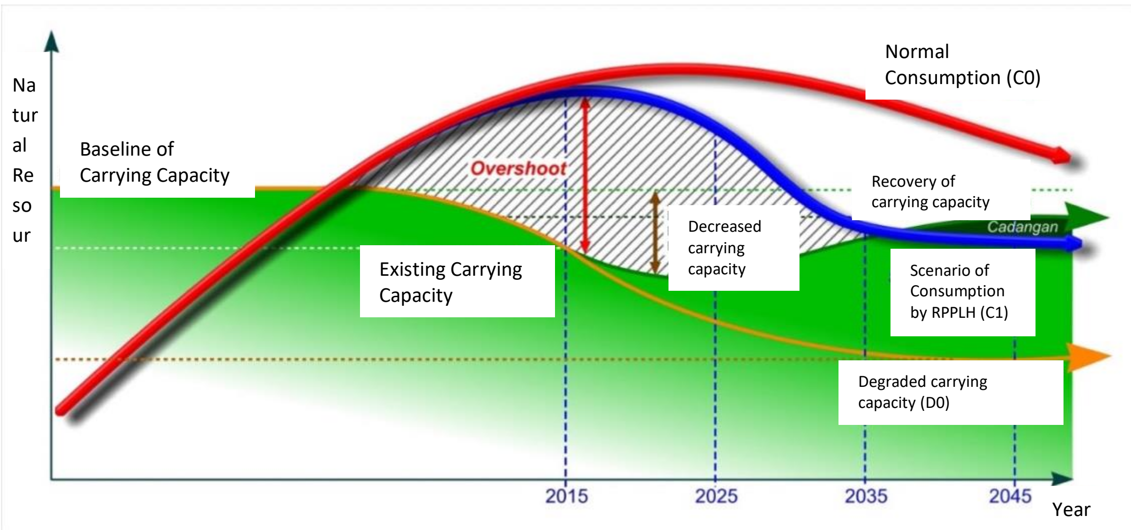

Figure 1. Scenario for environmental protection and management plan for the year 2045 (document of environmental protection and management plan for the year 2045)

It is an established point, however, that a nation without adequate infrastructure cannot compete effectively. The economy is bound to be inefficient or unproductive and will eventually lack sustainability (Jolaoso et al., 2013). The challenges are how to develop the infrastructure to be sustainable. The development of infrastructure is still being done without further consideration of the environmental carrying capacity. Still, there is some hesitation whether the infrastructure development is feasible to carry capacity in an ecological perspective. Avoiding this issue could lead to an impact where this development might damage the environment and trigger various disasters in the area.

We often hear in the news that natural disasters ruin some infrastructure projects. One of the examples was the flash flood incident in Luwu Utara, South Sulawesi Province, in July 2020. It destroyed the settlements and various main infrastructures like bridges and roads. On the other hand, Luwu Utara is also widely known as an area with a high potential for flooding because of the high intensity of rain. Furthermore, people had made even worse destruction due to deforestation, littering into the river, ad building houses or massive buildings close to the riverbank area (Pebrianto, 2020, November 24).

The other example is liquefaction in Palu, Central Sulawesi Province, which happened in September 2018 and was triggered by an earthquake and tsunami. Many researchers have been trying to find out the leading causes of the disaster. One study mentioned that the carrying capacity of water flows is low in this area. Thus, when the earthquake occurs, it will trigger a liquefaction beacon. The liquefaction has drowned many houses. The houses were not built to withstand high potential liquefaction (Likuifikasi, 2018. October 2).

From these two examples, we can see that infrastructure must consider the conditions of the environment. Infrastructure development should consider the environmental carrying capacity to achieve sustainable infrastructure. Sustainable infrastructure is defined as an interrelationship of organized principles that create a favorable built environment that meets the present needs without degrading the ecological sustainability and jeopardizing the ability of the future generations to meet theirs (Munyasya & Chileshe, 2018). Considering environmental carrying capacity in the planning process is mentioned in Government Regulation No. 13/2017 about the Revision of Government Regulation No.26/2008 regarding National Spatial Planning. Article 8, Paragraph 1 stated that controlling the development of cultivation activities should not exceed the carrying capacity of an environment. It is stated that the assessment of the environmental carrying capacity is done through the ecological footprint. It means that the analysis will be carried out by looking at the Land Capability Unit (SKL). Hence in 2016, the Center for Ecoregion Development Control (P3E), Ministry of Environment and Forestry, issued reports of the carrying capacity of an environment in ecoregion in several islands in Indonesia as a new approach in assessing the environmental condition.

The progression of carrying capacity has gradually attached the importance of human activity on the carrying capacity. The evaluation object has gradually shifted from a single resource and environmental element to the carrying capacity for multiple or comprehensive elements. Nowadays, carrying capacity is widely employed in urban planning, resource, and environmental management and becomes the key indicator to measure sustainable development (Bao et al., 2020).

The Government Regulation No. 46/2016 about Procedure to Prepare Strategic Environment Assessment, Article 13, Paragraph 1 mentions that several aspects should be fulfilled in analyzing and preparing the strategic environmental assessment of policies, plans and/or programs. It includes carrying capacity for development, prediction of impact and risk for the environment, the performance of ecosystem services, the efficiency of natural resources, level of vulnerability and capacity of climate change adaptation, level of resilience, and potential biodiversity (Umam, 2021). Moreover, the condition of ecosystem services will become an important indicator in preparing Strategic Environment Assessment (SEA/KLHS).

Millennium Ecosystem Assessment (MEA) explains that ecosystem services are viewed as benefits from the ecosystem to be obtained by society. How ecosystems are affected by human activities will have consequences on the supply of ecosystem services such as food, freshwater, fuelwood, fiber, diseases prevalence, the frequency and magnitude of floods and drought, and local and global climate.

MEA itself is an international institution founded in 2001. They published "Ecosystems and Human Well-being: A Framework for Assessment". It was launched by Secretary-General of PBB, Kofi Annan, in July 2001 and was distributed in 2005. MEA also classified the ecosystem services into four main functions, provisioning, regulating, supporting, and cultural services. Each function consists of ecosystem services related to each other, as shown in Figure 2.

Provisioning Services

Products obtained from ecosystems

- Food
- Fresh water
- Fuelwood
- Fiber
- Bio chemicals
- Genetic resources

Regulating Services

Benefits obtained from regulation of ecosystem services

- Climate regulation
- Disease regulation
- Water regulation
- Water purification
- Pollination

Cultural Services

Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Supporting Services

Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

Figure 2. Relation between Function and Ecosystem Services (Ecosystems and Human Well-being: A Framework for Assessment)

Although ecosystem services have been classified into four main functions, they have specific relations with each other. Some ecosystem services are compatible with one another (e.g., a natural wetland habitat can also be used as a recreation area); others exclude each other (e.g., draining a fen for crop production destroys the former habitat services). These complex relationships between different ecosystem services may have fatal effects if humans focus only on a certain ecosystem service (e.g., the carrier service) without paying attention to the natural prerequisites for other ecosystem services (Tobias, 2013). Thus, the analysis process shall not only use one ecosystem service but also consider each ecosystem service's dependability.

Since P3E established a carrying capacity report of the ecoregion in several Indonesian islands in 2016, the strategic environmental assessment should consider ecosystem services data as a part of that report. It should be included in the development of the infrastructure planning process by considering the environment's carrying capacity.

When P3E studied the carrying capacity of several ecoregions in Indonesia, they had considered the previous study on carrying capacities, such as an international study from MEA and local study by the Research Center for Environment University of Gadjah Mada (PSLH-UGM). These studies explained the process in the ecosystem services index and map in the ecoregion. However, the current study will not explain the ecosystem services in every ecoregion, but they will be used as an indicator in the analysis process.

Ecosystem service definition is the service of ecological systems. The natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet (Costanza et al., 1997). It is far cheaper to maintain ecosystem services than to invest in more expansive and often less effective alternatives (Silori, 2015).

The use of ecosystem services as an indicator to assess the effect of changing carrying capacity as the result of infrastructure development has not yet been fully understood. Therefore, this research aims to give detailed steps on how the ecosystem services could be used as the basic information of environmental carrying capacity. In particular, the indicators stated in the ecosystem services could help the infrastructure planning process.

This research seeks to learn how the carrying capacity environment could be used in the infrastructure planning process, especially for public works and housing infrastructure, to reduce environmental damage. The result analysis could be used to provide suggestions and recommendations towards the mitigation and adaptation actions that should be prepared once the development of infrastructures is initiated.

2. Methodology

The methodology explains the data collection and analysis process using the quantitative approach that supports by data of ecosystem services and information on planning infrastructure. The quantitative process was performed by measuring each data and making an evaluation resulting in an overlaid matrix. The evaluation process was executed by overlaying the spatial data of ecosystem services and spatial data of planning infrastructure via ArcGIS application to produce a map and an overlaid result matrix.

Furthermore, the suggestions and recommendations were produced by evaluating the result from overlaid matrix and map. These suggestions and recommendations would be helpful in infrastructure development.

Since the case of the study is in East Kalimantan Province, all the data analyses are related to the locus of study. Dam planning in East Kalimantan Province was selected due to the impact on the environment and the availability of water sources. Additionally, the Sepaku Semoi Dam will be constructed in East Kalimantan Province-making the locus selection even more suitable. The dam will provide water supply for the New Capital of Indonesia as it will be relocated to East Kalimantan Province.

2.1 Data

Relevant data is needed in the first step of the analysis. Data being used in this study was compiled from the previous study conducted by P3E. The study was about the environmental carrying capacity of the ecoregion in Indonesia. The data was obtained from the planning of "Sepaku Semoi" dam located in the East Kalimantan province.

The carrying capacity report by P3E provides some information about several ecosystem services in every ecoregion. Ecosystem services as the content of carrying capacity in the ecoregion are described. Ecosystem services located in one ecoregion can be different from other ecoregions. It depends on the strategic issues and its characteristic.

Researchers were looking for a relation between ecology and the character of the area. Understanding the factors that determine where an ecological boundary is located and how it influences our understanding of ecological processes is a fundamental issue that ecologists and land planners face (Wiens et al., 1985). It is generally accepted that ecological zones should be hierarchical. Their sizes are dependent upon the scale of the study, and their boundaries are based on semi-permanent landscape components (Bailey et al., 1994). This basis allows recognition of an ecological unit regardless of the current land use or successional status of the vegetation (Wright et al., 1998).

The scope of the ecoregion has been described differently. Some researchers saw the ecoregion as a single-purpose framework of a particular characteristic that is believed to be important in causing ecosystem quality. The most commonly used single-purpose framework has been potential natural vegetation, physiography, hydrology, climate, and soils. One reason for using a single-purpose framework is that a scientifically rigorous method for defining ecological regions must address the process that causes components to differ from one place to another (Omernik, 1995).

In general, the P3E report mentions twenty-two ecosystem services classified into four main functions (similar to MEA's classification illustrated in Figure 2). The following are the ecosystem services affecting the ecoregion in Kalimantan Island as a part of the P3E report (with the letter and number as a code of each ecosystem service used for the analysis process):

- ecosystem service for provision of food (P1)
- ecosystem service for provision of water (P2)
- ecosystem service for provision of fiber (P3)
- ecosystem service for provision of energy (P4)

- ecosystem service for provision of genetics resources (P5)
- ecosystem service for regulating climate (R1)
- ecosystem service for regulating water management and floods (R2)
- ecosystem service for regulating disaster prevention and protection (R3)
- ecosystem service for regulating water purification (R4)
- ecosystem service for regulating processing and decomposition of waste (R5)
- ecosystem service for regulating preservation air quality (R6)
- ecosystem service for regulating natural pollination (R7)
- ecosystem service for regulating pest and disease (R8)
- ecosystem service for cultural related shelter and place to live (C1)
- ecosystem service for cultural related recreational and ecotourism (C2)
- ecosystem service for cultural related aesthetic and natural beauty (C3)
- ecosystem service for supporting the formation of layers and soil fertility (S1)
- ecosystem service for supporting nutrient cycle (S2)
- ecosystem service for supporting primary production (S3)
- ecosystem service for supporting biodiversity (S4)

P3E provides an index and map for each ecosystem service in the carrying capacity report. Muta'ali (2019) stated that previous indexes and maps used the data and inputs from experts. The data are maps of the ecoregion and land coverage. These data sources were obtained from satellite imagery and taken with the ArcGIS application. Furthermore, the expert provided input by giving opinions, scoring, and pairwise comparison with Analytic Hierarchy Process (AHP) (Muta'ali, 2019). The index and maps of ecosystem services have been generated based on these resource data (Hsb, 2017). However, the current study will not explain the index and maps of ecosystem services from the previous survey.

The index of ecosystem services has several classifications, divided into five categories:

- index 0 – 0,1 is very low carrying capacity, symbolized with red color,
- index 0,1 – 0,23 is low carrying capacity, symbolized with pink color,
- index 0,23 – 0,4 is medium carrying capacity and symbolized with yellow color,
- index 0,4 – 0,7 is high carrying capacity and symbolized with green color, and
- index 0,7 – 1,0 is very high carrying capacity and symbolized with dark green color.

Each ecosystem service provides information about the average index in every province. From Table 1, the East Kalimantan Province has the highest index in ecosystem services for energy provision. It means that some of the areas in East Kalimantan have the potential to provide energy resources. The ecosystem services index also provides information about the type of ecoregions and land covering in each ecosystem service.

Table 1: Index of Ecosystem Services in Ecoregion Kalimantan.

Province	Index of Ecosystem Services																			
	P1	P2	P3	P4	P5	R1	R2	R3	R4	R5	R6	R7	R8	C1	C2	C3	S1	S2	S3	S4
West Kalimantan	0.31	0.33	0.69	0.62	0.51	0.47	0.49	0.55	0.4	0.61	0.43	0.46	0.5	0.38	0.42	0.41	0.49	0.43	0.45	0.52
South Kalimantan	0.32	0.28	0.57	0.53	0.43	0.38	0.41	0.44	0.33	0.49	0.35	0.36	0.42	0.34	0.38	0.38	0.45	0.34	0.36	0.44
Central Kalimantan	0.28	0.34	0.71	0.58	0.54	0.42	0.5	0.54	0.39	0.55	0.41	0.44	0.45	0.38	0.42	0.38	0.48	0.41	0.42	0.55
East Kalimantan	0.24	0.41	0.67	0.61	0.57	0.5	0.54	0.59	0.44	0.64	0.48	0.8	0.52	0.36	0.49	0.49	0.5	0.45	0.48	0.57
North Kalimantan	0.24	0.48	0.73	0.79	0.62	0.77	0.79	0.64	0.6	0.77	0.66	0.7	0.71	0.35	0.66	0.63	0.55	0.61	0.69	0.59

Source: Carrying Capacity of Kalimantan Island, 2016.

Besides the index, the carrying capacity report also offers maps of each ecosystem service shown in spatial data and drawn with a different color to indicate the classification of ecosystem services (Center for Controlling Ecoregion Development of Kalimantan, 2016).

As stated before, the object study is planning of "Sepaku Semoi" dam in East Kalimantan province, so the ecosystem services for the provision of water in Kalimantan Island will be chosen as sampling data ecosystem services. Map of ecosystem service~~s~~ for the provision of water as one of the ecosystem services in ecoregion Kalimantan gives information about spatial data included in the picture of each classification ecosystem service. From the map in Figure 3, the ecosystem services for the provision of water with a very high classification-as the highest carrying capacity-is located in the north part of Kalimantan Island, and in some parts of South Kalimantan is where the lowest classification of ecosystem services for the provision of water located.

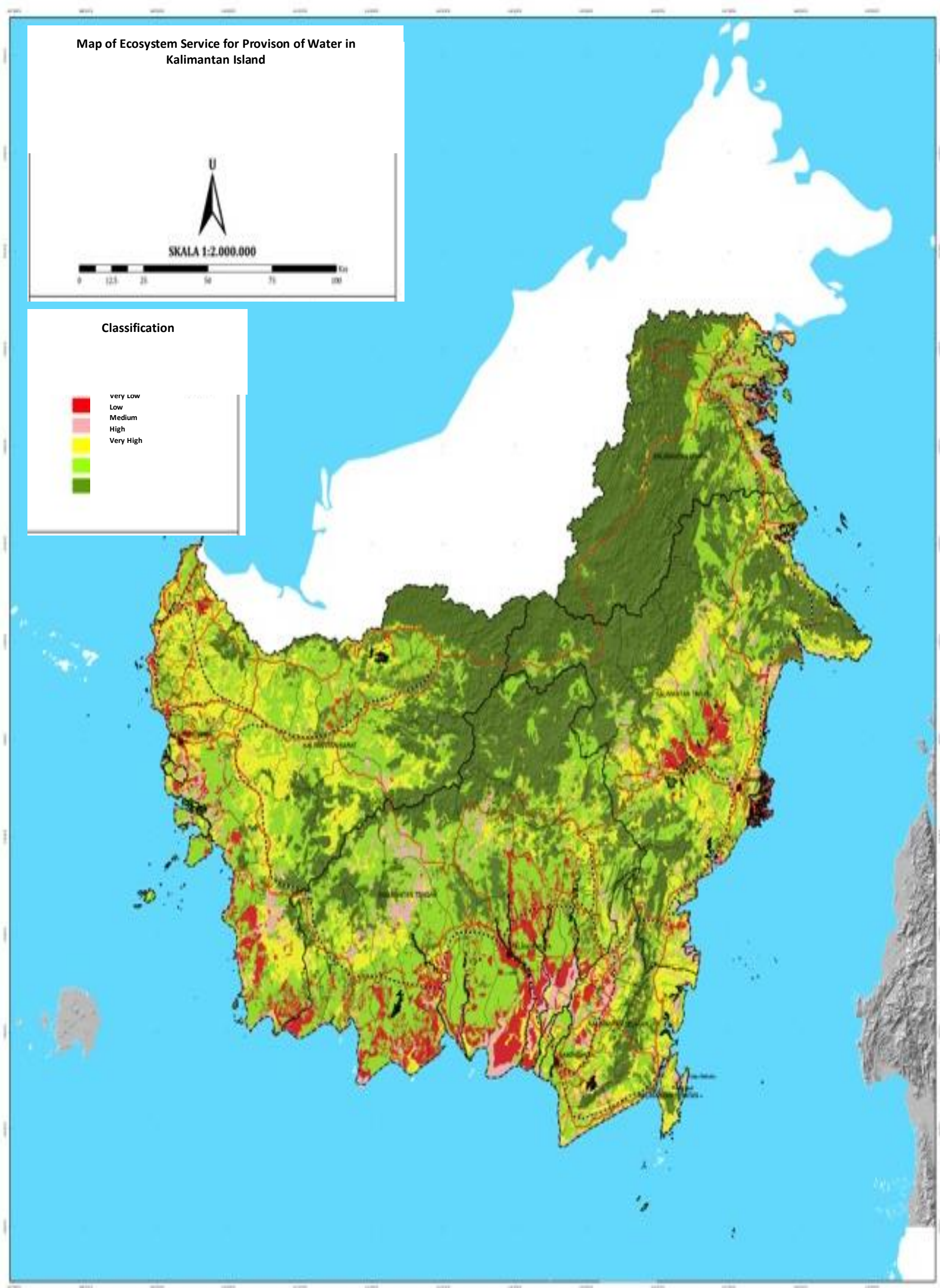

Figure 3. Map of ecosystem service for provision of water in ecoregion Kalimantan Island (Carrying Capacity Report of Kalimantan Island, 2016)

The map of ecosystem service generated in the P3E report is on a scale of 1:250.000. According to Government Regulation No. 8 of 2013 about the accuracy of spatial planning map, Article 14, the map must be made with a scale of 1:250.000 for spatial planning of province. In Article 15, a more detailed map with a scale of 1:50.000 must be used for spatial planning of the city/district region. Therefore, the Ministry of Environment and Forestry assigned the local planning and development agency (Bappeda) in the city or district region to develop an ecosystem service map on a scale of 1:50.000. This will be useful for development planning in their area.

Furthermore, ecosystem service also provides information about the total distribution area of each classification. A sample distribution of ecosystem services for water provision in each province in Kalimantan Island is shown in Table 2.

Table 2: Distribution total area of ecosystem service for provision of water in each province in ecoregion Kalimantan Island.

Province	Very low - low		Medium		High – very high	
	Ha	%	Ha	%	Ha	%
West Kalimantan	1,414,829	2.64	3,742,717	6.99	9,565,913	17.86
South Kalimantan	638,483	1.19	1,127,911	2.11	1,946,228	3.6
Central Kalimantan	2,756,417	5.15	1,486,331	2.78	11,062,937	20.65
East Kalimantan	1,168,640	2.18	2,299,934	4.29	9,207,075	17.19
North Kalimantan	401,192	0.75	342,136	0.64	6,240,180	11.65
Grand total	6,379,569	11,91	8,999,032	116,8	38,022,334	70,99

Source: Carrying Capacity of Kalimantan Island, 2016.

As the basic human needs, the water resource is essential. Several areas in Kalimantan play an important role in providing water. Table 2 shows the total area of 38,022,334 Ha of water provision in Kalimantan, equal to 70,99 % of the index value of high-very high in ecosystem service of water provision. The table shows that Central Kalimantan has the highest percentage of the total area with high-very high value for water provision and the highest percentage of the total area with a very low-low value of the same ecosystem services. This happens because the Central Kalimantan is located on the highest mountain on Kalimantan island. The Bukit Raya, as the highest mountain, served as a recharge area for water provision. On the other hand, in some areas in Central Kalimantan province, there are also vegetation with low density such as bushes that created a higher runoff for water, reducing water availability and quality.

In the meantime, the plan data of dam construction was collected from several resources, such as the National Medium Term Development Plan (RPJMN) 2020-2024, Strategic Plan of Ministry of Public Works and Housing 2020-2024, and Masterplan of Public Works and Housing of Infrastructure in Kalimantan. Those data stated a total of 61 units of dam infrastructures which 18 of those are multifunction dams (Ministry of Public Works and Housing, 2020). The "Sepaku Semoi" dam in Penajam Paser Utara district, East Kalimantan province, is included in the dam-construction plan data. The “Sepaku Semoi” dam, supports the existing dams built in East Kalimantan such Manggar dam in Balikpapan (capacity 14,2 million m^3), Teritip dam in Balikpapan (capacity 2,43 million m^3), Aji Raden dam in Balikpapan (capacity 0,49 million m^3), Samboja dam in Kutai Kartanegara (capacity 5,09 million m^3), Kalhol intake in Mahakam river (capacity 0,02 million m^3) and Lempake dam in Samarinda (capacity 0,67 million m^3). The "Sepaku Semoi" dam produces 11 million m^3 of water which will be used for irrigation systems and water supply for Balikpapan city of 2,500 liters/second. In addition, the "Sepaku Semoi" dam will support the water supply for the new capital of Indonesia in East Kalimantan. The total area of dam development is 378 Ha, and 36 Ha is reserved for the dam's main building. These datas were obtained from surveys and maps of public works and housing infrastructure planning prepared by the Center of Data Resources and Technology Information, Ministry of Public Works, and Housing (Ministry of Public Works and Housing, 2019).

2.2 Analysis

After collecting all the data, the next step is the analysis process. The analysis process is carried out in several stages, as in Figure 4.

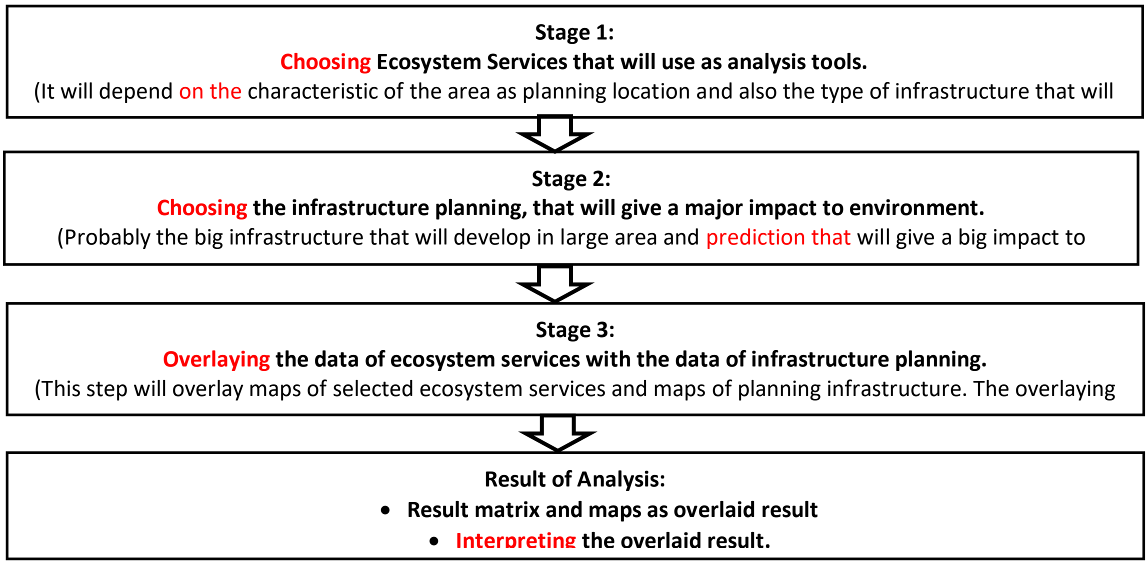

Figure 4. The Stages of Analysis Process of using Ecosystem Services until Develop a Result (Analysis result).

The first step is to choose ecosystem services that will be used as analysis tools. It will be chosen from the characteristic of the ecoregion and also from the type of infrastructure. The Environmental Protection and Management Plan document (RPPLH) for 2015 -2045 provides information about the issue and characteristics of each ecoregion in the big island in Indonesia and information about related ecosystem services with that ecoregion. For the ecoregion of Kalimantan island, there are ecosystem services that have a significant impact for the year 2015-2045, such as (Ministry of Environment and Forestry, 2015)

- ecosystem service for food provision (P1)
- ecosystem service for water provision (P2)
- ecosystem services for energy provision (P4)
- ecosystem services for the provision of genetics resources (P5)
- ecosystem services for regulating water management and floods (R2)
- ecosystem services for carbon saving

Furthermore, related to the type of infrastructure, some literature of study can be used as consideration for choosing the ecosystem services. For examples from "Ecosystems and Human Well-being: Policy Responses", chapter 7: Freshwater Ecosystem Services - Millennium Ecosystem Assessment by Aylward can be concluded ecosystem services that are affected to development of irrigation systems and dams, such as (Aylward, 2005):

- ecosystem service for provision of food (P1)
- ecosystem service for provision of water (P2)
- ecosystem services for regulating water management and floods (R2)
- ecosystem services for regulating disaster prevention and protection (R3)
- ecosystem services for regulating water purification (R4)
- ecosystem services for cultural related to recreational and ecotourism (C2)
- ecosystem services for cultural related to aesthetic and natural beauty (C3)
- ecosystem services for supporting primary production (S3)
- ecosystem services for supporting biodiversity (S4)
- ecosystem service for educational and science

The second stage is to decide the infrastructure that has the highest impact on ecosystem services and its potential to change the environment's carrying capacity. The chosen infrastructure will likely be a massive one and is usually stated in the National Medium Term Development Plan (RPJMN) and surely one will produce the highest impact on the environment. Defining the infrastructure considers the total area of infrastructure development. The development of infrastructure in the greater area provides more impact to the environment compared to otherwise.

The program development of "Sepaku Semoi" dam stated in RPJMN 2020-2024 became a National Strategic Project in Presidential Decree No. 109/2020 regarding the acceleration of National Strategic Project implementation. "Sepaku Semoi" dam will have a tremendous impact on the existing environment.

Subsequently, the data related to the selected infrastructure, such as the location detail of existing or planning infrastructure, service coverage of existing or planning infrastructure, and environmental issues, are considered. Infrastructure data use data of spatial planning of the same scale of ecosystem service map. The ideal scale for the map is 1:50.000 for the city/district area, as stated in Government Regulation No. 8/2013 regarding the accuracy of the spatial planning map. On the contrary, the ecosystem service map prepared by P3E, Ministry of Environment and Forestry, has only a 1:250.000 scale.

The third stage is to overlay the ecosystem service maps, and the existing or planning infrastructure maps. The overlaying process was executed using ArcGis application.

3 Results and Discussions

Figure 5 shows the map of "Sepaku Semoi" dam planning overlaid with ecosystem service of water provision for the ecoregion of Kalimantan. The overlaid process is done on a 1:250.000 scale due to the scale of the ecosystem service map at 1:250.000.

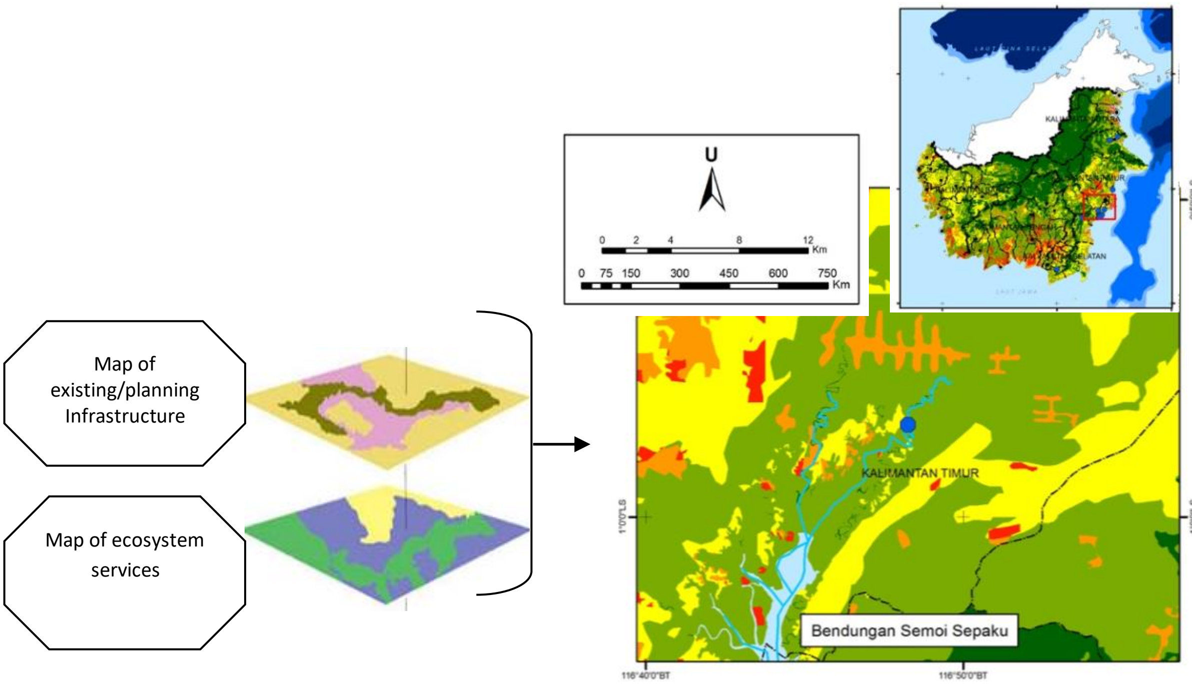

Figure 5. Process and result of overlaying a map of ecosystem service of water provision with a map of planning "Sepaku Semoi" dam in East Kalimantan province.

Besides the overlaying maps, there is also information about the index value of each ecosystem service, type of land cover, and type of ecoregion where the infrastructure will be developed. Table 3 shows the result of overlaying "Sepaku Semoi" dam with all ecosystem services.

Table 3: Result of overlaying as information about the type of land cover, type of ecoregion, and index of ecosystem services where the planning infrastructure is located.

Develop / Planning Infrastructure	Type of Land Cover	Type of Ecoregion	Ecosystem Services Index										
			P1	P2	P4	P5	R2	R3	R4	C2	C3	S3	S4
"Sepaku Semoi" Dam	Mangrove	Fluvio-marine	0.42	0.29	0.64	0.65	0.59	0.54	0.41	0.77	0.46	0.48	0.67

Source: Analysis result.

Table 3 shows that "Sepaku Semoi" dam will be located in a mangrove area and fluvio-marine ecoregion type. The type of area provides information about the important aspect in providing recommendations for protecting the existing ecosystem within the dam area. The mangrove area is one of the land cover types in Kalimantan, mostly located in the coastline area, and functioned to conserve the area and endemic creatures such as crabs and shrimps. The fluvio-marine area is formed by a joint of river and sea. The information about the type of land cover and type of ecoregion is really important, as a consideration to give suggestion and recommendation to maintain the existing environment condition including the habitat that lives in that area.

The next stage is to interpret the value of index ecosystem services of Sepaku Semoi's location plan. These interpretations are categorized into two values, "feasible" or "non-feasible". Feasible means that the development effect gives small or none to the environment. Non-feasible means that the development has a large impact on the environment.

Table 4 displays the procedures of interpretation as the correlation of the ecosystem service index-the interpretation value symbol.

Table 4: Procedure for giving interpretation from the value of index ecosystem services.

Index of Ecosystem Services	Classification of Index of Ecosystem Services	Value of Interpretation	Symbol of Interpretation
0 – 0.1	Very low	Feasible	√
0.1 – 0.23	Low	Feasible	√
0.23 – 0.4	Medium	Non Feasible	x
0.4 – 0.7	High	Non Feasible	x
0.7 – 1.0	Very high	Non Feasible	x

Source: Analysis result.

Furthermore, Table 5 offers the result of interpretation.

Table 5: Result of interpretation of each index ecosystem service where the "Sepaku Semoi" dam will be located.

No.	Planning Infrastructure	Location	Ecosystem Services of Provisioning				Ecosystem Services of Regulating			Ecosystem Services of Culture		Ecosystem Services of Supporting	
			P1	P2	P4	P5	R2	R3	R4	C2	C3	S3	S4
1	"Sepaku Semoi" Dam	Penajam Paser Utama District	X	X	X	X	X	X	X	X	X	X	X

Source: Analysis result.

The interpretation in Table 5 shows the plan of the "Sepaku Semoi" dam located in an ecosystem service categorized as non-feasible. The index detail displays it as a medium to very high category. Even though it is non-feasible, we should not directly decide that dam location should be avoided, but we can use these results as strict cautionary guidelines to maintain the dam's condition. The guidelines are provided in recommendations and suggestions.

A further and detailed discussion with the experts of P3E of Kalimantan as the institution producing these ecosystem service data is compulsory. They will provide data on how to produce the perfect interpretation, recommendation, and suggestion to construct "Sepaku Semoi" dam in this specific location.

The hypothesis of this research confirms that the environment's carrying capacity has played an important role in planning the "Sepaku Semoi" dam. The purpose of carrying capacity data is to minimize the impact of infrastructure on the environment, indicated as feasible or non-feasible to develop the dam infrastructure.

Suggestion and Recommendation

Recommendations and suggestions are defined by the interpretation matrix in Table 5, as the discussion with experts and stakeholders is taken into account. The discussion increases the point of view to widen the options for the solution. For instance, the Ministry of Environmental and Forestry will review the conversation about conservation areas regarding the Land Coverage Map, Indicative Map, and Social Forest Area (Ministry of Environment and Forestry Regulation No. SK.744/MENLHK-PKTL/REN/PLA.0/1/2019). The local government will review the land ownership aspect, and the Directorate General of Water Resources of the Ministry of Public Works and Housing will review the technical aspect. All these results are intended to make the recommendation easily implemented.

The recommendations and suggestions are offered as mitigation and adaptation plan. As for the non-feasible interpretation, the recommendation and suggestion can be used as a mitigation plan. The recommendation and suggestion can be used for the adaptation plan for the feasible interpretation.

For instance, the general recommendation for "Sepaku Semoi" dam plan in East Kalimantan could be given as follows:

a. Human settlement should be considered as it is vital in keeping the water quality of dam from domestic pollutants.
b. The dam location should avoid earthquake-prone areas to maintain the dam's infrastructure. The warning for the condition must be included in the planning process.
c. The conservation land must be provided because the dam is located in the ecoregion mangrove area. These areas function as conservation.

The recommendation related to ecosystem service of water provision are:

a. The dam must consider a green belt area, which functions as a water catchment area. Conserving the green area will protect the water source and make it sustainable.
b. Managing the sediment into the dam will prolong the dam's function and infrastructure.

Furthermore, the general suggestion for the planning of "Sepaku Semoi" dam in East Kalimantan are:

a. The selection of dam location, regulated in Decision of Director General of Water Supply as Head of Dam Safety Commission No. 05/KPTS/2003 about a) Guidelines for Dam Safety Assessment, b) Guidelines for General Dam Design Criteria and c) Guidelines for Dam Safety Inspection and Evaluation.
b. The provision of mangrove area substitution should be located surrounding the dam location.

The suggestion related to ecosystem service of water provision:

a. The dam planning should take the location and condition of the watershed into account, which will function as the water source to the dam.
b. The dam plan needs to take the green belt area near the dam to function as a water catchment area so the green belt should be a conservation area.

The recommendation and suggestion of mitigation action are below:

a. The greenery of the area surrounding the dam includes compiling the regulation for deforestation, especially in the catchment area. It will function to conserve water resources.
b. Managing the sanitation system within the settlement area located nearest the dam to protect water pollution from domestic waste.
c. Managing the sedimentation using the method of dredging in the river to fend off sediment from entering the dam.
d. Conservation planning areas must be established to conserve the mangrove area replacement.
e. Avoiding the development of a dam in an earthquake zone.

By considering the infrastructure located in disaster-prone areas, the recommendation and suggestion are related to the mechanism of building back better (BBB) introduced by Sandeeka Mannakara in 2014. The BBB framework consists of three main categories, 1) Risk Reduction, 2) Community Recovery, and 3) Implementation. This framework, specifically on the aspect of risk reduction, has two principles: 1) Improvement of Structural Design, depicting improving structural designs and enforcing through revised building codes; and 2) Land use planning, representing the use of hazard and risk-based land-use plans to minimize risks (Erlinna et al., 2020).

The recommendation, suggestion, mitigation, and adaptation action, could be explained in more detail. They could refer to each ecosystem service that has been overlaid with the dam's planning and be an example for ecosystem service of water provision.

Conclusions

Overall, the research hypothesis has been justified using ecosystem service as an indicator in infrastructure planning, a solution in giving less impact or less damage to the environment. The steps of using ecosystem service have been clarified to formulate the result. The recommendation and suggestion should be taken afterward.

This research uses the environment carrying capacity data on a scale of 1: 250.000 due to the availability of the data. This might not be in detailed information, especially for planning infrastructure in a small area. Hopefully, the local government, especially the planning and development agency (Bappeda) of the city/district region, could prepare the data of ecosystem services on a more detailed scale at 1: 50.000.

The water catchment areas that function as water sources play a vital aspect in the dam infrastructure development. The river can be a water source. For instance, the "Sepaku Semoi" dam planning is closed to Mahakam River. Further research could look up the relationship between data of ecoregion ecosystem services with the character of river area affected by the development of dam infrastructure. Additionally, further research could assess ecosystem services in another planning object of public works and housing infrastructures such as road planning or waste management site planning.

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