Environmental Carrying Capacity based on Ecosystem Services for Sustainable Development in Banggai Island

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Abstract Environmental carrying capacity based on ecosystem services has been widely used to maintain the environment against development. Environmental carrying capacity assessed in this study to estimate the ability of Banggai Island regency in provisioning food and water, regulating water flow and flood, and regulating of prevention and protection of natural disasters. The environmental carrying capacity was calculated based on ecoregion, vegetation, and land cover. The results subsequently presented in the map. This study pronounced that Banggai Island has a lower environmental carrying capacity for food water provision, as well as protection against natural disasters. This study is highlight carrying capacity profile of Banggai Island as a possible tool for government and multi-stakeholders in directing the development.

1. Introduction
Over the past decades, Indonesia experiences in biodiversity loss with regards to ecosystem functions [1,2]. Forest conversion [3], land use change [4–6], land use intensification [1,7,8], and natural disasters [9] have led potential degradation on natural resources. This, in turn, declines the ecosystem services. Indonesia as islands of Wallace, also known as the biodiversity hotspot [10]. Banggai Island, located in Sulawesi Indonesia, has been reported as a unique biodiversity resource. The natural ecosystem in Banggai Island has a very important role in various aspects of life. However, ecosystem services provided are increasingly diminishing in line with increasing human needs and developments [11]. Massive utilization of ecosystems services that are not followed by conservation will affect the decline of environmental carrying capacity [12,13] and may lead to the degradation of the ecosystem [14,15].

Ecosystem services refer to the function of nature that can be obtained for human wellbeing. This concept initially introduced by [16] in the ecology of the landscape. Based on Millennium Ecosystem Assessments, ecosystem services grouped into four categories, namely supporting services, regulating
services, provisioning services, and cultural services. Ecosystem services being a big concern since nature will not provide services long life, while human obtain the daily needs from the ecosystems. Ecosystem services profile can be an import tool for decision making of the government [17–19]. The ecosystem services profile will integrate ecosystem service tradeoff to manage the land use [20], forecasting the ecological condition in the future and decide the plan [21], and adapt and the actions against the ecosystem services condition [22].

Ecosystem services in Banggai Island may decline and seem more anthropic [23]. There are three possible reasons follows: (i) community activities related to their livelihoods in agriculture push the land-use change [24,25], (ii) economic business activities tend to extractive (see, for example [26], (iii) human behavior to pollute the environment see for instance [27,28]. Shifting cultivation is still a major problem in Banggai Island [29]. This study highlight the profile of the environment carrying capacity based on ecosystem services of provisioning services for food, provisioning services for water, regulating services of water flow and flood, and regulating services of prevention and protection of natural disasters. We then explain the possible actions of the government in implementing sustainable development by pay attention to the environmental carrying capacity.

2. Material and Method

2.1. Study site
This study located in Banggai Island, a regency in Central Sulawesi, Indonesia (1°06' 30" SL to 1°35' 58" SL and 122°37' 6.3" EL up to 123°40' 1.9" EL). The annual temperature ranges from 27ºC to 32 ºC. The relative humidity reported by 82% in June and 73% in October with annual rainfall by 127.10 mm (Central Bureau of Statistics Central Sulawesi, 2018). Figure 1 shows the administrative map of Banggai Island. Based on the morphology, structure and formation processes, Banggai island is divided into four main units namely mountain (hills structural), karst hills, intrusive hills and lowlands and surrounded by ocean [11].

2.2. Data analysis
The environmental carrying capacity was calculated based on ecoregion, vegetation, and land cover (Equation 1). The ecosystem services obtained by weighting and comparison of the landforms and land cover contribution to the ecosystem services. The higher the value of ecosystem services, the higher the environment carrying capacity. The assessment of the role of each type of landform, type of vegetation, and type of land cover was carried out by an expert based valuation method, namely an assessment carried out by some experts in a focus group discussion. Weighting related to the role and contribution of landforms, vegetation, and land cover to ecosystem services was determined by the analytical hierarchy process (AHP) method. To this study purpose, we calculated provisioning services for food and water. The regulating services consisted of water flow and flood management; and prevention and protection of natural disasters. Ecosystem services will show environmental carrying capacity indicative based classes (Table 1).

\[
ES = (w_{bl} \times s_{bl})+(w_{veg} \times s_{veg})+(w_{pl} \times s_{pl})
\]

equation 1

where ES is ecosystem services, \(w_{bl}\) is weighted for ecoregion, \(s_{bl}\) is the score for ecoregion, \(w_{veg}\) is weighted for vegetation, \(s_{veg}\) is the score for vegetation, \(w_{pl}\) is weighted for land cover, \(s_{pl}\) is the score for land cover. The carrying capacity of rice (Equation 2) was measured separately to support the carrying capacity of provisioning food on ecosystem services.
where $CC_{rice}$ is the carrying capacity of provisioning rice, $PR$ is the productivity of the rice field which planted by rice (kg/ha), $AP$ is the total area planted by rice (ha), $\alpha$ is index conversion of paddy to be rice (62.74%), $Po$ (number of population), $RN$ is the standard need for rice (kg). The interpretation of carrying capacity of provisioning rice estimated as “<1” if the area is not able or “>1” if the area able to provide the need of rice for their population by themselves.

![Figure 1](image_url)

**Figure 1.** Administrative are of Banggai Island Indonesia.

| Class of Carrying Capacity | Ecosystem services indices |
|----------------------------|---------------------------|
| Very low                  | 1.00 - 1.80               |
| Low                       | 1.81 - 2.60               |
| Moderate                  | 2.61 - 3.40               |
| High                      | 3.41 - 4.20               |
| Very high                 | 4.21 - 5.00               |

3. **Results and discussion**

3.1. *Provisioning services for food*
Ecosystems everything that comes from biological resources from above ground and water, which are intended as food or drinks for human consumption. Provision of food by ecosystems comes from agricultural and plantation, livestock food, marine and forest products. We found only 38% of areas had high and very high carrying capacity status (Table 2, Figure 2A). A total of 62% area of Banggai Island show low to moderate carrying capacity. The distribution of regions had a high food providing service mostly found in land cover dominated by dryland agriculture, mixed farming, secondary forest, and shrub. These land cover types are majority located in the District of Bulagi. It indicates that maintaining ecosystems related to food providers will, in turn, support food production. Hence, the regions which showed lower ecosystem services can be managed not for agricultural purposes in regional development of Banggai Island. We also measured the carrying capacity of Banggai Island in providing rice. The results show that Banggai Island was not able to provide rice to fulfill the need of population in Banggai Island (CC rice = 0.1). It is not surprising since Banggai Island only have 5 of 12 districts that have paddy swim. We noted that the large area of paddy swim in Banggai Island was 559 ha from 2,488.9 the total large area of Banggai Island.

It is indicating that Banggai Island does not have an adequate carrying capacity related to the function of food supply. The collaboration between governments of Banggai Island and other neighbor government areas will be needed for maintaining the continuity of rice supply to Banggai Island. Also, the government of Banggai Island has to protect the area belong to agricultural wetland for paddy from the land use change. The network of irrigation infrastructure is one to be considered. Revitalization and develop the new irrigation for agriculture has to be a priority for increasing the carrying capacity of Banggai Island in providing rice.

The increasing demand for agricultural products, about the rising of population commonly increase the pressure of agricultural intensification. However, the negative impact on the environment has to be controlled. In developed countries, the productivity of agriculture can reach the maximum level. In parallel, high external inputs which are unsustain will follow. Therefore, we can see the conditions that high energy cost, the resistance of pesticide, and a decrease in soil carbon to support productivity. Maintaining ecosystem surrounding the agricultural fields will support the sustainability of agricultural productivity (see for example [30]. Managing water as one of an ecosystem services providers will benefit the food provisioning [31].

Table 2. Distribution of environmental carrying capacity in Banggai Island based on ecosystem services and their coverage area (Ha and %).

| CES | Provisioning services for food | Provisioning services for water | Regulating services of water flow and flood | Regulating services of prevention and protection of natural disasters |
|-----|-------------------------------|--------------------------------|-------------------------------------------|---------------------------------------------------------------------|
| Area (Ha) | % | Area (Ha) | % | Area (Ha) | % | Area (Ha) | % |
| Very Low | 1,002.72 | 0.42 | 3,147.83 | 1.31 | 93,582.2 | 39.09 | 56,599.0 | 23.64 |
| Low | 62,754.2 | 26.21 | 18,380.8 | 7.68 | 5,325.12 | 2.22 | 44,403.5 | 18.55 |
| Moderate | 84,270.3 | 35.20 | 157,806. | 65.92 | 0.00 | 0.00 | 98,928.2 | 41.33 |
| High | 55,973.3 | 23.38 | 59,853.9 | 25.00 | 29 | 57.75 | 138,252. | 41.33 |
| Very High | 35,386.4 | 7 | 197.72 | 0.08 | 2,227.43 | 0.93 | 1,620.85 | 0.68 |
| Total | 239,387. | 100.00 | 239,387. | 100.00 | 239,387. | 100.00 | 239,387. | 100.00 |

*CES: a class of ecosystem services.
3.2. **Provisioning services for water**

Water, as provided by ecosystems mainly originated from groundwater and rain which uses for agriculture, industry, and daily household needs. Provision of clean water services is strongly influenced by rainfall conditions and soil layers that can store water (aquifers) as well as factors that can affect groundwater storage systems such as landforms and types of land cover [32–34]. In this study, we found high to a very high carrying capacity of water covers 25% of all land cover in Banggai Island (Table 2, Figure 2B), particularly in primary dryland forest, secondary dryland forest, shrub, swam shrub, and mangrove areas. These land uses distributed in Tinangkung, North Tinangkung, South Tinangkung, Liang, Buko, and South Buko districts. Around 75 % or 176,890.76 ha of land cover identified does not have adequate carrying capacity (moderate to very low carrying capacity classes) related to the function of providing clean water. In terms of the ability of Banggai Island in providing clean water, is still relatively low. A water crisis that may occur potentially caused by drought or environmental damage at the location of existing water sources. This ecological condition suggests the local government have to be able to improve and maintain the environmental carrying capacity of water supply. Government policy related to water protection suggest that: (i) allocation of water use has to consider the potential of water resources; (ii) increasing the efficiency of the use of water resources in various sectors also has to be managed; (iii) Maintain the sustainability of natural water flow rainy and dry seasons; (iv) avoid physical buildings except water collection tanks and water flow distribution pipes in the area of water sources and water flow; (v) prevention of changes of the cave mouths or water sources that alter the changes of natural rock structures; and (vi) control the land clearing or deforestation around the water sources. Water management for food can be enhanced. Asian countries normally face water provision problem. An optimistic scenario suggested by [35] that water demand in line with food demand is possible by improving agriculture irrigation.

3.3. **Regulating services of water flow and flood**

Our study show that only 58% area had a high carrying capacity (Table 2, Figure 2C), means that Banggai Island potentially suffers by flood and uncontrolled water flow. The distribution of that regions are mainly in primary dryland forest, secondary dryland forest, mixed dryland agriculture, and secondary mangrove forest. These land covers distributed in Bulagi and Buko districts.

The operational function of the regulating services of water flow and flood is related to the process of the hydrological cycle, as well as natural infrastructure for water storage, flood control, and water maintenance [36–38]. The hydrology cycle is the movement of water in the hydrosphere which includes the evaporation process, cooling air mass (condensation), precipitation, and flow. The hydrological cycle that occurs in the atmosphere includes the formations of rain clouds, the of rain, evaporation, transpiration, and evapotranspiration [39–41]. While the hydrological cycle that occurs in the biosphere and lithosphere is a water ecosystem that includes surface flow, freshwater ecosystems, and ocean ecosystems, a normal hydrological cycle will have an impact on good water management arrangements for a variety of interests such as water storage, flood control, and maintenance of water availability. The regulation of the water system with the hydrological cycle is strongly influenced by the type of land cover and physiography of an area.

3.4. **Prevention and protection of natural disasters**

This ecosystem service refers to the capacity of natural infrastructure prevention and protection from land fires, erosion, abrasion, landslides, storms and tsunami. An ecosystem contains regulation element on natural infrastructure for prevention and protection of certain types of disasters, especially natural disasters.

In this study, we calculated only a total of 16% areas could provide high and very high carrying capacity of natural disaster protection in Banggai Island (Table 2, Figure 2D). The type of land cover
supported by primary dryland forest, secondary dryland forest, dry land agriculture, mixed dryland agriculture and secondary mangrove forest in North Bulagi and Buko districts.

The functions of preventing natural disasters are closely related to the presence types of land cover and landforms [42,43]. Above ground biomass that covered by dense vegetation can prevent areas from erosion, landslides, abrasion, and tsunami [44–46]. Also, landforms specifically have a direct impact on the source of the disaster, for example, erosion and landslides generally occur in structural and denudation landforms with hilly morphology [47–49].

4. Conclusion
The profile of environmental carrying capacity based ecosystem services contributes important information toward science development and practical decision making by Government. Understanding the need for development and the same direction to protect the environment for sustainability lead sustainable goals achievement to be possible. Here, we present the environmental carrying capacity of Banggai Island, in particular for food water provision, as well as protection against natural disasters, that shows low capacity. It suggests the multi-stakeholders to plan the development by protecting and improving nature for ecosystem services.

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