

# Carrying capacity of water resources in Bandung Basin

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**Abstract.** The concept of carrying capacity is widely used in various sectors as a management tool for sustainable development processes. This idea has also been applied in watershed or basin scale. Bandung Basin is the upstream of Citarum watershed known as one of the national strategic areas. This area has developed into a metropolitan area loaded with various environmental problems. Therefore, research that is related to environmental carrying capacity in this area becomes a strategic issue. However, research on environmental carrying capacity that has been done in this area is still partial either in water balance terminology, land suitability, ecological footprint, or balance of supply and demand of resources. This paper describes the application of the concept of integrated environmental carrying capacity in order to overcome the increasing complexity and dynamic environmental problems. The sector that becomes the focus of attention is the issue of water resources. The approach method to be carried out is to combine the concept of maximum balance and system dynamics. The dynamics of the proposed system is the ecological dynamics and population that cannot be separated from one another as a unity of the Bandung Basin ecosystem.

## 1. Introduction

The Bandung basin has been appointed as one of the National Strategic Areas (KSN) with a width of more or less 2,283 km<sup>2</sup> and it covers five administrative areas. The appointment of this region as KSN has implications for the escalation in the number of people who follow the global trend which is marked by the flow of urbanization. The calculation results show that the population in this area is predicted to reach 10.39 million people by 2020 [1]. The population increment means an increase in the availability of adequate water in quantity as well as quality though the amount of water as a resource relatively remains and even tends to decrease due to pollution. The existence of clean water in this area can be said as the blue gold for the survival of human life [2]. To achieve the balance of life and sustainable development, it is necessary to determine the carrying capacity of water resources in this area. This paper describes the development of the application of the carrying capacity concept and the method of carrying capacity assessment in Bandung Basin. The application of study on the carrying capacity water resource concept in this paper is presented as an integrated manner with other resources in an overall environmental unity [3].

## 2. The development of global carrying capacity concept

The concept of carrying capacity appeared when humans recognized that the availability of the limited resources must be able to meet the increase of human needs [4,5,6,7,8,3]. Taiwo and Feyisara (2017) define the terminology of carrying capacity as simply as the maximum number of populations that can be sustainably supported by the ecosystems in a certain area [9]. Sustainability means that there is a supportive and assimilative capacity in the concept of carrying capacity [10]. Therefore, the carrying capacity refers to the definition of extreme limits. When the limit is exceeded (an imbalance between



supply and demand occurs), undesirable negative effects may occur, such as the extinction of a particular species or organism, changes or environmental damage, the breakdown of a food chain, and so on.

At first, the terminology of carrying capacity emerged from the mechanical which was then initially used in genetic theory. With the increase of population and the reduce of agricultural land and food crises, the concept of carrying capacity gradually changes and is used to solve problems that arise in the development of humanity. Furthermore, the application of the concept of carrying capacity develops to various sectors such as environment, ecology, regional, resources and environment, tourism, fishery, and marine. Even today, the application of the concept of carrying capacity has been used widely as a management tool in various sectors [3,11,12,13,14,15,16]. The development of the carrying capacity concept in various sectors shows that this concept can be seen from various perspectives which general purpose is to anticipate the occurrence of overshooting or achieving a balance of a habitat in the objective sector.

To anticipate the occurrence of overshooting conditions, many researchers developed various methods of carrying capacity valuation [3,7,17,18,19]. Until now, however, the evaluation method on the results of the carrying capacity assessment has not been sufficient, so there is still a need to look for evaluation methods and a clear calculation of the concept of carrying capacity [3,20,21]. Taiwo and Feyisara (2017) stated that the carrying capacity of an area is not static [9]. The dynamics of carrying capacity indicate a relationship between humans and their environment. The relationship with different species varies and changes over time due to varieties of factors. These factors include population size, natural resources, natural assimilation, technology, and population resistance against environmental changes. Since the components within an ecosystem can change over time, the development of a carrying capacity assessment method needs to be directed to a dynamic system.

### **3. Carrying capacity of water resources**

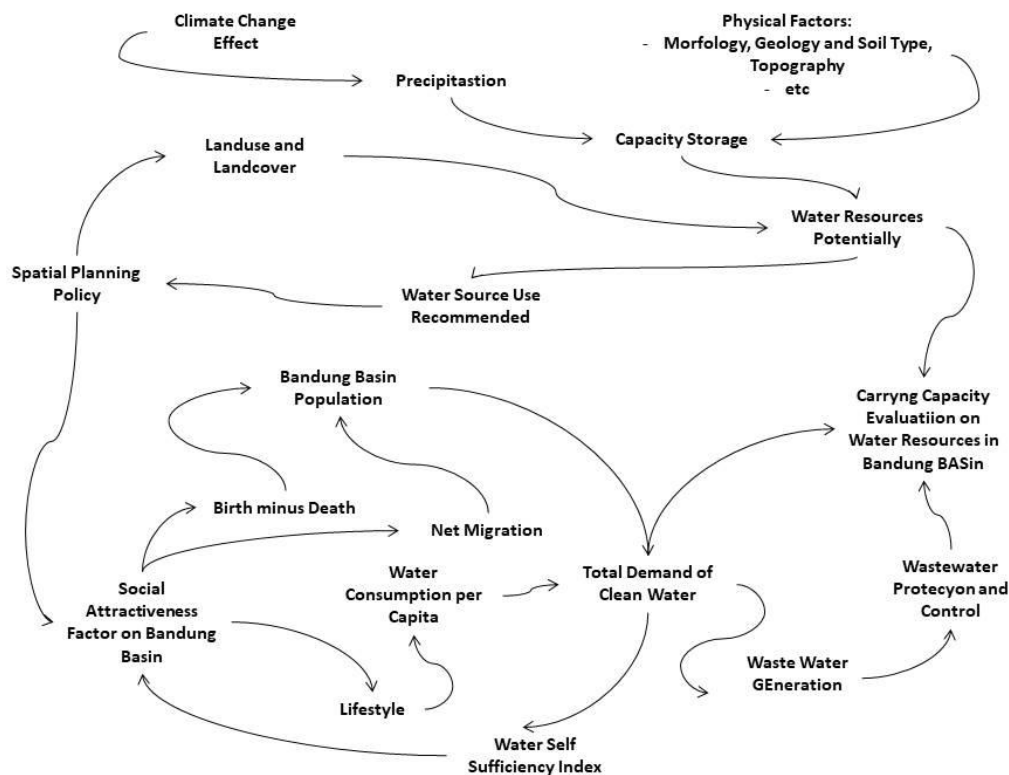
The water sector becomes strategic enough to be studied, not only as a national issue but also a global issue. The research results show that the availability of water sources that can meet human needs in quantity and quality are more and more difficult to find. Moreover, many regions of the world wide have experienced droughts and water scarcity [22,23,24,25]. Since water resources are a vital need for all humans and other living beings, this paper will examine the development of the concept of carrying capacity in the water sector.

The foundation of the carrying capacity concept in Indonesia is The Law Number 26 Year 2007 on Spatial Planning. Article 34, paragraph 4 stated that one of the foundations in the utilization of space is the compatibility between the carrying capacity and the capacity of the environment. Furthermore, the Regulation of the State Minister of Environment Number 17 Year 2009 stated that the scope of environmental carrying capacity in the determination of the spatial planning includes: 1) determination of land capability to allocate space utilization; 2) comparison between land availability and demand, and 3) comparison between water availability and demand.

The Ministry of Public Works is one of the institutions that often utilizes the concept of carrying capacity in a spatial study in Indonesia by using ecological footprint method and ability and suitability unit of land (SKL). The ecological footprint method in the concept of carrying capacity is the maximum number of populations that can be supported by a particular land area. Rusli (2009) defines ecological footprint as a resource management tool that can measure the amount of land and water needed by the human population to produce the resources they consume, and absorb waste from the utilization of these resources using certain technologies [8]. Kustiwan also defines ecological footprint as an indicator of sustainability and measuring instrument of the impact of human activities on the natural environment [26]. In this method, there are two aspects of ecological footprint, the ecological footprint of demand (EF Consumption) and ecological footprint of supply (Biocapacity). Ecological footprint of demand is calculated from the wide area of production land that can ecologically sustain a certain population. The ecologically productive land in question is cropland, graze land, forest land, fishing ground, carbon uptake land, and built-up land while ecological footprint of supply illustrate the

natural supply capacity to support human activities (Biocapacity). The results of biocapacity assessments are certainly different between regions due to the available natural resource differences and the productivity differences in each type of land, which is described as land productivity (ratios) of certain types of land to the average global productivity for the same type of land. An accurate database determines the results of the calculation and carrying capacity valuation using this ecological footprint method.

An application for ecological footprint valuation was developed by the Global Footprint Network (GFN) in 2003 and refined in 2008. The National Footprint Accounts edition calculates the ecological footprint (for consumption) and biological capacity from 201 countries around the world from 1961 to 2005 in which a full set of data is available through UN statistics [27]. The purpose of the National Footprint Accounts is to provide a strong and transparent scientific calculation that allows comparisons of state demands on global regenerative and absorptive capacity [28]. That is why this method is good enough for the comparative process and the initial foundation to make a wise decision, especially in spatial planning.



**Figure 1.** A model dynamic system framework on the carrying capacity of water resources.

Another method of carrying capacity that is often applied is the Land Capability and Compatibility Unit. In the concept of carrying capacity, this method is used to quantify a certain amount of land that is suitable for human life, both in quantity and quality. Through this method, the utilization of land should be adjusted to the ability of land, among others, they are seen from the morphological aspects, slope stability, foundation stability, erosion, drainage, water availability, waste disposal, ease of use, and against natural disasters [29]. Both ecological footprint and SKL focus on land availability and demand. Ecological footprint method analyzes the use and productivity of the land but very minimum analysis of water resource so that it is not suitable when it is used to value the carrying capacity of water resources in more detail. While in SKL method, water resources is only a part or one aspect of

analysis to determine the availability of water and the direct utilization of raw water without considering the natural assimilation. Because of the two regulations mentioned above, many researchers conduct a study of the carrying capacity of water resources to only limitedly compare water availability and demand [30,31]. Therefore, the development of methods for enhancing the depth of carrying capacity analysis, particularly for comprehensive water resources, is still open to be developed to be stronger and deeper.

Lihong conducted a study of the carrying capacity of water resources in Tarim watershed (Xinjiang, China), [17]. They explored a comprehensive method for evaluating the carrying capacity of water resources using the fuzzy theory approach. Data used in this case include population, the width of land area, annual average rainfall, and total availability of water resources (water supply). Xiufeng et al. predicted the carrying capacity of water resources in Jining City using non-linear dynamic models [32]. Prediction was based on the sustainable socio-economic development theory for the next 20 years. Wang and Xu applied the method of dynamic succession assessment in the carrying capacity of water resources through PSR (Pressure State Response) as a framework to build a system which was represented in three aspects of WEPC (Water Environment State Carrying Capacity), WESC (Water Environment State Carrying Capacity), and WERCC (Water Environment Response Carrying Capacity) [33]. The dynamic succession of these three aspects was assessed using a combination of fuzzy variable pattern and analytical hierarchies process (AHP) methods. Through spatial and temporal analysis, these study results can be used to compare the carrying capacity of the 31 provinces in China quite well.

Starting from some previous research and application development concept of carrying capacity of water resources in Indonesia, this paper tries to give an approach concept of water resources carrying capacity with dynamic system approach through the study case of Bandung Basin. Dynamic system is a methodology to understand certain complex problems. Dynamic system method tries to examine the problem and its characteristics. Then based on understanding its characteristics, the policy draft to control and improve the characteristics of the system in the desired direction will be executed [34]. Dynamic systems can also provide a unique mathematical framework to integrate the physical and social processes in the management of water resources [35]. This approach was chosen by reason that water resources and population variations change over time and space. Factor of population dynamics, directly or indirectly, will give an influence to the other carrying capacity factors. Therefore, in addition to the maximum population number as a boundary, the ecological dynamics in an ecosystem as a whole will provide an assessment of the carrying capacity of water resources within a single unified ecosystem system. Figure 1 shows a draft model framework that will be proposed to be assessed in evaluating the carrying capacity of water resources in the Bandung Basin using dynamic system methodology approach.

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