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Abstract. West Jawa is a very important province in Indonesia. There are six river basins in West Jawa, namely: Ciliwung-Cisadane, Citarum, Cimanuk-Cisanggarung, Cisadea-Cibareno, Ciwulan-Cilaki, and Citanduy. The capital city of Jakarta is in the Ciliwung-Cisadane River basin, but the public water supply is supplied mostly from the Citarum River basin, which has three hydropower reservoirs and irrigates 240,000 hectares of rice field. Water security in West Jawa plays an important part in the sustainable development of the nation. This paper formulates and computes the water security for river basins in West Jawa. The method of constructing water security dimension is adapted from the Asian Water Development Outlook, having five dimensions of 1) household water security; 2) economic water security; 3) urban water security; 4) environmental water security; and 5) resilience to water-related disasters. At the river basin level, the water security indices are designed to be effective, simple, widely available, having no ambiguity, and directly related to the progress of infrastructure development. The water security results are presented as a radar diagram, and spatially in the thematic map. It is concluded that the overall water security score in West Java is "capable" (score of 3). The weakest security is Ciliwung-Cisadane and Citarum as "engaged" (score of 2). Both river basins are suffering from "hazardous" environmental water security.

1. Introduction

1.1 Background

Water is essential for livelihood. Lack of water may threat all aspects of human life, the household, urban, economy, as well as the environment [1]. Too much water also causes flooding disaster. We need a condition of water security. There are several definitions of water security. The formal definition as follows: Water security is defined as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability [2].

There are some results on water security at the national level, for example [3]. However, only very few studies are available on water security at the river basin level [4, 5, 6]. In the Indonesian river basin, there are global studies [7-9]. Improvement of water security is carried out by infrastructures in the river basin. Therefore the water security index at river basin level is very important to be developed.

This paper formulates the water security indicators suitable for river basin level and computes the water security for river basins in West Jawa. The results can be used to identify the weakness in water resources management that can be improved.

1.2 Study Location

The location of the study is the river basins in West Jawa. West Jawa is a very important province in Indonesia. There are six river basins in West Jawa, namely: Ciliwung-Cisadane, Citarum, Cimanuk-Cisanggarung, Cisadea-Cibareno, Ciwulan-Cilaki, and Citanduy (figure 1). The capital city of Jakarta is in the Ciliwung-Cisadane River basin, but the public water supply is supplied mostly from the Citarum River basin, which has three hydropower reservoirs and irrigates 240,000 hectares of rice field. Water security in West Jawa plays an important part in the sustainable development of the nation.

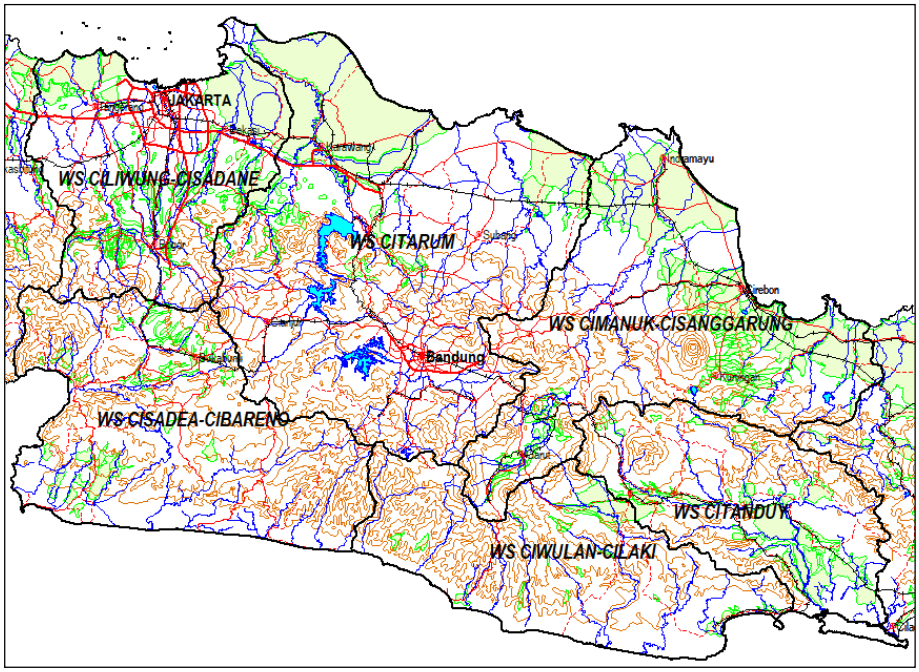

Figure 1. Study location.

2. Methodology

The method of constructing a water security dimension is adapted from Asian Water Development and Outlook [10]. This water security index is having five dimensions of 1) household water security; 2) economic water security; 3) urban water security; 4) environmental water security; and 5) resilience to water-related disasters. The scoring system also refers to ADB, from the best results is 5 (model), 4 (effective), 3 (capable), 2 (engaged), and 1 (hazardous). We modify the indicators of those five dimensions to be compatible with data availability in Indonesia, and to be used for predicting climate change.

3. Results and Discussions

3.1 Water Security Index

A detailed and comprehensive water security indicator should describe water security much better than simple indicators. However, the research criticized the complete comprehensive water security indicator concept that from 258 countries in the world, only 119 countries having data, and only 83 countries data can be evaluated [11, 12].

At the river basin level, the water security indices are designed to be effective, simple, widely available, having no ambiguity, and directly related to the progress of infrastructure development. Some of the good indicators with lack of data will be eliminated using this approach; The same case also applied for indicators having only local meaning, such as flooded area and rice field productivity.

3.1.1 Household Water Security. Household water security is represented by the percentage of public water supply coverage and sanitation access. Both sources of data are obtained from the Statistical Agency.

3.1.2 Economic Water Security. Economic water security measures the productive use of water to sustain economic growth in agriculture, industry, and energy sectors. Difficulties in obtaining relevant data on industry and energy simplify this economic water security dimension into a component of 1) Self Sufficiency in rice; 2) Ratio of Reservoir storage to water available in the basin; and 3) Coefficient of Variation of the inter-annual runoff.

3.1.3 Urban Water Security. There are some indicators of urban water scarcity. However, the most relevant available data representing urban water security is the percentage of piped water supply. This statistical data is annually available from the Statistical Agency.

3.1.4 Environmental Water Security. Environmental water security plays an important role in the sustainability of water resources [13]. It can be defined as the amount of water available to the environment after the available water is taken to meet existing water demands [14, 15].

$$WSI_{EWR} = withdrawal/(MARR-EWR) \quad (1)$$

where:
WSI_{EWR} = Water Security Indicator for Environment
Withdrawal = Water withdrawal for various purposes
MARR = Mean Annual Renewable Resource
EWR = Environmental Water Requirement

3.1.5 Water-Related Disaster Resilience
Resilience to water-related disasters is the ability to cope with the harmful effects of rainfall variability. Heavy rainfall cause floods and landslides while less rainfall leads to drought disaster. Rainfall variability is measured as its coefficient of variation. There are inter and intra-annual rainfall coefficient of variation using a monthly time-series.

The water-related disaster resilience will be increased as more storage is built in the basin to stabilize the runoff fluctuation [14]. It is shown in table 1 concerning the score of the indicators for water-related disaster resilience.

$$WSID = (Storage + CVinter\text{-}annual + CVintra\text{-}annual) / 3 \quad (2)$$

where:
WSI_D = Water Security Indicator for Disaster
Storage = Storage indicator
$CV_{inter\text{-}annual}$ = Inter-annual rainfall coefficient of variance indicator
$CV_{intra\text{-}annual}$ = Intra-annual rainfall coefficient of variance indicator

Table 1. Components of water-related disaster resilience [15].

Storage		Inter-annual rainfall		Intra-annual rainfall	
Proportion of MARR (%)	Indicator	CV	Indicator	CV	Indicator
50	5	0	5	0	5
20	4	0.025	4	0.20	4
5	3	0.050	3	0.40	3
3	2	0.100	2	0.60	2
0	1	0.150	1	0.75	1

The formulation results of water security indicators to meet the requirements of data availability and can be used to predict the impact of climate change are summarised as follows.

Table 2. Summary of a water security index.

Water Security Dimension	Indicators	Source of Data
Household Water Security	- Percentage coverage of piped water supply - Percentage of sanitation access	Statistical Agency
Urban Water Security	- Percentage coverage of piped water supply	Statistical Agency
Economic Water Security	- Self-sufficiency in rice - Reservoir storage and CV of annual runoff	Statistical Agency Ministry of Public Works and Housing
Environmental Water Security	- Water available for environmental after water withdrawal from available water	Ministry of Public Works and Housing
Water Disaster Resilience	- Reservoir storage - The CV of annual rainfall	Ministry of Public Works and Housing

3.2 Water Security at River Basin

Applying the formulated water security index to the six river basins in West Jawa gives the following results in table 3.

Table 3. Water security index score.

River Basin	Household	Urban	Economy	Environment	Resilience	Overall	Description
Ws Ciliwung-Cisadane	3.0	3.0	1.7	1.0	2.0	2.1	engaged
Ws Citarium	3.0	3.0	3.3	1.0	3.0	2.7	engaged
Ws Cimanuk-Cisanggarung	3.0	3.0	3.0	5.0	2.5	3.3	capable
Ws Cisadea-Cibareno	3.5	3.5	2.7	5.0	2.0	3.3	capable
Ws Ciwulan-Cilaki	3.0	3.0	2.7	5.0	2.0	3.1	capable
Ws Citan Duy	3.0	3.0	3.0	5.0	2.0	3.2	capable
Average	3.1	3.1	2.7	3.7	2.3	3.0	capable

The average of the overall water security index in the six river basins is three or “capable.” Environment water security is the score the highest among another dimension. There is a wide gap in environment water security between river basins containing big cities of Jakarta and Bandung in Ciliwung-Cisadane and Citarum river basin, respectively, and the other river basins.

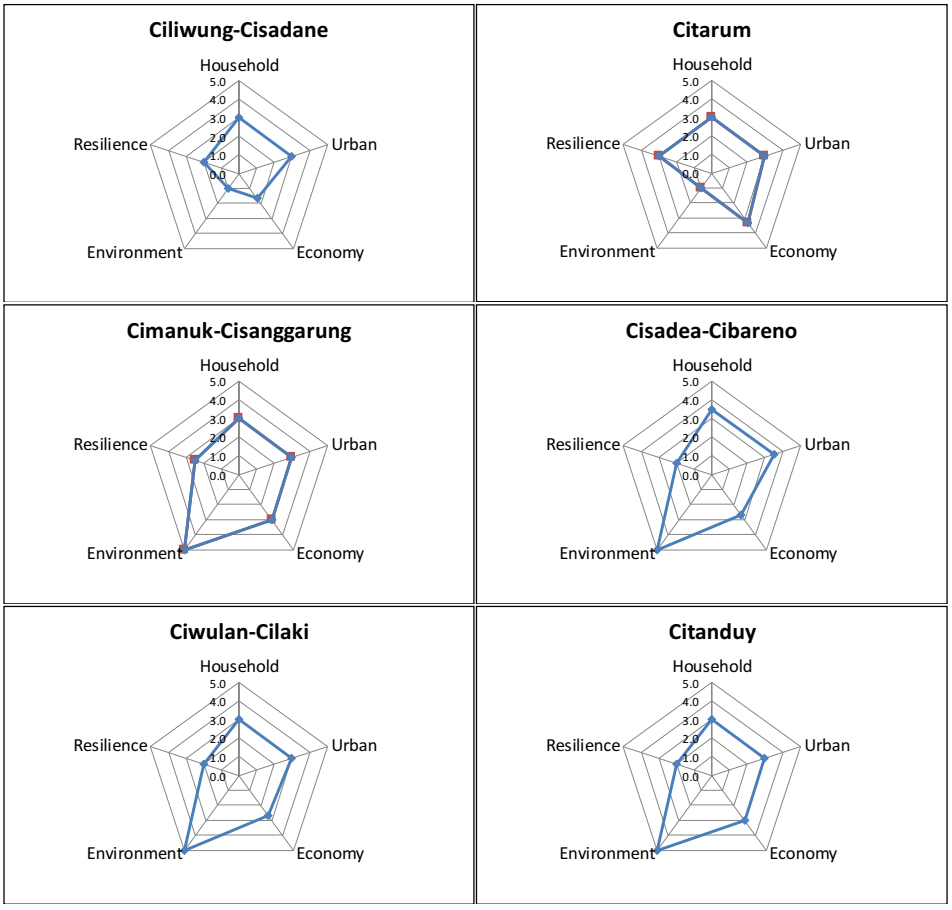

Figure 2. Radar diagram of water security index in the six river basin in West Java.

The lowest water security index is in the dimension of resilience to water-related disasters. All river basins without reservoir only score two or "engaged" because they cannot manage the variability of rainfall that might lead to flood and drought disasters.

The Radar Diagram of Water Security Index in the six-river basins in West Jawa shown in figure 2. Ciliwung-Cisadane river basin containing the Capital City of Jakarta is having the poorest water security index. Its dimensions of disaster resilience, environment, and economy water security are very low due to the high water demand for irrigation and public water supply.

The four river basins: Cimanuk-Cisanggarung, Cisadea-Cibareno, Ciwulan-Cilaki, and Citanduy are having a similar pattern of water security indicators. They have a very good environment water security with a maximum score of 5, which mean that water withdrawal is leaving enough water for environmental purposes. However, these four river basins are less resilience to water-related disasters. Cimanuk-Cisanggarung gives better resilience to water-related disasters since the Jatigede reservoir was built recently.

The rest of the two river basins, such as Ciliwung-Cisadane and Citarum basins, suffers from the minimum score in environment water security. No. water is left for the environment in Ciliwung-Cisadane river basin because of very high domestic, municipal dan industrial water demand for the capital city of Jakarta and surrounding. The water in the Citarum river basin is already allocated to irrigate more than 200 thousand hectares of irrigation and public water supply to the Eastern part of Jakarta. The three cascade reservoirs in Citarum: Saguling, Cirata, and Jatiluhur, improve the water security for the economy as well as resilience to water-related disaster.

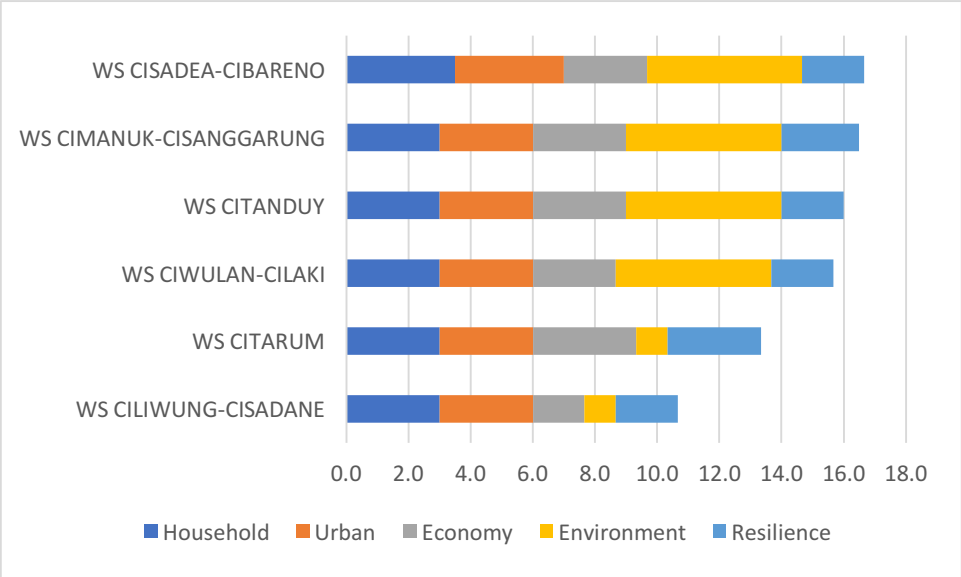

Figure 3. River basin water security index score.

The overall index scores of river basin water security are presented in figure 3. It shows that the two river basins located in the Northern Part of West Jawa get the worst total scores of 10.7 and 13.3 or average scores of 2.1 and 2.7 (engaged) for Ciliwung-Cisadane and Citarum river basin respectively. Both river basin suffers from environmental water security dimension because too much water for irrigation and public water supply no water left so that less water is available for environmental purposes.

The rank of overall water security in West Jawa, from the most secure, are 1) Cisadea-Cibareno; 2) Cimanuk-Cisanggarung; 3) Citanduy; 4) Ciwulan-Cilaki; 5) Citarum, and 6) Ciliwung-Cisadane.

4. Conclusions

This paper has formulated the practical indices of water security at river basin level using the most available data and based on water availability pattern to enable the possibility to predict the climate change impact to water security in the future. A case study in West Jawa concludes that the overall water security score in West Java is at a “capable” level (score of 3). The weakest security is Ciliwung-Cisadane and Citarum as “engaged” (score of 2). Both river basins are suffering from “hazardous” environmental water security due to water shortages allocated for environmental purposes.

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