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We are beginning a new chapter of the journal's life and with that comes the need to reaffirm our aims for this journal. Water Supply is an international peer-reviewed journal that focuses on all aspects of Water Supply, this allows us to focus not only on new scientific advances in this large subject area, but also gives us the opportunity to work on the technological aspects. This means that our readership is widespread throughout universities and within industry. For prospective authors, we offer expertise through our global editorial board and reviewer pool and strive to make sure that your experience with us is hassle free. We are looking to build our community and hope that you will want to be part of that. The scope of the journal falls within three distinct areas: Water Quality, Modelling and Management and we will accept papers within the following areas: -Water treatment technologies, including reuse and recycling -Drinking water quality -Water pollutants, characteristics and effects -Water supply in specific climates (e.g. arid, Semi-arid) -Water security, including water safety plans -Water distribution systems -Digitalisation of water distribution systems -Smart water supply systems -Hydraulics of water supply systems, including transients' -Water supply in mega cities -Optimisation of water supply systems -Karst systems -Artificial Intelligence methods in water supply -Climate change impacts on water supply -Water-energy-food-nexus -Integrated management of water resources (including reservoirs) -Water storage -Cascading effects between water infrastructure systems -Drought risk management -Leakage management -Water utility management including economic and social aspects -Asset management -Pump scheduling -Instrumentation

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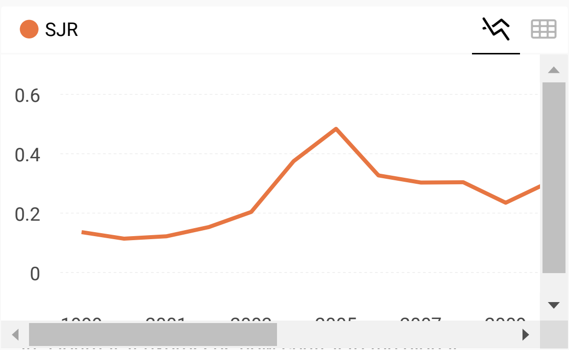

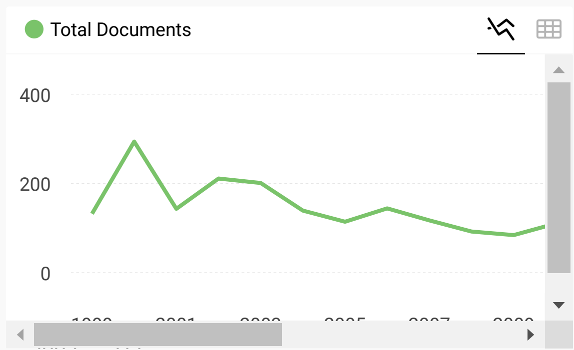

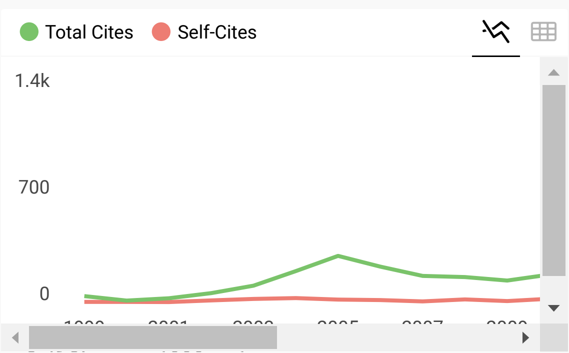

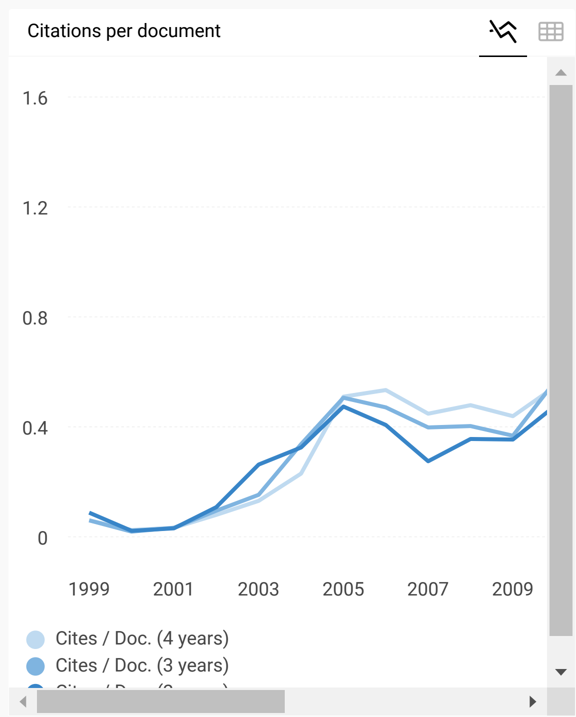

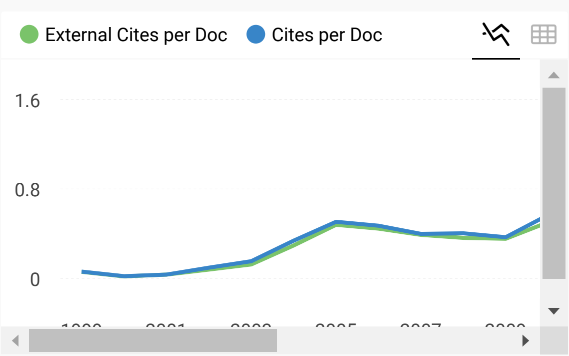

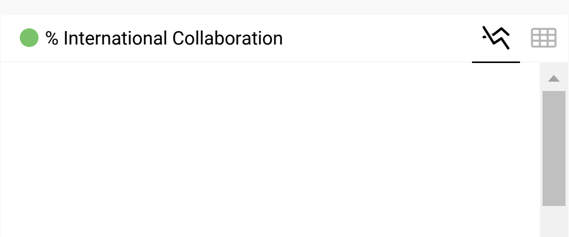

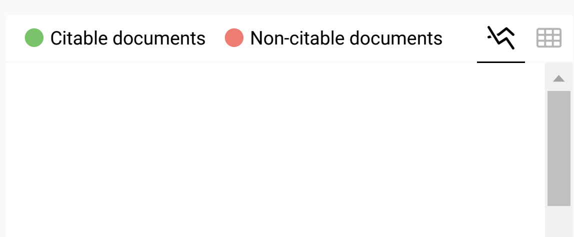

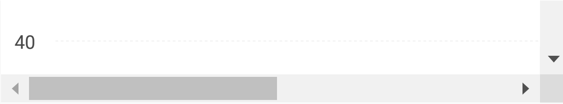

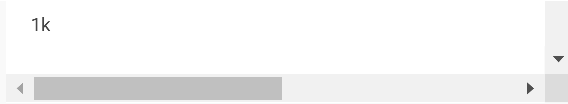

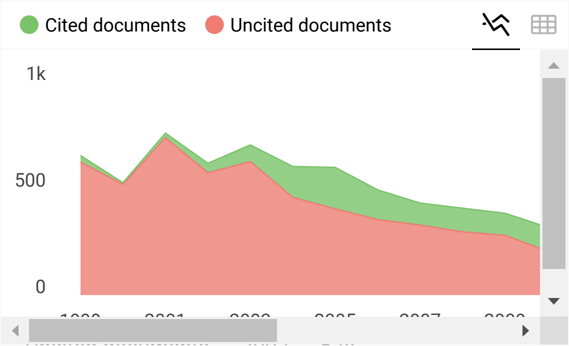

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Application of West Java water sustainability index to Citarum catchment in West Java, Indonesia

Iwan Juwana, Nitin Muttil and B. J. C. Perera

ABSTRACT

Water authorities in West Java, Indonesia have difficulties in implementing water improvement programs due to lack of tools for prioritisation of water-related issues and their respective programs. To facilitate more efficient management of the water resources, the West Java Water Sustainability Index (WJWSI) was recently developed. This paper outlines the tasks for developing WJWSI and highlights the results of its application in one of West Java catchments, Citarum catchment. The results showed that five out of the thirteen indicators and sub-indicators, namely 'Water Availability, Water Quality, Education, Water Loss and Poverty', had low sub-indices and thus had poor performances. Then, the sub-indices were aggregated using the geometric aggregation method to produce the final index. The results of the aggregation indicated that the overall condition of water resources in Citarum catchment was considered poor, with a final index value of 20.04. Based on the WJWSI application, recommendations are suggested to the relevant authorities in the Citarum catchment. It is expected that the implementation of these recommendations will improve the performance of these five indicators and sub-indicators from Poor to at least the next higher level of Poor–Medium, thus improving the value of the final index from 20.04 to 37.19.

Key words | Citarum catchment, Indonesia, sustainability index, West Java

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INTRODUCTION

The importance of water to living creatures is all too evident. Therefore, it is of utmost importance to maintain the sustainability of water resources, so that these resources can be utilised by humans and others, now and also in the future. To maintain and improve the quality of water resources, an adequate understanding of current condition of the water resources is required.

In one of the most densely populated provinces of Indonesia, West Java, the conditions of water resources are poor. The increase in population in the province has resulted in the increased demand for clean water. To fulfil the demand, both surface and groundwater resources in West Java are utilised. The availability of these water resources is abundant, due to high rainfall in most areas of West Java. However, this abundance of water is not properly managed, and has resulted in water shortages in some areas of the province (Rahmat & Wangsaatmadja 2007). In terms of their quality, most surface and groundwater resources in West Java are polluted by domestic, agricultural and industrial activities.

In the last decade, the provincial government of West Java has implemented various programs to improve the condition of water resources. However, these programs have not been successful. It is therefore important to obtain a comprehensive understanding on the current status of water resource conditions in West Java. Once this information has been obtained, relevant programs can be designed to improve the quality of the water resources. A water sustainability index is a useful tool to address this situation.

A water resource sustainability index offers the following benefits:

(i) It can be used to identify all factors contributing to the improvement of water resources (Sullivan 2002; Chaves

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& Alipaz 2007; Policy Research Initiative 2007), so that the resources can be used to fulfil present and future needs.

(ii) It can be used to assist decision makers to prioritise issues and programs related to water resource management.

(iii) It can be used to communicate the current status of existing water resources to the wider community (Policy Research Initiative 2007).

A new water sustainability index, called West Java Water Sustainability Index (WJWSI) was developed using the Delphi technique. This was specifically developed with the involvement of local water stakeholders and based on West Java natural and socioeconomic characteristics. This index will be able to not only obtain information on current condition of the water resources in West Java, but also to prioritise water issues for efficient management of water resources in West Java (Juwana *et al.* 2010a, b). The final structure of WJWSI is shown in Table 1.

This paper discusses the application of WJWSI to one of the catchments in West Java, namely the Citarum catchment. At the time of the application, the latest available data for the Citarum catchment was for 2008. Therefore, all relevant calculations in this study were based on this particular year. The paper outlines the stepwise procedure used in the application of WJWSI and the results have been used as the basis for recommendations suggested to the relevant authorities to improve the water resources management at the catchment scale.

CASE STUDY CATCHMENT AND DATA USED

The Citarum catchment occupies an area of approximately 7,400 km^2, which can be divided into three parts: upper (1,771 km^2), middle (4,242 km^2) and lower (1,387 km^2). As illustrated in Figure 1, three reservoirs have been built in the catchment, which are used to supply water for various purposes, such as domestic use, agriculture, power plants and fisheries. Average rainfall over the catchment is 2,300 mm/year, and the flow of the Citarum River, gauged at the inlet of Saguling, approximately equals 5.7 billion m^3/year.

In 2008, the total population within the catchment was just over 11 million. The majority live along the river banks, and have directly used the river for various domestic uses, including drinking water. Pressures on the catchment and its rivers come from pollutants from various activities within the catchment. Pollutants from the domestic sector originate from both direct and indirect discharge of 'black water' and 'grey water' of households. Hundreds of industries located along the river also pollute the river due to

Table 1 | Final framework of WJWSI

Component	Indicator	Sub-indicator	Unit	Threshold values Max.	Threshold values Min.
Conservation	Water Availability		m^3/cap/yr	1700[a]	500[b]
	Land Use Changes		%	100[a]	0[b]
	Water Quality		–	0[a]	−31[b]
Water Use	Water Demand		%	40[b]	10[a]
	Water Service Provision	Coverage	%	80[a]	0[b]
		Water Loss	%	30[b]	15[a]
Policy and Governance	Information Disclosure		–	100[a]	0[b]
	Governance Structure		–	100[a]	0[b]
	Public Participation	Education	%	100[a]	0[b]
		Poverty	%	20[b]	0[a]
		Health Impact	(cases/1,000 population)	2[b]	0[a]
		Sanitation	%	100[a]	0[b]
	Law Enforcement			100[a]	0[b]

[a]Preferable.
[b]Not preferable.

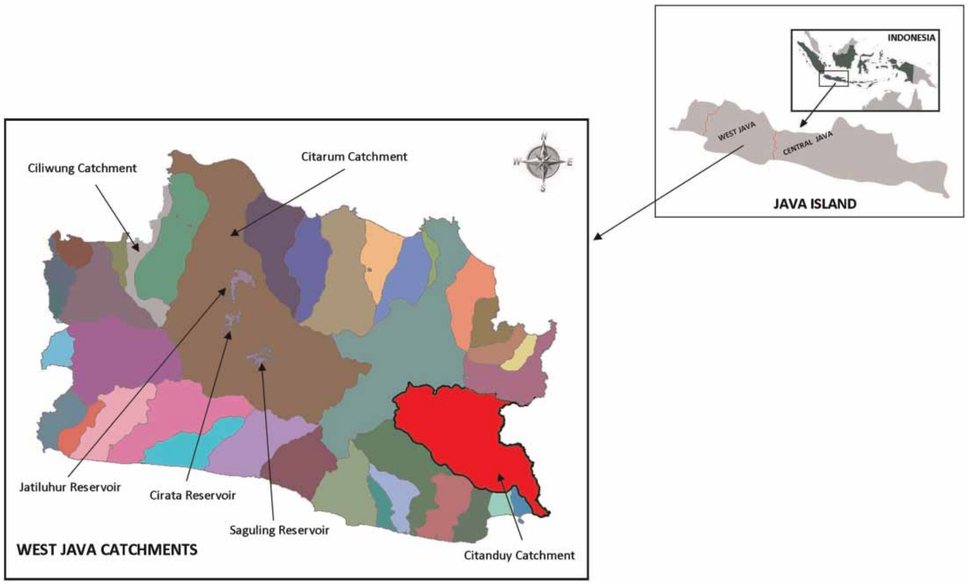

Figure 1 | Citarum catchment in West Java.

lack of awareness, as well as lack of law enforcement from relevant authorities. In addition, agriculture and livestock have also contributed to river pollution in the catchment.

The main data used for the application of WJWSI are taken from official and reliable sources of Indonesian databases, namely: Bureau of Meteorology of Indonesia, West Java Environmental Protection Agency (EPA), Health Department of Indonesia, Regional Forestry Service of West Java, Bureau of Statistics of Indonesia and Association of Water Companies of Indonesia. During the application, few outliers in the data were identified and dealt statistically with ensuring the quality of data and robustness of the index (Juwana 2012).

APPLICATION OF WJWSI TO CITARUM CATCHMENT

The steps followed in the application of WJWSI to the Citarum catchment are as follows.

Obtaining sub-indices

The sub-index values were obtained using either the 'continuous rescaling' method or the 'categorical scale' method as the data required to use these methods were available. The suitable method was chosen based on the nature of the WJWSI indicators and sub-indicators. Based on the characteristics of the indicators and sub-indicators, three groups were identified for computing the sub-index values (Juwana *et al.* 2012).

The first group of indicators and sub-indicators are 'Water Availability, Land Use Changes, Water Quality, Coverage, Education and Sanitation'. For this group, the higher the value of the indicator and sub-indicator, the more preferable it is, and vice versa. The sub-index values for this group were obtained using the continuous rescaling method (Equation (1))

$$\begin{aligned} S_i &= \frac{X_i - X_{\min}}{X_{\max} - X_{\min}} \times 100 && \text{when } X_{\min} \le X_i \le X_{\max} \\ S_i &= 0 && \text{when } X_i < X_{\min} \\ S_i &= 100 && \text{when } X_i > X_{\max} \end{aligned} \tag{1}$$

where S_i is the sub-index value for indicator i, X_i is the actual value for indicator i, and $X_{\min}$ and $X_{\max}$ are the minimum and maximum threshold values of the indicator. When Equation (1) is used, the $X_{\min}$ of the indicator is the least preferred value and $X_{\max}$ is the most preferred value.

Indicators and sub-indicators of the second group are 'Water Demand, Water Loss, Poverty and Health Impact'. For this group, the smaller the value of the indicator and sub-indicator, the more preferable it is, and vice versa. The sub-index values for this group were obtained using the modified continuous rescaling method (Equation (2)).

$$\begin{array}{ll} S_i = 100 - \left(\dfrac{X_i - X_{\min}}{X_{\max} - X_{\min}} \times 100\right) & \text{when } X_{\min} \le X_i \le X_{\max} \\ S_i = 100 & \text{when } X_i < X_{\min} \\ S_i = 0 & \text{when } X_i > X_{\max} \end{array} \tag{2}$$

The symbols used in Equation (2) are same as those used for Equation (1). When Equation (2) is used, the $X_{\min}$ of the indicator is the most preferred value and $X_{\max}$ is the least preferred value.

The third group consists of three indicators: 'Information Disclosure, Governance Structure and Law Enforcement'. For these indicators, the categorical scale was used to obtain their sub-indices, as shown in Equation (3)

$$S_i = \begin{array}{ll} 0 - {<}25 & \text{if } X_i \text{ meets criteria 1} \\ 25 - {<}50 & \text{if } X_i \text{ meets criteria 2} \\ 50 - {<}75 & \text{if } X_i \text{ meets criteria 3} \\ 75 - 100 & \text{if } X_i \text{ meets criteria 4} \end{array} \tag{3}$$

where X_i is the actual condition (similar to actual values for the non-categorical indicators and sub-indicators) assessed in a particular catchment. The criteria (1 to 4) that are used to obtain the sub-index for 'Information Disclosure' are defined in Table 2. This indicator examines the availability and accessibility of key data related to water resource management, for public use. Table 2 also shows the quartile scale that was proposed to quantify the sub-index for this indicator, with its criteria. Key data include rainfall, population, water quality, water use, coverage, water losses, education, poverty, sanitation, water-related diseases and land use.

Table 2 | Criteria for sub-index values of 'Information Disclosure'

Criteria	Sub-index
Few key data are available	0 – < 25
Key data are available, but only a few are accessible through the internet	25 – < 50
Key data are available, accessible, but not regularly updated	50 – < 75
Key data are available, accessible and regularly updated	75 – 100

The criteria that were used to obtain sub-indices for the other categorical indicators and sub-indicators can be found in Juwana (2012).

Aggregation of sub-index values

One of the most common methods used for aggregation of the sub-index values is the geometric method. This method is used by multiplying weighted sub-index values, as shown in the following equation (Swamee & Tyagi 2000):

$$I = \prod_{i=1}^{N} S_i^{W_i} \tag{4}$$

where I represents the aggregated index, N is the number of indicators to be aggregated, S_i is the sub-index for indicator i and W_i is the weight of indicator i. With this method, perfect substitutability and compensability among the sub-index values of the indicators do not occur (Nardo *et al.* 2005). This means that low values of some sub-indices would not be compensated by those high values of other sub-indices. Hence, poor indicator performances, shown by low sub-index values will be reflected in the aggregated index value (Juwana *et al.* 2012).

Index interpretation

Index interpretation is important to practically understand the meaning of the sub-index and aggregated index values. For the WJWSI, the interpretation for sub-indices and their aggregated index will be based on a quartile scale with four levels of 'Performance': Good (75≤value ≤100), Medium–Good (50≤value<75), Poor–Medium (25≤value<50) and Poor (value<25). The 'Performance' reflects the condition of the issue(s) related to an indicator, a sub-indicator, or the overall aggregated index at a particular time of assessment and would be used as the basis for relevant 'Priority of Action' to improve the water resource management at the catchment scale. The 'Priority of Action' reflects the priority of action to improve the 'Performance' of indicators or sub-indicators, which is the opposite of its respective 'Performance' (Juwana *et al.* 2012).

ANALYSIS AND RESULTS

The application of WJSWI in the Citarum catchment requires collecting required data for each indicator and sub-indicator. After all required data were collected, the sub-index for each indicator and sub-indicator was calculated. Then, all sub-indices were aggregated to obtain the final index. The following sub-sections present the details for calculating the sub-indices for the 13 indicators and sub-indicators used in the WJWSI.

Water availability

According to Falkenmark & Rockström (2004), the maximum amount of water available for human use is approximately 60% of the total rainfall, and this amount is used in the WJWSI application (the rainfall data were based on the average of 10 years rainfall in the catchment). This amount is then divided by the total population in the catchment to obtain the actual value of 'Water Availability'. The definition of water availability of Falkenmark & Rockström (2004) was used in this study, because of the lack of measured data for extraction of groundwater and the lack of sufficient number of streamflow measurement gauges in the catchment, to get an accurate estimate of the available water. Therefore, based on the rainfall and the total population, the actual value was calculated as 587.32 m^3/person for the Citarum catchment in 2008. Equation (1) was then used to calculate the sub-index for 'Water Availability' and it was 7.28. The low sub-index for 'Water Availability' in the Citarum catchment is caused by the large population living within the catchment. Recently the big cities in the catchment, such as Bandung, Depok and Bogor, have attracted people from other areas.

Land use changes

Ideally, the actual value of the 'Land Use Changes' indicator is obtained by comparing actual land use in the catchment with land use planning, issued by the Regional City Planning Body. However, in the Citarum catchment such land use data were not available. Therefore, the sub-index for land use changes was obtained by calculating the percentage of identified conservation areas within the catchment, which are supported with necessary planning documents. It was found that in 2008, as much as 84.68% of the total conservation area was supported with necessary planning documents. Using Equation (1), the sub-index for this indicator was calculated as 84.68.

Water quality

The actual value of 'Water Quality' was obtained by calculating the Storet value (Cude 2001; Indonesian Ministry of Environment 2003) for the 10 sampling points of water quality along the Citarum river, as practised by the West Java EPA. The Storet method assesses physical, chemical and biological parameters of water quality samples against an agreed water quality standard. If a water quality parameter meets the water quality standard, the Storet value is given as 0, otherwise it follows the Storet scoring system (Sholichin *et al.* 2010). The values of all parameters (physical, chemical and biological) are then added to obtain a single Storet value for a particular sampling point.

In the year 2008, the average Storet value for all 10 sampling points was −96.1. Using Equation (1), the sub-index for 'Water Quality' was calculated as 0. Poor water quality is caused by different factors. The major factor is the pollution from various activities along the rivers, particularly from domestic and industrial discharge. Lack of awareness by the general public has resulted in daily discharge of large amounts of pollutants into the rivers. This situation is worsened by the inadequacy of law enforcement and corrupt practices by relevant authorities, which allow some companies to discharge their untreated wastewater directly into the river.

Water demand

The first step to obtain the actual value of 'Water Demand' was to summarise the water used for different purposes including domestic, public facility, irrigation and industry. This was then expressed as a percentage of the available water in the catchment to obtain the actual value of the

'Water Demand' indicator. As mentioned earlier, the availability of water in the catchment was based on the 60% of the average rainfall in the last 10 years. For the Citarum catchment in 2008, this was calculated as 23.04%. The sub-index for this indicator was then computed using Equation (2) as 56.54.

Coverage

Within the Citarum catchment, there are 12 water service providers (WSPs). The actual value of the 'Coverage' indicator was obtained by considering the ratio of the population covered by the pipeline distributions of water companies to the total population within the catchment. Once this actual value was obtained (34.96%), the sub-index for 'Coverage' was calculated using Equation (1) as 43.70.

Water loss

The actual value of 'Water Loss' was obtained by considering the average loss of water both in the processes of water production and water distribution of all 12 WSPs in the Citarum catchment. In 2008, this was calculated as 40.10%. After the actual value was obtained, the sub-index for the 'Water Loss' indicator was calculated using Equation (2) as 0. The sub-index value for 'Water Loss' shows that all water companies in the catchment suffer from a high level of water loss.

Information disclosure

The sub-index for 'Information Disclosure' considered the availability and accessibility of key data, as well as regular data updates. The key data include rainfall, population, water quality, water use, water distribution coverage, water losses, education, poverty, sanitation, water-borne diseases and land use. Each of these data was assessed using the criteria in Table 2. The values for all these data were then averaged to obtain the sub-index of the 'Information Disclosure' sub-indicator. For the Citarum catchment, most of these data were available, but they could not be accessed by the public through the Internet. The sub-index value for this indicator was calculated as 37.27.

Governance structure

The sub-index for 'Governance Structure' was obtained by assessing the structure, job description and tasks of various water-related institutions. Clarity of structures and job descriptions, and identification of any tasks overlapping institutions are the criteria to obtain the sub-index for this indicator (Juwana 2012). The analysis for the Citarum catchment in 2008 shows that only a few institutions, which are responsible for the management of water resource issues in the Citarum catchment, have clear institutional structure and job descriptions. In some cases, overlaps of tasks occur among different institutions. For these reasons, the sub-index for 'Governance Structure' was estimated as 35.

Education

The actual value of 'Education' was obtained by calculating the percentage of people in the Citarum catchment who have completed primary education (BPS Team 2009). In 2008, this was calculated as 14.19%. The sub-index of the 'Education' indicator was then calculated using Equation (1) as 14.19.

Poverty

The actual value of 'Poverty' in the Citarum catchment was calculated using the percentage of people who fell below the poverty standard, defined by the Indonesian national government. According to this standard, poverty is defined as the inability of an individual to meet monthly basic living standard (BPS Team 2009). This standard is known as the poverty line, which is updated once every 3 years. In 2008, the poverty line for West Java was Rp 182,636.00 per person/month, equal to approximately USD 16.13 (by using 1 USD = Rp 11,320.00). The percentage of people under the poverty standard was calculated as 15.23%. Using this percentage value, the sub-index of the 'Poverty' indicator was computed using Equation (2) as 23.87.

Health impact

The actual value of 'Health Impact' was calculated by considering the number of haemorrhagic dengue cases for every 1,000 people. In the Citarum catchment for 2008, the actual value was calculated as 0.99. The sub-index for this indicator was then calculated using Equation (2) as 50.60.

Sanitation

The actual value of the 'Sanitation' indicator was obtained by calculating the percentage of people having basic sanitation facilities, in accordance with the national regulation on the minimum standard of sanitation facilities. According to this regulation, basic sanitation is defined as having any sanitation facility, such as pit latrine or closet (MDG Indonesia Team 2007). The actual value was calculated as 61.86%. Once this value was obtained, the sub-index was calculated using Equation (1) as 61.86. This value reflects that there were still around 40% of the population in the catchment (about 4 million) who had no access to basic sanitation facilities.

Law enforcement

The sub-index for 'Law Enforcement' was obtained by assessing procedures to enforce water-resource-related policies and regulations, compared with the actual implementation of the procedures. Currently, the West Java EPA already has procedures for regulation enforcement, but is not fully implemented, due to lack of support from other relevant institutions. For this reason, the sub-index for the 'Law Enforcement' indicator in the Citarum catchment was estimated as 40.

Sub-index values of indicators and sub-indicators

The sub-index values of the indicators and sub-indicators, as calculated above and their respective 'Performance' and 'Priority of Action' values are presented in Table 3.

Table 3 shows that some indicators and sub-indicators have performed poorly. They are 'Water Availability, Water Quality, Water Loss, Education and Poverty'. Only one indicator performed well, which is 'Land Use Changes'. The other indicators are considered either Poor–Medium or Medium–Good.

Better quality and management of water resources in the Citarum catchment can be best achieved by providing higher priority to the improvement of the indicators and sub-indicators that are poor in 'Performance'. The next section provides recommendations to improve poor performing indicators and sub-indicators to achieve at least a sub-index

Table 3 | Sub-indices of Citarum catchment for 2008

Indicator/sub-indicator	Unit	Actual value	Sub-index	Performance	Priority of action
Water Availability	m^3/cap/yr	587.32	7.28[a]	Poor	High
Land Use Changes	%	84.68	84.68[a]	Good	Low
Water Quality	–	−96.1	0.00[a]	Poor	High
Water Demand	%	23.04	56.54[b]	Medium–Good	Medium–Low
Coverage	%	34.96	43.70[a]	Poor–Medium	High–Medium
Water Loss	%	40.10	0.00[b]	Poor	High
Information Disclosure	–	–	37.27[c]	Poor–Medium	High–Medium
Governance Structure	–	–	35.00[c]	Poor–Medium	High–Medium
Education	%	14.19	14.19[a]	Poor	High
Poverty	%	15.23	23.87[b]	Poor	High
Health Impact	(cases/1,000 pop)	0.99	50.60[b]	Medium–Good	Medium–Low
Sanitation	%	61.86	61.86[a]	Medium–Good	Medium–Low
Law Enforcement	–	–	40.00[c]	Poor–Medium	High–Medium
Final Index			20.04	Poor	High

[a]Obtained using Equation (1).
[b]Obtained using Equation (2).
[c]Obtained using Equation (3).

value of 25, which would improve their 'Performance' from 'Poor' to 'Poor–Medium'. This in turn would improve the final index value from 20.04 to 37.19 (i.e. improve the performance of the final index from Poor to Poor–Medium).

RECOMMENDATIONS TO RELEVANT AUTHORITIES

It is recommended that water authorities in the Citarum catchment take appropriate actions to improve the sub-index values of these poor performing indicators and sub-indicators. Some actions are presented below, which as previously mentioned were based on the data from 2008.

Water availability

The 'Water Availability' indicator, with an actual value of 587.32 m^3/capita/year and a sub-index value of 7.28 had a Poor performance for 2008. To improve the performance to at least 'Poor–Medium' (or to a sub-index value of 25), the actual availability needs to be increased to at least 800 m^3/capita/year.

As mentioned earlier, the main factor causing low availability of water resources in the Citarum catchment is the density of population. One way to manage the population in the area is through the re-introduction of the 'transmigration' program, initiated in the early 1960s (Gondowarsito 1986). Through this program, people were encouraged to be relocated to less dense areas, outside the Java Island. They were given a piece of land, housing, and an establishment allowance to start a new life in a less dense area. This program was able to improve the well-being of the relocated people, as well as reducing the stress of the highly-populated areas (Gondowarsito 1990). However, this program was discontinued because people who had agreed to be relocated were unable to manage the land and housing given by the government, due to lack of skills (Gondowarsito 1990). Therefore, if this program is to be re-initiated in the future, government needs to provide the necessary skills for people to manage the land in the proposed areas.

Another way of managing the population is to create centres of activities in less dense population areas within the West Java Province and encourage people to move to those areas. At this stage, these centres (such as reliable shopping centres, leisure places and business areas) are concentrated in Bandung City in the Citarum catchment. Creating these centres in other areas will significantly reduce the motivation of people to migrate to Bandung City and other highly populated areas in the Citarum catchment. This can be done through the involvement and coordination of related stakeholders, particularly the Regional Planning Council as the responsible authority in planning and development, along with other business sectors, local governments and the community.

Other alternatives of increasing water availability in the Citarum catchment can be done through water harvesting programs. Recently, the government of Bandung City has initiated a program named 'A Million Bio-pores for Bandung City', which is undertaken by creating bio-pores in schools, offices, parks and other public areas. Other initiatives such as rainwater harvesting can also be introduced in highly-populated areas. Local government authorities should offer incentives to individuals and/or organisations that are willing to harvest rainwater in their houses.

Water quality

According to WJWSI results, in order to improve the performance of 'Water Quality' indicator from 'Poor' to 'Poor–Medium', its actual value needs to be increased from −96.1 to −23.25. The actual value of −23.25% will give the indicator a sub-index value of 25, which is the minimum value required for 'Poor–Medium' performance.

Poor water quality in the catchment, as previously mentioned, has mainly been caused by lack of awareness of stakeholders. To address this issue, the government, West Java EPA and community groups need to develop programs to improve community awareness on water resources. To be successful, program targets should be clearly stated and progress regularly monitored. Along with these community awareness programs, relevant authorities also need to enforce laws and regulations related to river water quality. To achieve this, close monitoring of the operation of wastewater treatment plants and other industries is required to ensure that industrial wastewater discharge meets the designated standards.

Education

The WJWSI results indicate that for the 'Education' indicator, in order to move from 'Poor' to 'Poor–Medium' performance, its actual value needs to be improved from 14.19 to 25%.

In the last few years, the Ministry of Education in Indonesia has launched programs to improve the quality of primary education, namely *Bantuan Operasional Sekolah* (School Operational Grant) and *Sekolah Gratis* (Free School for Everyone). These programs include the exemption of education fees for all primary students in Indonesia, providing necessary books to most elementary schools, and improving the quality of school infrastructure. However, these programs have not yet been fully implemented. There are still cases where schools collect money from students by giving various excuses (Auditan 2006; Widjajanti 2006). Consequently, students from low-income families are prevented from enrolling in these schools. Therefore, to effectively improve the quality of primary education, these obstacles need to be eliminated.

Water loss

Based on the WJWSI results, in order to improve this indicator from 'Poor' to 'Poor–Medium' performance, the average actual value of 'Water Loss' (of all water companies) in the Citarum catchment needs to be reduced from 40.10 to 26.25%.

According to Sukmayeni (2007), the water losses of the WSPs in Indonesia, including those in the Citarum catchment, were caused by both physical and non-physical factors. The physical causes that lead to water losses are leakages in water treatment plants, transmission systems and distribution systems. As for the non-physical causes, the losses mainly come from unbilled consumption, inaccuracies of customer metering and illegal connections (Djamal & Ali 2009). Yuwono (2009) suggests that higher priorities should be given to reducing the non-physical losses, as programs for reducing non-physical losses are more cost-efficient. It is believed that even though the non-physical losses are not real losses, they contribute to approximately 50% of the total unaccounted water of WSPs in West Java (Yuwono 2009).

Poverty

For 'Poverty', the WJWSI results indicate that a reduction of 0.23% of its actual value (from 15.23 to 15%) is needed to move the sub-indicator from 'Poor' to 'Poor–Medium' performance.

In the last few years, local, provincial and national governments have launched programs such as 'direct cash assistance' and 'cheap rice' to reduce the poverty level. The authorities reported that these programs have significantly reduced poverty in most provinces in Indonesia. However, such programs benefited the poor for a short period of time and some of these programs have been terminated. Once the programs were terminated, poverty levels increased. Along with the above short-term poverty reduction programs, it is also vital for the provincial and local governments to maintain and improve the implementation of long-term poverty alleviation programs. Two of the initiatives implemented in the last few years by the provincial government of West Java poverty reduction through entrepreneurship community trainings and capacity building of small enterprises (Suryahadi & Sumarto 2003). To reduce the poverty level significantly in the long-term, provincial and local governments need to ensure that such programs are increased, and the training and capacity building programs are monitored and evaluated.

CONCLUSIONS

The application of WJWSI to the Citarum catchment with data from 2008 showed that several indicators and sub-indicators performed poorly and thus needed higher priority of action. The final index value of 20.04 indicates that water resource performance in the catchment is considered as 'Poor'. To improve the water resource performance of the catchment, it is recommended that water authorities take immediate actions on the indicators and sub-indicators that are 'Poor' in their performances. These indicators and sub-indicators are: 'Water Availability, Water Quality, Water Loss, Education and Poverty'. Recommendations have been provided in this study for the improvement of these poorly-performing indicators and sub-indicators to at least the next higher performance level of 'Poor–Medium', thus improving the value of the final index from 20.04 to 37.19. Thus, the application of WJWSI presented in this study has provided useful information regarding the current condition of water resource in the Citarum catchment, which can be regularly monitored by the water authorities as well as by the general public.

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