Potential Water Availability Estimation of Water Resources Carrying Capacity for Bogor City Spatial Plan

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Abstract (English). The aim of the present research is to examine the effectiveness of rational method widely used in calculating water availability for spatial planning in Indonesia. The rational method is developed mainly for estimating the characteristics of drainage infrastructure instead of estimating water availability. We compare the effectiveness of rational method and Soil Conservation Service Curve Number (SCS-CN) method by testing their performance in estimating water availability in the Upper Cisadane river basin in West Java, Indonesia. The results shows that calibrated SCS-CN model performs better than Rational model with R² and NSE of 0.62 and 0.37. Result of model validation yields R² = 0.73 and NSE = 0.52. The result suggests that SCS-CN performs better than the rational model in simulating the character of water catchment area and is suitable for model of choice in water availability estimation.

Keywords: Bogor City, Regional Spatial Planning, Water availability, Water Balance, Water Resource Carrying Capacity

1. Introduction

Studies on the concepts of water resource carrying capacity (WRCC) and WRCC management have been widely carried out in support of sustainable socio-economic development (Dapeng et al., 2016), (Gong & Jin, 2009). WRCC has been proposed as a key indicator for studies on the amount of regionally available water resources (Ming, 2011). Previous studies used a variety of methods, including applying system dynamics methodologies to evaluate various development scenarios (Mei & Duhuan, 2010); distributed quantitative models based on optimization principles; and interaction of hydro-economy, water supply, water quality, and development constraints socioeconomic (Dou et al., 2015).

Recent concept of water availability distinguishes between blue waters reserves that are directly available and consumable by people, and green water reserves that are only available for plants and vegetations before getting into the air through evapotranspiration processes (Falkenmark, 2006; Schuol et al., 2008; Menzel & Matovelle, 2010). Water resource managers are faced with the challenge of calculating the amounts of water that enter, pass through, and leave individual watersheds to accurately estimate the availability of adequate water for human use. Estimation can be complicated since the relative magnitudes of the transfers of individual components in the hydrologic cycle can vary greatly (Gupta, 2011).
From the hydrologic cycle perspective, water availability can be estimated from the amount of water that can be utilized/stored after provisions have been made for evapotranspiration, infiltration and overland flow (Dingman, 2015). At the river basin level, water availability can be estimated by accounting for a variety of contributing factors, which includes climate-related variables, soil topography, geological characteristics, and types of above-ground vegetation. The method of estimating water availability using different equations has been proposed by some researchers. Most researchers calculate the water availability using the principle of hydrologic water balance (WB). The WB principles are then used in the model, such as the distributed hydrological model "Soil and Water Assessment Tool " (SWAT). Some researchers were used SWAT to estimate water availability, such (Behailu et al., 2014; Niagara et al., 2016; Maliehe & Mulungu, 2017; Guug et al., 2020) while others used hydrological models such as Mock, Nreca, Rainrun (Mulya et al., 2013; Suprayogi et al., 2012). In addition, other researcher (Djuwansah, 2010; Hatmoko et al., 2011; Post et al., 2012) were used long-term discharge data to predict water availability. Meanwhile, studies on runoff estimation using SCS-CN method to estimate water availability have been previously conducted by Bank (2010), Mahmoud (2014), Mishra et al. (2012), Osta and Masoud (2015), Singh and Goyal (2017), Uwizeyimana et al. (2019) and Zelelew (2017).

In Indonesia, the concept of water resource carrying capacity has been widely used in policy-making in line with the legal mandate of the Explanandum of Article 25 of Law No. 26/2007 on Spatial Planning. Meanwhile, the Regulation of the Minister for Environment No. 17/2009 on Guidelines for Determining Environmental Carrying Capacity in Regional Spatial Planning states that environmental carrying capacity is considered to contain two components: the environment’s capacity to supply resources (supportive capacity) and its capacity to assimilate refuse and waste (assimilative capacity). Natural resource capacity depends on ability, availability, and needs upon land and water. The Guideline advocates that the assessment of environmental carrying capacity is performed using three approaches, i.e.: an assessment of regional land capacity to accommodate space utilization; an assessment on the ratio of land availability vis-à-vis land needs; and an assessment of the ratio of water availability vis-à-vis water needs. Potential water availability is determined using a runoff coefficient method based on land use and annual rainfall information. Meanwhile, water need is calculated using a conversion result against decent living necessities.

This research questions the selected method of assessing water resource carrying capacity that had become widely used by water resource managers and practitioners as well as informing policy-making processes due to the Regulation and its Technical Guidance.

The Guidance advocates the use of Runoff coefficient model derived from a modification of rational methodology. Since the introduction of this guidance, water resource managers, practitioners, and policy makers have been increasingly using rational method based equation to assess water resource carrying capacity. The selection of rational method based equation seems counterintuitive since equations developed using rational method are commonly developed and used in determining the design of drainage establishments within small areas (usually not larger than a few acres) with low current flow characteristics (Thompson, 1999) or to determine maximum flood current (Raghunath, 2006). In the United States, rational method based equations are used to determine the peak flow in the design of sewage systems since the early twentieth century (ASCE, 1996). Therefore, the rational method cannot be used to estimate the potential water availability, since this method only using a runoff coefficient method based on land use and annual rainfall information. When used to calculate water availability the rational method is going to be less precise.

This study aims to conduct a runoff analysis using the SCS-CN method based on Geetha et. al.’s Soil Conservation Service Curve Number (SCS-CN) model (Geetha et al., 2007) and Rational method in accordance with the mandate of Regulation of the Minister for Environment No. 17 of 2009. The research evaluates both models by testing their performance and validity against observed data collected from the upper Cisadane river basin area in West Java, Indonesia (Fig. 1). Potential water availability estimation from the upper Cisadane river basin area is needed to track river flow changes as vital information used by PDAM Tirta Pakuan in meeting the growing clean water needs of the Bogor City as well as regional spatial planning in general.
2. Research Methodology

2.1. Study Location

This research was conducted in the upper Cisadane river basin area. The upper Cisadane river basin area extends between 106°29'00"–106°57'00" E and 06°30'20"–06°46'30" S. Batubeulah Outlet is located at 106°41'21" E 06°31'21" S. (Fig. 1) (Laksana, 2011). For modeling purposes, the upstream Cisadane river basin was divided into 11 sub-basins with their respective areas as follows: 0.10 (km$^2$), 21.50 (km$^2$), 6.33 (km$^2$), 0.90 (km$^2$), 58.30 (km$^2$), 92.85 (km$^2$), 112 (km$^2$), 34.85 (km$^2$), 196.01 (km$^2$), 205.67 (km$^2$), dan 99.14 (km$^2$). The total river basin area is around 827,631 km$^2$.

![Figure 1. Study Location and 11 Sub-basin](image)

2.2. Data Set

Hydrologic data collected for this study consists of daily rainfall (P), climatology data to determine evaporation and evapotranspiration, and stream gauge records (Q). Daily rainfall (P) and stream gauge records (Q) data for six years (January 2004–December 2009) that is available for upper Cisadane river basin are were used in the study. Three years of discharge (Q) observation data (2004-2006) was used for model calibration, and two years of data (2008 and 2009) is used for model validation. The research made use of land use and soil maps, daily rainfall data (2004-2009), DEM (Digital Elevation Map), and RBI (Rupa Bumi Indonesia) map. Datasets from 2004-2008 were used since rainfall, discharge, land use and soil data for the years were available. The main purpose of this study is to test the performance and validity of the models, so the selection of data period is not restrictive and thus can be made arbitrarily.

2.3. Hydroclimate, Land Use, and Soil Characteristics of the Catchment Area

The upper Cisadane river basin consists of 11 sub-basins (Fig. 1) with a total river basin area of 827.631 km$^2$. It is located in a tropical climate area with a high intensity of rainfall. Climatological data used in this research includes: monthly rainfalls, maximum temperature, average humidity, solar radiation and wind speed. From 2004 to 2009, the ranges as follows: monthly rainfalls from the year 2004 – 2009 ranges from 26mm to 610mm, with around 300mm monthly average; maximum temperature ranges from 28°C to 34°C; average humidity ranges from 76% to 89%; solar radiation ranges from 15 to 48 n/N (%); and wind speed ranges from 2 to 54 km/month.

The watershed area is dominated by dry land forest + bushes (37%), paddy field (21.5%) and, secondary dry land forest (15.6%). The area used for human settlement stands on (7.6%) while the rest (17.93%) is used for plantation, dryland farming, empty land, waterbody, and bush (Fig 2a). Land use data with slope (Fig 2b) will be used for the rational method, while climatological data, land use and soil map (Fig 2a and Fig 2c) will be used for SCS-CN model. The dominant soil type in Cisadane watershed is ultisols (Junaidi, 2009).
2.4. Discharge (Q) Observation and Rainfall Data

Rainfall data is obtained from observation stations within the area of upper Cisadane river basin area. The rain measuring stations used are Pasir Jaya, Empang, and Cihideung Udik. Rain pattern and water level or runoff graphs, from both 2004 and 2005, suggests a fluctuating rainfall, yet relatively stable runoff (Fig 3); that is, the runoff trend generally follows the rain spread trend. This suggests that runoff or river flow condition is in a good state. This data is also in accordance with the discharge pattern of research results (Julian et al., 2011).
2.5. Estimating Water Availability (WA)


Water availability using a rational method is determined using weighted runoff coefficient based on land-use data and yearly rainfall data. The calculation is formulated as follows:

\[
C = \frac{\sum (c_i \times A_i)}{\sum A_i} \quad (1)
\]

\[
R = \frac{\sum R_i}{m} \quad (2)
\]

\[
SA = 10 x C x R x A \quad (3)
\]

where, 
- \(SA\) = water availability \((m^3/\text{year})\),
- \(C\) = weighted runoff coefficient,
- \(c_i\) = Land-use coefficient,
- \(A_i\) = Land Area \((\text{ha})\),
- \(R\) = average yearly rainfall data \((\text{mm/year})\),
- \(R_i\) = Rainfall in station \(i\),
- \(m\) = number of rainfall stations,
- \(A\) = Total Area \((\text{ha})\),
- 10 = conversion factor from \(\text{ha}\) to \(m^3\).

2) SCS-CN based Long-Term Hydrologic Simulation.

SCS-CN model is used to calculate runoff (Geetha et al., 2007). SCS-CN based long term hydrologic simulation is a method of calculating daily direct surface runoff by using an AMC dependent CN (curve number). CN is calculated as a component that considers the types of soil and land use in the basin. Total runoff in this method is the sum of direct surface runoff and base-flow. Direct surface runoff is calculated on the river basin outlets. Surface runoff, \(RO\), is calculated using the following procedure:

**Estimasi Total Runoff**

\[
Q_{rt} = q_{rt} + qb_{rt} \quad (4)
\]

**Base Flow**

\[
qb_{r,t+1,\text{NLAG}} = b_t F_t \quad (5)
\]

**Rainfall Excess (ROt) and Routing of Rainfall Excess**

\[
q_t = C0 \times RO_t + C1 \times RO_{t-1} + C2 \times q_{t-1} \quad (6)
\]

\[
COUR = \frac{1}{K} \quad (7)
\]

\[
C1 = C0 \quad (8)
\]

\[
C0 = \frac{COUR}{2 + COUR} \quad (9)
\]

\[
C2 = \frac{2 - COUR}{2 + COUR} \quad (10)
\]

**Initial Abstraction (Ia)**

\[
I_{a(t)} = \lambda S \left( \frac{P}{P_s + S} \right)^\alpha \quad (11)
\]

Here, \(\lambda\) and \(\alpha\) are parameters to be optimized.

For the first five days, Ia is computed as follows,

\[
I_{a(t)} = \lambda S_t \quad (12)
\]

Here, \(\lambda\) is taken as 0.2.

**Potential Water Retention (St)**

\[
S = S_{t-1} - (1 - b) F_{t-1} + EV_{t-1} \quad (13)
\]

\[
F_{t-1} = P_{t-1} + RO_{t-1} \quad (14)
\]

\[
F_{t-1} = P_{t-1} + I_{a(t-1)} + RO_{t-1} \quad (15)
\]

If \(P_{t-1} \geq 0\), then \(F_{t-1} \geq 0\).

AMC II (average or normal condition) is taken as the basis from which adjustments to daily curve numbers are made so that they correspond to AMC I or AMC III. Different AMC class limits are provided for the dormant and growing seasons based on five-day antecedent precipitation, i.e., ANTRF and presented in Table 1.
Table 1. Antecedent Moisture Condition (AMC)

<table>
<thead>
<tr>
<th>AMC</th>
<th>Total five-day antecedent rainfall (ANTRF) (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dormant season</td>
<td>Growing season</td>
</tr>
<tr>
<td>I</td>
<td>≤1.3</td>
</tr>
<tr>
<td>II</td>
<td>1.3 – 2.8</td>
</tr>
<tr>
<td>III</td>
<td>&gt;2.8</td>
</tr>
</tbody>
</table>

CNt of the day which corresponds to CNII is converted to CNI or CNIII as follows (Hawkins et al. 1985)

\[
CN_{t} = \frac{CN_{d}}{2.3 - 0.013CN_{d}}
\]  
\[
CN_{m} = \frac{CN_{d}}{0.43 + 0.0057CN_{d}}
\]

Determination of Antecedent Rainfall (ANTRF)

For the first five days beginning from the first day of simulation (June 1 to June 5), CN is taken as CN0 valid for AMC II (normal condition). As the time (day) advances, CN varies with AMC levels, dependent on the amount of antecedent rainfall (ANTRF)

\[
ANTRF = P_{(t-1)} + P_{(t-2)} + P_{(t-3)} + P_{(t-4)} + P_{(t-5)}
\]  

Determination of Antecedent Moisture Condition (AMC)

Computing of Surface Runoff (RO)

Computing daily runoff, with time t as subscript yield, where

\[
RO_{t} = \frac{Pe_{t}}{Pe_{t} + S_{t}}
\]  
\[
Pe_{t} = P_{t} - I_{t} - (\lambda S_{t})
\]  
\[
S_{t} = \frac{25400}{CN_{t}} - 254
\]

Here , \( \lambda = 0.2 \). \( Pe_{t} > 0 \), else \( RO_{t} = 0 \)

The parameters, that is the factors describing base flow bf, storage coefficient K, and the coefficient and exponent of the initial abstraction \( \lambda_1 \) and \( \alpha \), parameters which were to be optimized, were calibrated. The performance of the calibration and validation model was evaluated using streamflow data.

2.6. Calibration and validation

The performance of the calibrated and validation model was evaluated against streamflow data. To find the optimal parameter set, an optimization algorithm of the multi-objective complex evolution was implemented and two statistical evaluation was used as the objective function to assess the model’s statistical performance.

Model evaluation was carried out statistically using 1) correlation coefficient (\( R^2 \)) and 2) Nash–Sutcliffe efficiency (NSE) between the daily and monthly simulated and observed stream flows, which describes the prediction skill of modeled stream flows as compared with the observations. According to Waseem et al. (2017), NSE and \( R^2 \) can give better agreement even for very poor models.

Two years of data (2004 – 2005) were used to calibrate the models for upper Cisadane catchment, and three years of data (2006 – 2008) were used for validation

2.7. Water Demand

The standard used to determine water demand was developed by Cipta Karya, Ministry of Public Work and Housing of Indonesia. Using information on area population and activity, water demand was calculated for two categories: domestic needs and non-domestic needs (Table 2).
Table 2. Water Use Standard (Cipta Karya Kementerian PUPR)

<table>
<thead>
<tr>
<th>No</th>
<th>Needs</th>
<th>Cities Category based on population scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Metro</td>
</tr>
<tr>
<td>1</td>
<td>Daily Consumption (Ltr/day)</td>
<td>170</td>
</tr>
<tr>
<td>2</td>
<td>School (Ltr/pers/day)</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Hospital (Ltr/bed/day)</td>
<td>200</td>
</tr>
<tr>
<td>4</td>
<td>Clinic (Ltr/day)</td>
<td>2000</td>
</tr>
<tr>
<td>5</td>
<td>Mosque (Ltr/day)</td>
<td>3000</td>
</tr>
<tr>
<td>6</td>
<td>Office (Ltr/Worker/day)</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>Market (Ltr/ha/day)</td>
<td>12000</td>
</tr>
<tr>
<td>8</td>
<td>Hotel (Ltr/bed/day)</td>
<td>150</td>
</tr>
<tr>
<td>9</td>
<td>Restaurant (Ltr/table/day)</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>Military base (Ltr/per/day)</td>
<td>60</td>
</tr>
<tr>
<td>11</td>
<td>Industrial (Ltr/sec/day)</td>
<td>0.5</td>
</tr>
<tr>
<td>12</td>
<td>Tourism (Ltr/sec/day)</td>
<td>0.2</td>
</tr>
</tbody>
</table>

3. Results and Discussion

3.1. Estimation of Water Availability Potential

1) Rational Model

The calculation result of runoff estimated using the rational model compared with the values of Q observed at the catchment area is presented in Fig 4, with no parameter needed to be calibrated. The yearly runoff calculation is shown in Table 3.

When compared with the observed runoff data collected from the stations in the basin area, the estimation results fail to predict the runoff accurately. The estimation results of the rational method also perform poorly in statistical tests. The calibrated monthly determination coefficient ($R^2$) and Nash-Sutcliffe efficiency value (NS) were 0.62 and -2.35 respectively, and validation were $R^2 = 0.69$ and NSE = -0.83. However, the model estimated a fairly accurate up and down trend fluctuation as can be seen in Figure 4 where simulated Q < observed Q.

![Runoff Simulation using Rational Model and Q Observation Data Year 2004 - 2008](image.png)

Figure 4. Runoff Simulation using Rational Method and Q Data
Table 3. Potential Water Availability using Rational Method

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall (mm)</th>
<th>WA Potential (m$^3$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>3408.13</td>
<td>8824255.18</td>
</tr>
<tr>
<td>2005</td>
<td>3401.22</td>
<td>8806381.03</td>
</tr>
<tr>
<td>2006</td>
<td>3169.38</td>
<td>8206106.03</td>
</tr>
<tr>
<td>2007</td>
<td>4029.61</td>
<td>10433367.32</td>
</tr>
<tr>
<td>2008</td>
<td>3887.67</td>
<td>10065869.64</td>
</tr>
</tbody>
</table>

2) SCS-CN based Long-Term Hydrologic Simulation.

Model (Geetha et al., 2007) is based on the concept of SCS-CN in simulating catchment response/behavior. The model is useful to derive runoff from precipitation, with daily time steps needed to capture daily runoff variations. The model is calibrated to obtain a model that best match field realities. The model simulation result is calibrated using flow data measured in Batu Beulah. The model output is compared to the Q observed (Fig 5)

![Figure 5. Runoff Simulation and Q Observation](image)

The ranges and values of the parameters selected for trials and optimization of the model are given in Table 4.

Table 4. Range of Estimates Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>bf</th>
<th>K</th>
<th>λ1</th>
<th>α</th>
<th>NLAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.82-1</td>
<td>20–100</td>
<td>0.2–1</td>
<td>10–20</td>
<td>0–10</td>
</tr>
</tbody>
</table>

Table 5. Calibration and Validation Result

<table>
<thead>
<tr>
<th></th>
<th>R$^2$</th>
<th>NSE</th>
<th>Relative mistake (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>0.62</td>
<td>0.37</td>
<td>17.4</td>
</tr>
<tr>
<td>Validation</td>
<td>0.72</td>
<td>0.52</td>
<td>13.85</td>
</tr>
</tbody>
</table>

From the R$^2$ and NSE value, it reveals that the model shows a satisfactory performance in the upper Cisadane catchment. Calibrating the model against 2004 – 2005 data yield values of R$^2$ = 0.62 and NSE = 0.37 (Tab 5). A deviation from the normal trend in observed data is noted on April-July 2015, lowering model performance. Normalizing the observed Q value to the precipitation value for this period improved the model performance to yield R$^2$ = 0.72 and NSE = 0.53. It might be interpreted that the model should perform better than suggested by the R$^2$ and NSE values calibrated against 2004 – 2005 data, assuming that Q behaves normally.

The result simulates the runoff using the long term SCS method in the upper Cisadane catchment is between 28 -100 m$^3$/sec during the wet season (Nov–Apr) and between 8 – 68 m$^3$/sec during the dry season (May-Oct). There are several drastic drops in August 2004, July 2006 and, July 2008 that correspond to the drops in precipitation in all three data points (Table 6). This indicates a major role of precipitation in the model in simulating runoff.
Table 6. Potential Water Availability Using SCS-CN Method (m³/sec)

<table>
<thead>
<tr>
<th>Month</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>71.494</td>
<td>47.733</td>
<td>65.626</td>
<td>34.242</td>
<td>28.725</td>
</tr>
<tr>
<td>February</td>
<td>88.409</td>
<td>67.560</td>
<td>95.674</td>
<td>87.795</td>
<td>97.837</td>
</tr>
<tr>
<td>March</td>
<td>48.510</td>
<td>60.960</td>
<td>59.470</td>
<td>68.385</td>
<td>106.612</td>
</tr>
<tr>
<td>April</td>
<td>80.826</td>
<td>57.054</td>
<td>57.439</td>
<td>76.910</td>
<td>63.883</td>
</tr>
<tr>
<td>May</td>
<td>63.068</td>
<td>48.406</td>
<td>44.210</td>
<td>65.307</td>
<td>28.850</td>
</tr>
<tr>
<td>June</td>
<td>25.332</td>
<td>40.129</td>
<td>38.950</td>
<td>45.912</td>
<td>32.395</td>
</tr>
<tr>
<td>July</td>
<td>23.753</td>
<td>45.838</td>
<td>10.223</td>
<td>35.653</td>
<td>16.127</td>
</tr>
<tr>
<td>August</td>
<td>7.990</td>
<td>40.640</td>
<td>22.185</td>
<td>35.988</td>
<td>29.269</td>
</tr>
<tr>
<td>September</td>
<td>53.283</td>
<td>49.801</td>
<td>17.530</td>
<td>18.557</td>
<td>44.797</td>
</tr>
<tr>
<td>October</td>
<td>40.834</td>
<td>68.809</td>
<td>24.277</td>
<td>65.422</td>
<td>71.550</td>
</tr>
<tr>
<td>November</td>
<td>83.031</td>
<td>72.234</td>
<td>72.355</td>
<td>85.194</td>
<td>100.449</td>
</tr>
<tr>
<td>December</td>
<td>80.207</td>
<td>55.906</td>
<td>91.416</td>
<td>100.422</td>
<td>80.915</td>
</tr>
</tbody>
</table>

3.2. Estimating Water Resources Carrying Capacity (WRCC)

Estimation of domestic sector water needs is done by estimating water needs for the next few years, namely through analysis of population growth in the planned area. Domestic water needs for cities are divided into several categories based on region and population density. The amount of water demand calculated based on data from the book was published by the Bogor City Government in 2015, which representative of the actual number of water requirements. All of the components of domestic and non-domestic water needs are available in this book, such as water requirements for offices, markets, restaurants, military bases, industries, tourism.

Analysis of water needs in the non-domestic sector is carried out using the DG Cipta Karya standard of the Ministry of Public Works and Housing (Table 7).

The analysis was carried out using statistical data on public facilities available in Bogor City. Analysis of water demand in the non-domestic sector is carried out using facility availability data. This is done with the assumption of growth in the number of facilities to population growth per year, more or less constant. An estimate of the water resources carrying capacity shown in table 8 and figure 6.

Table 7. Estimated Water Demand

<table>
<thead>
<tr>
<th>No</th>
<th>Division</th>
<th>Monthly Usage (litre)</th>
<th>Monthly Usage (m³)</th>
<th>Annual Usage m³/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Domestic (year 2014)</td>
<td>4638240000</td>
<td>463840</td>
<td>55658880</td>
</tr>
<tr>
<td></td>
<td>Non Domestic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>School</td>
<td>72310080</td>
<td>72310.08</td>
<td>867720.96</td>
</tr>
<tr>
<td>3</td>
<td>Hospital</td>
<td>12144000</td>
<td>12144</td>
<td>145728</td>
</tr>
<tr>
<td>4</td>
<td>Clinic</td>
<td>8820000</td>
<td>8820</td>
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Water Demand per month (litre) = 4871890125 4871890124 5846268149
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**Table 8.** Water Resources Carrying Capacity Bogor City (million m³/year)

The calculation results of both the rational model and the calibrated SCS-CN model shows that the amount of potential water available for use exceeds the water demand of the population of Bogor City.

4. **Conclusions**

Watershed modeling construction to simulate long-term hydrological behavior of watersheds is complicated. Input parameters of the model may vary greatly with changes in seasonal and hydrological conditions, challenging the accuracy of models and equations. Due to its simplicity and familiarity, rational method is widely applied as a quick-fix and is treated among policy-makers as the select instrument in estimating water availability. The consequence of this selection is paramount since water availability estimation provides important information in the making of spatial planning policies.

This research recommends the use of the estimation result of our calibrated SCS-CN model as an alternative to the practice of estimating potential water availability by using rational model. The estimation results of the two models are tested against observation data collected from the Upper Cisadane Riverbasin. Comparison results suggest that the calibrated SCS-CN model performs better than the rational model in representing natural conditions. The simulation result produced by the calibrated SCS-CN model is closer to actual observed daily flow when compared to the simulation result of commonly-used rational model. This observation is also supported by better performance in statistical validity testing.

While more testing is still required, this research presents evidence that the advocated use of rational model as the instrument of choice for water availability estimation is not without problems and therefore should be questioned and challenged further.

**Figure 6.** Estimated Water Resources Carrying Capacity (WRCC)
5. Acknowledgement

The research received financial support from the Ministry of Research and High Education Grant PDD 2018 (Decree No. 3/E/KPT/2018 and Contract No. 2108/LPPM/UP/III/2018). The researchers would like to thank the late Herr Soeryantono Ph.D., as co-promoter of the project, whose example and dedication will continue inspiring our future projects.

References


