Land Cover and Groundwater Recharge Changes Study Using Conservation Index in the Highland Ciburial Village, Bandung Regency

M. H. Z Nurrachman¹*, I Sumardi¹ and T Lastini¹

¹Forestry Engineering Department, School of Life Sciences and Technology, Bandung Institute of Technology, Ganesa 10, Bandung, West Java 40132, Indonesia

E-mail: mhfizh.zhafran@outlook.com

Abstract. Ciburial Village, Cimenyan Region, is a potential location for Bandung Basin groundwater recharge area. Based on West Java Local Regulation No. 1 Year 2008 (Perda No.1/2008) about Northern Bandung Region Management, Ciburial Village is classified as protection area. As a matter of fact, constructed area in Ciburial Village has been increasing. Thus, it causes decreasing in water protection function. Hence, study on degraded land impact estimation to water conservation in Ciburial Village is needed. To estimate how much impact had been done by degraded land, spatial use in Ciburial Village was analyzed. To analyze spatial use, land cover of Ciburial Village is divided into four types, settlements, forests, agricultures and grasslands. Each land cover’s water conservation ability was approached by conservation index. The spatial analysis between 2006 and 2015 shows the decreased area of good level and normal level water conservation index by 1.45 hectares and 1.25 hectares respectively and shows the increased area of critical level water conservation index by 2.7 hectares. Land cover changes also impact on actual conservation index, which decreased from 0.610 on 2007 to 0.606 in 2015.

1. Introduction

Groundwater is one of primary raw water sources for municipal activity in Bandung City. Nowadays groundwater in Bandung has become primary source for domestic use instead of surface water which has been polluted [1,2]. Bandung Public Waterworks uses groundwater 38 million m³ annually and industrial activity uses it up to 50 million m³ annually. The consequence of high groundwater abstraction in Bandung City was groundwater level in Bandung City dropped from +4 (upward) m on 1920 to -60 (downward) m in 1990[3]. The amount is still increasing, recorded in 2004, groundwater level in Bandung City dropped into -100 m below the ground and it keeps running until today [3].

One of groundwater recharge zones for Bandung City’s groundwater is Northern Bandung Region. However, the development in Northern Bandung Region is inevitable [4]. Cimenyan District, one of the districts of Bandung Regency in Northern Bandung Region, has area of 5,308.00 hectares and it has constructed area of 1,130.85 hectares (21.3% of Cimenyan’s area) [5]. Development in Cimenyan District shows erosion potential of 57.59 tons/hectare/year [6]. The erosion results in the increased runoff from 331.1 mm out of 1,474.3 mm precipitation (22%) in 2006 to 457.4 mm out of 1,800.3 mm precipitation (25%) in 2015 [6]. Because of the increased runoff, it causes decreasing in infiltration. In order to conserve more water for Bandung City’s groundwater, we need to calculate or at least
estimate the water entering Bandung City’s aquifer. Hence, in order to estimate the conserved water, we conduct research in water conserving model using conservation index.

2. Method and materials

2.1 Study site

The research was conducted in Ciburial Village, Cimenyan District, Bandung Regency. Ciburial Village has an area of 5.99 km². The area of the study site is 1.65 km² and located in the upper stream of Ciburial Village, 6.835°-6.852°S and 107.654°-107.675°E (Figure 1). Plot elevation was on 1,175-1,375 m asl. Ciburial Village has climate condition with average annual precipitation of 1,500 mm, average humidity of 77%, and average air temperature of 24-25°C [7].

Study site’s land cover is divided into four types, namely constructed area, forest area, agriculture area, and grassland area. To estimate the conserved water, we used conservation index by spatial analysis.

2.2 Spatial analysis

2.2.1 Types and data source. The spatial data source was secondary data. The spatial data used was spatial physical characteristic data. The detail of data types and data source is presented in Table 1.

| Data Types               | Data Source                                                                 |
|-------------------------|-----------------------------------------------------------------------------|
| 1. Administrative Map   | Geospatial Information Agency, scale 1:25,000, year 2015                    |
| 2. Contour and River Map| Geospatial Information Agency, scale 1:25,000, year 2015                    |
| 3. Soil Texture Map      | Settlement and Housing Service West Java Prov., year 2005                  |
| 4. Satellite Imagery     | Digital Globe (Quick Bird year 2007, WorldView-02 year 2012, and WorldView-03 year 2015) and Airbus (SPOT 6 year 2014) |

2.2.2 Spatial processing. To get useful data from the raw data, we processed every data uniquely. Contour and river map data were processed to be a slope/topography data. Satellite imagery was digitized to be a land cover data. Ground truth was conducted to validate digitization process.

2.2.3 Conservation index analysis. Conservation index is a parameter of hydrological ability in an area to conserve water. The index has value ranging from 0 to 1, in which 0 is totally runoff and 1 is totally infiltrated. The conservation index comes from hydrological balance, which precipitated water is equal to infiltrated water plus runoff water and evaporated water. Assuming that there is not enough energy to evaporate water, the balance becomes precipitation (P) and it is equal to infiltration (I) and
runoff (R). Then, the equation was divided by precipitation. The result is 1 equal to infiltration per precipitation and runoff per precipitation. The infiltrated water per precipitated water is the conservation index $IK^8$. Since $R/P$ is equal to runoff coefficient ($C$), and we need to estimate conservation index, the runoff coefficient is calculated. The runoff coefficient uses five parameters, namely rainfall, soil texture, slope, elevation, and land cover. However, with a small catchments of study site, rainfall and elevation parameters can be neglected\cite{8}.

$$P = I + R$$  \hspace{1cm} (1)

$$1 = (I/P) + (R/P)$$  \hspace{1cm} (2)

$$IK = 1 - C$$  \hspace{1cm} (3)

To calculate the runoff coefficient, we used modified Hassing Runoff Coefficient\cite{8}. Hassing Runoff Coefficient is a runoff coefficient based on topography, soil texture, and land cover\cite{9}. The detail of Hassing Runoff Coefficient is presented in Table 2.

**Table 2. Modified Hassing Runoff Coefficient Classification.**\cite{11}

| Physical Condition  | $C_T$ (Topography) | $C_S$ (Soils) | $C_V$ (Land Cover) |
|---------------------|--------------------|--------------|-------------------|
| Very flat (<1%)     | 0.03               | 0.04         | 0.04              |
| Undulating (1-10%)  | 0.08               | 0.08         | 0.11              |
| Hilly (10-20%)      | 0.16               | 0.16         | 0.21              |
| Mountainous (>20%)  | 0.26               | 0.26         | 0.40              |

Conservation index can be divided into two groups, natural conservation index ($IK_A$) and actual conservation index ($IK_C$). Natural conservation index is a parameter which shows ability of an area to conserve water naturally or assumed forest. On the other side, actual conservation index is a parameter which shows ability of an area to conserve water on actual/existing land use. Then, water conservation status can be estimated by actual conservation index which has normal level value ranging from 0.46-0.69. If it is higher than 0.69 it means good level and if it is lower than 0.46 it means critical level\cite{8}.

### 3. Results and Discussion

#### 3.1 Topography

*Based on contour* map data from Geospatial Information Agency, the study site was dominated by high slope/mountainous area (>20% slope). The mountainous area consists of 72.11 hectares or 44% of study site area (Table 3). Figure 2a shows almost every part of study site which has high slope. Part of study site that has flat slope is scattered nearby streams or ridges.

#### 3.2 Soil texture

Based on soil texture map data from Settlement and Housing Services West Java Province year 2005, the soil texture was sandy clays throughout the study site (Table 3 and Figure2b).

**Table 3. Distribution of topography and soil texture in study site.**

| Physical Condition | Area (ha) | Percentage from Total (%) |
|--------------------|-----------|----------------------------|
| **Topography**     |           |                            |
| Very flat (<1%)    | 0.46      | 0.3                        |
| Undulating (1-10%) | 28.50     | 17.4                       |
| Hilly (10-20%)     | 62.82     | 38.3                       |
| Mountainous (>20%) | 72.11     | 44.0                       |
| **Soil Texture**   |           |                            |
| Sandy clays        | 163.89    | 100                        |

3
3.3 Land cover
Data from satellite imagery shows changing area of settlements, forests and agricultures (Table 4). The settlements seem increasing over the time, the forests and agricultures are both increasing and decreasing. Population growth in upper Ciburial Village has pushed local communities to expand settlements[4]. Local activities affect land use. Between 2007 and 2012, *Eucalyptus* spp. and *Gmelinaar borea* were planted in part of the study site, it was shown by satellite imagery and ground truthing. On the other side, the grassland has no changes. According to the interviews with local community, the grassland was used as grazing area which has been established since 2000.

| No  | Land Cover    | 2007 Area (ha) | %  | 2012 Area (ha) | %  | 2014 Area (ha) | %  | 2015 Area (ha) | %  |
|-----|---------------|----------------|----|----------------|----|----------------|----|----------------|----|
| 1   | Settlements   | 7,21           | 4,4| 9,34           | 5,7| 9,45           | 5,8| 9,92           | 6,1|
| 2   | Forests       | 6,71           | 4,1| 10,29          | 6,3| 10,06          | 6,1| 9,66           | 5,9|
| 3   | Agricultures  | 149,59         | 91,3| 143,89        | 87,8| 144,01        | 87,9| 143,94        | 87,8|
| 4   | Grasslands    | 0,37           | 0,2| 0,37           | 0,2| 0,37           | 0,2| 0,37           | 0,2|
|     | Total         | 163,89         | 100| 163,90         | 100| 163,90         | 100| 163,90         | 100|

After collecting the needed data, we could estimate average actual conservation index in study site as in Table 5. After estimating actual conservation index, then we valued water conservation status. Water conservation status in study site is shown in Table 6.

| No  | Water Conservation Status | 2007 Area (ha) | 2012 Area (ha) | 2014 Area (ha) | 2015 Area (ha) |
|-----|---------------------------|----------------|----------------|----------------|----------------|
| 1   | Good                      | 88,66          | 87,89          | 87,63          | 87,17          |
| 2   | Normal                    | 68,01          | 66,66          | 66,81          | 66,80          |
| Level | 2007 | 2012 | 2014 | 2015 |
|-------|------|------|------|------|
| Critical | 7.21 | 9.33 | 9.44 | 9.91 |
| Total   | 163.88 | 163.88 | 163.88 | 163.88 |

Generally, water conservation ability in study site still has good ability to conserve water. It is shown by 87.17 hectares (>50% of total area) of good water conservation status in 2015. On the other side, critical water conservation ability in the study site has been increasing over years (Figure 3). Major changes occurred due to the increased settlements. Settlements has the lowest ability to infiltrate water. It affects to increase runoff coefficient and decrease conservation index.

![Figure 3](image-url)

**Figure 3.** Map of changes in study site between 2007-2015 (a) Land cover, (b) Distribution of actual conservation index, and (c) Water conservation status.

4. Conclusion

During the period between 2007-2015 land use changes occurred in study site. Major changes cover land use changing into settlements because of population growth. Spatial analysis between 2006 and 2015 shows the decreased area of good level and normal level water conservation index by 1.45 hectares and 1.25 hectares respectively and the increased area of critical level water conservation index by 2.7 hectares. Land cover changes also impact on actual conservation index which decreased from 0.610 on 2007 to 0.606 in 2015.

Overall, water conservation ability in the highland Ciburial Village is still at good level despite the land degradation. However, we have to be wary of land degradation because settlements growth has
increased relatively stable over the years. We need to keep it balance in order to conserve water availability.

5. References

[1] Delinom R M 2009 Structural geology controls on groundwater flow: Lembang Fault case study, West Java Indonesia Hydrogeology Journal 17(4) 1011-1023
[2] Surtikanti H 2005 Kesehatan lingkungan di daerah aliran Sungai Cikapundung akibat pencemaran air Jurnal Pengajaran MIPA 6(2) 38-46
[3] Wangsaatmadja S, Sutadian A D, and Prasetiati MAN 2006 Groundwater resources management in Metropolitan Bandung (Kanagawa: Institute for Global Environment Studies (IGES))
[4] Rasyidi M S 2009 Menujuketersediaan air yang berkelanjutan di DAS Cikapundung Hulu: Suatupendekatan SYSTEM DYNAMICS Master Thesis(Bandung: Institut Teknologi Bandung)
[5] Statistics of Bandung Regency 2017 Cimenyan Subdistricts in Figures (Bandung: Statistics of Bandung Regency)
[6] Rigine M, Ardiadika W, Nurachman R, and Nurrachman M H 2016 Rancangan Agroforestri untuk Pengendalian Erosi di Desa Cimenyan dan Desa Ciburial Bachelor Thesis (Bandung: Institut Teknologi Bandung)
[7] Desa Ciburial 2015 Profil Desa Ciburial. <https://ciburial.desa.id/profil-desa-ciburial/> (Accessed on 22 September 2016)
[8] Sabar A 1999 Indeks Konservasi Sebagai Instrumen Pengendalian Pemanfaatan Ruang di Kawasan Bopunjurdalamb Rangka Rancangan Keppres Makalah Bahan Diskusi di Bappenas. (Bandung: Institut Teknologi Bandung)
[9] Hassing J M 1995 Hydrology In: B. Thagesen, ed Highway and Traffic Engineering in Developing Countries (London: E&FN Spon) p198-210.