Analysis of Recharge Area Potential of Upper Cisadane Watershed

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Abstract. This research is being conducted on Upper Cisadane Watershed, Bogor, West Java Province. The aim of this research is to investigate the recharge area and analyze the recharge potential. The data consisted of infiltration rate, slope, soil type, and existing landuse as land unit approach which is collected by purposive sampling. Beside that, climate data were collected to estimate the evaporation. The analysis of the data use SCS-CN method to assess the volume of surface runoff, Penman-Monteith method to assess the evaporation, and Water Balance Method to assess the groundwater as the recharge potential. The recharge area would be classified into several areas into the highest to the lowest recharging area. The result of this study would be the total of groundwater fluxas the recharge potential based on each classified recharge area. The condition of recharge area could be one of the reasoning in develeoping the urban water system. The land with the good condition has surplus as ΔS=+490,26 mm, and the critical one has deficit as ΔS=(-)543,49. The condition of the highest recharging area would be analysed as the criteria of potential recharging area and the area should be managed well in the future. The condition of the lowest recharging area would be restored depend on its problem.

Key Word: Recharge Area, Run-off, SCS-CN, Upper Cisadane Watershed.

1. Introduction
Population growth, urbanization, and land use changes are the main factors in land degradation [1]. High population pressure can lead to the threat of the existence of protected forest areas because they are converted into settlement and other land use. This is the background of shrinking the extent of forest land and natural vegetation as a recharge area, which influences the hydrological cycle in a watershed [2]. Changes in land use almost certainly follow the pattern of types of forest use to agriculture, plantations, then continue to settlements with the development of urban areas. Such changes are obviously very influential on the regional water balance and the watershed hydrological regime in question. According to a research, One of the visible hydrological effects is an increase in surface runoff and a decrease in the rate of infiltration of rainwater [3].

Cisadane watershed is one of the priority watersheds in the land conservation work area in the context of medium-term development [4]. A research stated that there had been an increase in peak discharge in the Upper Cisadane watershed in 2003 at 81.22 m³/second to 81.73 m³/sec in 2010 [5]. The increasing of peak discharge was due to more surface runoff due to the development of settlements in the watershed area. This can be seen by increasing the CN (curve number) value of the Upper Cisadane watershed, from 38.5 to 39.4. CN value is a factor that influences the amount of surface runoff rate [6], large CN (curve number) shows high surface runoff and low infiltration rate,
while small CN number (curve number) shows low surface runoff and high infiltration rate \[7\],\[8\]. Basically surface runoff is controlled by the rate of infiltration (absorption) which has a correlation with vegetation cover, topography and soil type \[9\].

According to the Ministry of Forest, the reduction of water catchment areas as a result of land use changes occurring in the Upper Cisadane watershed can have an impact on other parts of the Cisadane watershed, both the middle and downstream \[4\]. With the reduction of green land as a water catchment area, there will be an increase in the amount of water that is not absorbed and flows on the surface. Based on these conditions, this study was conducted with the aim of identifying the critical condition of recharge areas and their effect on watershed water balance and predicting the potential rate of water infiltration in each recharge area condition in the Upper Cisadane Watershed. The aim of this research is investigating the recharge area and analysing the recharge potential.

2. Methods

The study areas were classified based on some parameters such as soil type, land use, and slope. Score were given into those parameters to classify the area into good, medium, and critical land based on the condition of the the study area that showed by those parameters. The volume of surface runoff was analyzed by using SCS-CN methods. The SCS-CN methods considered the value of CN (Curve Number) to show the condition of land cover and AMC (Antecedent Moisture Condition) to show the moisture of the land. The volume of surface runoff was estimated based on the land classification. The evaporation of the area will be analyzed by using Penman-Monteith methods. The Penman–Monteith equation approximates net evapotranspiration, requiring as input daily mean temperature, wind speed, relative humidity and solar radiation. Water Balance methods to analyze the groundwater as the recharge potential, which consider the evaporation and surface runoff volume.

3. Results and Discussions

3.1. Land Condition and Land use of Upper Cisadane Watershed.

The general condition of the location of the study included matters relating to administration, physical conditions and social conditions of the upstream Cisadane watershed (Cianteun and Cisadane Hulu watersheds). This watershed is administratively located in Bogor City/Regency. Cianteun watershed is administratively spread in 63 villages (9 sub-districts) in Bogor Regency while Upper Cisadane watershed is located in 147 villages (19 sub-districts) in the Bogor City/Regency. The main river that flows in the Cisadane watershed is Cisadane River. The river originates from Gunung Gede (2,958 m asl), flows along 126 km to the estuary around Tanjung Burung in Tangerang Regency. The upstream part of the Cianteun watershed is on Mount Kendeng (1,749 m asl) and Mount Salak (2,211 m asl). Water flows from Mount Kendeng past the Cikaniki River and joins the Cianteun River in Ciujung Village, Cibungbulang District, Bogor Regency.

The variation in the height of the upstream part of the Cisadane watershed is very diverse, dominated by hilly and bumpy areas. 45.6% of the total Upper Cisadane watershed is an area with an altitude of 200-500 m above sea level. In the Cianteun watershed 40.5% of the area is at an altitude of 500-1000 m above sea level. The Cisadane watershed upstream is a
concentration of green areas dominated by seasonal agricultural land, fields, rice fields, and moor, but apart from that, the upstream Cisadane watershed is also developing into settlements, especially the Cisadane Hulu watershed.

The geological structure of study area consists of andesite, alluvial fan flow, sediment, silt, and tuffbreksi tufan and capili. In General, it is covered by volcanic rock that comes from deposits (sedimentary rocks) the two volcanoes, i.e. Mount Salak and mount Pangrango (in the form of rocks breksi tupaan/kpal). This Rock is a bit of the ground level and away from the flow of the river. Generally, in the form of surface deposits of alluvial composed by soil, sand, and gravel deposition, weathering results are certainly good for vegetation.

The functions of the two watershed areas (Upper Cisadane and Cianteun) enter into forest areas such as Gunung Halimun Salak National Park, Production Forests, and Limited Production Forests as well as Gunung Gede Pangrango National Park. Distribution of soil types in the upstream part of the Cisadane watershed is relatively more diverse compared to the middle and downstream. Dystropept dominates the soil type upstream while the Paleudult type of land dominates in the middle and downstream. The land condition of Upper Cisadane Watershed in this study was differ into three conditions of land, which are good, medium, and critical. The data of the land condition of Upper Cisadane was showed in the table 1.

| Land Condition | Land Uses | Area          |
|----------------|-----------|---------------|
| Good           | Forest area (primary and secondary), plantation, field, and bushes area | 2756.93 Ha (3.21%) |
| Medium         | Field, empty land, plantation, settlement, paddy field, and bushes area | 68919.54 Ha (80.36%) |
| Critical       | Field, empty land, settlement, and paddy field | 14090.45 Ha (16.43%) |

Upper Cisadane watershed was dominated by medium land condition, it was condition which is in the between of good and critical land. It covered more than 80% of Upper Cisadane Watershed. It consisted of settlement and agriculture area.

3.2. Rainfall Condition.

Rainfall condition in Upper Cisadane Watershed is showed in the table 2. The data of rainfall is collected from 2004 to 2014. The average of the rainfall data is used to analyze the groundwater in Upper Cisadane watershed. The average rainfall in Upper Cisadane Watershed is 3647.8 mm.

3.3. Evapotranspiration, Surface Runoff, and Groundwater.

Evapotranspiration and surface runoff was assessed to analizing the groundwater supply using Thornwaite-Mather. This method assumed that Groundwater is evapotranspiration and surface runoff substracted by rainfall. The evaporation, surface runoff, and groundwater in Upper Cisadane showed in Table 3.
Table 2. Rainfall in Upper Cisadane Watershed

| Year | Rainfall (mm) |
|------|---------------|
| 2004 | 3311.7        |
| 2005 | 3018.2        |
| 2006 | 2655.1        |
| 2007 | 3720.7        |
| 2008 | 4155.4        |
| 2009 | 3887.2        |
| 2010 | 5269.6        |
| 2011 | 2523.8        |
| 2012 | 3247.1        |
| 2013 | 4069.2        |
| 2014 | 4268.2        |

Average 3647.8

Evaporation and surface runoff in good to critical land condition increase significantly. It affected to groundwater in Upper Cisadane. Based on the analyzing, the groundwater supply in Upper Cisadane watershed showed a varied result. In the good land condition, groundwater supply still in surplus state. Meanwhile, in the medium until the critical land condition, the groundwater supply is deficit. The land condition has big effect to hidrology condition in Upper Cisadane watershed. So, in maintaining the hidrology condition, the first step is maintaining the land condition.

Table 3. Evapotranspiration, Surface Runoff, and Groundwater (mm).

| Land Condition | ET     | Q       | \(\Delta S\) |
|----------------|--------|---------|--------------|
| Good           | 1211.04| 1946.50 | 490.26       |
| Medium         | 1391.11| 2339.73 | (-) 83.04    |
| Critical       | 1495.92| 2695.37 | (-) 543.49   |

Based on Table 3, the ideal recharge area is in good land condition because the groundwater still in the surplus state. The land uses in the good land condition are forest area (primary and secondary), plantation, field, and bushes area but it covered only 3.21% of Upper Cisadane watershed. It is too narrow for the recharge area. the medium land condition need to be upgraded to good land condition. It has potential to be recharge because it is covered more than 80% of Upper Cisadane watershed and the degradation of the land still in the medium state.

4. Conclusion

The ideal land for recharge area must be in a good land condition. Good land condition can save the groundwater better that the medium and the critical land. In Upper Cisadane Watershed, The land with the good condition has surplus as \(\Delta S=490.26\) mm, and the critical one has deficits \(\Delta S=543.49\). So, in maintaining the hidrology condition, the first step is maintaining the land condition.
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