Development model of watershed recharge zone based on Indonesia regulation in Cisadane Watershed-West Java, Indonesia

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Abstract. This research aimed to generate watershed recharge zone with weighted value, and determine the effect of rainfall factor for watershed recharge zone assessment. Determining watershed recharge zone is one of essential part in integrated water resources management. Watershed recharge zone is used for preventing land use conversion that mostly happened in urban area watershed. In Indonesia, Ministry of public works and housing was determined recharge zone spatial criteria as stated in Ministry regulation number 10/2015, consist of following factors: rainfall, slope, land use and soil texture and use weighted method to generate recharge zone. The selection of Cisadane Watershed for case study based on watershed varying characteristics and was determined to be one of priority watershed in Indonesia. Each factors (rainfall, slope, landuse and soil texture) will be further analysed with spatial classification as a grid with 2 modelling scheme: modelling with slope, land use and soil texture as internal factor and modelling with rainfall as external factor. These scheme result rainfall is sensitive factor to generate watershed recharge zone and increase potential water recharge from domination of ‘average-good’ to ‘moderate-good’ in Cisadane Watershed. This research is a desk study and further can be developed with ground test validation.

1. Introduction
Groundwater is an important water resource to supply water demand in rural and urban environment and it contributes about 34% of the total annual water supply around the world [1]. Therefore, groundwater has fundamental role for basic needs and human activities. The use of groundwater for irrigation and domestic demand is very important both in quantity and quality [2,3]. The demand for clean water is increasing by significant population growth and economic development day by day. Currently, the challenge is to fill increasing water demand due to limited water availability and decreasing of natural water resources. Long term unsustainable use of groundwater and over exploitation have caused depletion of groundwater in many region [4]. In addition, the damage of water recharge areas due to land use changing from permeable areas such as: forest to impermeable areas such as: housing and industrial area made groundwater condition worse. This cause the sustainable use and management of groundwater resources are gaining significant importance [5,6].
The conventional method for watershed recharge zone assessment is mainly based on the existing storage capacities, infiltration rate and outflow rate from the aquifer systems (ground field survey) [7]. This method is time consuming and costly. Along with technology development, application of geographical information system (GIS) for groundwater research has become a breakthrough [1]. Delineating watershed recharge zone using integrating of remote sensing data and geographical information system (GIS) is more effective in terms of cost and time than conventional method. GIS is very reliable tool for processing huge number of spatial data and for extracting surface data related groundwater recharge such as: land use, and slope [8].

Integration of remote sensing data and GIS for delineating watershed recharge zone is used by many researchers and each research involved different factors for generating recharge zone [1]. In Indonesia, determination of watershed recharge zone is regulated through Ministry of Public Works and Housing Regulation number 10/2015, consist of 4 factors: slope, land use, rainfall and soil texture with weighted method for each factor. Based on previous research, groundwater recharge process is influenced by land use changing that affect hydrological processes on watershed [7]. Slope which is the rate of elevation changing is also significant factor for identifying watershed recharge zone, steep slope can result higher runoff than flat slope. Beside of land use and slope, soil texture has a significant impact on infiltration rate [9]. Land use, slope and soil texture is used as internal factors or watershed characteristics factor for determining watershed recharge zone. As external factor, rainfall is the most influenced factor for watershed recharge area and the major water of source in the hydrological cycle [10].

The main aim of present study is to generate watershed recharge zone based on Indonesia regulation with weighted method and evaluate the significance of rainfall factor as external factor compare with internal factor. The main difference between this research and the previous is using measurable grid and its centroid to visualize each factor and watershed recharge zone, it can be easier to validate each grid centroid with further ground test. This research using Cisadane Watershed as study case with total area 140200 ha and was determined to be one of priority watershed in Indonesia.

2. Research methodology

2.1. Study area

Cisadane Watershed is cross province watershed in Indonesia, it is located in West Java (75% of total area), Banten (24.5% of total area) and the rest in Sukabumi. It is determined as one of priority watershed in Indonesia, because of land use change, urbanized river basin and watershed potential in irrigation sector. Based on weather condition, Cisadane Watershed has a fairly warm average temperature around 23.48°C (with upstream temperature average of 21.23°C and downstream temperature average of 25.73°C). Topographically, the watershed is Salak Mountain area in the upstream and fairly flat area on the downstream (Figure 1). Rainfall rate in location study was influenced by temperature and humidity, upstream area has annual rainfall about 3200 mm-3700 mm and the downstream is about 1583 mm.
2.2. Methodology
This study consists of four main steps: (1) data collection, (2) spatial data construction for recharge zone factor, (3) generating watershed recharge zone with 2 modeling schemes (internal and rainfall factors), (4) result interpretation and conclusion. Figure 2 describes the methodological flowchart used in this study. Development spatial data for recharge zone factor (land use, slope, soil texture, and rainfall) using weight scale 1-5 from spatial classification that does not support recharge to most supported recharge. Watershed recharge zone delineation was generated based on the sum of each factor using Equation 1 (scheme 1) and Equation 2 (scheme 2).

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\text{Watershed recharge weight} = \sum_{i=1}^{n}(\text{land use} + \text{slope} + \text{soil texture})
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\]

3. Results and discussion

3.1. Land use classification
Land use is one of the influenced factors for watershed recharge [11]. Cisadane Watershed is dominated by agricultural areas, settlements, and forests. As the population grows, land use changes from recharge area to impermeable areas significantly for the past 10 years. Spatial classification weight for land use are 5 for forest (17%), 4 for shrubs (1%), 3 for plantation (17%), 2 for paddy field, fishpond, swamp (43%), 1 for housing and commercial area (22%) (Figure 3). Weight value 5 describes the most supporting classification for recharge area, for example: forest is more supported recharge than other land use types.

3.2. Slope classification
Based on previous studies using weighted methods, slope is one of the most influencing factors for delineating water recharge zones [12-15]. Cisadane Watershed has steep slopes in upstream and relatively flat in downstream. Spatial classification weight for slope are 5 for slope < 5% (60%), 4 for slope 5-20% (35%), 3 for slope 20-40% (1%), 2 for slope 40-60% (4%), 1 for slope >60% (0%) (Figure 4).

3.3. Soil classification
Soil texture affects the infiltration rate to subsoil, therefore it is one of the analyzed factors for watershed recharge zone [15,16]. The location study area is dominated by sandy clay and clay sand. Spatial classification weight for soil texture are 5 for sand (0%), 4 for clay sand (22%), 3 for sandy clay (16%), 2 for fine sandy clay (62%) and 1 for clay (0%) (Figure 5).
3.4. Rainfall classification

Based on previous study, rainfall is one of most influence external factor for delineating water recharge zone [12]. Spatial classification weight for rainfall are 5 for annual rainfall >3000mm (84%), 4 for annual rainfall 2000-3000mm (0%), 3 for annual rainfall 1000-2000mm (16%), 2 for annual rainfall 500-1000mm (0%), 1 for annual rainfall <500mm (0%) (Figure 6).

Figure 2. Methodological flow chart.

Figure 3. Land use spatial weighted value.

Figure 4. Slope spatial weighted value.
3.5. Watershed recharge zone delineation

Watershed recharge zone map was classified into vary recharge classification, 7 classification [11], 5 classification [17], 4 classification [18,19]. This research was classified into 5 recharge zone classification (‘poor’, ‘average’, ‘moderate’, ‘good’, ‘very good’). Sensitivity analysis is done by eliminating one or more factor for watershed recharge zone [13,16,20]. Based on first scheme (internal factors), recharge zone map results recharge potential ‘poor’ (0%), ‘average’ (24.39%), ‘moderate’ (49.70%), ‘good’ (20.26%) and ‘very good’ (5.57%) (Fig.7). Due to internal factor (land use, slope and soil texture), Cisadane Watershed is quite suitable for water recharge zone. The second scheme (rainfall factor included) results recharge potential ‘poor’(0%), ‘average’ (7.74%), ‘moderate’ (54.16%), ‘good’ (32.46%) and ‘very good’ (5.64%) (Figure 8). It can be concluded that rainfall is sensitive factor to generate watershed recharge zone. For Cisadane case with mostly heavy rainfall, rainfall factor can increase potential water recharge from domination of ‘average-good’ to ‘moderate-good’.
4. Conclusion

Generating watershed recharge zone using integration of remote sensing data and GIS is efficient in time, cost and suitable for quick decision making of water resources management. All internal factors (land use, slope, soil) and external factor (rainfall) are influential factor of watershed recharge zone. According to watershed recharge zone map, Cisadane Watershed is classified into 5 zone, ‘poor’, ‘average’, ‘moderate’, ‘good’ and ‘very good’. Based on internal factor (land use, slope and soil texture), Cisadane Watershed is quite suitable for water recharge zone. Rainfall is sensitive factor to generate watershed recharge zone. This method can be widely applied and developed to recharge zone assessment. This research is a desk study and further can be developed with ground test validation. The result of watershed recharge zone map can be one of references for sustainable water resources management planning.

Acknowledgments

This research was supported by Ministry of Research and Technology. The Authors would like to thank to Ministry of Public Works and Housing, Meteorology Climatology and Geophysics Council, Geospatial Information Agency for available data. Thanks to Bandung Institute of Technology and Universitas Trisakti for supporting this research and thanks to reviewers for useful inputs for improving the quality of the manuscript.

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