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Clarification of Watershed Recharge in Cisadane River Basin through Ground Test

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ABSTRACT KARDAS is an area used to protect groundwater from its usage as a water source. Meanwhile, the recharge zone is normally determined in Indonesia through the Regulation of the Ministry of Public Works and Housing (Permen PUPR) Number 10/2015 with the focus on certain physical parameters such as soil texture, land use/land cover, annual rainfall, and slope provided with relative potency values from 1 which represents very low to 5 which is very high. This system was used to review four parameters in a small grid unit of 1 km2 each in the Cisadane River Basin with a 1,545.47 km2 area divided into 1,710 units and the most dominant grid placed at the middle part while the rest are at the edge of the basin. This research focused on the clarification methods to determine the potential recharge variables for this river basin in order to serve as a reference for the potential recharge zone in Indonesia. The KARDAS map obtained showed a very high potential with a score of 17-20 covering 183 km2 (10.45%), high potential with a score of 13-16 involving 943 km2 (56.96%), medium potential with 584 km2 (32.59%), and 0 small potential. Moreover, KARDAS desk study results were clarified using the field or ground test to ensure accuracy and this involved using 14 units as samples to represent the five potentials through temporary quantitative cumulative scores. The desk study or secondary data results were found to be only 50% accurate with a limited point survey but the application of qualitative perception showed that only 1 point does not match with the medium and high potentials this indicates the accuracy was 93% which is categorized to be good

KEYWORDS River Basin; Potential Recharge Zone (KARDAS); Grid Unit; Ground Test Accuracy; Watershed Recharge.

1 INTRODUCTION

A potential recharge zone (KARDAS) is an area used to protect groundwater from its usage as a water source. It is important to note that the recharge zone in Indonesia is normally determined based on the Regulation of the Ministry of Public Works and Housing (Permen PUPR) Number 10/2015 using 4 variables which include the rainfall, slope, land use, and soil texture by assigning the same weight for each while having different spatial criteria. Moreover, spatial analysis is usually used to clarify the location and boundaries of water recharge areas in the catchment based on the existence of the Groundwater Basin (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2015). This Groundwater Basin was defined as an area limited by hydrogeological boundaries which allow the occurrence of all hydrogeological events such as the recharge process, drainage, and groundwater release (Kementerian ESDM Republik Indonesia, 2018). Furthermore, geographical information system (GIS) is fast and reliable to process a huge number of spatial data and extract surface data related to water resources such as slope and land use (Basavaraj and Nijagunappa, 2011; Saha et al., n.d.; Al-Ruzouq et al., 2019). It has been reported that the delineation of recharge zones using GIS is faster and more effective in terms of cost Nampak et al. (2014) and this method can also be applied to watershed recharge zone using input from desk study data. Meanwhile, Saputra (2015) argued that the slope map obtained from topographic data processing needs to be validated using a survey due to the sensitivity of the results to the method used in processing the data. Another study also showed the need to validate land-use change through a visual survey because of its vulnerability in the Cisadane watershed (Prasetya et al., 2016). Previous studies by Hidayat et al. (2021*a*) and Hidayat et al. (2021*b*) used a total of 1,710 measurable grids with 1,000 x 1,000 m area and centroid to visualize each factor and watershed recharge zone, and the further ground test was discovered to be easier in validating each grid centroid. Therefore, this present research aims to clarify the recharge variables including the slope, land use, and soil texture obtained from desk study through limited survey points. The process involved the selection of the Cisadane watershed as the research location because it is one of the priority watersheds in Indonesia with an area of 1545.47 km^2 and due to a decline in its recharge potential as the land-use changes.

2 RESEARCH METHODS

The watershed recharge zones in Indonesia are normally delineated using spatial criteria which include four variables of rainfall, slope, land use, and soil texture. Hidayat et al. (2021*a*) assigned a weight value of 1 to each variable for the least supportive recharge to a weight value of 5 for the most supportive recharge as described in Table 1. It is important to note that some previous research have used both the physical factors such as slope, land use, and soil texture and dynamic factors such as rainfall to determine watershed recharge zone (Thapa et al., 2017; Pinto et al., 2017) (Bathis and Ahmed., 2016), while others only considered the physical factors (Al-Abadi and Al-Shamma'a, 2014; Singh et al., 2019). Hidayat et al. (2021*b*) also examined the importance of rainfall as a dynamic factor in determining watershed recharge zone. The 7 rain stations including Citeko, Pasir Jaya, Kracak, Rancabungur, Pondok Betung, Bendung Pasar Baru, and Cengkareng used to determine the annual rainfall data to analyze the watershed recharge zone are presented in the Figure 1.

The watershed recharge potential map was calculated from the summation of weights and classified as follows:

1. 3 variables including slope, land use, and soil texture: 13-15 indicates very high potential, 10-12 for high potential, 7-9 for medium potential, 4-6 for low potential, and 3 for very low potential
2. 4 variables including the rainfall, slope, land use, and soil texture: 17-20 for very high potential, 13-16 for high potential, 9-12 for medium potential, 5-8 for low potential, and 4 for very low potential

The value of each variable plays an important role in delineating the recharge zone using GIS and this is the reason it is important to clarify each variable obtained from desk study through the ground test with limited survey points using the method explained in the Figure 2.

The land use clarification method involves determining the coordinates of survey location based on the distribution of survey points and comparing land use from desk study with the dominance of the grid surveyed. Meanwhile, the slope clarification method involves the determination of the coordinates of the survey location and recording using GPS 5 points coordinates at one location with a certain distance difference to calculate the average slope. The soil texture was also clarified by determining the coordinates of the survey location, taking a photo of soil surface appearance and soil samples, and evaluating the soil texture through a feel.

The clarification of the initial soil texture through feel was described by Yolcubal et al. (2004) as indicated in Figure 3. The steps involve taking a small amount of soil with the size of a golf ball and adding water slowly up to the moment the soil mix attains putty consistency. This is to be followed by the squeeze of the ball to ensure it stays together or falls apart and later pressed to form a ribbon when it has been confirmed to be cohesive. The soil texture is determined based on the period the ribbon is able to stay together before it falls apart. The ribbon test is normally followed by the slow addition of water to a small amount of soil in the palm to produce a muddy puddle and the soil texture is confirmed to be gritty, smooth, or equally gritty and smooth based on the feel to the touch.

2.1 Survey Point Selection

A limited survey point was used to clarify each variable from the desk study with the locations used observed to include 6 points upstream, 2 points in the middle, and 6 points downstream as indicated in Table 2. These points were selected based on the criteria for medium, high, and very high recharge potential and spread throughout the Cisadane watershed as presented in Figure 4.

3 RESULT

The internal and physical factors of the watershed which include the land use, slope, and soil texture parameters used for the analysis showed that the Cisadane watershed is dominated by medium recharge potential with 53.70% and high recharge potential with 44%. The potential was observed to have increased significantly with the addition of the rainfall factor to have a four-parameter analysis, hence the very high recharge increased by 4.69x from the previous value and the high recharge by 1.29x as indicated in Figure 5 and Table 3. This implies the rainfall factor contributes substantially to the very high recharge potential of the watershed (Hidayat et al., 2021a).

3.1 Upstream Clarification Result (Points 1-6)

There are 6 survey points at the Cisadane upstream side as described in Figure 5 and these include:

1. Pesantren Mina 90 (6°37’54.17”S, 106°47’19.28”E)
   The average slope is 5,5% but previously <5% (weight value of 4), land use is for residences (weight value of 1), clay sand (weight value of 4), and Rrt Pasirjaya is 3,585 mm (weight value of 5).This indicates it has a total value of 14 which is a high potential recharge
2. Jl. Gunung salak endah (6°38’42.24”S, 106°41’0.77”E)
   The average slope is 5,7% (weight value of 4), land use is for paddy field (weight value of 2), Sandy clay (weight value of 3), and Rrt Kracak is 3,869 mm (weight value of 5). This implies it has a total value of 14 which is a high potential recharge
3. Jl Gunung Menir (6 6°38’42.19”S, 106°41’0.76”E)
   The average slope is 8% (weight value of 4), land use is for paddy field (weight value of 2), soil texture is sandy clay but previously clay sand (weight value of 3), and Rrt Kracak is 3,869 mm (weight value of 5). This means it has a total value of 14 which is a high potential recharge
4. Cibungbulang (6°34’38.67”S, 106°39’39.53”E)
   The average slope is 3% (weight value of 5), land us is for residences (weight value of 1), Fine sandy clay (weight value of 2), and Rrt Kracak is 3,869 mm (weight value of 5). This means it has a total value of 13 which is a high potential recharge
5. Cimandirasa (6°36’1.93”S, 106°34’54.27”E)
   The average slope is 20% (weight value of 3), land use is for forest (weight value of 5), clay sandy soil (weight value of 4), and Rrt Kracak is 3,869 mm (weight value of 5). This signifies that it has a total value of 17 which is a high potential recharge
6. Leuwisadeng (6°34’52.26”S, 106°35’19.37”E)
   The average slope is 5,8% but previously <5% (weight value of 4), land use is for paddy field (weight value of 2), soil texture is sandy clay but previously fine sandy clay (weight value of 3), and Rrt Kracak is 3,869 mm (weight value of 5). This denotes that it has a total value of

Table 1. Spatial criteria of each recharge variable

Variable	Spatial Criteria
Rainfall	5 for annual rainfall >3,000mm, 4 for annual rainfall 2,000-3,000mm, 3 for annual rainfall 1,000-2,000mm, 2 for annual rainfall 500-1,000mm, and 1 for annual rainfall <500mm
Slope	5 for slope < 5%, 4 for slope 5-20%, 3 for slope 20-40%, 2 for slope 40-60%, and 1 for slope >60%
Land Use	5 for the forest, 4 for shrubs, 3 for plantation, 2 for paddy field, fishpond, and swamp, and 1 for housing and commercial areas
Soil texture	5 for sand, 4 for clay sand, 3 for sandy clay, 2 for fine sandy clay, and 1 for clay

Table 2. Survey location

Survey point	Grid Location	Coordinate
1	Pesantren Mina 90	6°37’54.17”S 106°47’19.28”E
2	Gunung Salak Endah	6°38’42.24”S 106°41’0.77”E
3	Jalan Gunung Menir	6°40’59.06”S 106°39’49.15”E
4	Cibungbulang	6°34’38.67”S 106°39’39.53”E
5	Cimandirasa	6°36’1.93”S 106°34’54.27”E
6	Leuwisadeng	6°34’52.26”S 106°35’19.37”E
7	Ciseeng	6°27’37.95”S 106°42’24.78”E
8	Pesantren Az Zikra G. Sindur	6°24’33.78”S 106°40’5.73”E
9	PTPN Serpong	6°18’22.35”S 106°39’37.76”E
10	Cisauk	6°19’10.66”S 106°38’30.09”E
11	Karawaci	6°13’59.69”S 106°36’47.30”E
12	PAP Tangerang	6° 9’29.85”S 106°38’46.66”E
13	Slapang	6° 7’27.29”S 106°36’55.81”E
14	Jalan Gaga	6° 5’13.46”S 106°37’25.67”E

14 which is a high potential recharge.

3.2 Middle Clarification Result (Points 7-8)

There are 2 survey points at the Cisadane middle side as described in Figure 6 and these include:

7. Ciseeng (6°27’37.95”S, 106°42’24.78”E)
   The average slope is 1,75% (weight value of 5), land use is for paddy field (weight value of 2), Fine sandy clay (weight value of 2), and Rrt Rancabungur is 1,572 mm (weight value of 3). This implies it has a total value of 12 which is a medium potential recharge.
8. Gunung Sindur (Az Zikra) (6°24’33.78”S, 106°40’5.73”E)
   The average slope is 3,5% (weight value of 5), land use is dominated by paddy fields and shrubs but previously residences (weight value of 2), Fine sandy clay (weight value of 2), and Rrt Rancabungur is 1,572 mm (weight value of 3).This indicates it has a total value of 12 which is a medium potential recharge.

3.3 Downstream Clarification Result (Points 9-14)

There are 6 survey points at the Cisadane downstream side as described in Figure 8 and these include:

9. PTPN Serpong (6°18’22.35”S, 106°39’37.76”E)
   The average slope is 2,75% <5% (weight value of 5), land use is for residences (weight value of 1), sandy clay (weight value of 3), and Rrt St. Pondok Betung is 2,079 mm (weight value of 4). This indicates it has a total value of 13

Table 3. Recharge potential analysis without and with rainfall variable

Potential recharge	total grid	Internal Factor (3 parameters)		Potential recharge	total grid	Rainfall factor (4 parameters)		Description
		total area (ha)	% area			total area (ha)	% area	
5 very high	43	3,448	2.23%	5 very high	183	16,155	10.45%	increase
4 high	734	68,112	44.07%	4 high	943	88,027	56.96%	increase
3 medium	933	82,987	53.70%	3 medium	584	50,365	32.59%	decrease
2 low	0	0	0.00%	2 low	0	0	0.00%	-
1 very low	0	0	0.00%	1 very low	0	0	0.00%	-
total	1,710	154,547	100.00%	total	1710	154,547	100.00%	

which is a high potential recharge.

10. Cisauk (6°38'42.19"S, 106°41'0.76"E)
The average slope is 2,25% (weight value of 5), land use is dominated by residences but previously paddy fields (weight value of 1), soil texture is between sandy clay and fine sandy clay (weight value of 2), and the Rrt Pondok betung is 2,079 mm (weight value of 4). This denotes that it has a total value of 12 which is a medium potential recharge.
11. Karawaci (6°13'59.69"S, 106°36'47.30"E)
The average slope is 2,75% (weight value of 5), land use is for residences (weight value of 1), fine sandy clay (weight value of 2), and Rrt St. Pasarbaru is 1,403 mm (weight value of 3). This signifies that it has a total value of 11 which is a medium potential recharge.
12. PAP Tangerang (6° 9'29.85"S, 106°38'46.66"E)
The average slope is 1,5% (weight value of 5), land use is dominated by residences but previously paddy field (weight value of 1), fine sandy clay (weight value of 2), and Rrt St. Pasarbaru is 1,403 mm (weight value of 3).This means it has a total value of 11 which is a medium potential recharge.
13. Slapang Kab. Tangerang (6° 7'27.29"S, 106°36'55.81"E)
The average slope is 2,25% (weight value of 5), land use is for residences and industries (weight value of 1), soil texture is between sandy clay and fine sandy clay (weight value of 2), and Rrt St. Pasarbaru is 1,403 mm (weight value of 3). This implies it has a total value of 12 which is a medium potential recharge.
14. Jalan Gaga Kab. Tangerang (6° 5'13.46"S, 106°37'25.67"E)
The average slope is 1% (weight value of 5), land use is for paddy field (weight value of 2), sandy clay (weight value of 3), and Rrt Cengkareng is 1,683 mm (weight value of 3). This infers it has a total value of 13 which is a high potential recharge.

4 DISCUSSION

The 14 survey points showed there are 7 points indicating 50% that produced different results when the ground test was compared to the desk study. The differences were based on the land use such as the point 8 (Gunung Sindur) located in the middle during the desk study to have residences but found in reality to be dominated by paddy fields and shrubs, thereby, increasing its water recharge potential. Locations 10 and 12 in the downstream were also stated to have paddy fields in the desk study but were observed to be dominated by a residential and industrial area in reality and this decreased its water recharge potential because infiltration occurs more easily in paddy fields or shrubs than residences.

The land slope was also discovered to be different as observed in point 1 located upstream (upper Bogor City) which was recorded to have an average slope of 5.5% during the ground check but less than 5% in the desk study. A similar observation was made in Point 6 located in Leuwisadeng with a difference of 0.8

Some differences were also observed in terms of soil texture in Points 3, 6, 10, and 13, in which Point 3 in Gunung Menir has brown soil that can be shaped into balls with a long ribbon of 1.5-2 cm but it was initially interpreted to have sandy clay. Moreover, Point 6 in Leuwisadeng has reddish-brown soil that can be shaped into balls with a long ribbon of 2-2.5 cm and medium texture but was also initially found to be sandy clay. Point 10 in Cisauk has brown-reddish soil that can be shaped into balls with a long ribbon of 2-3 cm and sandy texture but initially reported to be between sandy clay and fine sandy clay. Point 13 in Slapang has brown to slightly gray soil that can be shaped into balls with a long ribbon of 2-3 cm and medium texture but the initial interpretation showed it is between sandy clay and fine sandy clay. All the differences observed between the desk study and ground test are, therefore, presented in the following Table 4.

5 CONCLUSIONS

This research can be used to complement the regulation normally applied to delineate potential watershed recharge zone in Indonesia provided in Permen PUPR, using land use, soil texture, and slope as the parameter for the clarification. It is important to note that the 6 points selected upstream, 2 points in the middle, and 6 points downstream were based on the criteria for the medium, high, and very high recharge potential and spread throughout the Cisadane watershed. The results showed that 1 out of 14 points (7%) experienced

Table 4. Difference between desk study and ground test

Point	Location	Ground test	Desk study	Recharge Potential Classification
1	Pesantren Mina	Average slope ground test 5,5%	The slope from desk study <5%	The total value decreased from 15 to 14 but is still the same on high potential recharge
3	Gunung Menir	The soil texture of the sandy clay	clay sand from desk study	The total value decreased from 15 to 14 but is still the same on high potential recharge.
6	Leuwisadeng	The average slope from the ground test is 5,8%, The soil texture of the sandy clay	The slope from desk study <5% soil texture fine sandy clay	Total value of 14 indicates high potential recharge
8	Gunung sindur	Land use is dominated by paddy fields and shrubs.	land use from desk study is residences	Total value increase of 12, previously 11, but still on medium recharge potential.
10	Cisauk	Land use is dominated by residences Soil texture between sandy clay- fine sandy clay	land use from desk study is paddy field Soil texture is fine sandy clay	The total value decreased from 13 to 12, changing from high to medium potential recharge
12	PAP Tangerang	Land use is dominated by residences	land use from desk study is paddy field	The total value decreased from 12 to 11 but is still the same on medium potential recharge.
13	Slapang	Soil texture between sandy clay- fine sandy clay	Soil texture is sandy clay	The total value of 12 which is a medium potential recharge.

a difference in the classification of recharge potential made using the ground test and desk study and this includes the Cisauk – point 10 which was changed from high to medium potential because the land use is dominated by residential or commercial areas. This simply indicates that the data obtained through desk study need to be validated using a ground test. It is also recommended that an additional point of clarification be included in future research to increase the sample population towards obtaining a suitability trend of the recharge potential between the desk study and the ground test. Moreover, the next survey point needs to be selected by considering the criteria for vulnerability to changes in land use and slope, especially the upstream.

DISCLAIMER

The authors declare no conflict of interest.

AVAILABILITY OF DATA AND MATERIALS

All data are available from the author.

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