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Conservation Of Groundwater By Absorbing Rainfall In The Cihideung Watershed

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ABSTRACT

This research aims to: analyze built-up area, rainfall potential, and the effort of groundwater conservation in the Cihideung watershed. An experimental method was done to discover the depth of groundwater. Landsat 8 Images are used to analyze the land cover. Rainfall volume is measured by multiplying the rainfall, area and depth of the well. The infiltration measurement uses a double ring infiltrometer. Built-up land area is 1.563 km^2 (14.77 %) and non-built-up area are 9.022 km^2 (85.27 %). Infiltration measurement using a double ring infiltrometer. The potential for rainfall that occurs on 100 m2 of built-up land needs to be absorbed into the soil. To absorb rainfall, it is carried out in infiltration wells, so that it becomes a groundwater supply. Groundwater conservation is needed to increase groundwater supply to overcome drought in the dry season. Infiltration wells have a role in storing rainfall to increase the supply of groundwater so that the groundwater table becomes shallower.

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1. INTRODUCTION

Water is the main need for the sustainability of life of humans, animals, and plants. Water is the substance that made life on Earth possible. It plays a key role in both the individual and population development of all species and Water is the basic requirement for the development of civilization (Klimaszyk P et al., 2020; Shit P.K et al., 2021). Water resources were a main part of life in accordance with the environmental ecosystem. The biophysical assessment and economic valuation should be conducted jointly to account for the different values of ecosystem services (ecologic, social and economic) and to strengthen the recognition of human dependency on nature (Grizzetti B et al., 2016). Water is basically one of human primary need that serves not only as consumption but as other function as well that support human life needs (Ridwana R et al., 2022). The life in an ecosystem needs water in accordance with the characteristics of organisms in that ecosystem. Water was the most important natural resource for all living things but it also becomes a problem in its existence or occurrence, circulation, and distribution. The availability of water of acceptable quality in Egypt is limited and getting even more restricted (Luthfi A et al., 2017; Sallata, 2015).

The water needs for life sustainability of human have some characteristic and certain conditions to make the water safe for human consumption. Water is essential for society. Due to excellent distribution systems for clean drinking water and wastewater, safe and reliable water transport is guaranteed (Morsi M.S, 2020). The United States Geological Survey (USGS) website explains that in general, the volume of water is relatively stable, but its characteristics change through a natural process known as the hydrological cycle. Besides useful for plants and animals, groundwater is also fulfilling the needs of human.

In Indonesia, 65% of water resources for household needs are from well water (Trisna Y, 2016). Water from rainfall is infiltrated and moves into the soil (percolation) and is stored in the ground. Soil infiltration is a water cycle where some rainfall moves into the soil and antecedent soil water content was an important factor influencing deep percolation (Dewi Y.S et al., 2017). This groundwater moves through the soil pore which is known as interflow. Infiltration continues until the saturated soil, so the water that fills the soil pore would be stored. The existence of water in the soil pore is heavily affected by adhesion and cohesion between water and soil (Daniel G et al., 2022). In the rainy season, the rain that falls will seep into the soil pores.

Changes in groundwater level depend on the amount and speed of rainfall moves into the soil, groundwater extraction, and soil permeability (Murtilaksono K, Wahyuni E.D et al., 2002). The size of discharge and volume of river waters is affected by water resource in the ground. The existence of river flow would continuously be preserved as long as groundwater is available to be used by people. When many people think of a water source, they think of lakes, rivers and streams; in other words, surface water. However, of all of the usable freshwater in the world, approximately 97 percent of it is groundwater (Barid B, and Sari W, 2013). River flows would be dried in the dry season and overflow in the rainy season. The size of water springs and infiltration are affected by the availability of groundwater, so where does the groundwater come from?

Rainfall infiltration is affected by land cover, especially vegetation. Vegetation decreases and land cultivation processes such as compression will change the infiltration rate characteristics. Infiltration occurred when the land surface is soil with a lot of plants. Rainfall, if it is not intercepted by vegetation or artificial surfaces such as roofs or pavements falls directly on the earth and either evaporates, infiltrates, or lies in depression storage (Firmanda R et al., 2022). The level of infiltration in a land is affected by soil characteristics. Soil

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characteristics such as; groundwater content, porosity, texture, organic material content, and soil structures will affect the infiltration rates (Musa J.J, 2012). Vegetation roots influence the infiltration because it makes the soil cracked, and this cracked soil will make water be easier to be infiltrated. One such feedback is the alteration of the infiltration capacity of soils through biotic processes. This positive feedback and vegetation are increasingly used to mitigate landslide risks (Harisuseno D et al., 2019; Thompson E, 2010).

The water cycle shows the continuous and complex movement of water within the earth and atmosphere in which water moves from the land and ocean surface to the atmosphere and back in form of precipitation. Movement water is shown by the hydrological cycle picture (Huang G, Zheng M, and Peng J, 2021; Wang W, 2021). The need for water continuously increasing along with the development of population, industry, settlement, and public facilities. The increase in water needs in the future cannot be fulfilled only by surface water, so that technological development for groundwater conservation is to help reduce groundwater consumption and maintain both the quantity and quality of the available groundwater (Heryani N, 2014). Its development shapes the land surface to be impermeable, so the rainfall could not be absorbed into the soil. This causes a decrease in the groundwater supply. The expansion of built-up land causes a decrease in groundwater level (Maurya A.K, 2021). Management of water resources and soil conservation are needed to effectively plan for the sustainability of the catchment. Soil and water conservation however involve understanding the complex hydrological processes both at the surface and subsurface level (Noeraga M.A, 2020). The movement and change of water are shown in Water Cycle represented in Figure 1.

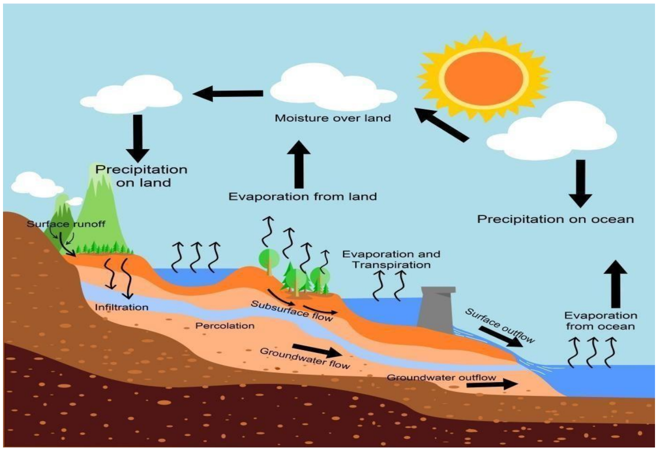

Figure 1. Water cycle
Source: she-persisted.life

Groundwater supply that decreases caused by the expansion of built-up land and farming land decreases the function of soil. The reduction of matric suction due to rainfall infiltration induced the additional settlement of shallow foundations in unsaturated soil (Srivastava P, 2013). The decrease in soil function has an impact on the water supply to fulfill the water needs of people. When raining, rainfall on the built (becomes surface run-off streaming on the surface of the land and ending in the river, because the soil is covered by impermeable layers or lacks dense vegetation (Jeong S et al., 2018; Sugandi D, and Pascawijaya R, 2020). Because there are changes in land use that turn into built-up land, which causes the soil to be impermeable. During rainfall on this built-surface, rainfall will not permeate through the soil, instead will be formed as surface runoff (Iskandar D, Sugandi D, 2015). Infiltration level decreases have a role as groundwater supplier, so the groundwater level would be deeper

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and even drought. In the dry season, there would be drought, otherwise, in the rainy season there would be floods and landslides (Sugandi D et al., 2020). Therefore, rainfall infiltration with groundwater extraction was unbalanced. Water is the most common substance on the earth; it is necessary for all life. The supply of fresh water on a sustained basis is equal to the annual precipitation (Aripbilah S.N, and Suprapto H, 2021). The decrease of groundwater level affects the fulfilling of water needs, so in the dry season there would be a drought. Significantly groundwater levels decreased because of groundwater extraction occurred in Bandung area and around. The main sources of groundwater recharge are ecological water replenishment and precipitation (Foth H.D, 1990; Xu C et al., 2022). This is a serious problem, on the one hand, people have to fulfill their needs such as settlements, industry, and trade as the causes of the land surface became impermeable (Ridwana R et al., 2019). The increase in imperviousness has a major impact on groundwater (Ridwana R et al., 2021). The increase in urbanization results in reduction in infiltration, which affects the groundwater recharge and storage and the built-up area has a significant effect on the groundwater recharge in HCM (Mishra N et al., 2014; Adhikari R.K, 2020). On the other hand, the water supply comes from rainfall absorption as a main need of people is decreased. Therefore, there should be an effort to increase water absorption by conservation of water and soil. This research aims to;

a. How much is the built-up land area of Cihideung Watershed?
b. How much is the potential rainfall volume that infiltrates into the soil in Cihideung Watershed?
c. How is the effort of groundwater conservation to supply groundwater in Cihideung Watershed?

2. METHODS

Experimental method was used in this research. This method was used to measure rainfall volume in a certain area of built-up land and did measurement of infiltration rates put in a well with a depth of 2 m. To analyze a decrease of shallow groundwater level is by conducting some stages as follows: analyze the area of land use in built-up land and rainfall volume. This measurement is carried out if the land area is every 100 m2, then the of rainfall on the land is volume absorbed into the infiltration well. While the type of soil analyzed is texture, because the coarser infiltration ould be higher infiltration rate.

The research area is Cihideung Watershed. Land cover was analyzed by utilizing Remote Sensing techniques through Landsat 8 OLI Images analysis. Landsat imagery is analyzed based on elements of interpretation, such as; Hue, texture, shape, size, pattern, height, site shading and associations. The results of the image inter-pretation become a land use map. To measure rainfall volume. Rainfall is obtained from 1 station, namely Cisarua Station. So, for the Cihideung watershed it is assumed to have the same rainfall thickness. infiltration rate, and capacity on 6 samples, the measurement of groundwater level is conducted in 3 points during 3 periods, that is 1995, 2010, and 2021.

Measurement of rainfall volume is evaluated using this formula:

$$V = R.A$$

Where, V = volume (m3), R = rainfall (mm) and A = area (km2)

Reservoir well to measure rainfall volume that infiltrates using this formula:

$$V = A.d$$

Where, V = volume (m^3), A = area of the circle (m^2) and d = well's depth (m)

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The infiltration rates were measured using a double ring infiltrometer. Rainfall that is compared with the infiltration rates will obtain the infiltrated rainfall volume. Infiltration rate and capacity are the volumes of water poured that are reduced with the factor (correction) of evaporation divided by small cylinder area of infiltrometer and time required for infiltration, which is measured with this formula:

$$Ft = fc + (fo – fc)\ e^{-kt}$$

Where,
f = real infiltration capacity (cm/hour)
fc = constant infiltration rate (cm/hour)
fo = initial infiltration rate (cm/hour)
k = geophysical constant
t = time from the beginning of rain (minute)
e = exponential number (2,718)

3. RESULTS AND DISCUSSION

Landcover

From the analysis of Landsat 8 shows that land is used by various community activities to meet needs. Image analysis results are shown in Figure 2. The need for land to be settlement continuously developed, so the increase in population number in the settlement demands increased water needs. Land cover in Cihideung Watershed is shown in **Table 1**.

Forests and plantations area in Cihideung Watershed continuously decreased because of land use change to settlements and farming, so the ability to absorb rainfall is getting less, and it affects the water supply in soil.

Table 1. Land cover area in Cihideung Watershed (km^2)

No	Land cover	Area 2001	Area 2021
1	Forests	4.390	4.081
2	Fields	3.592	1.530
3	Plantations	0.912	0.583
4	Settlements	1.411	2.636
5	Rice fields	0.051	1.576
6	Shrubs	0.121	0.121
7	Vacant land	10.741	0.058
	Area	10.585	10.585

Forests and plantations area in Cihideung Watershed continuously decreased because of land use change to settlements and farming, so the ability to absorb rainfall is getting less, and it affects the water supply in soil.

Rainfall Volume

Most of people especially in the research area fulfills their need of clean water by using artesian well. Groundwater drilling affects the decrease of groundwater surface. Built-up area makes the rainfall infiltration into the soil decrease, while the need of water is increase. The decrease of groundwater shown by groundwater level that goes deeper. To increase groundwater supply, it needs to put precipitation to the artificial infiltration. This artificial infiltration is to accelerate groundwater conservation and increase groundwater surface. Monthly rainfall is shown in **Table 2**. Rainfall volume that potential to be surface flow and soil infiltration is measured by the thickness of rainfall and multiplied by the research area. The volume of rainfall is shown in **Table 3**.

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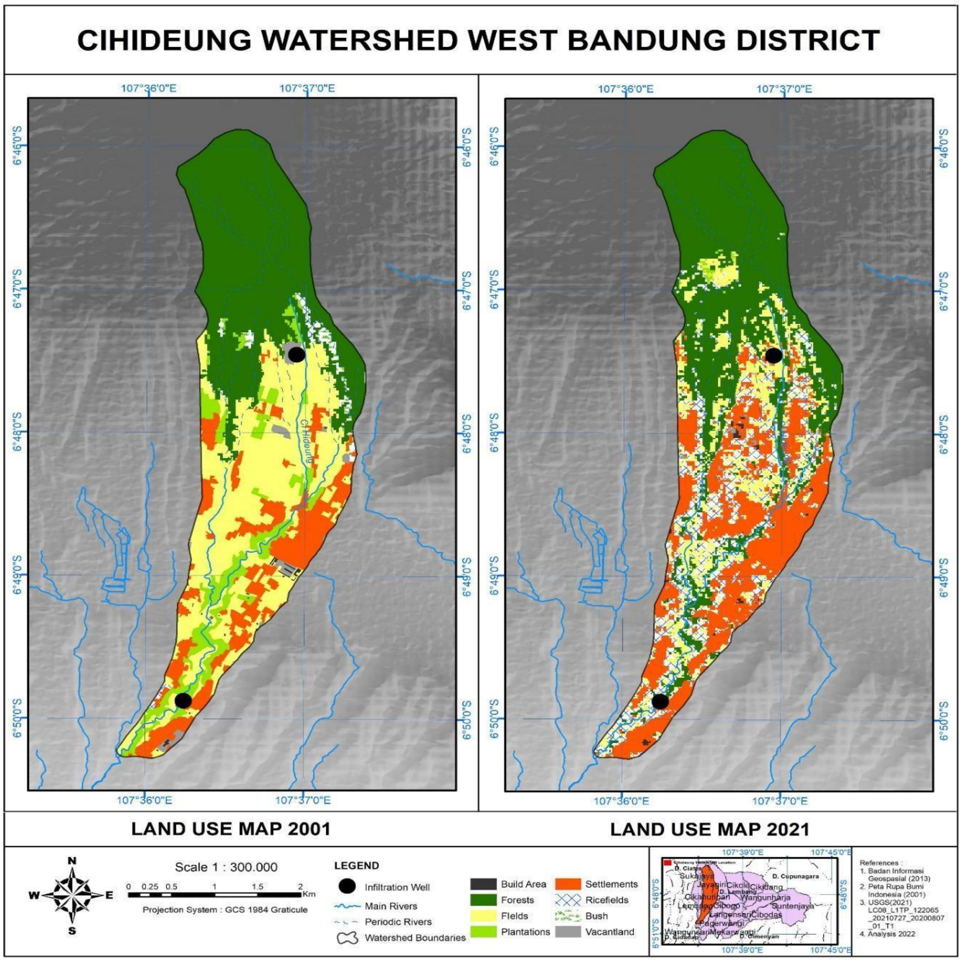

Figure 2. Landuse (Landcover)

Table 2. Monthly Rainfall in Cisarua Station
Source: *Balai Besar Wilayah Sungai Ci Tarum,* 2021

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Oct	Nov	Dec
2010	264.7	223.6	403.7	172.9	219.4	41.0	59.1	54.3	163.4	147.4	374.6	244.7
2011	27.7	70.7	123.5	197.5	158.8	43.7	24.4	0	1.4	10.3	0	0
2012	159.9	207.1	143.3	140.9	64.5	67.9	0	1	21.4	60.2	302	591.3
2013	261.3	204.3	325.3	302.5	178.7	139.1	107.9	4.6	5.7	27.6	167.7	425.2
2014	226.5	138.2	415.9	308.3	35.3	128	62.8	13.4	2.5	21.6	197.3	477.2
2015	240.5	368.9	282.4	218.1	61.9	26.4	0	0	2	9.6	210.2	334.6
2016	191.4	441.5	446.5	175.1	119.8	152.7	141.9	57.6	230.3	521	400.4	192.7
2017	118.8	170.6	435.3	205.5	42.6	38.7	38.1	6.1	59	231	538.2	242.1
2018	142.6	287.3	380.5	167.8	59.6	10.4	2	4.9	2.5	56.4	332.6	310.4
2019	116.1	378.1	293.1	347.1	67	0.0	4.0	0	0	28.1	98.0	205.4
Mean (mm)	175	249	324.9	223.6	100.8	64.8	44	14.2	48.8	111.3	262.1	302.4
Day rainfall	17	18	18	16	14	9	7	5	5	6	9	13
Rain/days (mm)	10.29	13.83	18.05	13.98	7.20	7.20	6.29	2.84	9.76	18.55	29.12	23.26
Rain intensity	0.43	0.58	0.75	0.58	0.30	0.30	0.26	0.12	0.41	0.77	1.21	0.97

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Table 3. Rainfall Volume (m^3)

Rainfall	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Oct	Nov	Dec
Mean (mm)	175	249	324.9	223.6	100.8	64.8	44	14.2	48.8	111.3	262.1	302.4
Area	17	18	18	16	14	9	7	5	5	6	9	13
Rain/days (m)	10.29	13.83	18.05	13.98	7.20	7.20	6.29	2.84	9.76	18.55	29.12	23.26
Volume Rainfall (m^3)	0.43	0.58	0.75	0.58	0.30	0.30	0.26	0.12	0.41	0.77	1.21	0.97

Table 3 shows that the distribution of rainfall occurs in October – May which is called the rainy season, while low rainfall occurs in June – September which is called the dry season.

Groundwater conservation is by increasing soil infiltration with the infiltration wells in the smallest land unit which is every 100 m2, by calculating the rainfall volume in that land unit area. Rainfall absorption is carried out for each 100 m2 land unit, so that the volume of rainfall can be accommodated in wells with a depth of 2 m. The calculation of rainfall is shown in **Table 4**.

Table 4. Rainfall volume in land unit of every 100 m^2

Year	Month											
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Oct	Nov	Dec
Thickness (m)	0.175	0.249	0.3249	0.2236	0.1008	0.0648	0.044	0.0142	0.0488	0.1113	0.2621	0.3024
Rain/days (mm)	10.29	13.83	18.05	13.98	7.20	7.20	6.29	2.84	9.76	18.55	29.12	23.26
Rain days (m)	0.0109	0.01383	0.01805	0.01398	0.0072	0.0072	0.00629	0.0028	0.00976	0.01855	0.02912	0.0232
Area							10 m^3					
Volume rainfall (m^3)	0.43	0.58	0.75	0.58	0.30	0.30	0.26	0.12	0.41	0.77	1.21	0.97

In the land units of 100 m2, the low rainfall thickness is in August that is 0.0142 (14.2 mm) and the high rainfall thickness is in December which is 0.3024 meters (302.4 mm). The lowest rainfall volume occurs in May with a volume of 0.282 m3, while the highest is in November with a volume of 2.912 m3. The potential rainfall volume needs to be infiltrated through the infiltration wells to increase groundwater supply. The highest rainfall is 2.912 m, so the infiltration wells with a length of 1 meter and a wide of 1 meter, therefore the rainfall thickness is 2.912 meters.

From the result of the observation of groundwater surface, there was conducted groundwater drilling in 1994, 2002, and 2021 in 3 areas that decreases their groundwater surfaces. The result of groundwater drilling is shown in **Table 5**.

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Table 5. The groundwater depth Cihideung Watershed

Area	Year, groundwater depth (m)		
	1994	2002	2021
Sariwangi	7	11	19.5
Politeknik	8	13.5	21
Karyawangi	10	0	0

The data from groundwater drilling shows that groundwater surface is continuous-ly decreased. This condition will continually decrease if there were not any effort to in-crease the infiltration rate. The decrease in groundwater surface affects the water supply for people. **Table 6** shows the infiltration rate.

Table 6. Data of Infiltration Rate

Time	Samples						
	1	2	3	4	5	6	Mean (mm)
Thickness (mm)	104	102	90	7	86	83	6.10
Time (minute)	27	36	39	42	45	48	48
Infiltration (mm/h)	0.45	53.33	138.46	124.29	1114.67	103.75	164.3383

From 6 samples conducted a measurement of infiltration rate shows that the samples have a high class. The high infiltration rate shows that the land is easy to absorb rainfall, but if the land is developed into built-up land, it will make rainfall difficult to be absorbed. Soil infiltration is influenced by the type and nature of the soil, the type of soil in the study area is andosol with a loose texture containing clay and sand. Soil infiltration is influenced by the type and nature of the soil, the type of soil in the study area is andosol with a loose texture containing clay and sand. If rainfall volume is put into the infiltration wells with a depth of 1 meter, the rainfall will run out at a certain time. The highest rainfall is 302.40 mm with the highest infiltration rate of 104 mm. Rainfall that was put into the infiltration well is shown in **Table 7**.

Table 7. Time of rainfall that infiltrates

Highest rainfall	302.40	302.40	302.40	302.40	302.40	302.40
Infiltration mm	104.00	102.00	90.00	87.00	86.00	83.00
Infiltration mm/h	2.91	2.96	3.36	3.48	3.52	3.64
Infiltration mm/Sec	174.46	177.88	201.60	208.55	210.98	218.60

If the table shows that rainfall put into the infiltration wells with the highest rainfall thickness is in December at 302.40 mm with the infiltration rate and capacity, so the rainfall in the infiltration wells will run out by infiltration. The fastest time is 174.46 minutes (2.91 hours) and the longest is 218.60 minutes (3.64 hours).

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Groundwater Conservation

Rainfall that does not infiltrate potentially becomes the surface flow. From 6 samples conducted the calculation of infiltration capacity shows the soil's ability in infiltrating rainfall. Infiltration capacity is shown in **Table 8**. The result of infiltration capacity measurement shows that the soil characteristics such as soil texture and structure affect the level of capacity. Rough texture and granular structure have a high infiltration capacity. But even though the soil texture and structure support the infiltration of rainfall, it would be useless if the land is covered by built-up land such as settlements, industry, and social and public facilities. Rainfall that occurs on the land (built up) will become runoff and on a 100 m^2 land unit the potential for runoff can be calculated, so that the runoff on the land unit can be absorbed by rainfall. The development of settlements, industry, and social and public facilities affect the ability of the soil layer in absorbs rainfall and even it potentially becomes the surface flow, because makes the land to be impermeable should absorb the rainfall in accordance with the built-up land area. Rainfall infiltration to the infiltration wells will decrease the surface flow and increase the absorption. Automatically the groundwater surface will increase which shows the groundwater surface becomes shallower. While the non-built-up land is by shaping reservoir so the rainfall would not flow on the surface.

The groundwater level is getting deeper, even in the dry season, groundwater often runs out, so to fulfill the need for water, people search for water resources in other areas. Observation result from 1994 shows that groundwater surface continuously decreased. This is caused by the development of settlements in the Cihideung area, so the soil layer has no ability to absorb rainfall. In the upstream area of Cihideung, drought frequently occurred, because the artesian wells were dry in the area of Karyawangi Village, Polytechnic, and around.

Table 8. Infiltration Capacity

	Infiltration Capacity (m/hour)					
Samples Time (minute)	1	2	3	4	5	6
3	1.531	1.477	1.301	1.301	1.255	1.204
3	1.477	1.380	1.255	1.255	1.230	1.146
3	1.415	1.301	1.204	1.204	1.204	1.079
3	1.342	1.204	1.146	1.146	1.146	1
3	1.255	1.079	1.079	1.146	1.079	0.954
3	1.146	0.903	1	1.079	1	0.903
3	0.903	0.778	0.954	1	0.954	0.903
3	0.778	0.699	0.903	1	0.845	0.845
3	0.778	0.602	0.845	0.903	0.845	0.845
3	0.778	0.477	0.778	0.845	0.778	0.778
3	0.778	0.301	0.602	0.699	0.602	0.699
3	0.778	0.301	0.301	0.477	0.477	0.602
3	0.778	0.301	0.301	0.301	0.301	0.477
3	0.778	0.301	0.301	0.301	0.301	0.477

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3	0.778	0.301	0.301	0.301	0.301	0.301

The decrease in groundwater level was felt during the dry season. People are difficult to fulfill their need for water. To increase the groundwater surface, the water supply should be put into the soil. Groundwater supply can be conducted by increasing the water infiltration, where the water supply comes from rainfall. Condition and soil characteristic shows that the infiltration rate and capacity can be done by put the rainfall into an infiltration well. Rainfall that flows in the infiltration well makes the water as if it is absorbed into the soil. Rainfall that occurs in Cihideung Watershed needs a large area and is not effective, therefore the infiltration wells are made in every smallest land unit of 100 m2. By infiltrating rainfall volume in the unit of 100 m2, the precipitation on that land would be infiltrated. On the built-up land, rainfall stored in the infiltration wells with the rainfall of 302.40 mm can be absorbed in the infiltration well with a size of 1 m3 and will quickly absorb in time of 2.91 hours (174.46 minutes) and the longest is in 3.64 hours (218.60 minutes).

From **Table 4** rainfall volumes in the land of 100 m2 ha are varied, the lowest with a volume of 0.284 m3 in the dry season, while the highest rainfall volume is 2.912 m3. It means that the infiltration well should accommodate the volume of 2.912 m3. By infiltrating the rainfall, soil erosion can be decreased besides increasing the groundwater surface. Although the infiltration levels are different from the infiltration capacity, as long as there was water in the infiltration well, that water would continually be absorbed until it dried.

4. CONCLUSION

The development of built-up land forms a closed resistant layer and becomes impermeable. The waterproof layer will reduce the function of the soil as a medium for absorbing rainfall. Less rainfall will reduce the supply of groundwater. This is felt in the dry season (June - September).

The availability of groundwater continues to decline, because the groundwater table is getting deeper. The decrease in the groundwater level is due to the extraction of groundwater which is used to meet needs, while the supply of water from rainfall decreases due to the expansion of built-up land. This water supply due to rainfall does not absorb into the ground. To increase groundwater surface, water conservation needs to be conducted by infiltrating.

To increase water infiltration from rainfall, it is necessary to infiltrate rainfall in every unit of land, the smallest area of 100 m2 with a depth that is in accordance with the volume of rainfall. Rainfall absorption can be done by making absorption wells. With infiltration wells, rainfall that occurs on the land can seep and supply groundwater.

5. REFERENCES

Adhikari, R. K., Mohanasundaram, S., & Shrestha, S. (2020). Impacts of land-use changes on the groundwater recharge in the Ho Chi Minh city, Vietnam. *Environmental Research, 185*, 19-28. https://doi.org/10.1016/j.envres.2020.109440

Aripbilah, S. N., and Suprapto, H. (2021). Analisis Kekeringan Di Kabupaten Sragen Dengan Metode Palmer, Thornthwaite, dan Standardized Precipitation Index. *Jurnal Sumber Daya Air, 17*(2), 111-124. https://doi.org/10.32679/jsda.v17i2.742

Barid, B., and Sari, W. (2013). Pengaruh Hujan terhadap Perubahan Elevasi Muka Air Tanah pada Model Unit Resapan dengan Media Tanah Pasir. *Jurnal Ilmiah Semesta Teknika, 16*(1), 57-64. https://doi.org/10.18196/st.v16i1.433

Daniel, G., Gómez, C. G., Ochoa, C. G., Abigail, A. T., & Zamora, I. M. (2022). Soil Water Balance and Shallow Aquifer Recharge in an Irrigated Pasture Field with Clay Soils in the

DOI: https://doi.org/10.17509/gea.v21i1
p- ISSN 1412-0313 e- ISSN 2549-7529

Willamette Valley, Oregon, USA. *Hydrology, 9*(4), 60, 1-12. https://doi.org/10.3390/hydrology9040060

Dewi, Y. S., and Pratama, G. R. (2017). Kualitas Sumber Air Bersih Penduduk Di Rw 1 Kelurahan Kebayoran Lama Utara, Kecamatan Kebayoran Lama. *Jurnal Ilmiah Fakultas Teknik LIMIT'S, 7*(2), 34-45.

Firmanda, R. R., and Harisuseno, D. A. P. (2022). Studi Pengaruh Sifat Fisik Tanah terhadap Laju Infiltrasi pada Lahan Pertanian. *Jurnal Teknologi dan Rekayasa Sumber Daya Air, 2*(1), 67-80. https://doi.org/10.21776/ub.jtresda

Foth, H. D. (1990). *Fundamentals of Soil Science (Soil Water Chapter 5).* New York, John Wiley and Sons, 54-72.

Grizzetti, B., Lanzanova, D., Liquete, C., Reynaud, A., and Cardoso, A. C. (2016). Assessing water ecosystem services for water resource management. *Environmental Science & Policy, 61*, 194–203. https://doi.org/10.1016/j.envsci.2016.04.008

Harisuseno, D., Khaeruddin, D. N., and Haribowo, R. (2019). Time of Concentration Based Infiltration under Different Soil Density, Water Content, and Slope during a Steady Rainfall. *Journal of Water and Land Development, 41*(IV-VI), 61-68. DOI: 10.2478/jwld-2019-0028

Heryani, N., Kartiwa, B., and Sosiawan, H. (2014). Pemetaan Potensi Air Tanah untuk Mendukung Pengembangan Pertanian Lahan Kering. *Jurnal Sumberdaya Lahan, 8*(2), 95-106. DOI: 10.2018/jsdl.v8i2.6472

Huang, G., Zheng, M., and Peng, J. (2021). Effect of Vegetation Roots on the Threshold of Slope Instability Induced by Rainfall and Runoff. *Hindawi Geofluids*, 1-19. https://doi.org/10.1155/2021/6682113

Iskandar, D., and Sugandi, D. (2015). Flood Mitigation Efforts In The Capital Region Of Jakarta. *International Journal of Conservation Science, 6*(4), 685-696. DOI: 10.36868/ijcs

Jeong, S., Kim, Y., Park, H., and Kim, J. (2018). Effects of rainfall infiltration and hysteresis on the settlement of shallow foundations in unsaturated soil. *Environmental Earth Sciences, 77*(494). https://doi.org/10.1007/s12665-018-7690-1

Klimaszyk, P., and Gołdyn, R. (2020). Water Quality of Freshwater Ecosystems in a Temperate Climate. *Water MDPI, 12*(9), 2643, 1-7. https://doi.org/10.3390/w12092643

Luthfi, A., Saleh, M., and Diartho, H. C. (2017). Ability To Pay And Willingness To Pay Analysis Of Clean Water Needs From Dusun Sepuran, Jember Regency. *Journal of Indonesian Applied Economics, 7*(2), 190-200. https://doi.org/10.21776/ub.jiae.2017.007.02.5

Maurya, A. K. (2021). Development Of Technologies For Groundwater Conservation, India: Need Of Future Generations. *International Journal of Multidisciplinary Research and Explorer (IJMRE), 1*(10), 86-91. https://doie.org/10.1212/IJMRE.2021758261

Mishra, N., Khare, D., Gupta, K. K., & Shukla, R. (2014). Impact of Land Use Change on Groundwater - A Review. *Advances in Water Resource and Protection (AWRP), 2*, 28-41.

Morsi, M. S. (2020). Study of the Hydrochemistry Characters of Surface Water Resources in Minia District in Comparing to its Guideline for Drinking Water and Domestic used-Minia Upper Egypt. *International Journal of Water Research, 2*(1), 1-10. https://doi.org/10.36266/IJWR/105

Murtilaksono, K., and Wahyuni, E. D. (2002). Hubungan Ketersediaan Air Tanah dan Sifat-Sifat Dasar Fisika Tanah. *Jurnal Tanah dan Lingkungan, 6*(2), 46-50. DOI: 10.29244/jitl.6.2.46-50

Musa, J. J., Adewumi, J. K., Ohu, J., & Bolaji, G. A. (2012). Effect Of Surface Runoff On Sediment Yield Of Some Soils In Gidan Kwano Area Of Niger State, Nigeria. *International Journal of Life Sciences Biotechnology and Pharma Research, 1*(2), 86-94.

Noeraga, M. A. A., Yudana, G., and Rahayu, P. (2020). Pengaruh Pertumbuhan Penduduk Dan Penggunaan Lahan Terhadap Kualitas Air Bersih. *Jurnal Desa-Kota, 2*(1), 70-85. https://doi.org/10.20961/desa-kota.v2i1.17058.70-85

Ridwana, R., Danoedoro, P., Herumurti, S., Himayah, S., Ihsan, M., Arrasyid, R., & Urfan, F. (2019). Linear Spectral Mixture Analysis Land Cover for Assessment Level Subpixel: A Case Study of Tasikmalaya City Area Based on Landsat Imagery. In IOP Conference Series: Earth and Environmental Science (Vol. 286, No. 1, p. 012042). IOP Publishing.

Ridwana, R., Sugandi, D., Arrasyid, R., Himayah, S., & Pamungkas, T. D. (2021). Multitemporal landsat image utilization for spatial prediction of built up area in tasikmalaya city, indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 683, No. 1, p. 012101). IOP Publishing.

Ridwana, R., Sugandi, D., Ismail, A., & Jupri, J. Distribution of Infiltration Wells for Surface Runoff Control in Bandung District. (2022). Jurnal Geografi Gea, 22(2), 125-134.

Sallata. (2015). Konservasi Dan Pengelolaan Sumber Daya Air Berdasarkan Keberadaannya Sebagai Sumber Daya Alam. *Jurnal Sumber Daya Air, 12*(1), 75–86. https://doi.org/10.20886/buleboni.5056

Shit, P. K., Bhunia, G. S., Adhikary, P. P., and Dash, C. J. (2021). *Introduction to Groundwater and Society: Applications of Geospatial Technology.* Groundwater and Society: Applications of Geospatial Technology, 3-10.

Srivastava, P. K., Han, D., Ramirez, M. R., and Islam, T. (2013). Machine learning techniques for downscaling SMOS satellite soil moisture using MODIS land surface temperature for hydrological application. *Water Resources Management, 27*, 3127–3144. DOI: 10.1007/s11269-013-0337-9

Sugandi, D., and Pascawijaya, R. (2020). Decreasing The Surface Run-Off Through Rainfall Absorption In The Bandung Basin, Indonesia. *Journal of Environmental Hydrology, 28*, 1-12. DOI: 10.15406/ijh.2019.03.00216

Sugandi, D., Ridwana, R., Ismail, A., Ismail, J. R., & Sephana, R. D. (2021). Surface Runoff Management Model Of Bandung Regency Through Remote Sensing Analysis. *Jurnal Geografi GEA, 21*(2), 123-134. DOI: 10.17509/gea.v21i2.38798

Thompson, E., Harman, C. J., Heine, P., and Katul, G. G. (2010). Vegetation-infiltration relationships across climatic and soil type gradients. *Journal Of Geophysical Research*, 115, G02023, 1-12. DOI: 10.1029/2009JG001134

Trisna, Y. (2018). Kualitas Air Dan Keluhan Kesehatan Masyarakat Di Sekitar Pabrik Gula Watoetoelis. *Jurnal Kesehatan Lingkungan, 10*(2), 220-232. DOI: 10.20473/jkl.v10i2.2018.241-251

Wang, W., Chen, L., and Xu, C. Y. (2021). Hydrological Modeling in Water Cycle Processes. *Water MDPI, 13*(14), 1882, 1-12. https://doi.org/10.3390/w13141882

Xu, C., Sun, Y., Shi, B., Wang, X., Li, R., Li, M., Xi, B., and Feng, C. (2022). Study on the Processes Influencing and Importance of Ecological Water Replenishment for Groundwater Resources: A Case Study in Yongding River. *Water, 14*(5), 828, 1-17. https://doi.org/10.3390/w14050828

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