JOURNAL OF
ENVIRONMENTAL HYDROLOGY
Open Access Online Journal of the International Association for Environmental Hydrology

VOLUME 28 2020

DECREASING THE SURFACE RUN-OFF THROUGH RAINFALL ABSORPTION IN THE BANDUNG BASIN, INDONESIA

Dede Sugandi[1]
Ramadhan Pascawijaya[2]

[1]Study Program of Geography Education, Universitas Pendidikan Indonesia
[2]Mapping Survey and Geography Information, Universitas Pendidikan Indonesia

Expansion of the built-up area was increasing the surface run-off in the Bandung basin. This research aims to analyze land use change, volume of rainfall that was not absorbed by built-up area and the attempts to decrease surface run-off volume in the built-up area. Method that used is spatial analysis. The formula calculates the volume of rain: Ih = L x K, and measures the volume of rainfall: V = R x A. The results show a built-up area change from 458,507,000 m^2 to 535,155,000 m^2. The built-up area expansion affected the increase in surface run-off from the average volume of 34,250,473 m^3 to 39,079,976 m^3. The way to decrease the volume of flooding which continuously increased is by absorbing the volume of rainfall in each built-up area of every 100 m^2. The highest rainfall volume in December has been up to 1,100 m^3 in order that each built-up area of 100 m^2 have to absorb rainfall of 1,100 m^3 in the infiltration wells. Because the built-up area is different, it is calculated from the depth of the rainfall multiplied by large, giving the volume of rainfall that must be absorbed. By storing and absorbing the rainfall in each built-up area, the surface run-off increase could be avoided in the area of Bandung basin.

INTRODUCTION

One of the implications of population concentration is changes in land function, such as from agricultural lands to non-agricultural lands or from non-agricultural lands to another non-agricultural land use. Limited lands and the dynamics of the urban community's activities cause competition in land uses and land-use changes (Adibah et al., 2013). The concentration of population has demanded to build various facilities such as housing, social and public facilities. The existing land is indispensable side to construct facilities as changing the land use from agriculture, forests, and plantations to residential land and public and social facilities (Saptono and Rahma, 2007; Mangeswuri and Paramita, 2012). As a consequence, the conversion of land use to meet life needs influences land surface characteristics of flow (Bhaduri, 2000; Enger et al., 2006). The land-use changes play an essential role in the water balance changes in Goseng catchment, indicated by increasing surface run-off along with the decline of vegetation cover (Nugroho et al, 2012).

However, population growth and migration in limited land encourage people to live in disaster-prone areas (Katherina, 2017; Prakash et al., 2015). The environment can be defined as the surroundings in which an entity operates. It includes air, water, land, natural resources, flora, fauna, humans and their interrelation (Sawant, 2013). Changes in land use and land cover are significant in global climate Change (Goldewijk et al., 2017). The Kelani River watershed includes 23% of the total urban area of the Colombo district. Similarly, the entire area of land-use transformation covered 37.7% of the area within the watershed region of the Colombo district. Eventually, this research identified the significant impact of Colombo district floods in May 2016 on land-use changes (Dammalage and Jayasinghe. N. T, 2019).

The impact of the population's concentration is an obstacle in gaining the standard of sustainable life quality because it affects environmental quality. The urbanization has led to severe environmental problems in ZJP, not only on the city scale but also on the regional scale. Maintaining a balance between the continuing process of urbanization and environmental sustainability is a significant issue facing the local government (Yang et al., 2014). Land-use change is a crucial issue considering global dynamics and their response to hydrologic soil characteristics and water management in a catchment (Welde and Gebremariam, 2017). A watershed is a hydrologic unit which water drains, running downhill, to a shared destination or which produce water as the end product by the interaction of precipitation and the land surface (Jain et al., 2010). Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment (Sefouhi et al., 2010). Human beings have to utilize land, causing disturbance to the stability and equilibrium of the environment (Iskandar and Sugandi, 2015).

Environmental balance has been in an obstacle to experiencing a sustainable decent life. Sustainable water systems often comprise complex combinations of traditional and new system components that mimic natural processes (Sukojo, 2003; Scholz, 2013; Gogate and Rawal, 2015). Urban run-off pollution is caused when the run-off while travelling across the urban environment, acquires contaminants that affect water quality (Waters et al., 2011). The impact of land uses can cause significant changes in the hydrological regime of a river basin (Al-Mamun et al., 2016). The increase in flood peak and a decrease of the rangelands, forests, and bare lands between 1984 and 2011, indicating a good correlation between flooding areas and land-use changes (Apollonio et al., 2016).

Expansion of built-up area such as settlements and commercial buildings shapes a waterproof layer. The peak flow is faster in the watershed area as the potential for flooding (Koyari et al., 2012; Weng, 2001). The hydrological conditions upstream of the Ciliwung watershed are changing due to climate and land-use changes. Any changes in this area may increase the flood frequencies, which may have incalculable consequences downstream of the watershed where the Jakarta city is located (Emam et al., 2016).

The healthy environment must be kept and maintained because sustainable life is influenced by environmental sustainability. Collaborative conservation strategies for protecting and managing natural resources help in creating a healthy eco-system. A collaborative approach gives a chance in which conservation issues are targeted collectively by using adaptive management of whole eco-systems, including human communities (Singh et al., 2014). Settlement on floodplains contributes to flooding disasters by endangering humans and their assets. However, the economic benefits of living on the floodplain outweigh the dangers for some societies. Pressures from population growth and shortages of land also promote settlement on floodplains (Prasad, 2002). Developing, testing and implementing indicators to identify and assess vulnerability to floods is an essential pre-requisite for effective disaster risk reduction (Sanayanbi et al., 2014). Conservation is closely related to the socio-economy of the inhabitants. If the land is damaged, the sustainability of the resources will decrease, and eventually, this will impact on the sustainability of life and development (Klijn, 2015 and Sugandi, 2014). The climate change effects in the Sundarbans Mangrove forest through changing its biodiversity composition in terms of loss of wildlife habitats, which is responsible for accelerating tiger human conflicts (Haque, 2015).

The mentioned statement reveals that the environment supports human life in which humans as environmental components that should be in the use of land always consider environmental balance.

The leading cause of surface run-off increases is due to changes in land use. Urban as a centre of human activity, as well as high population density, will induce urban areas dominated by built-up area (Rushayati et al., 2011). Run-off corresponding to rainfall and infiltration. In the infiltration (source) areas of PZWR (Protection Zones of Water Resources), the hydrogeological structure undergoes significant water infiltration, while large volumes of groundwater accumulate in the accumulation area (Bhura et al., 2015; Duffková, 2008). The upstream watershed has developed as a built area so that there is not enough extensive land that can be used as a retention basin (Saud, 2007). Settlement land with flood area correlates 0.849, flood height correlates 0.592, and flood height correlates 0.592 (Tambunan, 2007). A review of catchment studies (n = 37) conducted in East Africa evaluating the impacts of Land Use and Land Cover Changes (LULCC) on discharge, surface run-off, and low flows (Guzha et al., 2018).

The built-up area causes increased surface run-off while to reduce it, reducing surface run-off is through conservation. Conservation techniques such as percolation pond, check dam, etc., can be recommended for better management of land and water resources for sustainable development of the watershed (Sindhu et al., 2013). Agricultural and forest monitoring is a valued instrument needed by public authorities (PA) for determining land uses, planning natural resources management and collecting taxes (Nex et al., 2015). To reduce flow discharge, the rainfall must be absorbed into the soil. Jifa (2018) said the implication this development is decreasing of urban open space area by 1 - 2% per year, and followed by increased surface run-off during rain. Infiltration well is one of the efficient rainwater utilization to reduce run-off.

The expansion of built-up area gives rise to an increase in surface run-off and flooding so that the tremendous efforts overcome surface run-off and flooding by increasing the absorption. Therefore, this study aims to:

1. Analyzing land use change in Bandung basin by using remote sensing

2. Analyzing the volume of rainfall that was not absorbed by built-up area in Bandung basin
3. Analyzing the attempts to decrease surface run-off volume in the built-up area in Bandung basin

METHODS

The Bandung basin has a bowl-like shape bordered by mountains as the basins seem like small rivers that empty into the upper part of Ci Tarum located on the plains of Bandung. It covers the area of Bandung City, Cimahi City, Bandung Regency, West Bandung Regency and part of Sumedang Regency. The emergence of Ci Tarum's rivers is located in the plains region, namely, Rancaekek and Dayeukkolot.

Changes in land use are by using satellite, namely Landsat 7 imagery in 2010 and Landsat 8 imagery in 2015. Steps in the analysis was preparing Landsat 7 and 8 imagery, interpretation of Landsat 7 and 8 imagery, ground check, adjusting the results of interpretation with ground check. Landsat 7 using band true color 321 (Red Green Blue) and Landsat 8 can be used band 543 (N- Infrared, red, green) to identify vegetation and water surface. The difference lies on the length of spectral range. The second identification of Landsat imagery was conducted by geometric and radiometric correction to harmonize the information of object from the imagery. The research method used is remote sensing by Software Er Mapper consisting of stages as follows: preparation, interpretation, survey, reinterpretation and report. The results of the imagery analysis were carried out the survey by data collection in the field. The analysis techniques were started from (a) cropping (b) sharpening imagery; (c) classification imagery. In the sample area, the volume of rainwater is measured on the built-up area. Rainfall is calculated from 3 BMKG stations spread in the basin of Bandung. The data is the average of rainfall in 10 years, so the authors take the average of thickness in rainy day and hourly average. This is used to determine the amount of rainfall that must be absorbed in the building area.

$$R_h = \frac{R_m}{R_d} / 24 \qquad (1)$$

where R_h = rainfall mm/hour, R_m = rainy day/month, R_d = number of days

While the measurement of rainfall volume was evaluated by using the formula, this model is also used to measure the volume of rain that occurs in the smallest unit of the land area of 100 m^2, namely:

$$V = \text{R x A} \qquad (2)$$

where V = volume (m^3), R = rainfall (mm), A = area (km^2).

RESULTS AND DISCUSSION

Changes in Land Use

The Bandung is well known as a basin area because the middle of the basin is plain. Activities of population and development are concentrated in the plains region. As the logical consequence to meet the population needs, it causes changes in land use as the alteration of water movement process. The changes are being the built-up area in which rainfall that occurs on the land will become surface run-off.

The wider built-up area has encouraged the land unable for absorbing rainfall. Land Use and Land Cover Change (LUCC) can reflect the pattern of human land use in a region and plays an essential role in space soil and water conservation (Chang et al., 2018). The Bandung basin is an area bordered by mountains, and the middle is plain. In this research, the boundaries of basin land use are by analyzing the Landsat 7 Imagery in 2010 and Landsat 7 imagery in 2015. From the results of the analysis, there are six classes of land use forms. The results of the 2010 Landsat Imagery analysis are shown on the Map which can be seen at Figure 1.

a. The imagery of paddy fields is depicted in the dark blue, regular, square and rectangular with the embankment.

b. Forests are shown in reddish, rough texture, irregular and path.

c. Mixed gardens are shown in pink, rough texture, regular and settlement.

d. Uplands and fields are revealed by bright red mixed, square shape, slightly rough texture, regular patterns and settlement.

e. Shrub and bushes are shown by bright red, rather smooth texture, and irregular patterns.

f. Plantations are shown in pink, regular patterns, and smooth texture of the path.

g. Settlements, offices and industries are shown in white, square and rectangle, uniform size, rough texture, regular pattern, and many roads.

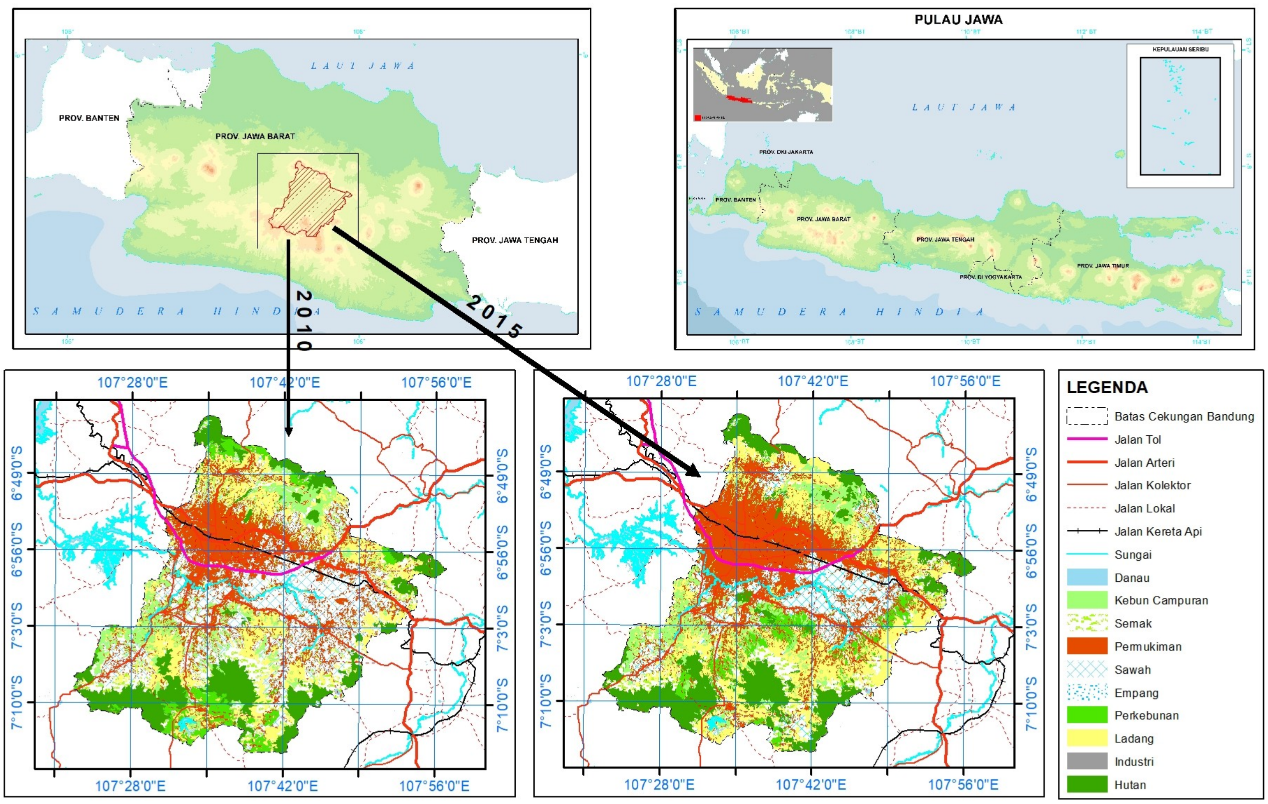

Figure 1. Land Use Change in 2010 and 2015

The analysis of imagery is classified into seven forms of land use shown in Map as an analysis of changes in land use form shown in Table 1.

Table 1. Comparison of the Land Use Area in 2015

	Year				
		2010	2015	Change	
	Landuse	Size (km²)	Size (km²)	Increase	Decrease
1	Settlement and Industry	458,507	535.155	76,648	-
2	Bush	121,337	129.272	7,935	-
3	Plantation	82,681	85.580	2,899	-
4	Mixed garden	182,685	182.489	-	196,000
5	Forest	265,927	269.243	-	16,684
6	Moor	282,569	395.448	112,879	-
7	Paddy field	517,791	334.310	-	183,481
	Total	1911,498	1911,498	200,361	396,165

The area of built-up area and moor increases while the reduced area is paddy fields and forests. Changes in built-up area increase the area of impermeable surface.

The Volume of Surface Run-off

When raining, rainfall on the built-up area becomes surface run-off streaming on the surface of the land and ending in the river. The flow that moves on the built-up area is hampered by various buildings such as sidewalks, settlements and substandard drainage buildings, while the volume of the moving surface run-off increases in the river body, and it overflows as the flow on the surface will be concentrated in the plain causing flooding. The volume of a surface run-off is calculated from the average rainfall of three stations.

Table 2. Monthly average rainfall (mm) in 2006-2015

Station	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Des
Lembang	142.1	221.9	201.8	204.1	178.5	62.2	62.0	26.9	60.8	104.5	299.0	262.3
Cisondari	142.1	170.2	158.6	151	152.6	50.7	26.2	22.4	40.2	76.3	168.4	192.3
Cileunca	241.0	268.7	266.8	265	133.8	57.9	35	37	52.7	118.2	292.0	336.9
Rainfall	175.1	220.2	209.1	206.7	155.0	56.9	41.1	28.8	51.2	99.7	253.1	263.8
Day/rain	16	16	15	16	7	3	2	2	2	4	13	15
Rain/day	10.9	13.8	13.9	12.9	22.1	19	20.5	14.4	25.6	24.9	19.5	17.6
Rain/hour	0,454	0,575	0,579	0,538	0,921	0,792	0,854	0,600	1,067	1,038	0,813	0,733

Source: Dinas PU Pengairan, 2016.

July is the time that has the lowest rainfall of around 35 mm/ day, and the highest rainfall occurs in the month of 336 mm/ day, whereas the lowest rainfall in hours happens in January around 0.454 mm/hour, and the highest occurs in September around 1,067 mm/ hour.

Daily rainfall that prevails calculated in units of hours, therefore rainfall is classified into 24 hours. The thickness of rainfall in hours is small, but the thickness of rainfall multiplied by area will be a large volume of water.

Table 3. Volumes of Surface run-off in the Bandung Basin

Month	Rainfall (mm/hour)	Built Land (100 m^2) 2010	Volume (m^3)	Built-up area (100 m^2) 2015	Volume (m^3)
January	0,454	4.585.070.000	20.816.218	5.351.550.000	24.296.037
February	0,575		26.364.153		30.771.413
March	0,579		26.547.555		30.985.475
April	0,538		24.667.677		28.791.339
May	0,921		42.228.495		49.287.776
June	0,792		36.313.754		42.384.276
July	0,854		39.156.498		45.702.237
August	0,600		27.510.420		32.109.300
September	1,067		48.922.697		57.101.039
October	1,038		47.593.027		55.549.089
November	0,813		37.276.619		43.508.102
December	0,733		33.608.563		39.226.862
Total			411.005.676		479.712.945
Average			34.250.473		39.079.976

The presented Table 3 shows that the thickness of rainfall is small but multiplied by the area of built-up area into an enormous volume of water. The built-up area in 2010 was 458,507,000 m^2, while in 2015 it was 535,155,000 m^3. The adverse effect of the change in the land into built-up area is the volume of increased surface run-off.

To incline the volume of the flow, the enormous effort to reduce surface run-off by absorbing surface run-off is needed. Increasing the volume of recharge in large volumes requires vast land, costs and energy. Therefore, to increase surface run-off, applying the volume of rainfall falls on each building absorbed into the soil through infiltration wells. This water infiltration model is calculated for each smallest unit of land with 100 m^2.

Increased Infiltration

The volume of flowing rainfall built-up area needs to be absorbed into the soil based on the volume of rainfall in the smallest unit. As built-up area is in a different large, thickness of rainfall that falls on a building multiplied by its land area then obtained by rainfall volume. For more accessible, the smallest unit model of a building 100 m2 is required to construct. With this volume, it will be easy to calculate the water that needs to be absorbed. The volume of flow inland units per 100 m^2 with the duration of rain in 5 and 10 hours is shown in Table 4.

The constructed land model of the entire area is divided into the smallest unit of land area per 100 m^2 so that there are 5,351,550,000 with the volume of water/hour/day. Rainfall often occurs, especially the rainy season and the frequency of rain in a month as many as 16 days. The duration of rain in a day can reach more than 10 hours. This study uses old rain models about 5 and 10 hours, in order that an

Table 4. The volume of surface run-off on land units per 100 m^2

Month	Volume (m^3)	Built-up area/100 m^2	The volume of water (m^3)	Rainfall	Rainfall Time (5 hours), m^3	Rainfall Time (10 hours) m^3
January	24.296.037	5.351.550.000	0,00454	16	0,363	0,726
February	30.771.413	5.351.550.000	0,00575	16	0,460	0,920
March	30.985.475	5.351.550.000	0,00579	15	0,434	0,869
April	28.791.339	5.351.550.000	0,00538	16	0,430	0,861
May	49.287.776	5.351.550.000	0,00921	7	0,322	0,645
June	42.384.276	5.351.550.000	0,00792	3	0,119	0,238
July	45.702.237	5.351.550.000	0,00854	2	0,085	0,171
August	32.109.300	5.351.550.000	0,006	2	0,060	0,120
September	57.101.039	5.351.550.000	0,01067	2	0,107	0,213
October	55.549.089	5.351.550.000	0,01038	4	0,208	0,415
November	43.508.102	5.351.550.000	0,00813	13	0,528	1,057
December	39.226.862	5.351.550.000	0,00733	15	0,550	1,100

illustration of the water volume falling on the built-up area in the smallest unit of 100 m^3 can be calculated.

The given table 4 shows the rainiest days occur from November to April with the highest volume of water at 0.01067 m^3. If the assumed duration of rain by 5 and 10 hours, it can be known that the volume of water must be absorbed into the soil. The volume of water from a land unit of 100 m^2 has a different volume, and the largest is 1,100 m^3. The rainfall that falls on each built-up area is entering the infiltration wells, so it did not become the surface run-off. Rainfall on land cover whose water will be stored in infiltration wells, including parking lots, roof area, and pavement roads, buildings and others (Rizal N.S, Iqbal K, and Abduh M; 2017). This infiltration wells are effective for collecting and absorbing rainfall.

DISCUSSION

The expansion of built-up area occurred in the Bandung basin had been analyzed from the 2010 Landsat 7 imagery and 2015 Landsat 8 imagery, showing there are seven classes of land use forms. Changes in land use from ricefields, forests, other agriculture to settlements, industries, or other buildings have affected the surface layer of the land. The soil surface that functions to absorb rainfall turns into a waterproof layer so that rainfall drops to the surface to be impermeable.

By analyzing the 2010 Landsat 7 Imagery and the 2015 Landsat 7 imagery, there are seven classes of land use forms. The expansion of land usage form occurs in settlements and industries around 76,648 Km^2. Hence, changes in land use affect the volume of surface run-off, especially built-up area. The built-up area spreads across the plain and estuary of the tributary to Ci Tarum. Subsequently, changes to built-up area cause increased surface run-off.

The expansion of built-up area was from 458,507 km^2 in 2010 to 535,155 km^2 in 2015. The built-up area caused surface run-off rising to 57,101,039 m^3 in September. This surface run-off is originally from the built area and is concentrated in the plains region, namely Dayeuhkolot, Majalaya and Rancaekek. The concentration of surface run-off that makes the area experience flooding every year.

The volume of surface run-off causes flooding. In order to address it, reducing surface run-off is by absorbing the rainfall on the built-up area in the smallest unit of land 100 m^2. By absorbing rainfall in each built-up area, then there is no rainfall into a surface run-off. The smallest unit of the land considered representative in each area of 100 m^2. It means each unit of land must absorb the volume of rainfall so that no rainfall becomes the surface run-off.

The volume of rainfall that drops on each of the smallest land units at least 100 m^2 permeates the water volume of 1,100 m^3 in December, with 10 hours of rain. To absorb rainfall in the smallest unit, making infiltration wells that can accommodate 1,100 m^2 of water is needed. With the infiltration wells made on each built land 100 m^2, the rainfall on the built-up area will not become surface run-off. If applied to all the built-up area, the rainfall on the built-up area would not be the surface run-off.

CONCLUSION

Analysis of Landsat imagery in 2010 and 2015 reveals a change in land use, especially the land expansion of 535,155 km^2 (535,155,000,000 m^2). The built-up area has a water-resistant nature so that the falling rainfall cannot absorb. The waterproof layer causes an increase in surface run-off.

In 2015, the expansion of built-up area resulted in an increase in average surface run-off volume from 34,250,473 m^3 in 2010 to 39,079,976 m^3 in 2015. The highest volume of rainfall occurs in December, in order that the volume must be absorbed. With infiltration wells in each of the smallest built-up area units, rainfall does not have the potential to be surface run-off that causes flooding.

Making retention ponds requires a large area, because to accommodate a very large volume. The built-up area was 535,155,000,000 m^3 used as the smallest unit to be 5,351,550,000 m^3. By the volume of rainfall having a potential as a surface run-off, it must be absorbed through infiltration wells able to permeate 1,100 m^3 on the built-up area of 100 m^2. The rainfall would not be the surface run-off by storing and absorbing them in the infiltration wells.

ACKNOWLEDGMENTS

Thank for Prof. Dr Kadarohman, M.Sc as the UPI Chancellor for encouragement in the preparation of this article.

REFERENCES

Adibah. N. Kahar. S. and Sasmito, B, (2013). Aplikasi Penginderaan Jauh Dan Sistem Informasi Geografis Untuk Analisis Daerah Resapan Air (Studi Kasus : Kota Pekalongan), Jurnal Geodesi Undip 2 (2), p. 141-153.

Al-Mamun. A, Salleh M.N, Nuruzzama. M, Dom. N.M, Mohd, Amin. Z.M, Eusuf. M.A and Chowdhury. A.J.K, (2016). Impact Of Improper Landuse Changes On Flash Flood and River System-A Case Of Sg Pusu. ARPN Journal of Engineering and Applied Sciences 11 (8), p. 5373-5379.

Apollonio. C, Balacco. G, Novelli. A, Tarantino E and Piccinni. A.F, (2016). Land Use Change Impact on Flooding Areas: The Case Study of Cervaro Basin (Italy). Journal of Sustainability MDPI 8, p. 3-18

Bhaduri. B, Harbor. J, Engel. B and Grove. M, (2000). Assessing watershed-scale, long-term hydrologic impacts of land-use change using a GIS-NPS model. Environmental management, 26(6), p.643-658.

Bhura. C.S, Singh. N.P, Mori. P.R, Prakash. I and Mehmood. K, (2015). Estimation of Surface Run-off For Ahmedabad Urban Area using SCS-CN Method and GIS. International Journal of Science Technology and Engineering 1 (11), p. 411-416.

Dammalage. T. L and Jayasinghe. N. T, (2019). Land-Use Change and Its Impact on Urban Flooding: A Case Study on Colombo District Flood on May 2016. Engineering, Technology and Applied Science Research 9 (2), p. 3887-3891.

Dinas PU Pengairan, (2016). Data Curah Hujan. Bandung Jawa Barat.

Duffková. R, (2008). Evaluation of Management-Dependent Changes in the Water Regime of Extensive Grasslands. Journal of Soil and Water Resv 3 (1), p. 1–11.

Emam. A.R, Mishra. B.K, Kumar. P, Masago. Y and Fukushi. K, (2016). Impact Assessment of Climate and Land-Use Changes on Flooding Behavior in the Upper Ciliwung River, Indonesia. Journal of Water MDPI 8, p. 2-10.

Enger. E.E, Smith. B.F and Bockarie. A.T, (2006). Environment Science: A Study of Interrelationship, tenth edition, New York: Mc Graw Hill International Edition.

Gogate. N.G and Rawal. P.M, (2015). Identification of Potential Stormwater Recharge Zones in Dense Urban, Context: A Case Study from Pune city. International Journal of Environment Resources 9 (4), p. 1259-1268.

Goldewijk. K.K, Dekker. S.C and Zanden. J.L, (2017). Per-capita estimations of long-term historical land use and the consequences for global change research. Journal of Land Use Science Taylor 7 and Francis 12 (5), p. 313–337

Guzha. A.C, Rufino. M.C, Okoth. S. Jacobs. S and Nóbrega. R.L.B, (2018). Impacts of land use and land cover change on surface run-off,discharge and low flows: Evidence from East Africa. Journal of Hydrology: Regional Studies 15, p. 49–67

Haque. M.Z, Reza. M.I.H, Rahim. S.A, Abdullah. M.P, Elfithri. R and Mokhtar. M, (2015). Behavioral Change Due To Climate Change Effects Accelerate Tiger Human Conflicts: A Study On Sundarbans Mangrove Forests, Bangladesh. International Journal of Conservation Science 6 (4), p. 669-684.

Iskandar. D and Sugandi. D, (2015). Flood Mitigation Efforts In The Special Capital Region Of Jakarta. International Journal Of Conservation Science 6 (4), p. 685-696.

Jain. S.K, Tyagi. J and Singh. V, (2010). Simulation of Run-off and Sediment Yield for a Himalayan Watershed Using SWAT model. Journal of Water Resource and Protection 2 (3), p. 276-281.

Jifa. A.N, Rachmansyah. A and Afandhi. A, (2018). Analysis of Infiltration Well Dimensional in Kedungkandang District, Malang City, Indonesia. Indonesian Journal of Environment and Sustainable Development 9 (1), p. 33-38.

Katherina. L.K, (2017). Dynamic Of Population Growth And Flooding Incidents In Cities:Case Of Surabaya. Jurnal Kependudukan Indonesia 1 (2), p. 131-144.

Klijn. F, Kreibich. H, De Moel. H and Rowsell. E.P, (2015). Adaptive flood risk management planning based on a comprehensive flood risk conceptualization. Mitigation Adapt Strateg Glob Change 20, p. 845–864.

Koyari. E, Priyantoro and Sisinggih. D, (2012). Pola Pengendalian Banjir Kawasan Bambu Kuning Kota Jayapura. Jurnal Teknik Pengairan 3 (2), p. 240–249.

Mangeswuri. D.R and Paramita. P.N, (2012). Perkembangan Ketersediaan Dan Kebutuhan Perumahan Di Batam. Jurnal Ekonomi dan Kebijakan Publik 3 (2), p. 409-417.

Nex. F, Delucchi. L, Gianelle. D, Neteler. M, Remondino. F and Dalponte. M, (2015). Land Cover Classification and Monitoring: the STEM Open Source Solution. European Journal of Remote Sensing 48, p. 811-831.

Nugroho. P, Marsono. D, Sudira. P and Suryatmojo. H, (2012). Impact of land-use changes on water balance. The 3rd International Conference on Sustainable Future for Human Security Sustain 2012, p. 256-262

Prakash. CR, Asra. M, Venkatesh. J and Sreedevi. B, (2015). Monitoring Urban Land-Cover Features using Resourcesat LISS-III Data. International Journal of Advanced Remote Sensing and GIS 2015, 4 (1), p.1064-1069.

Prasad. S.V, (2002). Community Based Disaster Preparedness: A Guide For Development Workers On Cyclones And Floods, India.

Rushayati. S.B, Alikodra. H.S, Dahlan. E.N and Purnomo. H, (2011). Pengembangan Ruang Terbuka Hijau Berdasarkan Distribusi Suhu Permukaan Di Kabupaten Bandung. Jurnal Forum Geografi 25 (1), p. 17-26.

Sanayanbi. H, Zaphu. V.V, Monica.N, Vanlalremruatpui. T.B.C, A. Bandyopadhyay. A, (2014). Vulnerability Assessment of Arunachal Pradesh to Floods. International Journal of Innovative Research in Science, Engineering and Technology 3 (4), p. 81-92.

Saptono. P and Rahma. H, (2007). Dampak Perkembangan Permukiman Terhadap Perluasan Banjir Genangan Di Kota Semarang. Jurnal Geografi UNNES 4 (1), p. 35-43.

Sawant. V.R (2013). Integrated Flood Management in Urban Flooding. International Journal of Research and Development-A Management Review 2(2), p. 13-16.

Scholz. M, (2013). Sustainable Water Systems. Journal of Water, Vol. 5 (1), p. 239-242

Sefouhi. L, Kalla. M and Aouragh. L, (2010). Trends and Problems of Municipal Solid Waste Management in Batna City and Prospects for a Sustainable Development. International Journal of Sustainable Water and Environmental Systems 1 (1), p. 15-20.

Sindhu. D, Shivakumar. B.L and Ravikumar. A.S, (2013). Estimation Of Surface Run-off In Nallur Amanikere Watershed Using Scs-Cn Method. IC-RICE Conference, p. 404-409.

Singh. M, Sinha. A.K and Singh. P, (2014). Maintaining The Biodiversity of Informal Protected Areas: A Collaborative Conservational Approach, International Journal Of Conservation Science 5 (1), p. 107-116.

Sugandi. D, (2014). A Model Of Environmental Conservation For Sagara Anakan, International Journal Of Conservation Science 5 (1), p. 95-106.

Sukojo. B.M, (2003). Penggunaan Metode Analisa Ekologi dan Penginderaan Jauh Untuk Pembangunan System Informasi Geografis Ekosistem Pantai, Jurnal MAKARA, Sains 7(1), p. 32-37.

Tambunan. M.P, (2007). Kaitan Penggunaan Lahan Perkotaan Dengan Banjir, Departemen Geografi, FMIPA Universitas Indonesia [online] : http://geografi.ui.ac.id/portal/sivitas-geografi/dosen/makalah-seminar/kaitan penggunaan-lahan-perkotaan-dengan-banjir/ acceced Oktober 2018.

Waters. S, Farrell-Poe. K and Wagner. K, (2011). When it Rains it Runs Off: Run-off and Urbanized Areas in Arizona. Arizona Cooperative Extension, The University of Arizona, p. 1-5.

Welde. K and Gebremariam. B, (2017). Effect of land use land cover dynamics on hydrological response ofwatershed: Case study of Tekeze Dam watershed, northern Ethiopia. Journal of International Soil and Water Conservation Research 5, p. 1–16.

Weng. Q, (2001). Modeling Urban Growth Effects on Surface Run-off with the Integration of Remote Sensing and GIS. Journal of Environmental Management 28 (6), p. 737–748.

Yang. X, Yue. W, Xu. H, Wu. J and He. Y, (2014). Environmental Consequences of Rapid Urbanization in Zhejiang Province, East China. International Journal of Environmental Research and Public Health 11, p. 7045-7059.

Saghravani, S.R., Yusoff, I., Mustapha, S., and Saghravani, S.F., 2013. Estimating Groundwater Recharge Using Empirical Method: A Case Study in the Tropical Zone, Sains Malaysiana 42(5) (2013): 553–560

Salim, E., 1979. Environment and Development, Publisher Mutiara Sumber Widya, Jakarta.

Schnoor, J.L., 1996. Environmental Modeling Fate And Transport of Pollutants in water, air, and soil. A Wiley-Interscience Publication, John Wiley & Sons, Inc, New York. P. 466–470.

Subastaryo, 2003. Ground Water Management Model In Infiltration Basin In Semarang Regional District. Semarang, Central Java Province. Post Graduate Thesis, University of Diponegoro.

Yadav, A., Sonje, A., Mathur, P., and Jain, D.A., 2012. A Riview on artificial ground water recharge, Int J Pharm Bio Sci: 3(3): P. 304-311.

ADDRESS FOR CORRESPONDENCE
Dede Sugandi
Study Program of Geography Education
Universitas Pendidikan Indonesia
Bandung, Indonesia
dedesugandi@upi.edu