Anuário do Instituto de Geociências
Universidade Federal do Rio de Janeiro
https://revistas.ufrj.br/index.php/aigeo/

ISSN 0101-9759
e-ISSN 1982-3908

Effect of Vegetation Cover Changes on the Runoff Coefficient Characteristics in the Cisangkuy Watershed, Indonesia

Efeito das Mudanças na Cobertura Vegetal nas Características do Coeficiente de Escoamento na Bacia Hidrográfica de Cisangkuy, Indonésia

Arif Ismail[1], Klaus Greve[2], Millary Agung Widiawaty[3], Moh Dede[4,5,6] & Nandi Nandi[4]

[1] Universitas Pendidikan Indonesia, Faculty of Social Sciences Education, Bandung City, West Java, Indonesia
[2] Universität Bonn, Meckenheimer Allee, Geographisches Institut, Bonn, Germany
[3] University of Birmingham, School of Geography, Earth and Environmental Sciences, Edgbaston, Birmingham, United Kingdom
[4] Universitas Pendidikan Indonesia, Faculty of Social Sciences Education, Bandung City, West Java, Indonesia, Graduate School
[5] Universitas Padjadjaran, Graduate School, Bandung City, West Java, Indonesia
[6] Universitas Padjadjaran, Center for Environment and Sustainability Science, Bandung City, West Java, Indonesia
E-mails: arifismail@upi.edu; klaus.greve@uni-bonn.de; mxw445@student.bham.ac.uk; moh19008@mail.unpad.ac.id; nandi@upi.edu

Abstract

The hydrological response of a watershed is a key aspect of watershed management. Long-term monitoring is faced with a lack of empirical data. This study implements Cook's method to determine the run-off coefficient in the Cisangkuy watershed. This method involved watershed characteristic data such as slope, soil, stream, and vegetation greenness. Run-off related to vegetation greenness, as the component of hydrological responses, data retrieved from satellite imageries (Landsat series) over 30 years using Google Earth Engine were used for this analysis. High-density vegetation areas in the Cisangkuy watershed tended to degrade from 1990 to 2010 and then increased significantly from the last ten years until 2020. Meanwhile, there was no significant change in the run-off coefficient over the 30 years measured. Non-vegetated areas increased over low- and moderate-vegetation lands, especially after 2010. The Cisangkuy watershed has a high run-off coefficient with a larger area compared to other classes with a run-off coefficient of 60-63%. In the Cisangkuy watershed, a decrease in the area of the normal category run-off coefficient contributes to an increase in this phenomenon in the high and extreme classes. The physical characteristics of the watershed, especially in terms of the utilization of water resources and flood mitigation, were examined in this study to achieve sustainable management.

Keywords: Landscape; Google Earth Engine; Watershed management

Resumo

A resposta hidrológica de uma bacia hidrográfica é um aspecto fundamental para o gerenciamento de bacias. O monitoramento de longo prazo enfrenta a falta de dados empíricos. Este estudo implementa o método de Cook para determinar o coeficiente de escoamento na bacia hidrográfica de Cisangkuy. Esse método envolveu dados característicos da bacia, como inclinação, solo, curso d'água e verdor da vegetação. Dados relacionados ao escoamento em relação ao verdor da vegetação, como componente das respostas hidrológicas, foram recuperados de imagens de satélite (série Landsat) ao longo de 30 anos usando o Google Earth Engine para esta análise. As áreas de vegetação de alta densidade na bacia de Cisangkuy tenderam a degradar de 1990 a 2010 e aumentaram significativamente nos últimos dez anos até 2020. Enquanto isso, não houve mudança significativa no coeficiente de escoamento ao longo dos 30 anos medidos. As áreas não vegetadas aumentaram sobre terras com vegetação baixa e moderada, especialmente após 2010. A bacia de Cisangkuy possui um coeficiente de escoamento elevado com uma área maior em comparação com outras classes, com um coeficiente de escoamento de 60-63%. Na bacia de Cisangkuy, a diminuição da área com coeficiente de escoamento normal contribui para um aumento desse fenômeno nas classes alta e extrema. As características físicas da bacia, especialmente em termos de utilização de recursos hídricos e mitigação de inundações, foram examinadas neste estudo para alcançar um gerenciamento sustentável.

Palavras-chave: Paisagem; Google Earth Engine; Gestão de bacias hidrográficas

Received: 26 September 2023; Accepted: 10 March 2024

1 Introduction

The hydrological response of a watershed to rainfall input is an indicator of the level of environmental degradation. Hydrologically, an ideal watershed condition is able to absorb as much water into the soil during the rainy season as water storage and to provide water to its surroundings during the dry season. Based on the physical environmental characteristics of a watershed (Linsley, Kohler & Paulhus 1975), the hydrological response of a watershed can be known. Climate, topography, geology, geomorphology, soil, vegetation, and land use can affect the hydrological response of a watershed (Chanapathi & Thatikonda, 2020). The hydrological response of a watershed is measured on the basis of the discharge and sediment indicators and then analyzed on the basis of the flow regime coefficient, run-off, sediment, flood, and water use index.

The run-off coefficient (RC) is the main parameter when data on watersheds are very limited or nonexistent. RC determines the amount of rainfall that will be converted into a surface flow. RC plays a crucial role in anticipating the maximum discharge within a watershed (Atharinafi & Wijaya 2021). It is essential for assessing watershed degradation levels, understanding flood possibilities (Dede et al. 2023a), overseeing and managing land utilization (Miardini & Susanti 2016), and understanding water balance (Resubun, Wahjunie & Tarigan 2018).

One way of predicting the flow coefficient is Cook's method. Suprayogi et al. (2022) revealed that the change of agricultural land use to built-up land reduces infiltration capacity and contributes to the direct increase of flow coefficient in the 10-year measurement period. Research in the Ayung watershed has shown that land use change due to the tourism sector has increased run-off coefficients (Dharmayasa et al. 2022). Cook's method was also applied in the upper Ciliwung River basin, land use change caused an increase in run-off coefficients and triggered an increase in peak discharge (Nahib et al. 2021). This method has a greater weight for slope parameters than for vegetation cover aspects (Miardini 2015). Nevertheless, the role of vegetation cover is an interesting phenomenon to be studied further due to its connection with land conservation and rehabilitation activities.

The Cisangkuy watershed, part of the Citarum River basin, has become a priority for conservation and rehabilitation in Indonesia. The Citarum River basin plays an important role in meeting the water needs of several districts and cities in West Java (Rachmadita et al. 2024). However, the increasing population has resulted in a critical environmental condition, marked by the presence of hydrometeorological disasters and heavily polluted water quality (Rosdiana et al. 2021).

Water balance analysis in 2015 showed a water deficit in the Cisangkuy watershed with a very vulnerable level of water availability (Primadita, Nugroho & Kusuma 2022). The Cisangkuy watershed located in Bandung Regency of West Java has experienced an annual population increase of approximately 2.58% over 30 years, as per the Indonesian Statistical Agency (BPS) data. This rate is notably high, especially given its position in the Greater Bandung Metropolitan Area (Sugito et al. 2023).

The issue is related to the poor land management upstream of the Cisangkuy watershed, where the forest decreased by 41% (1997-2005) and 35% (2005-2014) (Yulianto et al. 2022). The impact of this conversion caused an increase in the area of critical land and sedimentation (Imansyah 2012). The level of erosion in the Cisangkuy watershed is classified as moderate to severe erosion (50-330 tons/ha/year) (Chaidar et al. 2017). The degradation phenomenon in the Cisangkuy watershed needs to be reviewed from the perspective of vegetation density dynamics and RC changes using Cook's method.

Changes in vegetation cover as a representation of the landscape (land use and land cover, LULC) are the main parameters that reflect multitemporal. Anthropogenic activities cause changes in vegetation cover, which can be analyzed based on NDVI values in long-term measurements (Ezaidi et al. 2022). Therefore, the research aims to study the spatial and temporal dynamics of vegetation cover that drive RC changes in the Cisangkuy watershed.

2 Methodology and Data

This research is located in the Cisangkuy watershed (31,015 ha) which is an area the upstream of Citarum River basin (Figure 1). Cisangkuy watershed is located in Bandung Regency, West Java Province, Indonesia. Its river flows through six sub-districts, namely Pangalengan, Cimaung, Banjaran, Arjasari, Pameungpeuk, and Baleendah (Subarna 2015). The population growth rate from 1990–2020 in the area was 77.27%. Therefore, this phenomenon directly increases demand for built-up areas for housing, industry, and amenities as well as agricultural land. The Cisangkuy Watershed has an annual rainfall of 2,100-3,500 mm and a temperature of 18-31.8 ^{o}C (Sarminingsih 2007). The Cisangkuy is located at an elevation of 658-2,054 m above sea level with a morphological variation of mountainous and flatland regions.

Data used in estimating the flow coefficient based on Cook's method include slope maps, infiltration rate, drain density, and vegetation cover. The slope maps were

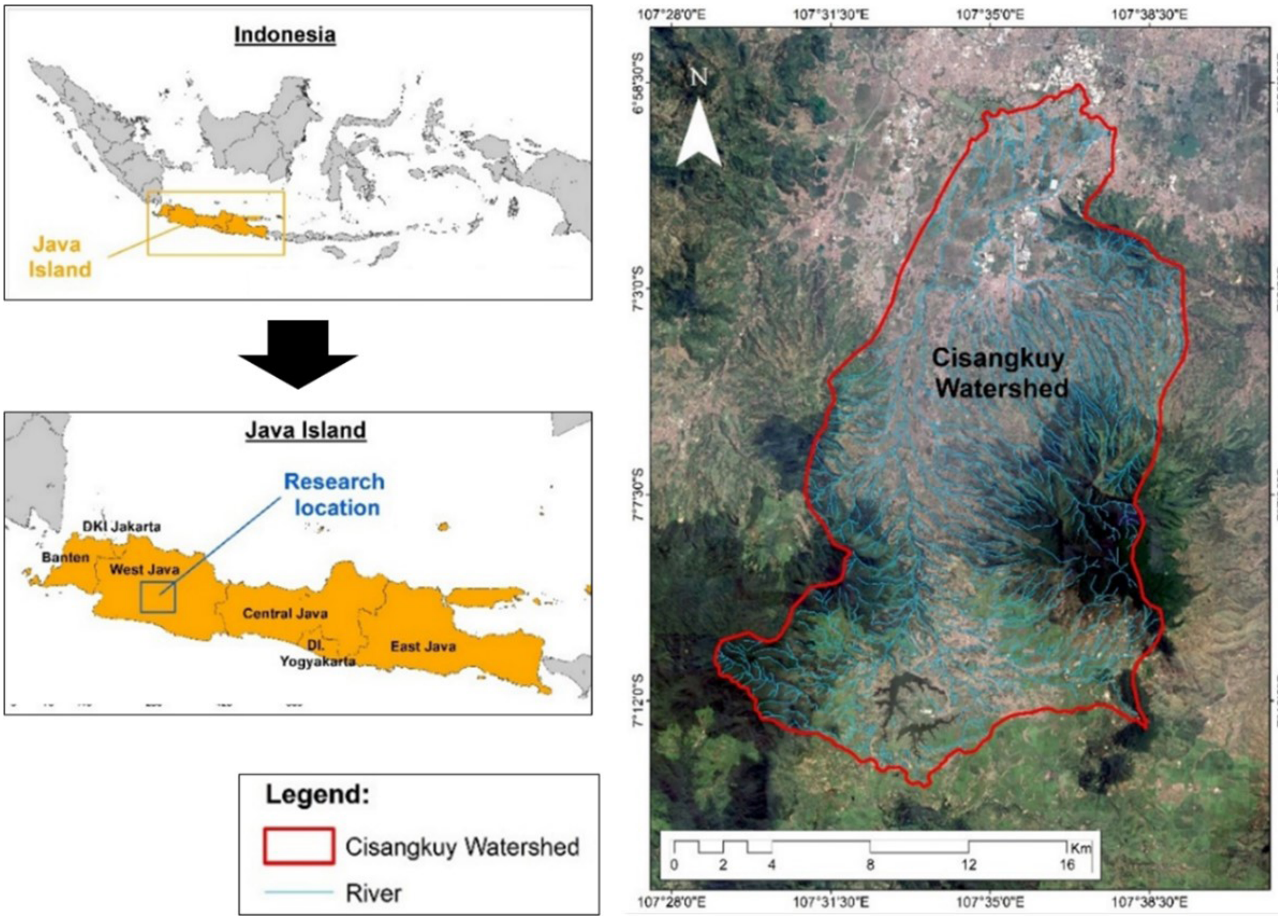

Figure 1 Research location showed the Cisangkuy watershed.

obtained based on the analysis of elevation data obtained from the SRTM 1 arc-second DEM data (Yue et al. 2017). The vegetation cover was obtained based on NDVI values extracted from the Landsat 5 TM, 7 ETM, and 8 OLI data from 1990, 2000, 2010, and 2020 (Equation 1) (dos Santos et al. 2022; Himayah et al. 2019; Xu & Guo 2014). The data acquisition spans from June 1st to August 30th in every decade, a time specifically chosen to coincide with the dry season in West Java, Indonesia, this timeframe minimizes cloud cover interference and mitigates the impact of variations in seasonal pixel values (Dede et al. 2023b).

$$\mathrm{NDVI} = \frac{\mathrm{NIR-R}}{\mathrm{NIR+R}}$$

Where NDVI is the Normalized different vegetation index, NIR is the Near-infrared band, and RED is known as the red band.

Google Earth Engine enables researchers to acquire an optimal, cloud-free mosaic by aggregating pixel values from multiple images during a set time (Cho et al. 2021; Samira, Souiher & Djamal 2022), specifically referencing the median. To effectively study changes in vegetation cover, a series spanning 5-20 years is deemed more suitable, allowing for clearer observation of landscape differences (Widiawaty et al. 2020). Data processing of Landsat to obtain NDVI values was carried out using Google Earth Engine cloud-based software, with algorithms written in the Java programming language (Onačillová et al. 2022). The analysis scale pertains to the average pixel value of comprehensive Landsat series imagery, specifically set at 30 meters. Vegetation cover is obtained based on the NDVI values classification which is divided into low, moderate, and high vegetation cover classification. Non-vegetation land cover has index values of 0-0.1, low vegetation cover (0.1-0.3), moderate (0.3-0.6), and high (0.6-1).

Other data, such as infiltration, was obtained based on information on the type of soil which was estimated to have its infiltration rate based on the soil texture characteristics. The type of soil was obtained from the soil resources map of Jakarta Sheet (MB48), Pusat Penelitian Tanah dan Agroklimat in 2000. The characteristics of the soil at the study site consist of 'endoaquepts' and 'dystrudepts' in the downstream, ‘hapludox’ and ‘kandiudult’ in the middle as well as ‘hapludans’ and ‘dystrudepts’ in the upstream of the river. The genesis of the soil comes from volcanism and fluvial processes originating from volcanic and alluvial materials from the transition zone of the southern mountains and the Central Depression / Bandung Zone in West Java. (Clements et al. 2009).

For stream density, this analysis was performed using line density (Sahu, Prasad & Ahmad 2022). The four biophysical parameters of the watershed were then given weights based on Cook’s method to obtain the RC value (Table 1). RC was divided into five types, namely extreme (> 75%), high (50-75%), normal (25-50%), and low (<25%). The data were then merged using the overlay method with GIS software with the procedures shown in Figure 2. Overlay generates new insights by combining diverse sets of data in the research process, enhancing the analysis of a particular area (Ismail et al. 2022; Susiati et al. 2022).

Table 1 Weights and scores for the Cook’s method.

Parameter	Information	Weight
Slope (%)	Very steep (>30)	40
	Steep (10-30)	30
	Moderate (5-10)	20
	Flat to gentle (0-5)	10
Infiltration (soil texture)	Rock, thin soil	20
	Clay	15
	Sandy loam, silty loam, loam, clay loam	10
	Sand, loamy sand	5
Vegetation greenness (NDVI)	< 0.1	20
	0.1-0.3	15
	0.3-0.6	10
	> 0.6	5
Stream density (km per sq. km)	> 8	20
	3.2-8	15
	1.6-3.2	10
	<1.6	5

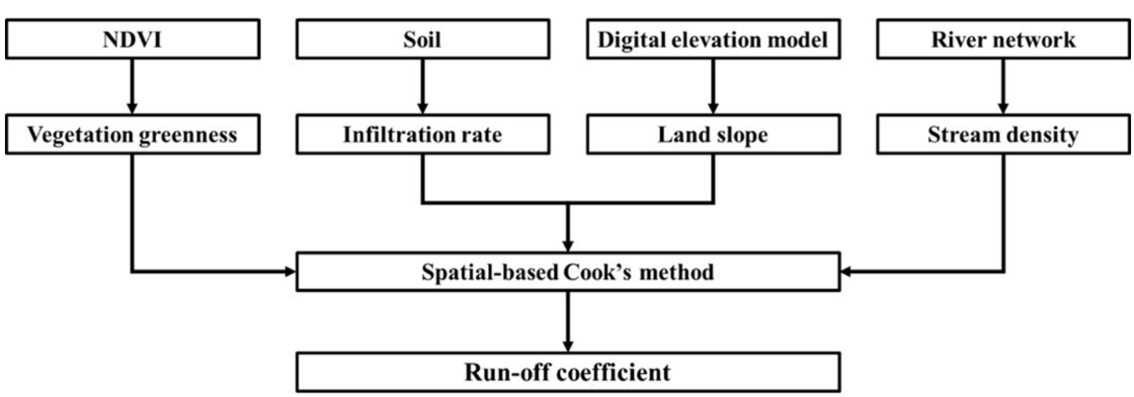

Figure 2 Process to determine run-off coefficient.

3 Results

3.1 Vegetation Cover Change

Vegetation coverage of the Cisangkuy watershed during the 30-year measurement period decreased from 30,632 ha (1990) to 29,551 ha (2020), which means it has a rate of change of 36 ha/year. The highest rate of change was 44.5 ha/year from 2000-2010, the vegetation coverage of the Cisangkuy watershed was relatively good with a proportion of over 90% (Figures 3 and 4). Non-vegetated land is found downstream of the watershed, associated with the river and road network. The change from vegetated land to non-vegetated land is quite visible downstream of the river basin, as it is closer to the center of growth in West Java – Bandung City (Yulianto, Fitriana & Sukowati 2020). The area of low-vegetation density land increased by 21 ha/year over 30 years. Meanwhile, medium-vegetation land also had an increasing trend, at 7.29 ha/year (1990–2000) and 10.89 ha/year (2000–2010). These values eventually decreased in the last 10 periods, where the area decreased to 60.24 ha/year (2010–2020).

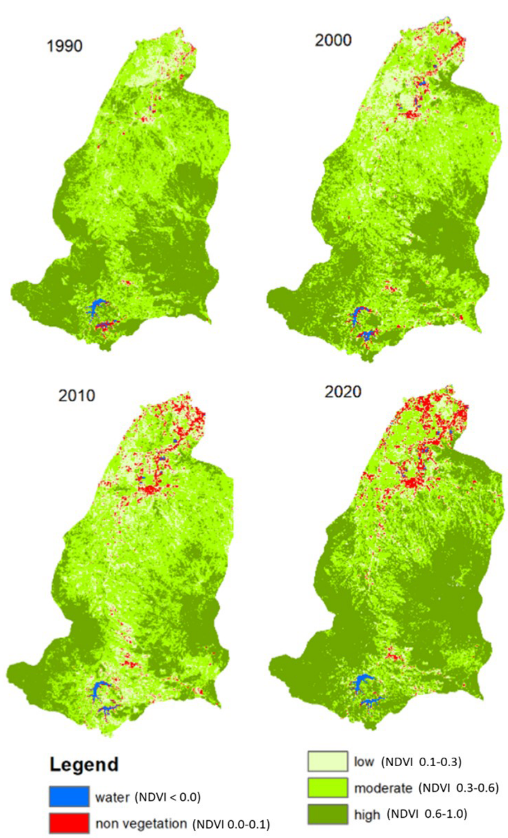

Figure 3 Vegetation cover in 1990, 2000, 2010, and 2020.

Land use in the medium vegetation cover class is generally agroforestry and plantations with high-value commodities such as coffee, tea, quinine, bamboo, and other perennial plants (Mulyono et al. 2019; Takeuchi, Tsunekawa & Abdoellah 2005). The decrease in the area of medium vegetation cover in the last 10 years indicates that the pattern of agroforestry farming supported by the community is continuing to decline, even though these agroforestry lands produce high canopy coverage (DaRocha et al. 2016).

For densely vegetated land, dynamic changes are observed due to the restoration from conversion threats. During the period 1990–2000, the land cover of this area significantly declined to 293.42 ha/year. However, this worrying situation has changed as during the period 2010–2020 its area augmented by 834.99 ha/year. The increased contribution comes from medium-vegetated lands, this shows the success of reforestation with agroforestry schemes based on community empowerment programs and community-based forest management (Aisharya et al. 2022; Mahandani et al. 2020). Changes in vegetation density need to be observed from variations in land use to understand its characteristics. Referring to Topographic Maps from the Indonesian Geospatial Agency (BIG), there are 6 types of land use in the Cisangkuy watershed (Table 2). In Indonesia, the NDVI values can be transformed into categories such as forest, plantation, shrubs and bushes, paddy fields, seasonal farming, settlement, and water bodies (Indarto, Nadzirah & Belagama 2020).

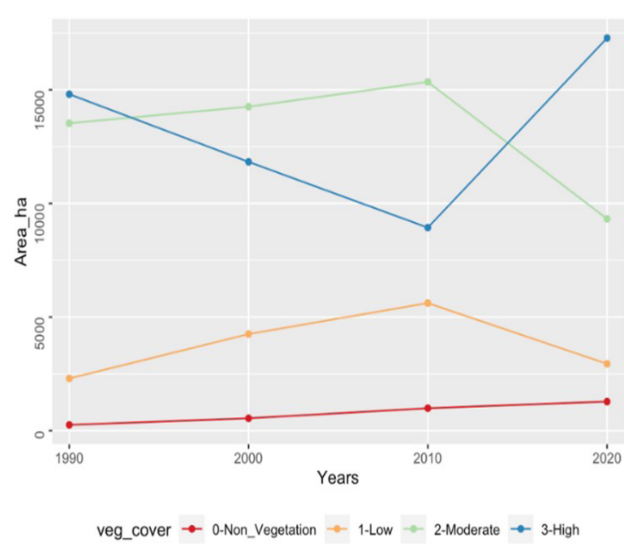

Figure 4 Vegetation cover in the latest 30 years.

Table 2 Land use distribution in Cisangkuy watershed.

Landuse	Area (ha)	%
Forest	7,402	22.48
Plantation	8,261	27.12
Shrubs and bushes	2,267	7.44
Paddy field	6,653	21.84
Seasonal farming	4,429	14.54
Settlement	2,003	6.57
Total	31,015	100

The pattern of cultivation of agricultural land is the most dominant, it is spread from the upstream, middle and downstream, followed by wet and dry agricultural land. The built-up area is relatively small because it only covers 6.57% of the watershed, with a distribution pattern that spreads upstream and extends following the road network to the downstream area. The dominant 22.48% forest is located in the upstream area around which there are plantation areas. Plantations are also widely spread on the mountain slopes to the mountain base, this follows the traditional environmental management philosophy of the Sundanese, the dominant ethnic group in West Java, to plant trees on steep slopes (Dede et al. 2021; Mulyadi, Dede & Widiawaty 2022).

3.2 Distribution of Run-off Coefficient (RC)

The dynamics of the vegetation cover, which is based on calculating the NDVI value, is one of the inputs for estimating the RC using Cook's method. Vegetation cover is a dynamic parameter because it can change for 5-10 years depending on the spatial situation at the study site (Aljohani, Jaafar & Lam 2021). In addition, Cook's method involves three other parameters, namely slope, infiltration, and stream density (Figure 5). The land slopes in the Cisangkuy watershed show the existence of two upriver in the west and east, in the upstream area there is Mount Malabar. On the east side, this upstream is located in the area of Mount Puntang and Mount Mandalawangi. Meanwhile, infiltration in the Cisangkuy watershed has a clustered pattern because of ancient volcanic material distribution and sedimentation (Sukiyah & Khoirullah 2020). Meanwhile, downstream areas have lower infiltration than upstream areas. The river flow pattern in the Cisangkuy watershed has a trellis pattern because this area is mountainous and hilly, this condition causes the flow density to vary widely.

All of these data are then combined by overlay after previously being given scores and weights, this process produces the RC distribution in the Cisangkuy watershed as shown in Figure 6. RC is classified into 4 classes based on percentiles, namely low (<25%), normal (25-50%), high (50-75%), and extreme (>75%). Low and normal RC are distributed in the downstream and upstream of the watershed, associated with areas with flat to gentle morphology. This differs from the high RC spread in the upstream region with a hilly-mountainous morphology. In a hilly landscape, the extreme RC is distributed in the upstream watershed in a dispersed pattern. Slope control in Cook's method looks very dominant, compared to other parameters. It can be seen that changes in vegetation cover do not have a major impact on changes in RC values, technical-mechanical conservation activities can be combined with vegetative rehabilitation to retain and absorb water into the soil (Dede et al. 2022a).

In terms of the distribution pattern, RC is in the normal and high categories forming clustered. However, the extreme category of RC fragments began to appear among the high-category areas. This phenomenon indicates that there is a massive change in land use, especially in extreme landscapes that are not monitored by certain institutions (Dede et al. 2022b). Low RC is found only in areas known as reservoirs. In the Cisangkuy watershed, there is the Saguling Reservoir which controls water regulation, sedimentation, and pollution as well as a source of electrical energy to drive turbines. High RC has been anticipated by the government through bioretention policies, dry ponds, infiltration basins, and vegetated filter strips, although their effectiveness is still questionable (Maryati, Humaira & Adianti 2016).

Over 30 years it appears that each RC class has not changed much in terms of. Table 3 shows the estimated RC value each year between 25-85%, this is classified as the low-extreme category. This value also indicates that rainfall in the Cisangkuy watershed cannot be stored properly as a recharge for groundwater. If recharge is not balanced with RC, groundwater use and evapotranspiration will threaten the carrying capacity of water resources (Kendarto, Asdak & Hapsari 2019; Ko et al. 2018; Mulyadi, Dede & Widiawaty 2020). Changes in vegetation density in

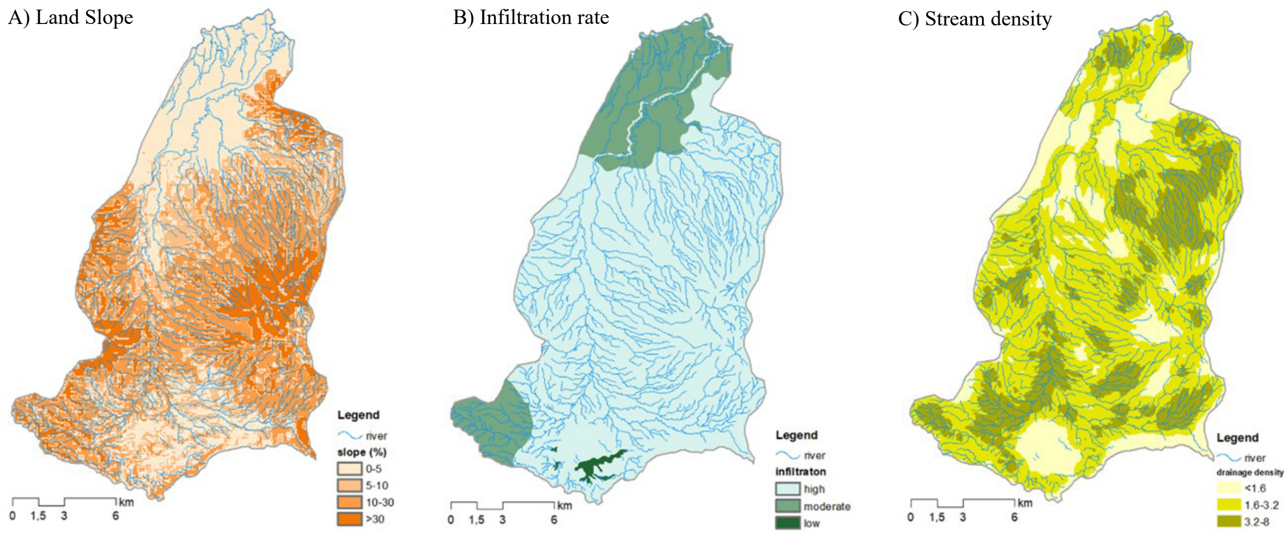

Figure 5 Three additional parameters for runoff coefficient analysis: A. Land slope; B. Infiltration rate; C. Stream density.

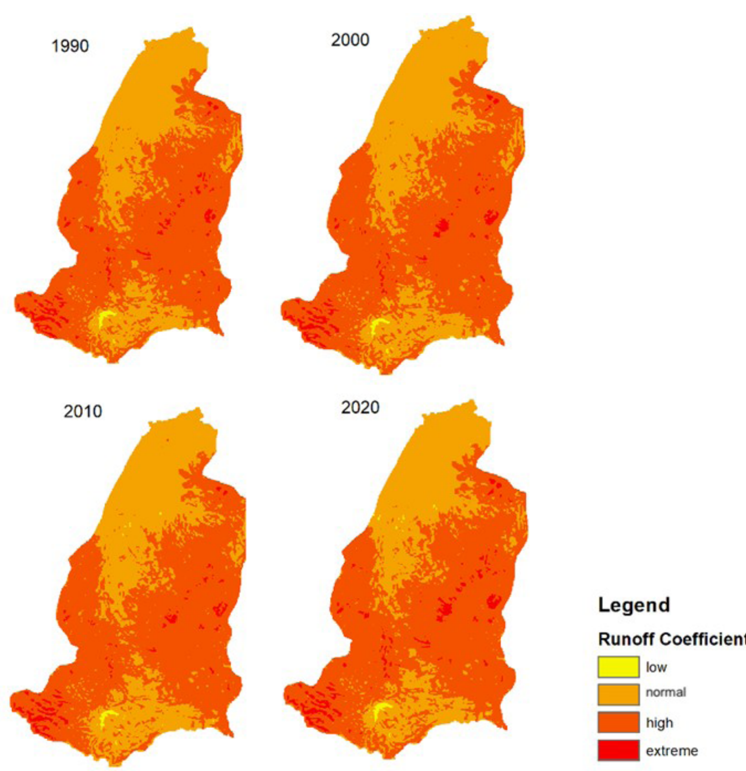

Figure 6 Run-off coefficient in 30 years.

Table 3 Summary of run-off coefficient data.

Year	Min	Max	Mean	Standard deviation
1990	25	85	58.16	12.27
2000	25	85	57.28	12.67
2010	25	85	56.45	12.72
2020	25	85	58.11	13.18

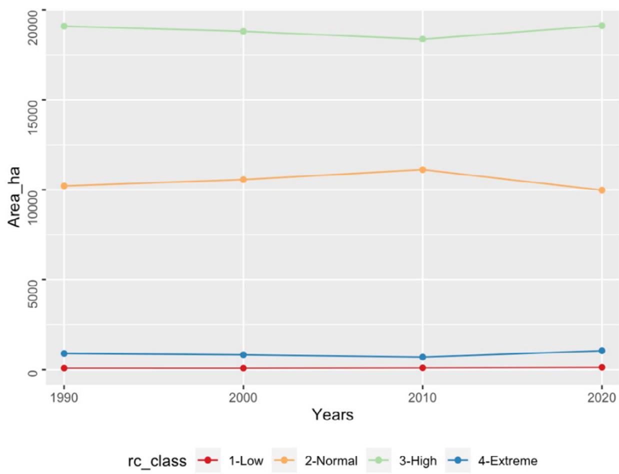

Figure 7 Run-off coefficient changes in 30 years.

the Cisangkuy watershed do not significantly affect RC as shown in Figure 7. The average value of RC in the high class has a larger area than the other classes with a percentage of 60-63%. In the Cisangkuy watershed, there is a pattern in which the decrease in an area with normal RC contributes to an increase in RC in the high and extreme classes. Changes in RC have contributed to the increased frequency of flooding in densely populated downstream areas due to increased flow rates during the rainy season (Dede et al. 2019).

The conservation and rehabilitation of the Cisangkuy watershed with reforestation efforts to re-form primary and secondary forests has the potential to be disturbed by various socio-economic challenges. This effort can be realized if all stakeholders and residents can create a sustainable agricultural system through agroforestry, spatial re-zoning, and the application of ideal rewards and punishments (Tomaszewski et al. 2020; Wong, Greve & Szarzynski 2022). If traced carefully, similar efforts have long been carried out through the establishment of a watershed management communication forum 'Forum DAS' (Pujatmiko 2007), 'Gerakan Nasional Kemitraan Penyelamatan Air' (Utama 2017), and the 'Citarum Harum' (Hapsoro & Yeru 2022). Simulation of the existence of community-based agroforestry is proven to produce better hydrological conditions than other agricultural lands, shrubs, grasses, and bare land because it can keep a maximum discharge at 80.67 m^3/second (Nilda, Adnyana & Merit 2015).

On the other hand, pragmatic efforts are also needed to normalize river flow because the vegetative and engineering processes require quite a long time (Chalid et al. 2021). Eventually, the community, government, and all parties need to have confidence that dense, high canopy and diverse vegetation provide ecosystem services that are beneficial to the environment in the long term, both in terms of water management, provision of clean air, and pollutant filtration (Dede et al. 2023a; Lallam, Megnounif & Ghenim 2018; Sunardi et al. 2022).

4 Conclusion

Changes in vegetation density have occurred in the Cisangkuy watershed, non-vegetated land and low vegetation have continued to increase in area over the 1990–2020 period. Environmental restoration efforts have begun to show results over the last 10 years as evidenced by increasing vegetation density through community-based forestry and agroforestry programs. Even so, the increase in vegetation density only occurred in lands that previously had moderate canopy cover.

During the threat of an urbanizing landscape, this situation does not play an important role in controlling RC in the Cisangkuy watershed. Over the past 30 years, the high and extreme RC class has had an increasing trend accompanied by a decrease in an area with the normal RC class. The increase in RC threatens residential areas downstream of the Cisangkuy watershed because water is unable to be absorbed into the ground due to built-up land and poor irrigation systems. This situation is a warning that there is a threat of flooding which can continue to expand if there is no policy intervention for watershed-based disaster management.

There is a need for further studies on environmental management that incorporate technical and vegetative approaches. In addition, in the future, there is a need for an in-depth study of the causal relationship between biogeophysical and socio-economic aspects in controlling run-off, including river normalization activities, harvesting rainwater run-off, and biopores.

5 Acknowledgments

The first author expresses gratitude to the Rector and the Directorate of International Affairs in Universitas Pendidikan Indonesia for providing the opportunity to pursue valuable learning experiences in Germany. Additionally, heartfelt thanks are extended to colleagues in the Geographisches Institut at Universität Bonn for their collaborative efforts and support.

6 References

Aisharya, I.Y., Gunawan, B., Abdoellah, O.S., Gunawan, W. & Dewa, J.J.P.K. 2022, 'Role and Interaction Between Local Actors in Community-Based Forest Management in Upper Citarum Hulu', *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan*, vol. 12, no. 2, pp. 335-51, DOI:10.29244/jpsl.12.2.335-351.

Aljohani, N.M., Jaafar, M. & Lam, K.C. 2021, 'Urban planning in Al-Madinah Al-Munawarah using new green spaces modelling through GIS application', *Indonesian Journal of Geography*, vol. 53, no. 3, pp. 340-7, DOI:10.22146/ijg.64991.

Atharinafi, Z. & Wijaya, N. 2021, 'Land use change and its impacts on surface runoff in rural areas of the Upper Citarum Watershed (Case study: Cirasea subwatershed)', *Journal of Regional and City Planning*, vol. 32, no. 1, pp. 36-55, DOI:10.5614/jpwk.2021.32.1.3.

Chaidar, A.N., Soekarno, I., Wiyono, A. & Nugroho, J. 2017, 'Spatial analysis of erosion and land criticality of the Upstream Citarum Watershed', *Geomate Journal*, vol. 13, no. 37, pp. 133-40, DOI:10.21660/2017.37.34572.

Chalid, A., Prasetya, B., Humam, I.A. & Assidik, M.L. 2021, 'Normalizing the river of Cisangkuy to reduce the flood risk in the future', *IOP Conference Series: Earth and Environmental Science*, vol. 708, 012029, DOI:10.1088/1755-1315/708/1/012029.

Chanapathi, T. & Thatikonda, S. 2020, 'Investigating the impact of climate and land-use land cover changes on hydrological predictions over the Krishna River Basin under present and future scenarios', *Science of the Total Environment*, vol. 721, 137736, DOI:10.1016/j.scitotenv.2020.137736.

Cho, D.F., Schwaida, S.F., Cicerelli, R.E., Almeida, T., Ramos, A.P.M. & Sano, E.E. 2021, 'Desempenho do algoritmo de classificação de imagens Random Forest para mapeamento do uso e cobertura do solo no Cerrado Brasileiro', *Anuário do Instituto de Geociências*, vol. 44, 37979, DOI:10.11137/1982-3908_2021_44_37979.

Clements, B., Hall, R., Smyth, H.R. & Cottam, M.A. 2009, 'Thrusting of a volcanic arc: A new structural model for Java', *Petroleum Geoscience*, vol. 15, no. 2, pp. 159-74, DOI:10.1144/1354-079309-831.

DaRocha, W.D., Neves, F.S., Dáttilo, W. & Delabie, J.H. 2016, 'Epiphytic bromeliads as key components for maintenance of ant diversity and ant–bromeliad interactions in agroforestry system canopies', *Forest Ecology and Management*, vol. 372, pp. 128-36, DOI:10.1016/J.FORECO.2016.04.011.

Dede, M., Asdak, C. & Setiawan, I. 2022a, 'Spatial-ecological approach in cirebon's peri-urban regionalization', *IOP Conference Series: Earth and Environmental Science*, vol. 1089, 012080, DOI:10.1088/1755-1315/1089/1/012080.

Dede, M., Nurbayani, S., Ridwan, I., Widiawaty, M.A. & Anshari, B.I. 2021, 'Green development based on local wisdom: A study of Kuta's Indigenous House, Ciamis', *IOP Conference Series: Earth and Environmental Science*, vol. 683, 012134, DOI:10.1088/1755-1315/683/1/012134.

Dede, M., Sunardi, S., Lam, K.C. & Withaningsih, S. 2023b, 'Relationship between landscape and river ecosystem services', *Global Journal of Environmental Science and Management*, vol. 9, no. 3, pp. 637-52, DOI:10.22034/gjesm.2023.03.18.

Dede, M., Susiati, H., Widiawaty, M.A., Lam, K.C., Aiyub, K. & Asnawi, N.H. 2023a, 'Multivariate analysis and modeling of shoreline changes using geospatial data', *Geocarto International*, vol. 38, no. 1, 2159070, DOI:10.1080/10106049.2022.2159070.

Dede, M., Wibowo, S.B., Prasetyo, Y., Nurani, I.W., Setyowati, P.B. & Sunardi, S. 2022b, 'Water resources carrying capacity before and after volcanic eruption', *Global Journal of Environmental Science and Management*, vol. 8, no. 4, pp. 473-84, DOI:10.22034/GJESM.2022.04.02.

Dede, M., Widiawaty, M.A., Pramulatsih, G.P., Ismail, A., Ati, A. & Murtianto, H. 2019, 'Integration of participatory mapping, crowdsourcing and geographic information system in flood disaster management (Case study Ciledug Lor, Cirebon)', *Journal of Information Technology and its Utilization*, vol. 2, no. 2, pp. 44-7, DOI:10.30818/jitu.2.2.2555.

Dharmayasa, I.G.N.P., Surakit, K., Jindal, R. & Thongdara, R. 2022, 'Investigation on impact of changes in land cover patterns on surface runoff in Ayung Watershed, Bali, Indonesia using geographic information system', *Environment and Natural Resources Journal*, vol. 20, no. 2, pp. 168-78, DOI:10.32526/ennrj/20/202100161.

dos Santos, A.M., do Carmo, N.C., Nunes, F.G., de Aguiar, L.A. & da Silva, C.F.A. 2022, 'Digital image classification: A comparison of classic methods for land cover and land use mapping', *Anuário do Instituto de Geociências*, vol. 45, 47481, DOI:10.11137/1982-3908_2022_45_47481.

Ezaidi, S., Aydda, A., Kabbachi, B., Althuwaynee, O.F., Ezaidi, A., Haddou, M.A., Idoumskine, I., Thorpe, J., Park, H.J. & Kim, S.W. 2022, 'Multi-temporal Landsat-derived NDVI for Vegetation Cover Degradation for the Period 1984-2018 in Part of the Arganeraie Biosphere Reserve (Morocco)', *Remote Sensing Applications: Society and Environment*, vol. 27, 100800, DOI:10.1016/j.rsase.2022.100800.

Hapsoro, C.D. & Yeru, A.I. 2022, 'The colonial legacy of Mooi Indië and the Captive mind in the environmental policy of citarum harum', *Wacana*, vol. 23, no. 1, pp. 200-24, DOI:10.17510/wacana.v23i1.1063.

Himayah, S., Ismail, A., Ridwana, R., Arrasyid, R., Affriani, A.R. & Ihsan, M. 2019, 'Correlation between land surface temperature and vegetation greenness using multi-temporal images', *IOP Conference Series: Earth and Environmental Science*, vol. 286, no. 1, 012043, DOI:10.1088/1755-1315/286/1/012043.

Imansyah, M.F. 2012, 'Studi Umum Permasalahan dan Solusi DAS Citarum serta Analisis Kebijakan Pemerintah', *Jurnal Sosioteknologi*, vol. 11, no. 25, pp. 18-33, 22 July 2022, <https://journals.itb.ac.id/index.php/sostek/article/view/1086>.

Indarto, I., Nadzirah, R. & Belagama, H.R. 2020, 'Pemetaan lahan sub-optimal berbasis nilai NDVI Sentinel 2A: Studi pendahuluan', *Jurnal Presipitasi: Media Komunikasi dan*

Pengembangan Teknik Lingkungan, vol. 17, no. 3, pp. 194-204, DOI:10.14710/presipitasi.v17i3.194-204.

Ismail, A., Widiawaty, M.A., Jupri, J., Setiawan, I., Sugito, N.T. & Dede, M. 2022. 'The influence of free and open-source software-geographic information system online training on spatial habits, knowledge and skills', *Geografia-Malaysian Journal of Society and Space*, vol. 18, no. 1, pp. 118-30, DOI:10.17576/geo-2022-1801-09.

Kendarto, D.R., Asdak, C. & Hapsari, A. 2019, 'Remote sensing data, landsat 8 OLI/TIRS for identification of evapotranspiration spatial distribution in sub DAS Cisangkuy West Java Indonesia', *IOP Conference Series: Earth and Environmental Science*, vol. 334, 012022, DOI:10.1088/1755-1315/334/1/012022.

Ko, I.H., Putuhena, W., Kim, Y.J. & Kim, S.S. 2018, 'Spatial and temporal water balance analysis considering structural and non-structural measures in the Cisangkuy River Basin', *Jurnal Sumber Daya Air*, vol. 14, no. 2, pp. 87-96, DOI:10.32679/jsda.v14i2.437.

Lallam, F., Megnounif, A. & Ghenim, A.N. 2018, 'Estimating the Runoff Coefficient using the analytic hierarchy process', *Journal of Water and Land Development*, vol. 38, no. 1, pp. 67-74, DOI:10.2478/jwld-2018-0043.

Linsley, R.K., Kohler, M.A. & Paulhus, J.L.H. 1975, *Hydrology for engineers*, McGraw Hill, 22 July 2022, <https://archive.org/details/hydrologyforengi0000lins>.

Mahandani, D., Mulyawan, S.S., Roosmini, D., Witteveen, L., Botden-Scheltinga, T. & Mayangsari, I.D. 2020, 'Participatory mapping and poetry route for determining environmental problems in upper citarum living lab', *Proceedings of the 3rd International Conference on Economic and Social Science*, EAI, DOI:10.4108/eai.17-10-2018.2294316.

Maryati, S., Humaira, A.N.S. & Adianti, P. 2016, 'Green infrastructure development in cisangkuy subwatershed, bandung regency: Potential and problems', *Procedia-Social and Behavioral Sciences*, vol. 227, pp. 617-22, DOI:10.1016/j.sbspro.2016.06.123.

Miardini, A. & Susanti, P.D. 2016, 'Analysis physical characteristics of land for estimated runoff coefficient as flood control effort in Comal Watershed, Central Java', *Forum Geografi*, vol. 30, no. 1, pp. 58-68, DOI:10.23917/FORGEO.V30I1.1131.

Miardini, A. 2015, 'Kajian Degradasi Lahan Sebagai Dasar Pengendalian Banjir di DAS Juwana', PhD Thesis, Universitas Gadjah Mada.

Mulyadi, A., Dede, M. & Widiawaty, M.A. 2020, 'Spatial interaction of groundwater and surface topographic using geographically weighted regression in built-up area', *IOP Conference Series: Earth and Environmental Science*, vol. 477, 012023, DOI:10.1088/1755-1315/477/1/012023.

Mulyadi, A., Dede, M. & Widiawaty, M.A. 2022, 'The role of tradisional belief and local wisdom in forest conservation', *Jurnal Geografi Gea*, vol. 22, no. 1, pp. 55-66, DOI:10.17509/gea.v22i1.43702.

Mulyono, A., Suriadikusumah, A., Harriyanto, R. & Djuwansah, M.R. 2019, 'Soil quality under agroforestry trees pattern in upper citarum watershed, Indonesia', *Journal of Ecological Engineering*, vol. 20, no. 1, pp. 203-13, DOI:10.12911/22998993/93942.

Nahib, I., Ambarwulan, W., Rahadiati, A., Munajati, S.L., Prihanto, Y., Suryanta, J., Turmudi, T. & Nuswantoro, A.C. 2021, 'Assessment of the impacts of climate and LULC changes on the water yield in the Citarum River Basin, West Java Province, Indonesia', *Sustainability*, vol. 13, no. 7, 3919, DOI:10.3390/su13073919.

Nilda, N., Adnyana, I.W.S. & Merit, I.N. 2015, 'analisis perubahan penggunaan lahan dan dampaknya terhadap hasil air di DAS Cisadane Hulu', *Ecotrophic: Jurnal Ilmu Lingkungan*, vol. 9, no. 1, pp. 35-45, DOI:10.24843/EJES.2015.V09.I01.P05.

Onačillová, K., Gallay, M., Paluba, D., Péliová, A., Tokarčík, O. & Laubertová, D. 2022, 'Combining landsat 8 and sentinel-2 data in Google Earth engine to derive higher resolution land surface temperature maps in urban environment', *Remote Sensing*, vol. 14, no. 16, 4076, DOI:10.3390/rs14164076.

Primadita, B.D., Nugroho, E.O. & Kusuma, M.S.B. 2022, 'Analisis Risiko Dampak Perubahan Iklim pada Ketersediaan Air, Banjir dan Kekeringan di DAS Citarum', *Proceeding of the Civil Engineering, Environmental, Disaster and Risk Management Symposium*, pp. 1-8, 25 July 2022, <https://shorturl.at/hMNS0>.

Pujatmiko, R. 2007, 'Efektifitas forum DAS dalam Membantu Kelembagaan Pengelolaan DAS (Studi Kasus Forum Komunikasi DAS Cidanau di Provinsi Banten)', Master Thesis, Universitas Indonesia, 28 July 2022, <https://lontar.ui.ac.id/detail?id=111707>.

Rachmadita, R., Widiana, A., Rahmat, A., Sunardi, S. & Dede, M. 2024, 'Utilizing satellite imagery for seasonal trophic analysis in the freshwater reservoir', *Journal of Multidisciplinary Applied Natural Science*, vol. 4, no. 1, pp. 63-75, DOI:10.47352/jmans.2774-3047.188.

Resubun, M.L., Wahjunie, E.D. & Tarigan, S.D. 2018, 'Analisis potensi Ketersediaan dan Kebutuhan Air di Daerah Aliran Sungai Cisangkuy', *Jurnal Ilmu Tanah dan Lingkungan*, vol. 20, no. 2, pp. 57-62, DOI:10.29244/jitl.20.2.57-62.

Rosdiana, R., Hapsari, R.K., Kusuma, E.O. & Kusuma, M.S.B. 2021, 'Konsep Pengembangan Daerah Aliran Sungai Citarum Hulu (Studi Kasus: Sub DAS Cisangkuy)', *Jurnal Teknik Sipil*, vol. 28, no. 3, pp. 281-8, 28 July 2022, <https://shorturl.at/jkwY9>.

Sahu, I., Prasad, A.D. & Ahmad, I. 2022, 'Integrated tool for morphometric analysis using QGIS', in R. Jha, V.P. Singh, V. Singh, L.B. Roy & R. Thendiyath (eds), *River and Coastal Engineering: Hydraulics, Water Resources and Coastal Engineering*, Springer International Publishing, pp. 103-13, DOI:10.1007/978-3-031-05057-2_9.

Samira, D., Souiher, N. & Djamal, B. 2022, 'Extraction of urban areas using spectral indices combination and Google Earth engine in algerian highlands (Case study: Cities of Djelfa, Messaad, Ain Oussera), *Anuário do Instituto de Geociências*, vol. 45, 44537, DOI:10.11137/1982-3908_2022_45_44537.

Sarminingsih, A. 2007, 'Evaluasi Kekritisan Lahan Daerah Aliran Sungai (DAS) dan Mendesaknya Langkah-Langkah Konservasi Air', *Jurnal Presipitasi*, vol. 2, no. 1, pp. 8-14, 25 July 2022, <http://eprints.undip.ac.id/528>.

Subarna, D. 2015, 'Strategi Konservasi pengelolaan Daerah Aliran Sungai Berbasis Variabilitas Iklim di DAS Cisangkuy

Citarum Hulu', PhD Thesis, IPB University, 22 July 2022, <https://repository.ipb.ac.id/jspui/handle/123456789/77258>.

Sugito, N.T., Gumilar, I., Hernandi, A., Handayani, A.P. & Dede, M., 2023, 'Utilizing semi-variograms and geostatistical approach for land value model in urban region', *International Journal of Engineering*, vol. 36, no. 12, pp. 2222-31, DOI:10.5829/ije.2023.36.12c.12.

Sukiyah, E. & Khoirullah, N. 2020, 'The bandung city spatial planning policies in geological perspective', *Journal of Geological Sciences and Applied Geology*, vol. 4, no. 1, pp. 48-53, 22 July 2022, <https://journal.unpad.ac.id/gsag/article/viewFile/29147/13967>.

Sunardi, S., Nursamsi, I., Dede, M., Paramitha, A., Arief, M.C.W., Ariyani, M. & Santoso, P. 2022, 'Assessing the influence of land-use changes on water quality using remote sensing and GIS: A study in Cirata Reservoir, Indonesia', *Science and Technology Indonesia*, vol. 7, no. 1, pp. 106-14, DOI:10.26554/sti.2022.7.1.106-114.

Suprayogi, S., Widyastuti, M., Hadi, M.P., Christanto, N., Tivianton, T.A., Fadhilah, G. O., Rahmawati, L. & Fadlillah, L.N. 2022, 'Runoff coefficient analysis after regional development in Tambakbayan Watershed, Yogyakarta, Indonesia', *Jurnal Ilmu Lingkungan*, vol. 20, no. 2, pp. 396-405, DOI:10.14710/jil.20.2.396-405.

Susiati, H., Dede, M., Widiawaty, M.A., Ismail, A. & Udiyani, P.M. 2022, 'Site suitability-based spatial-weighted multicriteria analysis for nuclear power plants in Indonesia', *Heliyon*, vol. 8, no. 3, e09088, DOI:10.1016/j.heliyon.2022.e09088.

Takeuchi, K., Tsunekawa, A., & Abdoellah, O.S. 2005, 'Kebon Tatangkalan: A disappearing agroforest in the Upper Citarum Watershed, West Java, Indonesia', *Agroforestry Systems*, vol. 63, no. 2, pp. 171-82, DOI:10.1007/s10457-004-1182-x.

Tomaszewski, B.M., Moore, E.A., Parnell, K., Leader, A.M., Armington, W.R., Aponte, O., Brooks, L., Herold, B.K., Meyers, B.S., Ruggero, T. & Sutherby, Z. 2020, 'Developing a Geographic Information Capacity (GIC) profile for disaster risk management under united nations framework commitments', *International Journal of Disaster Risk Reduction*, vol. 47, 101638, DOI:10.1016/j.ijdrr.2020.101638.

Utama, S. 2017, 'Strategi Tim GNKPA Kabupaten Kutai Kartanegara dalam Upaya Mensosialisasikan Gerakan Nasional Kemitraan Penyelamatan Air (GNKPA) pada Publik Eksternal', *Jurnal Paradigma*, vol. 1, no. 2, pp. 75-92, DOI:10.30872/jp.v1i2.333.

Widiawaty, M.A., Ismail, A., Dede, M. & Nurhanifah, N., 2020, 'Modeling land use and land cover dynamic using geographic information system and Markov-CA', *Geosfera Indonesia*, vol. 5, no. 2, pp. 210-25, DOI:10.19184/geosi.v5i2.17596.

Wong, I., Greve, K. & Szarzynski, J. 2022, 'Evolution of spatial disaster risk assessments: A bibliometric analysis'. *Lecture Notes in Informatics*, vol. 328, pp. 77-87, 27 July 2022, <https://researchr.org/publication/WongGS22>.

Xu, D. & Guo, X. 2014, 'Compare NDVI extracted from landsat 8 imagery with that from landsat 7 imagery', *American Journal of Remote Sensing*, vol. 2, no. 2, p. 10, DOI:10.11648/j.ajrs.20140202.11.

Yue, L., Shen, H., Zhang, L., Zheng, X., Zhang, F. & Yuan, Q. 2017, 'High-quality seamless DEM generation blending SRTM-1, ASTER GDEM v2 and ICESat/GLAS observations', *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 123, pp. 20-34, DOI:10.1016/j.isprsjprs.2016.11.002.

Yulianto, F., Fitriana, H.L. & Sukowati, K.A.D. 2020, 'Integration of remote sensing, GIS, and shannon's entropy approach to conduct trend analysis of the dynamics change in Urban/Built-Up Areas in the Upper Citarum River Basin, West Java, Indonesia', *Modeling Earth Systems and Environment*, vol. 6, pp. 383-95, DOI:10.1007/s40808-019-00686-9.

Yulianto, F., Khomarudin, M.R., Hermawan, E., Nugroho, N.P., Chulafak, G.A., Nugroho, G., Nugroho, U.C., Suwarsono, S., Fitriana, H.L. & Priyanto, E. 2022, 'Spatial and temporal distribution of estimated surface runoff caused by land use/land cover changes in the Upstream Citarum Watershed, West Java, Indonesia', *Journal of Degraded and Mining Lands Management*, vol. 9, no. 2, pp. 3293-305, DOI:10.15243/jdmlm.2022.092.3293.

Author contributions

Arif Ismail: conceptualization; methodology; software; investigation; funding; writing – original draft. Klaus Greve: conceptualization; methodology; resources; supervision. Millary Agung Widiawaty: formal analysis; visualization; writing – original draft. Moh. Dede: validation; writing – review & editing. Nandi Nandi: conceptualization; supervision.

Conflict of interest

All authors declare that they have no conflicts of interest.

Data availability statement

Data, scripts and code are available on request.

Funding information

This paper was partially-funded by Universitas Pendidikan Indonesia and Universitat Bonn through World Class University Program (Staff Exchanges) in year 2022 (6603/UN40/KP.06/2022).

How to cite:

Ismail, A., Greve, K., Widiawaty, M. A., Dede, M. & Nandi, N. 2024, 'Effect of Vegetation Cover Changes on the Runoff Coefficient Characteristics in the Cisangkuy Watershed, Indonesia', *Anuário do Instituto de Geociências*, 47:61104. https://doi.org/10.11137/1982-3908_2024_47_61104