

Profile assessment and protection of Way Karang Spring as a priority water spring in South Sumatera, Indonesia



Laila Fahriati ^{a, 1, *}, Aliefika Karuniati ^{a, 2}, Nisrina Salsabila ^{b, 3, }

^a Balai Pengelolaan Aliran Sungai dan Hutan Lindung Musi, Sumatera Selatan, Indonesia

^b Department of Biology, Faculty of Biology, Universitas Gadjah Mada, Yogyakarta, Indonesia

¹ lailafahriati@gmail.com ^{*}; ² aliefika.karuniati@gmail.com; ³ nisrina.s@mail.ugm.ac.id

^{*} Corresponding author

ARTICLE INFO

Article history

Submission

May 12, 2022

Revision

June 9, 2022

Accepted

June 26, 2022

Keywords

South Sumatera

Watershed

Water spring

Way Karang

ABSTRACT

Currently, the quantity, quality, and quantity of springs in various regions of Indonesia have changed or decreased. This is due to various factors, including deforestation and changes in how water catchment areas function. Limited data and information has been identified as a weakness in spring protection efforts. In this regard, an integrated, spatially-based database that is easily understood and accessible to all parties is required for reference in planning activities. This research aims to provide the public with a complete picture of data and information on priority springs. Data was collected using the desk study method and interviews with relevant agencies, communities, and other stakeholders. The spring data collected included general, biophysical, socioeconomic and spring management information. Way Karang Spring was selected to be the subject of this research after several assessments. Based on the result, Way Karang Spring is classified as having interrupted status damage, and spring protection efforts are being made to restore the spring's quality. This spring is extremely important to the community. Way Karang Spring must be preserved to meet the water needs of the local community.



This is an open-access article under the [CC-BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license



Conflict of interest: The authors declare that they have no conflicts of interest.

Introduction

A watershed is a land area that accommodates and stores rainwater^{1,2} and drains it into the sea, lake, or swamp through the outlet. The process of water movement affects and is influenced by various existing spatial attributes, so watershed-based spatial planning is necessary. Watershed management is a human effort to regulate the mutual relationship between natural resources with humans in the watershed and all its activities to realize the sustainability and harmony of the ecosystem and the increasing benefits of natural resources for humans in a sustainable manner.

Water is a natural element that can renew its existence through the hydrological cycle. Water is one of the basic elements every living thing needs in the process and survival³. Hendrayana stated that a spring is where groundwater seeps or flows out to the ground surface naturally⁴. The condition of springs in various regions in Indonesia has experienced changes or

decreases in quantity, quality, and quantity. This is due to various factors, including deforestation and changes in the function of water catchment areas. Some indicators of damage to water catchment areas include flooding, drought, sedimentation, landslides, declining groundwater levels, destruction of biodiversity, and declining spring discharge due to the disruption of land cover functions in upstream areas⁵.

A weakness encountered in spring protection efforts is limited data and information⁶. In this regard, to support the Spring Protection Program, it is necessary to develop an integrated, spatially-based database that is easily understood and accessible to all parties for reference in planning activities. The springs database development begins with compiling a Profile of Priority Springs that are the object of spring protection measures. With the compilation of these Spring Profiles, it is hoped that the wider community and interested parties will be able to obtain data and information easily and completely to plan activities to save and protect springs sustainably and sustainably.

Therefore, a spring profile was prepared to establish a complete spring base as public information that can be used as a reference in planning and formulating policies and implementation in saving and protecting springs. This research aims to provide the public with a complete picture of data and information on priority springs, increase public understanding and awareness of the importance of saving and protecting springs, and provide data and information as reference material for planning activities to save and protect springs.

Method

Location

This research was conducted at selected springs located inside and outside the forest area, where people's lives depend on these springs and are, therefore, a priority to save and protect. The Musi River watershed has 63 springs spread across 48 villages in South Sumatra Province, and the spring selected for this study was Way Karang Spring.

Data Collection

Data were collected in primary and secondary data, following the method used by Arifjaya⁷ and BPDAS Musi⁸. The method used for data collection includes the desk study method and interviewing the relevant agencies, communities, and other stakeholders. The collected data on springs included general, biophysical, socioeconomic, and spring management data.

The general data collected were the name and location of the spring, rock type, ecosystem type of the area, spring typology, area status, land ownership status, climate and rainfall, and topography or slope. The first biophysical data collected was spring discharge, which could be measured directly or by utilizing existing data and interviews with local communities to determine its continuity and the nature of its flow, including perennial springs, seasonal springs, or periodic springs. The next biophysical data collected were the performance of the water source, land use in the area around the spring, land cover condition of the area around the spring, vegetation type and tree species around the spring, and water quality (physical parameters: turbidity or clarity, smell, temperature, total dissolved solids; chemical parameters: pH, dissolved oxygen, NO₃ level; biological parameter: fecal coliform).

The socioeconomic data collected includes the function and use of the spring, the socioeconomic conditions of the community around the spring, community use of the spring, community dependence on the spring, local wisdom related to spring conservation, and the institutionalization of the community for spring conservation. The data on spring management includes parties managing and utilizing the spring, local government policies, and problems encountered.

Assessment of Spring Damage

The data from the spring inventory is used to identify and assess the condition or damage status of the spring⁸. The criteria and parameters used for spring damage assessment are (1) water quality, (2) water quantity or discharge, and (3) land cover around the spring (200 meters radius). The assessment is determined through the values and scores for each parameter, as shown in Table 1.

Table 1. Values and scores of spring damage assessment criteria

Criteria	Parameter	Indicator	Value	Score	Total Score (V x S x 10)	Explanation
Water quality (60% of total value)	Dissolved oxygen (mg/L)	< 3	0.15	5	7.5	Direct measurement
		3 – 6		3	4.5	
		> 6		1	1.5	
	Total dissolved solid (mg/L)	> 1500	0.15	5	7.5	
		1000–1500		3	4.5	
		< 1000		1	1.5	
	NO ₃ level (mg/L)	> 8	0.15	5	7.5	If there are no polluting activities then the total score is 1.5
		> 5–8		3	4.5	
		≤ 5		1	1.5	
	Fecal coliform (mg/100mL)	> 1000	0.15	5	7.5	If there are no polluting activities then the total score is 1.5
		> 100–1000		3	4.5	
		≤ 100		1	1.5	
Water quantity (30% of total value)	Difference between current spring water discharge and spring water discharge in the previous year during the same season	Water discharge decreased significantly by >30%	0.30	5	15	Previous data or interview results or direct measurement of spring quantity compared to the previous year's discharge
		Water discharge decreased by 10-30%		3	9	
		Fixed or increased water discharge		1	3	
Land cover around the spring (10% of total value)	± 200 meters radius	< 10 %	0.1	5	5	Direct observation
		10–30 %		3	3	
		> 30 %		1	1	

Note: NO₃ level and Fecal Coliform are measured if there are activities in the vicinity of the spring that could potentially contaminate the water quality.

Furthermore, to assess the condition or status of spring damage, the following equation I, where TS: is the total spring score and n: is the number of criteria.

$$TS = \sum_{i=1}^n value \times score \times 10 \quad (I)$$

The condition or status of spring damage was categorized into three levels according to the total score calculated above, where a total score of 0 to 20 indicates a good spring status, 21 to 35 indicates a disturbed spring status, and 36 to 50 indicates a damaged spring status.

Assessment of Priority Springs

The results of assessing the condition or damage status of the springs were used to determine the priority springs that would be profiled by adding several highly significant criteria. An assessment was then made of the selected priority springs that would be profiled.

Values and weights for each of the above criteria were determined to assess the priority springs. Priority springs were determined through calculations, as shown in the following Table 2.

Table 2. Priority spring assessment

Criteria	Description	Score	Value
Condition of spring damage status	Damaged	5	40
	Interrupted	3	
	Good	1	
Utilization of spring water sources	Household purposes	5	25
	Agricultural purposes	3	
	Not utilized	1	
Community dependence on spring water sources	Highly dependent	5	20
	Not too dependent	3	
	Not dependent at all	1	
Spring performance	The discharge of flowing water is greater than the amount of water needed	5	15
	The flowing water is equal to the amount of water needed	3	
	The flowing water discharge is less than the total water demand	1	

For the subsequent assessment of priority springs, the following equation II, where TS: is the total spring score, n: is the number of criteria, and the maximum score: is the highest score of each criterion.

$$TS = \sum_1^n \frac{value}{maximum\ score} \times score \quad (II)$$

Selected Priority Springs

Using the scoring table and scoring formula above, each selected priority spring will have a total score. This total score will then be used as the standard for prioritizing the selection of springs prioritized for rescue, protection, and rehabilitation by interested parties, especially those with authority (managers) or who benefit from the springs. Thus, the springs with the highest total scores were prioritized, followed by those with lower total scores, and grouped into three priorities according to the assessment results. Priority I has a score of 61 to 100, Priority II is 41 to 60, and Priority III has a score of 0 to 41.

Results and Discussion

Spring Condition

Selected Spring

Based on the prioritized spring assessment conducted by the procedures described above, 10 springs were selected as Priority I springs, as shown in Table 3. Considering the highest level of community dependency, Way Karang Spring was selected for the spring protection analysis.

Table 3. List of springs included in priority I

Spring's Name	Regency Or City	District	Village
Air Arpa	Pagaralam	Dempo Utara	Bumi Agung, Muara Siban
Air Irham	Pagaralam	Pagaralam Utara	Selibar
Tebat Bukit	Lahat	Kotaagung	Gedung Agung, Tanjung Bulan
Terkol I	Lahat	Pulaupinang	Kedaton
Air Kunder	Lahat	Pagargunung	Merindu
Curuk Merih	Lahat	Gumay Ulu	Sinjar Bulan, Tanjung Aur
Padang Paku 1	Lahat	Kotaagung	Tunggul Bute, Sukarami
Bedigul	Ogankomeringulu Selatan	Buaypemaca	Tanjung Jaya, Bedigul
Way Karang	Ogankomeringulu Selatan	Muaradua	Datar
Dukduk	Ogankomeringulu	Baturaja Timur	Tanjung Baru, Kemala

General Conditions

Administratively, Way Karang Spring is located in Datar Village, Muaradua District, South Ogan Komering Ulu Regency, South Sumatra Province. The location coordinates are 104° 0' 29.228" East and 4° 30' 19.980" LS. The spring is 190 meters above sea level within the Musi watershed, Komering sub-watershed.

The springs in Datar Village are located in sedimentary rock units, namely a mixture of clay and shale, and generally passive tuff and sandstone. Judging from the type of rocks around, the spring is supported by a good aquifer system because the rock types are sandy and sandstone, although there is tuff because both rock types are rocks with good permeability. Therefore, hydrogeological, the groundwater potential in the area mentioned is quite good. However, the productivity is small but significant for the local area, with a groundwater flow system through the voids between grains. Way Karang Spring is located in an area of other use, bordering a limited production forest. Accessibility to the spring is easy; a barrier about 50 meters from the village road has been built.

Based on the Schmidt and Ferguson Classification, the climate type in the Way Karang Spring area is Type B (wet), with rainfall in the Way Karang catchment area ranging from 1700-3900 mm/year. The geomorphology that forms the spring area is Hillocky acid volcanic tuff plains with steep hills (25-40%). The spring type is a "contact spring," i.e., a spring resulting from contact between an aquifer layer and an impermeable sandstone and tuff, occurring naturally. Based on the Minister of Energy and Mineral Resources Regulation No. 2/2007 on Groundwater Basins in Indonesia, Way Karang Spring is included in the Muaro Duo-Curup Groundwater Basin. The Muaro Duo-Curup Groundwater Basin has an area of 8251 km² covering the administrative areas of Bengkulu and South Sumatra Provinces.

Biophysics Conditions

Based on the nature of its flow, Way Karang Spring is considered a perennial spring, which is a spring that releases water throughout the year. The spring discharge is 1 liter/second with an inter-grain spring type. The biophysical quality of the water (odor, taste, color, and turbidity) is good; the water is tasteless and odorless, clear and colorless. The total dissolved suspension (TDS) value is 77 mg/l. Water temperature is in the range of 29-30°C.

Chemical quality is measured through pH levels and dissolved oxygen levels. Measurement of pH to express the intensity of the acidic or alkaline state, Way Karang Spring has a pH in the range of 7.02. Dissolved oxygen (DO) levels are the amount of oxygen available in water from photosynthesis and atmospheric or air absorption. The greater the amount of DO in the water, the better the water quality. The DO value in Kundur spring is 5.74.

Biological quality is based on the total coliform indicator, the first bacterial indicator used to determine whether water is safe for consumption. The total coliform value in Way Karang Spring is 170 MPN/100 ml. The threshold requirement for the MPN Coliform value based on Government Regulation of the Republic of Indonesia No. 22 of 2021 Appendix IV Class II is 5000 MPN/100 ml.

The soil type found within a 200 m radius of the springs is inceptisol with suborder dystropepts. This soil type is characterized by intensive weathering and rather advanced soil development, base leaching that affects base saturation in the lower layers, and clay leaching up to the B horizon so that the clay content in the lower layers tends to be high. The parent materials that form the soils in the spring area are andesite, basalt, diorite, and tephra. The land systems found in the spring area are hills clustered in the Bukit Baringin land system formation. Land use around the spring in the upstream part is used as dry plantation land and forest. The trees that grow around the spring are candlenuts, bamboo, areca nut, and durian trees.

Socioeconomic Conditions

Datar Village, located in Muaradua Sub-district, South Ogan Komerling Ulu Regency, has an administrative area of 700 hectares with population data as described in Table 4. Datar Village has the most difficult access among other villages in the Muaradua sub-district.

Table 4. Population data of Tanjung Jaya Village⁹

Regency or City	District	Village	Population		Total Population	Household
			Male	Female		
OKU Selatan	Muaradua	Datar	336	308	644	117

The livelihoods of the people of Datar Village are generally farmers. The community's agricultural activities are mostly gardening, and a small portion cultivates rice fields. There are no industries developed in this area. The surrounding community utilizes Karang Spring for consumption, daily toilet, and irrigation of rice fields. Most villagers still depend on this spring. The community built a building as a public bathing place around the spring. The level of dependence of the residents of Datar Village on the Way Karang Spring is high. The local population still relies on this water source for consumption, toilets, and irrigation of rice fields. Although there are currently clean water sources from boreholes at 4 (four) points in the village, Way Karang water is still needed.

Spring Protection Zoning

Delineation of Spring Protection Zones (Spring Infiltration)

A spring protection zone is the natural boundary of a spring's recharge area. Determining the boundaries of this protection zone is important, as all activities and land uses within the spring protection zone will affect the quality, quantity, and continuity of the spring's resources. Each zone mapping can be seen in Fig 1. Zone I (core zone) is located at a radius of 10 meters from the spring. Zone II (buffer zone) is located at the boundary of Zone I up to 200 meters upstream; the determination of this radius is influenced by geological and hydrogeological conditions, land use and allotment, topography, and slope conditions. Zone III is upstream of the buffer zone. The recharge zone for each spring varies in size according to the conditions and characteristics of the surrounding spring.

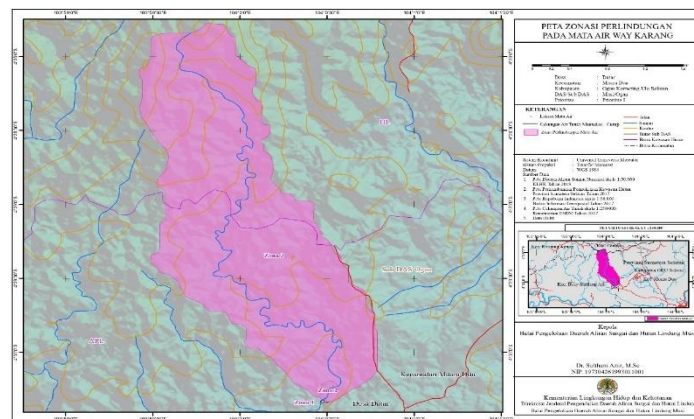


Fig 1. Protection zoning map of Way Karang Spring¹⁰

Spring Infiltration Area Analysis

Based on the delineation results, Zone I to Zone II of Way Karang Spring are in other use areas. At the same time, Zone III of Way Karang Spring is partly located in other use areas and partly in the Bukit Jambul-Gunung Patah Protected Forest area. The catchment area of Way Karang Spring covers 610.67 hectares. Zone I covers an area of 0.05 hectares with land cover

in dryland agriculture mixed with shrubs. Land criticality conditions in this zone are categorized as critical.

Zone II, with an area of 3.97 hectares, is dominated by land cover in the form of dry land agriculture mixed with shrubs. Land criticality conditions in this zone are in the critical category. Land cover in Zone III, which covers 338.58 hectares, is in other-use areas with critical land status. The other 268.09 hectares are in the Bukit Jambul-Gunung Patah Protected Forest area with critical and slightly critical conditions. Regarding landslide vulnerability status, the recharge area of Way Karang Spring is categorized as moderately vulnerable, with normal runoff type. The percentage of critical land conditions can be seen in Fig 2. Each zone's critical condition can be seen in Fig 3. The darker color indicates that the land is more critical than, the lighter color.

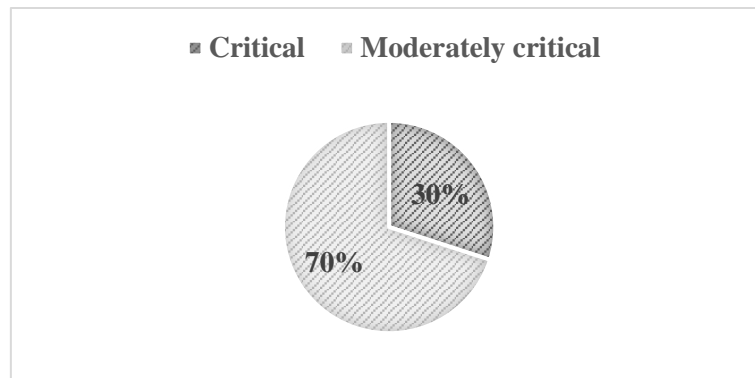


Fig 2. Critical land for Way Karang Spring recharge¹⁰

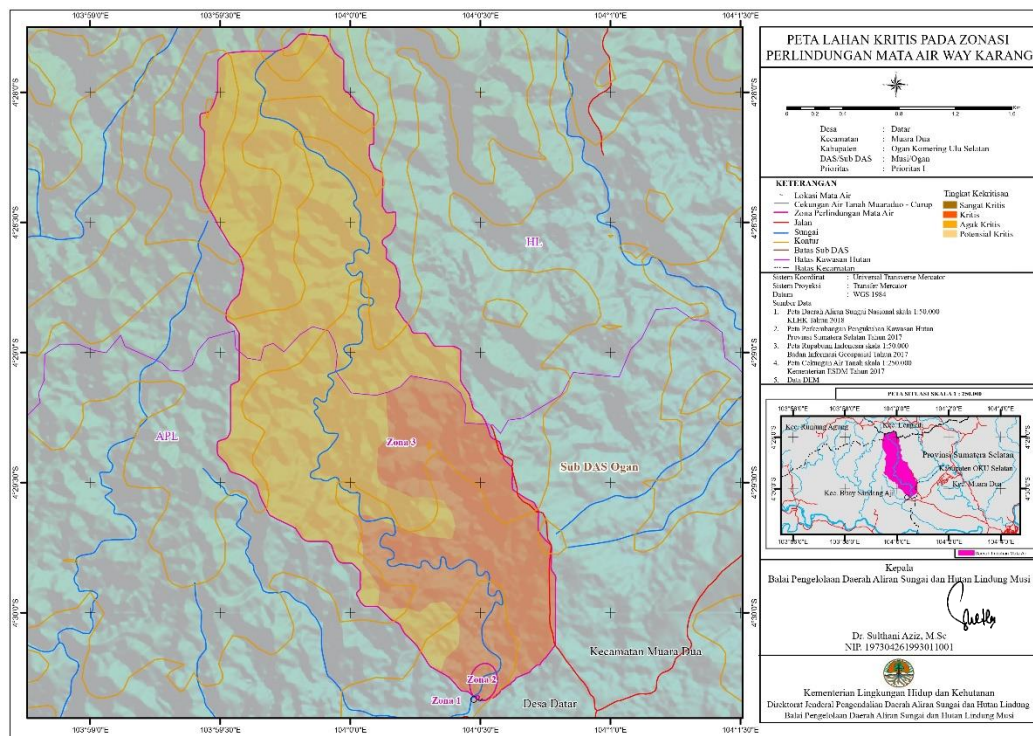


Fig 3. Map of critical land in the Way Karang Spring protection zone¹⁰

Spring Protection Plan

Identification of Potential Pollution and Destruction of Springs

Identifying potential pollution and destruction of spring water sources was carried out by observing the spring protection area, including Zone I at a radius of 10 m, Zone II at 200 m,

and Zone III at 300 m. The core zone of Way Karang Spring is in direct contact with the community's activities utilizing the spring water source in Datar Village, Muaradua Sub-district. Around the spring inundation, a barrier is built as a building that accommodates a courtyard for public bathing. Bathing and washing activities around the core zone are potential pollutants that must be addressed. Daily activities contribute to water pollution^{11,12}.

Way Karang Spring is still used as a source of consumption by residents. For this reason, residents built a special reservoir for drinking water separate from the reservoir for bathing and washing activities. However, the remaining water from bathing and washing activities is disposed of around the public bathing location, resulting in many puddles. To preserve the utilization of this spring, protection measures in this zone need to be immediately arranged^{13,14}.

Zone II, directly adjacent to the core zone, is dominated by bamboo and shrubs. Further upstream, dryland plantation crops such as coffee and rubber dominate. Land management activities in this zone must be regulated^{15,16} so as not to pollute springs and not damage infiltration areas.

Zone III, which is located in the other use areas and the Bukit Jambul Gunung Patah Protected Forest Area, has a level of land criticality that is somewhat critical and critical. This condition represents potential water source damage that must be addressed immediately. Land criticality affects the ability of land to absorb water, which in turn affects the role and function of water catchment areas. Efforts to address critical land, especially vegetatively, can be taken to protect the recharge zone of Way Karang Spring.

Spring Protection Activity Plan

The protection of springs aims to improve and enhance the quality and quantity of springs by preventing, overcoming, and restoring damage to springs and the areas around springs and spring catchment areas. Protection measures are directed at preventing the entry of potential pollutants into springs. The spring protection plan refers to the status of spring damage and the division of protection zones. Way Karang spring is classified as a spring with impaired status, so protection measures are taken as countermeasures against potential disturbances. The protection plan based on the potential for pollution in each zone is as follows.

Zone I

Land cover: dryland farming mixed with shrubs.

Land critical condition: critically.

Status of the area: other use areas.

Area: 0.05 Ha.

Pollution potential: there is a wall within a 10-meter radius, no fencing or restriction around the spring, and waste contamination from bathing and washing activities.

Protection plan: fencing and prohibition of land use in the core zone (minimum radius of 10 m); relocation of public baths out of the core zone; planting of water conservation type woods, shrubs, and grasses to increase water infiltration and spring discharge, and protect springs from potential damage; creation of adequate sanitation channels.

Zone II

Land cover: dryland farming mixed with shrubs and bushes.

Land critical condition: critically.

Status of the area: other use areas.

Area: 3.97 Ha.

Pollution potential: dryland farming and rubber plantations.

Protection plan: restriction of activities in zone II only as land for environmentally friendly agricultural and plantation activities; planting in the form of water conservation type woods, shrubs, and grasses to increase water infiltration and spring discharge and

protect springs from potential damage; socialization and action to overcome spring damage with the community.

Zone III

Land cover: dryland farming mixed with shrubs.

Land critical condition: critically.

Status of the area: other use areas and HL.

Area: 338.58 Ha and 268.09 Ha.

Pollution potential: the condition of land criticality and monoculture plantation patterns in coffee plantations can reduce the soil's ability to absorb water.

Protection plan: planting in the form of water conservation type woods, shrubs, and grasses to increase water infiltration and spring discharge and protect springs from potential damage; regulating water intake and land use for business activities: livestock, workshops, vehicle washing, swimming pools in buffer zones and spring recharge zones; development activities that have a major impact such as gas stations, highways, etc. must pay attention to the Environmental Impact Analysis.

Conclusion

Based on its damage status, Way Karang Spring is categorized as interrupted, so spring protection efforts are made to restore the quality of the spring. The level of community dependence this spring is high. However, the community has other water sources in the form of boreholes, there are only 4 units, and they are not sufficient for all residents—utilization of this water source by the community increases during the dry season. In addition, the community also utilizes Way Karang Spring for the irrigation of rice fields. The existence of Way Karang Spring needs to be preserved to fulfill the water needs of the local community. In the future, it is necessary to follow up by integrating the Way Karang Spring protection plan into the regional spatial plan to ensure its sustainability, implementing spring protection efforts by the appropriate protection plan, and monitoring water quality and quantity every year after protection efforts are implemented.

References

- 1 McFarland, A. R., Larsen, L., Yeshitela, K., Engida, A. N. & Love, N. G. Guide for using green infrastructure in urban environments for stormwater management. *Environ. Sci.: Water Res. Technol.* **5**, 643-659 (2019). <https://doi.org/10.1039/C8EW00498F>
- 2 Glendenning, C. J., van Ogtrop, F. F., Mishra, A.K. & Vervoort, R. W. Balancing watershed and local scale impacts of rainwater harvesting in India – A review. *Agricultural Water Management* **107**, 1-13 (2012). <https://doi.org/10.1016/j.agwat.2012.01.011>
- 3 PAAI. Quo Vadis, “Air Tanah untuk Tanah Air Indonesia”. Perhimpunan Ahli Air Tanah Indonesia. (Bandung, 2016).
- 4 Hendrayana, H. *Groundwater modeling*. (Universitas Gadjah Mada, 1994).
- 5 USAID. Kajian Kerentanan Mata Air (KKMA). Indonesia Urban Water, Sanitation and Hygiene, Penyehatan Lingkungan untuk Semua (IUWASH Plus). (Jakarta, 2020).
- 6 Groundwater Working Group. Matriks Penilaian Perlindungan Sumber Daya Air Tanah. (Groundwater Working Group, 2015).
- 7 Arifjaya, N M. Review Identifikasi dan Inventarisasi Sumber Mata Air. (Balai Pengelolaan DAS dan Hutan Lindung Citarum Ciliwung, 2017).
- 8 Balai Pengelolaan Daerah Aliran Sungai Musi. Laporan Identifikasi dan Inventarisasi Sumber Mata Air. (Balai Pengelolaan Daerah Aliran Sungai dan Hutan Lindung (BPDASHL) Musi, 2007).

- 9 Badan Pusat Statistik. OKU Selatan dalam Angka 2020. (Badan Pusat Statistik, 2019).
- 10 Balai Pengelolaan Daerah Aliran Sungai Musi. Data Lahan Kritis Wilayah DAS Musi Tahun 2018. (Balai Pengelolaan Daerah Aliran Sungai dan Hutan Lindung (BPDASHL) Musi, 2018).
- 11 Yang, D., Wang, F., & Zhu, S. Impacts From Human activities and Natural Background To Zn Contents In Jiaozhou Bay. *Proceedings of the 3rd International Conference on Advances in Energy and Environmental Science* (2015). <https://doi.org/10.2991/icaees-15.2015.241>
- 12 Mohd Adnan, M., Julkapli, N. & Abd Hamid, S. Review on ZnO hybrid photocatalyst: impact on photocatalytic activities of water pollutant degradation. *Reviews in Inorganic Chemistry* **36**, 77-104 (2016). <https://doi.org/10.1515/revic-2015-0015>
- 13 Hafidah, A. D., Damayanti, A. & Waryono, T. Wellspring characteristics in Rawapening watershed. *AIP Conference Proceedings - International Symposium On Current Progress In Mathematics And Sciences 2016* **1862**, 030164 (2017). <https://doi.org/10.1063/1.4991268>
- 14 Voivodic, A. Manancial De Contradições: O Conflito Entre O Morar E As Políticas De Preservação.. <https://doi.org/10.11606/d.8.2017.tde-19092017-142333>
- 15 Ryan, C.. Managing Nonpoint Source pollution In Western Washington: Landowner Learning Methods and Motivations. *Environmental Management* **6**, 1122-1130 (2008). <https://doi.org/10.1007/s00267-008-9240-1>
- 16 Gonçalves, D. & Rocha, C. Indicadores De Qualidade Da água E Padrões De Uso Da Terra Em Bacias Hidrográficas No Estado Do Paraná. *Pesq. agropec. bras.* **9**, 1172-1183 (2016). <https://doi.org/10.1590/s0100-204x2016000900017>

Author contributions

Laila Fahriati contributed to conducting this research. Aliefika Karuniati contributed to analyzing the spatial data of this research. Nisrina Salsabila contributed to translating and editing this manuscript. All authors read and approved the final manuscript.