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Research Paper

Evaluating the Quality Status and Sustainability of Anggoeya Spring in the Ecological Dimension using the Rapid Appraisal for Springs Method

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Abstract
Water quality is essential for community needs. This study uses physical, chemical, and biological parameters to evaluate the quality and sustainability of Anggoeya Spring, Kendari City. The Southeast Sulawesi Health Laboratory tests assessed compliance with water quality standards, while pollution levels were analyzed using the Pollution Index. Sustainability was examined through the RAP-SPRINGS method, focusing on ecological aspects. Results showed compliance with most standards, except for BOD, COD, and total coliform levels. Anggoeya Spring was classified as lightly polluted but ecologically sustainable. Key sensitive attributes-land cover in the catchment area, land cover within a 200 m radius, catchment area criticality, and water source utilization-highlight the need for targeted conservation and rehabilitation efforts. Therefore, prioritizing land and forest management in the catchment area and surrounding zones is crucial for sustaining Anggoeya Spring. This includes the need for improved raw water treatment, especially water treatment technology, due to the high total *coliform* content in Anggoeya spring water. This study evaluates water quality, determines pollution levels, and analyzes sustainability using the RAP-SPRINGS method. It emphasizes crucial ecological factors for conservation, advocates land rehabilitation, and highlights the necessity of improved water treatment. Ultimately, it contributes to environmental preservation and sustainable water management.

Keywords
Quality Status, Drinking Water, Sustainability, Protection of Springs, Ecological Dimensions

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1. INTRODUCTION

Water as one of the elements of natural wealth is very beneficial for human life and other creatures as a primary need in developing and maintaining life (Zulhilmi et al., 2019). The accessibility of safe water has recently begun to be threatened both in quality and quantity due to the degradation of land and forest resources (Zulfa and Aji, 2019), so springs require serious management, protection, and conservation efforts to provide water sustainably (Chiu et al., 2023). The reduction of surface water so that groundwater that comes out as springs in the mountains becomes an option for meeting water needs (Aurilia et al., 2021). However, its availability also depends on the infiltration of water into the soil which is influenced by vegetation cover factors and soil physical properties (Sari and Prijono, 2019). Good spring preservation can determine its sustainable utilization, so management with conservation measures is needed (Santoso et al., 2020).

The action in maintaining the availability of drinking water sources is to maintain raw water sources such as springs so that they do not experience changes in both quantity and quality (Faisal and Atmaja, 2019). Water scarcity in urban areas is a problem and requires attention from the government in the provision of water. One of the basic needs is clean water (Ermawati, 2022). Kendari City has several springs that have been developed and utilized by the government and community as raw water. One of them is Anggoeya Spring, which is in the Anggoeya watershed and has been utilized by PDAM Kendari City, serving Abeli, Poasia, and Kambu sub-districts (Junitriani et al., 2022). Anggoeya spring requires monitoring and evaluation that needs to be known by the community, along with the development of the population around the spring, the local community has utilized this water source for clean water needs such as washing, cooking, bathing, and as a source of drinking water (Sofyan et al., 2023). The lack of optimal conservation and management of the environment surrounding the water source play a crucial role in maintaining both the quantity and quality of water. If not managed properly, it can lead to a significant decline in water potential, posing a serious issue (Yuliani and Rahdriawan, 2014).

Regular assessment and monitoring of water quality and the environmental conditions of springs are essential to ensure their sustainability and prevent degradation, as these factors are subject to change over time (Nurrohman et al., 2019). Various elements, including rapid development and increasing settlement activities, significantly influence shifts in water quality and the surrounding environment (Habiebah and Retnaningdyah, 2014). These changes can lead to negative consequences, such as the deterioration of water quality and the overall condition of spring ecosystems (Piranti et al., 2018). The sustainability status of springs, particularly from an ecological perspective, is crucial in determining appropriate protection and management strategies (Reza et al., 2021). Effective management, regular monitoring, and supervision play a vital role in maintaining the sustainability of these water sources (Ameen, 2019). Additionally, sustainability is not only determined by water availability and utilization but also requires continuous maintenance, restoration, and protection to prevent environmental damage (Sudarmadji et al., 2016).

However, significant pollution from untreated wastewater discharge and soil erosion further threatens water resources, including springs and rivers (Astuti et al., 2024). To restore and maintain ecological balance, urgent measures are needed, including the implementation of more effective wastewater treatment systems, stricter enforcement of environmental regulations, and the adoption of sustainable watershed management practices. These efforts are essential to mitigate environmental degradation and ensure the long-term sustainability of freshwater ecosystems.

Assessing the quality status and sustainability of Anggoeya Spring using the Rapid Appraisal for Springs Method involves evaluating various ecological aspects. Springs are essential ecosystems that require thorough assessment to ensure their sustainability and ecological integrity. The Rapid Appraisal for Springs Method provides a framework for evaluating these ecosystems by considering physical, biological, and sociocultural characteristics. This approach helps identify risks and prioritize rehabilitation efforts, ensuring the long-term sustainability of springs like Anggoeya. The Springs Ecosystem Assessment Protocol (SEAP) is a fast assessment method that evaluates the condition and potential risks of springs using quantitative data and expert judgment. This method identifies ecological conditions and potential threats within a landscape, aiding in resource management prioritization (Paffett et al., 2018).

The Environmental Impact Index of Springs evaluates the ecological integrity of springs by considering factors such as vegetation absence, human and animal activities, and accessibility, all of which can affect ecosystem functions (Jung et al., 2023). Continuous monitoring of water quality and quantity is crucial for maintaining the sustainability of springs. Collaboration among scientists, stakeholders, and governmental agencies is essential for developing effective protection strategies (Katz and Currell, 2022).

The Rapid Application Development method, utilizing tools like Oracle Apex, supports the design of monitoring and conservation systems for natural springs. This approach helps identify factors contributing to ecological changes and promotes sustainable water resource management (Singgalen, 2024). Springs should be assessed within the context of basin-scale groundwater flow systems. Parameters such as elevation, temperature, and discharge rate provide insights into the hydrogeologic processes affecting springs, supporting sustainable water resource management (Tóth et al., 2022). This study aimed to assess the water quality status and sustainability of Anggoeya Spring in Kendari City, Southeast Sulawesi. The research is valuable in evaluating the water quality of Anggoeya Spring, which is managed by PDAM Kendari City. Additionally, it helps determine the sustainability status of spring management from an ecological perspective using MDS and Leverage analysis. This approach allows for identifying the level of management sustainability and the key influencing factors that contribute to effective spring conservation.

2. EXPERIMENTAL SECTION

2.1 Location

This research was conducted at Anggoeya Spring at coordinates 4°01'34.0" South latitude and 122°56'88.0" East longitude, in Anggoeya Village, Abeli Sub-district, Kendari City, Southeast Sulawesi Province (Figure 1). This research is survey research conducted from May to June 2022

2.2 Methods

This research utilizes two main approaches: assessing the water quality status and evaluating the sustainability of Anggoeya Spring's management and protection. The water quality status is determined by calculating the water pollution index, based on Government Regulation No. 22 of 2021, which sets Class I water quality standards for drinking water, in line with the Implementation of Environmental Protection and Management. Furthermore, it adheres to Minister of Health Regulation No. 2 of 2023, which serves as the implementation guideline for Government Regulation No. 66 of 2014 on Environmental Health. Several parameters were used to assess the water quality index by collecting water samples from the Anggoeya Spring source point. These samples were then analyzed in a laboratory to measure physical, chemical, and microbiological parameters, with results expressed according to the tested/measured parameters, as shown in Table 1.

Sample examination and analysis were conducted at the UPTD Health Laboratory Center of Southeast Sulawesi Province. The instruments and analytical methods utilized for testing each water quality parameter are detailed in Table 1. The water samples were tested based on five

Table 1. Parameters, Units and Quality Standards Based on PP No. 22 / Year 2021

Parameters	Unit	Threshold	Tools and Methods of Analysis
Physical			
Temperature	°C	Dev3	IKM/II/01/BLK-KDI/ (SNI06-6989.23-2005)
Smell	-	-	Organoleptics
Taste	-	-	Organoleptics
Color	Pt-Co-Unit	15	Visual Comparison
Turbidity	NTU	40	IKM/II/01/BLK-KDI/ (SNI06-6989.25-2005)
Total Dissolved Solids (TDS)	mgL^{-1}	1,000	Gravimetry
Chemistry			
pH	-	06-Sep	IKM/II/01/BLK-KDI/ (SNI06-6989.11-2004)
Ammonia (NH_3)	mgL^{-1}	0.1	Spectrophotometries
Chloride (Cl)	mgL^{-1}	250	Argentometry
Nitrate (NO_3)	mgL^{-1}	10	Spectrophotometries
Nitrite (NO_2)	mgL^{-1}	1	Spectrophotometries
Hardness (as $CaCO_3$)	mgL^{-1}	500	Spectrophotometries
Sulfate (SO_4)	mgL^{-1}	300	Spectrophotometries
Iron (Fe)	mgL^{-1}	0.3	Spectrophotometries
Fluoride (F)	mgL^{-1}	1.5	Spectrophotometries
MBAS Detergent	mgL^{-1}	0.05	Spectrophotometries
Mercury (Hg)	mgL^{-1}	0.001	AAS
Arsenic (As)	mgL^{-1}	0.01	AAS
Chromium VI (Cr^{6+})	mgL^{-1}	0.05	Spectrophotometries
Cyanide	mgL^{-1}	0.1	Spectrophotometries
Selenium (Se)	mgL^{-1}	0.01	AAS
Cadmium (Cd)	mgL^{-1}	0.003	AAS
Manganese (Mn)	mgL^{-1}	0.5	AAS
Zinc (Zn)	mgL^{-1}	3	AAS
Lead (Pb)	mgL^{-1}	0.05	AAS
BOD	mgL^{-1}	2	BOD meter
COD	mgL^{-1}	10	Spectrophotometries
Microbiology			
Total Coliform	MPN (100 mL^{-1})	50	Double Tube
Escherichia coli	MPN (100 mL^{-1})	100	Identification

parameters: physical characteristics, inorganic chemistry, organic chemistry, dissolved metals, and microbiology, with units expressed according to the measured parameters. The obtained test results were then compared against the Class I (Drinking Water Designation) river water quality standards, as outlined in Government Regulation of the Republic of Indonesia No. 22 of 2021 regarding environmental protection and management. Additionally, the evaluation was aligned with Minister of Health Regulation No. 32 of 2017, which sets environmental health quality standards and water health requirements for sanitation, swimming pools, solus per aqua, and public baths.

The measurement data were compiled using Microsoft Excel 2010 and analyzed through the Pollution Index method, as stipulated in KepMen LH No. 115 of 2003 concerning Guidelines for Determining Water Quality Status. The pollution index criteria are determined using the following equation:

$$PIj = \sqrt{\frac{(\frac{Cij}{Lij})^2_M + (\frac{Cij}{Lij})^2_R}{2}}$$

Where, PIj is the pollution index, Ci is the analyzed water quality concentration, Lij is the water quality standard concentration, (Ci/Lij) M is the maximum value of Ci/Lij, and (Ci/Lij) R is the average value of Ci/Lij. The value evaluation is as follows: 1). If $0 \leq PIj \leq 1.0$, it means that it meets the quality standard or the water quality is good, 2). If $1.0 < PIj \leq 5.0$ means lightly polluted, 3). $5.0 < PIj \leq 10$ means moderately polluted, and 4). $PIj > 10$ means heavily polluted (Nur Annisa et al., 2022). If there is a parameter that has a comparison result between the measurement value in the field (Ci) and the quality standard value (Li), $(Ci/Li) > 1.0$, then a new comparison value is used, with equation the $Ci/Li = 1.0 + 5$ log (value Ci/Li early).

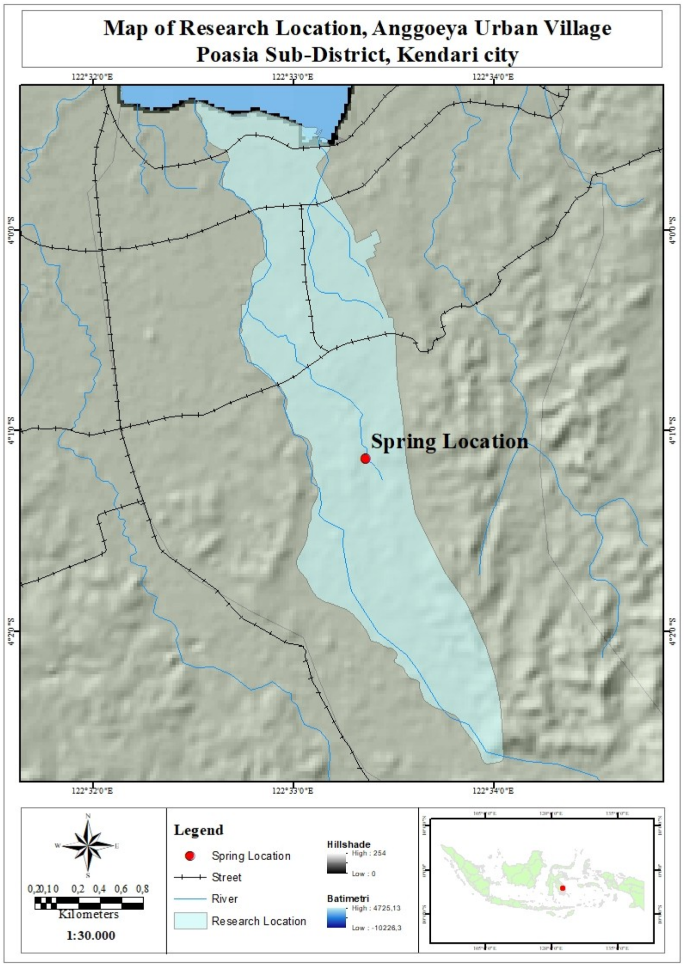

Figure 1. Maps Showing the Location (Red Square) of Research

The determination of the sustainability index for the ecological dimension of Anggoeya spring was carried out using the RAP-SPRINGS (Rapid Appraisal for Springs) method, a modification of the RAP-FISH (Rapid Appraisal for Fisheries) method. The use of attributes and indicators in the scoring process is the basis for modifying the model. The basis for the formulation of the attributes and indicators in RAP-SPRINGS is through literature studies and the conditions for sustainable management and protection of springs. Therefore, the attributes and indicators used can describe the sustainability of the protection of the Anggoeya spring area in the ecological dimension. There are three main stages in the method, namely the formulation of attributes and indicators, data collection, scoring process and data analysis with the RAP-FISH application that is added in MS. Excel (Pitcher and Preikshot, 2001; Kavanagh and Pitcher, 2004; Pitcher et al., 2013).

The formulation of attributes and indicators was based on a literature review. The attributes and indicators were adapted to the assessment criteria for sustainable spring protection according to the spring assessment criteria issued by the Sampara Watershed Management Center, 2007 Report on "Inventory, Identification and Design of Spring Rehabilitation Techniques". Eight attributes were developed in this study. These attributes are described in several indicators as the basis for developing questionnaires and questionnaires and determining the score for each indicator as shown in Table 2.

The compiled attributes and indicators were then translated into questionnaires and interview questionnaires as a guide for data collection. Primary data was obtained from direct observation (observation), interviews and questionnaires, and analysis of water samples. Respondents in primary data collection through questionnaires and interviews were selected using purposive random sampling technique with a total of 30 respondents, because with the number of respondents the information obtained was saturated. The respondents were divided into two categories, namely expert respondents and lay respondents. Expert respondents in this study were the manager of PDAM Anggoeya, Anggoeya Village Government, Karang Taruna. Meanwhile, lay respondents are from the surrounding community.

The scoring process involves converting primary and secondary data into a Likert scale ranging from 1 to 4, based on the indicators of each attribute. The scale is defined as follows: 1 = poor, 2 = not good, 3 = fairly good, and 4 = good. The average Likert scale score is then analyzed using the RAPFISH application, which functions as an add-in within Microsoft Excel.

Data analysis in the RAPFISH application is conducted using the Multi-Dimensional Scaling (MDS) method. The MDS analysis generates a graph and a sustainability index based on the results of the MDS ordinance, along with the coefficient of determination (R^2) and stress values. The R^2 and stress values serve as validation indicators of the model. A confidence level is considered acceptable if $R^2 > 50\%$, where a higher value approaching 100% indicates a more accurate model. Similarly, the stress value should be less than 0.20 (20%), as a lower stress value signifies a better MDS model, and vice versa.

The sustainability index value in the MDS model estimation falls within a range of 0–100% and is classified into four sustainability status categories, namely, 1). Unsustainable (0-25%), 2). Less sustainable (25.01 - 50.00%), 3). Moderately sustainable (50.01 - 75.00%) and 4). Sustainable (75.01 - 100%) (Pitcher and Preikshot, 2001; Fauzi and Anna, 2005). In addition to the results of the MDS analysis producing a sustainability index, it also produces Monte Carlo ordinance and sensitivity values. The Monte Carlo simulation results were used to determine the random error of the dimensions. A comparison of Monte Carlo simulation results with MDS analysis obtained a 95% confidence degree with a difference of about 5%. This means that the MDS results are relatively good to apply. Sensitivity analysis was conducted to determine the attributes that dominantly

Table 2. Attributes and Indicators and Scores Used in the Rap-Springs Method

Attributes and Indicators	Score
Spring condition	
a. Flow water throughout the year with constant flow	4
b. Water flows throughout the year with a non-constant discharge	3
c. Drains water during the rainy season only	2
d. Does not drain water/dry	1
Land cover condition at 200 meters radius	
a. Forested (has plant strata with heterogeneous plant species)	4
b. Dense perennial crops (heterogeneous/homogenous crop types with density above 300 trees/ha)	3
c. Sparse perennial crops (heterogeneous/homogenous crop types with plant density below 300 trees/ha)	2
d. Annual crops/empty land (land covered with annual crops or vacant land)	1
Land cover condition in the catchment area	
a. Forested (has a stratum of plant species heterogeneous)	4
b. Dense perennial crops (heterogeneous/homogenous crop types with plant density above 300 trees/ha)	3
c. Sparse perennial plants (heterogeneous/homogenous plant species with plant density below 300 trees/ha)	2
d. Annual crops/empty land (land covered with annual crops or vacant land)	1
Spring performance	
a. Good (if the flowing water discharge is greater than the amount of water demand)	4
b. Somewhat good (if the flowing water is equal to the amount of water needed)	3
c. Somewhat poor (if the flowing water is less than the amount of demand water)	2
d. Poor (if water discharge does not meet water needs)	1
Criticality level of 200 meters radius	
a. Class I and II (good and naturally normal)	4
b. Classes III and IV (beginning critical and moderately critical)	3
c. Class V (critical)	2
d. Class VI (highly critical)	1
Level of criticality of the catchment area	
a. Class I and II (good and naturally normal)	4
b. Classes III and IV (beginning critical and moderately critical)	3
c. Class V (critical)	2
d. Class VI (highly critical)	1
Utilization of spring water sources	
a. Utilized for household purposes	4
b. Utilized for household and agricultural purposes	3
c. Utilized for agriculture only	2
d. Not utilized	1
Community dependence on water sources	
a. The community is highly dependent on spring water	4
b. The community is quite dependent on spring water	3
c. The community is less dependent on springs (there are other sources)	2
d. The community is not dependent at all	1

influence changes in the sustainability of management and protection of Anggoeya Spring. Leverage attributes that require special attention are those with the highest Root Mean Square (RMS) value or those that exceed the average RMS value (Kavanagh and Pitcher, 2004).

3. RESULTS AND DISCUSSION

3.1 Water Quality Status of Anggoeya Spring

Water quality status is determined by physical, chemical and biological parameters that are adjusted to quality standards based on PP. No. 22/ Year 2021. The results of the analysis based on physical, chemical and biological parameters show that all parameters are generally in accordance with the quality standards, except for the BOD parameter with a value of 2.1 mgL^{-1}, COD with a value of 22.30 mgL^{-1} and total coliform with a value of 390 CFU (100 ml^{-1}) as presented in Table 3.

Water quality is determined by the condition of physical, chemical and biological parameters in the scale of environmental quality standards required by applicable regulations, with the aim of testing the quality of drinking water (Junitriani et al., 2022). Physical parameters of water that are important in determining water quality in springs are water temperature, taste, color odor, TSS and TDS (Manune et al., 2019). Water temperature in Anggoeya Spring is low and still in accordance with the required quality standards. The large number of trees around the spring is the cause of the low water temperature. Tree canopy density has a significant effect on sunlight intensity and air temperature, which also affects water temperature (Riyanti et al., 2021). Drinking water is good for consumption if it meets the requirements of odorless, turbid and colorless (Morintoh et al., 2015). The turbidity level of a water body is influenced by the presence of fine sand particles, organic silt, and microorganisms, which result from erosion and are transported into the water (Rinawati et al., 2016). An increase in turbidity occurs when the concentration of suspended particles or dissolved organic matter in the water is high. Consequently, the total dissolved solids (TDS) value has a positive correlation with water turbidity (Kifly et al., 2021). Similarly, the TDS parameter is determined by pollution from community activities that wash in water bodies using soap and other inorganic materials (Rinawati et al., 2016). TDS parameter values in Anggoeya Spring were normal and did not exceed the quality standard. Therefore, all physical parameters in Anggoeya Spring meet the quality requirements for the provision of drinking water that is good enough and hygienic for domestic use.

Chemical parameters in Anggoeya Spring such as pH, ammonia, chloride, nitrate, nitrite, hardness, sulfate, electrical conductivity (DHL), iron, fluoride, mercury, arsenic, chromium, cyanide, selenium, cadmium, manganese, zinc, lead, DO and detergent each showed acceptable values or met the quality standards for drinking water needs in class I water classification (Government Regulation No. 22 of 2021). However, the laboratory test results for the parameters The levels of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) have surpassed the established quality standards for Class I water classification.

The increase in BOD and COD values in Anggoeya Spring is attributed to the high organic matter content, which originates from agricultural and residential activities, including the use of fertilizers and waste from both sectors. As a result, elevated BOD levels are positively correlated with higher COD levels in water (Nurrohman et al., 2019). One of the main contributors to rising COD levels is wastewater from domestic and industrial activities (Aini and Juwitaningtyas, 2021).

A higher BOD value indicates a decline in water quality, as it signifies an increased demand for dissolved oxygen (DO) by decomposing microbes during the breakdown of organic matter (Alfatihah et al., 2022). In the case of Anggoeya Spring, the measured BOD value was 2.1 mg/L, slightly exceeding the quality standard of 2.0 mg/L. The relatively low BOD level contributes to a higher DO concentration, which is essential for aquatic microbes to facilitate respiration in their metabolic processes, enabling growth and reproduction (Sinaga et al., 2016). A higher DO value suggests better water quality, whereas a low DO value indicates severe pollution (Ramadhan et al., 2023).

The biological parameter that determines the quality of Anggoeya Spring water is Total Coliform, which is above the required quality standard value. The increased total Coliform value is thought to come from animal feces and mud due to the decomposition of the remains of leaves that fall in the spring (Aurilia et al., 2021). Water that has a high total Coliform cannot be consumed directly but must be cooked first and then consumed so that the bacteria in the water dies. According to Gafur et al. (2017), if the drinking water consumed has *Escherichia coli* exceeding the value of the established quality standard, it will cause diseases such as diarrhea, but the *Escherichia coli* parameter has a value of 0 or not detected, which means that Anggoeya Spring water does not contain *Escherichia coli*. Therefore, the biological quality of Anggoeya Spring water meets the drinking water quality requirements.

3.2 Pollution Index

The results of water quality tests to ensure that water quality is polluted with pollutants, carried out by analyzing the pollution index which shows a PI value of 1.96 which is in the range of $1.0 < PIj \leq 5.0$, which means Anggoeya Spring is lightly polluted. Carried out by analyzing the pollution index which shows a PI value of 1.96 which is in the range of $1.0 < PIj \leq 5.0$, which means Anggoeya Spring is lightly polluted. The analysis results assessing the water quality status of Anggoeya Spring using the pollution index method are summarized in Table 4.

Based on Table 4, the analysis using the pollution index method, referring to the quality standards set in Government Regulation (PP) No. 22 of 2021, resulted in a pollution index (IP) value of 3.18, categorizing the water quality of Anggoeya Spring as "lightly polluted." Likewise, when applying the pollution index method using the quality standards from PP No. 22 of 2021 Appendix VI (National Water Quality Standards for Class II), an IP value of 1.96 was obtained, which also classifies the spring in the "lightly polluted" category.

This condition is mainly attributed to high levels of BOD, COD, and Total Coliform, which exceed the specified quality standards. The contamination is suspected to originate from decomposed leaves, sediment, and fecal matter entering the spring. Lightly polluted water, when

Table 3. Results of Analysis of Physical, Chemical and Microbiological Parameters

Parameters	Unit	Threshold	Analysis Result	Classification
Physical				
Temperature	°C	Dev3	26	As per quality standards
Smell	-	-	No odor	As per quality standards
Taste	-	-	Tasteless	As per quality standards
Color	Pt-Co-Unit	15	5	As per quality standards
Turbidity	NTU	40	13.9	As per quality standards
Total Dissolved Solids (TDS)	mgL^{-1}	1,000	360	As per quality standards
Chemistry				
pH	-	06-Sep	6.38	As per quality standards
Ammonia (NH_3)	mgL^{-1}	0.1	¡0.02	As per quality standards
Chloride (Cl)	mgL^{-1}	300	6.45	As per quality standards
Nitrate (NO_3)	mgL^{-1}	10	3.1	As per quality standards
Nitrite (NO_2)	mgL^{-1}	0.06	0.02	As per quality standards
Hardness ($CaCO_3$)	mgL^{-1}	500	181.6	As per quality standards
Sulfate (SO_4)	mgL^{-1}	300	<0.71	As per quality standards
Iron (Fe)	mgL^{-1}	0.3	<0.1	As per quality standards
Fluoride (F)	mgL^{-1}	1.5	0.12	As per quality standards
MBAS Detergent	mgL^{-1}	0.05	0.12	As per quality standards
Mercury (Hg)	mgL^{-1}	0.001	0.0003	As per quality standards
Arsenic (As)	mgL^{-1}	0.05	0.0135	As per quality standards
Chromium(VI) (Cr^{6+})	mgL^{-1}	0.05	0.0047	As per quality standards
Cyanide	mgL^{-1}	0.02	0.0035	As per quality standards
Selenium (Se)	mgL^{-1}	0.01	0.0007	As per quality standards
Cadmium (Cd)	mgL^{-1}	0.01	0.0018	As per quality standards
Manganese (Mn)	mgL^{-1}	0.1	0.041	As per quality standards
Zinc (Zn)	mgL^{-1}	0.05	0.0399	As per quality standards
Lead (Pb)	mgL^{-1}	0.03	0.0005	As per quality standards
BOD	mgL^{-1}	2	2.1	As per quality standards
COD	mgL^{-1}	10	22.3	As per quality standards
DO	mgL^{-1}	6	7.8	As per quality standards
Microbiology				
Total Coliform	CFU (100 ml^{-1})	1,000	390	As per quality standards
Escherichia coli	CFU (100 mL^{-1})	0	0	As per quality standards

Source: primary data (2022)

used for drinking, can pose health risks. Additionally, the pollution index value increases as more parameters surpass the quality standard. Changes in water quality status from low to high pollution are influenced not only by the number of parameters exceeding the standard but also by various other contributing factors.These include land use changes on the land around the spring, household activities carried out by humans around the spring, and agricultural waste such as the use of fertilizers and pesticides (Yuniarti and Biyatmoko, 2019).

3.3 Sustainability Status of Anggoeya Spring (Sustainability Index and Leverage Attributes in the Ecological Dimension)

The results of the RAP-SPRINGS analysis are illustrated in Figure 2. The graph shows that the sustainability index of Anggoeya Spring protection for the ecological dimension is 75.62, which is sustainable. Reza et al. (2021) reported that the results of the analysis using RAP-WARES showed that the level of sustainability of Senjoyo spring management in the ecological dimension was 54.78, which is quite sustainable. This illustrates that the ecological dimension is important in the management and protection of springs. The coefficient of determination (R^2) has a value of 95.15% (>90%) in the Nonmetric Multidimensional Scaling (NMDS) analysis, confirming the accuracy of the model. While the

Table 4. Analysis Results of Anggoeya Spring's Water Quality Status Based on the Pollution Index Method

Parameter	Unit	Threshold (Li)	Analysis Result (Ci)	Ci/Li
Temperature	°C	Dev 3	26	-
Total Dissolved Solids (TDS)	mgL^{-1}	1,000	360	0.36
Sulfate (SO_4)	mgL^{-1}	300	0.71	0.0024
pH	-	06-Sep	6.38	0.35
Ammonia (NH_3)	mgL^{-1}	0.1	0.02	0.2
Chloride (Cl)	mgL^{-1}	300	6.45	0.02
Nitrate (NO_3) as N	mgL^{-1}	10	3.1	0.31
Nitrite (NO_2) as N	mgL^{-1}	0.06	0.02	0.33
Iron (Fe)	mgL^{-1}	0.3	0.1	0.33
Fluoride (F)	mgL^{-1}	1.5	0.12	0.08
MBAS Detergent	mgL^{-1}	0.05	0.12	2.4
Mercury (Hg)	mgL^{-1}	0.001	0.0003	0.3
Arsenic (As)	mgL^{-1}	0.05	0.0135	0.27
Chromium VI ($^{Cr6+}$)	mgL^{-1}	0.05	0.0047	0.09
Cyanide	mgL^{-1}	0.02	0.0035	0.18
Selenium (Se)	mgL^{-1}	0.01	0.0007	0.07
Cadmium (Cd)	mgL^{-1}	0.01	0.0018	0.18
Manganese (Mn)	mgL^{-1}	0.1	0.041	0.41
Zinc (Zn)	mgL^{-1}	0.05	0.0399	0.8
Lead (Pb)	mgL^{-1}	0.03	0.0005	0.02
BOD	mgL^{-1}	2	2.1	1.05
COD	mgL^{-1}	10	22.3	2.23
DO	mgL^{-1}	6	7.8	1.3
Total Coliform	CFU (100 mL^{-1})	1,000	390	0.39
Category				Value
Total Ci/Li				10.32
$(Ci/Li\ Max)^2$				7.32
$(Ci/Li\ Average)^2$				0.2
Pollution Index				1.96 (Lightly Polluted)

Source: primary data (2022)

stress (S) value is 13.56% (<25%), it indicates the goodness and suitability of the multidimensional model in the ecological dimension of sustainable analysis. The maximum stress value in the Rapfish model accuracy evaluation is acceptable is 25% (Fauzi and Anna, 2005).

The sustainability status of Anggoeya spring management and maintenance in the ecological dimension is determined by the influence of the attributes of community dependence on the spring, spring utilization, catchment area criticality, spring performance, land cover in the catchment area and land cover at a 200 m radius. In the leverage analysis based on Root Mean Square (RMS) changes to determine the level of sensitivity of the ecological dimension criteria that have the most dominant and significant influence on the sustainability of Anggoeya Springs are the attributes of land cover in the catchment area (RMS change of 7.09%), land cover at 200 m radius (RMS change of 7.58%), level of criticality of the catchment area (RMS change of 4.01) and utilization of springs (RMS change of 3.86).

Both attributes are very sensitive to determining the sustainability status of Anggoeya Spring in the ecological dimension. Field observations showed that the land cover at a radius of 200 meters still contained forest vegetation and annual crops owned by the community with a sparse density. Meanwhile, the land cover in the catchment area no longer has forests but is a mixed garden with a mixture of annual vegetation such as coffee, breadfruit, candlenut and coconut as well as annual plants. Settlement conditions do not yet have dense housing so that the vegetation cover of community plants still has a function to maintain the sustainability of Anggoeya Spring. However, despite its sustainable status, it is necessary to pay attention to land cover attributes in the catchment area and land cover at a radius of 200 m in the management and protection of springs (Arsana et al., 2022).

3.4 Sustainability Status of Anggoeya Spring

Sustainability index and leverage attributes in the ecological dimension The results of the RAP-SPRINGS analysis showed the sustainability index of Anggoeya Spring protection for the ecological dimension, determined by an MDS ordination value of 75.62%, within the range of values (75.01 - 100%) which means sustainable status. The analysis of the sustainability of Anggoeya Spring maintenance based on the ecological dimension using the RAP-SPRINGS method is illustrated in Figure 2.

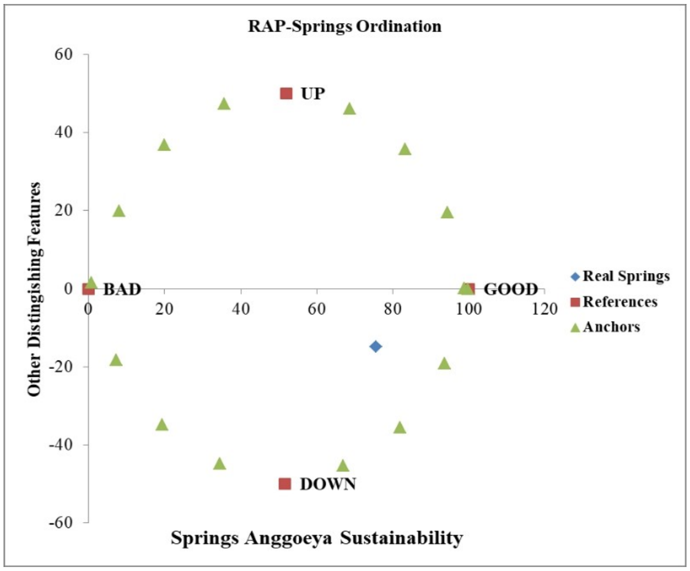

Figure 2. MDS Ordination Results of Sustainability Index of Anggoeya Spring Protection

The results of the RAP-SPRINGS analysis are illustrated in Figure 2. The graph shows that the sustainability index of Anggoeya Spring protection for the ecological dimension is 75.62, which is sustainable. Reza et al. (2021) stated that the analysis results using the RAP-WARES method indicated that the sustainability level of Senjoyo Spring management in the ecological dimension reached 54.78, categorizing it as moderately sustainable. This finding highlights the significance of the ecological dimension in the effective management and conservation of springs. The coefficient of determination (R^2) was recorded at 95.15%, indicating a high level of model accuracy (>90%) in the Nonmetric Multidimensional Scaling (NMDS) analysis, confirming the accuracy of the model. While the stress (S) value is 13.56% (<25%), it indicates the goodness and suitability of the multidimensional model in the ecological dimension of sustainable analysis. The maximum stress value in the Rapfish model accuracy evaluation is acceptable is 25% (Fauzi and Anna, 2005).

The sustainability status of Anggoeya Spring's management and conservation in the ecological dimension is influenced by several key attributes, including community dependence on the spring, its utilization, the level of criticality in the catchment area, spring performance, as well as land cover both within the catchment area and within a 200 m radius. Through leverage analysis using Root Mean Square (RMS) changes, the sensitivity level of ecological dimension criteria was assessed. The findings indicate that among these attributes, land cover in the catchment area has the most dominant and significant impact on the sustainability of Anggoeya Spring (RMS change of 7.09%), land cover at 200 m radius (RMS change of 7.58%), level of criticality of the catchment area (RMS change of 4.01) and utilization of springs (RMS change of 3.86). Both attributes are very sensitive to determining the sustainability status of Anggoeya Spring in the ecological dimension. Field observations showed that the land cover at a radius of 200 meters still contained forest vegetation and annual crops owned by the community with a sparse density. Meanwhile, the land cover in the catchment area no longer has forests but is a mixture of annual vegetation such as coffee, breadfruit, candlenut, and coconut as well as annual plants. Settlement conditions do not yet have dense housing so the vegetation cover of community plants still has a function to maintain the sustainability of Anggoeya Spring. However, despite its sustainable status, it is necessary to pay attention to land cover attributes in the catchment area and land cover at a radius of 200 m in the management and protection of springs (Arsana et al., 2022).

3.5 Validation Test for the Accuracy of the Model Used

To determine the accuracy of the sustainability model for the management and protection of Anggoeya Spring, a statistical analysis was conducted, namely R^2 with a value of 0.95 and a stress value (S) of 0.14 as shown in Table 5 below.

Table 5. Statistical Values of Rap-Springs Analysis Results on the Ecological Dimension

Statistical Indicator	Statistical Value	Percentage (%)
R^2	0.95	95.15
Stress (S)	0.1356	13.56

The Monte Carlo analysis results show an average value of 74.31. This value has a relatively small difference with the MDS value of 1.31 (still below the 5% value) and shows that the ordinance results are clustered around the MDS value.

The validation test refers to the results of MDS and Monte Carlo analysis in the RAP-Springs model, to assess the effect of errors in the scoring process on attributes due to limited information, errors in scoring by respondents, the data analysis process carried out repeatedly is relatively stable and data input errors and data loss can be avoided (Reza et al., 2021). The results of the small difference between the MDS and Monte Carlo ordinance values indicate that:1) errors in the analysis process, especially the assessment of attributes, can be minimized or avoided; 2). variations in multidimensional assessments due to differences in opinion are relatively small; 3). the data analysis process carried out repeatedly is relatively stable; 4). data input errors and data loss can be avoided (Kahirun et al., 2023; Reza et al., 2021). Several attributes that determine the sustainability of Anggoeya Spring maintenance were analyzed using leverage based on Root Mean Square (RMS) changes. The results of the leverage analysis in graphical form are presented in Figure 3.

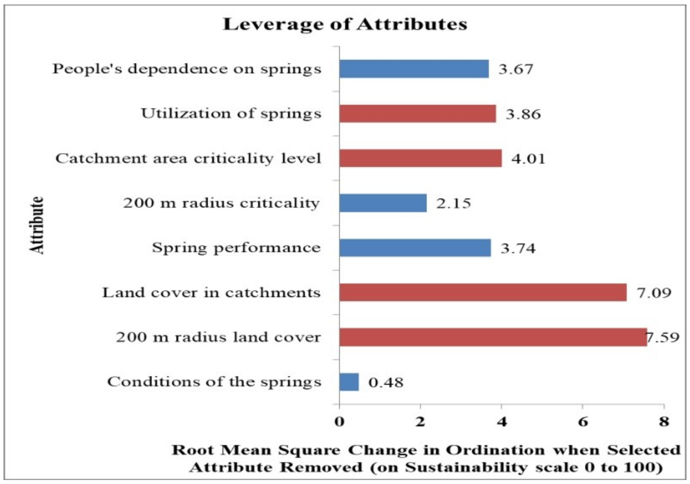

Figure 3. Leverage Graph of Sensitive Attributes in the Sustainability Index of Anggoeya Spring Protection

Validation test for the accuracy of the model used by using Monte Carlo analysis with 25 iterations at 95% confidence interval. The Monte Carlo values can also be seen in the graph (Figure 4).

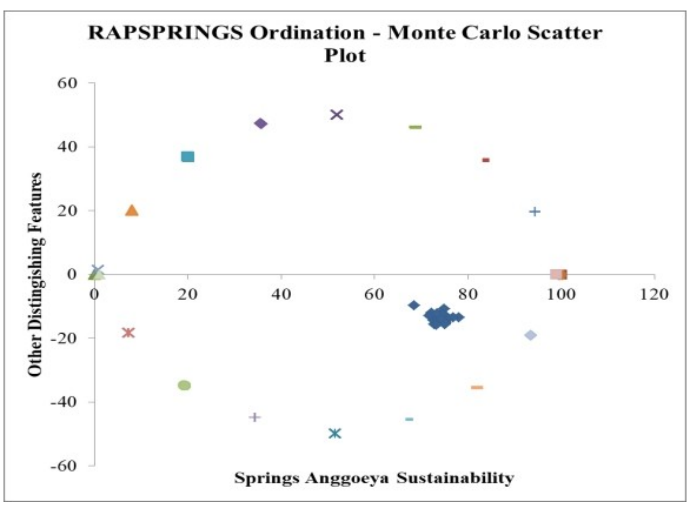

Figure 4. Monte Carlo Analysis of the Sustainability Analysis of Anggoeya Spring Protection

3.6 Management and Protection Strategy for Anggoeya Spring

adequate water infiltration into the ground, which serves as a crucial source for the spring. Anggoeya Spring is located in Anggoeya Village, within the protected area of Poasia Sub-district, Kendari City, Southeast Sulawesi Province. It plays an important role as a water source for the surrounding community but is currently facing water quality challenges due to pollution. Based on the results of the pollution index analysis, the water in Anggoeya Spring is categorized as lightly polluted. The main cause of this pollution is the entry of pollutants from animal waste and weathering of plant leaves carried by surface flow into the spring. If not addressed immediately, this pollution could increase and threaten the availability of clean water in the area.

To protect and maintain water quality, comprehensive conservation measures are needed. One of the main measures is the construction of a safety wall around the spring to prevent surface runoff and erosion from carrying sediments and pollutants into the water source. In addition, strict regulations prohibiting washing and bathing activities at the spring site are needed to avoid further contamination from human waste and detergent soap residues that can damage water quality.

The results of the analysis of the sustainability of Anggoeya Spring management indicate that the main factor affecting the sustainability of the spring is the land cover in the catchment area, especially within 200 meters of the spring. The rapid expansion of settlements around this area increases the risk of critical land, which results in reduced water infiltration into the soil and decreased spring discharge. Therefore, efforts to conserve land cover are crucial to maintaining the balance of the spring ecosystem.

In a broader context, the carrying capacity of watersheds in terms of water management criteria is also a highly dynamic aspect that must be monitored on an ongoing basis (Kahirun et al., 2023). Factors such as land use change, population increase and the intensity of human activities around the watershed can affect water quality and availability. Therefore, an integrated management approach that includes spring conservation, land cover protection and strict regulation of potentially polluting activities is necessary to ensure the sustainability of water resources in the region.

4. CONCLUSIONS

Based on PP No. 22 of 2021 using the Pollution Index method, Anggoeya Spring falls into the lightly polluted category with a value of 1.95–1.96. This is due to elevated levels of BOD, COD, and Total Coliform, indicating organic pollution rather than heavy metals, making it easier to manage. Despite being classified as sustainable, Anggoeya Spring requires continuous efforts to maintain its condition, especially by preserving land cover in the catchment area and within a 200-meter radius. As it is in a densely populated area, its sustainability is at risk, making protection and rehabilitation a high priority. Additionally, improving raw water treatment and implementing appropriate technology are essential to address high BOD and COD levels effectively.

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