

Estimation of Groundwater River Availability in Leang Lonrong Cave Using ARIMA Model and Econophysics Valuation Approach

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Abstract

This quantitative descriptive study uses the ARIMA model approach to predict groundwater river water availability. It assesses its valuation with an econophysics orientation in the Leang Lonrong Cave area of TN Bantimurung Bulusaraung. Secondary data from 2010-2023, including Water Discharge and Water Level data from the River Basin Center of Pompengan Jeneberang (BBWS) and primary data on the Valuation of Willingness to Pay, were utilized. The analysis reveals that water discharge predictions (2024-2030) in the Gua Leang Lonrong area indicate consistent annual water availability, with the highest discharge projected in December 2030 (5.08 m³/s) and the lowest in September 2024 (1.12 m³/s). Valuation of utilizing Leang Lonrong River water through willingness to pay showed residents willing to pay Rp 42,142.85/month for clean water management. At the same time, visitors are willing to contribute Rp 21,596.77/visit to enhance water quality management. Elasticity analysis modeling water discharge with willingness to pay suggests a relatively elastic relationship, with a minor impact, indicating unresponsiveness to changes in water discharge percentages. Statistical and economic methods were employed to analyze daily water discharge patterns and evaluate residents' willingness to pay for underground river water utilization. The ARIMA model (0,1,1) forecasted future water discharge patterns with a mean absolute percentage error (MAPE) of 33.7%. The study surveyed 62 respondents, finding an average willingness to pay approximately IDR 21,596.77 per visit to maintain Leang Lonrong River water quality management.

Keywords: ARIMA, Leang Lonrong Cave, Water Discharge, WTP

Introduction

Karst mountains are found throughout the Indonesian archipelago, with an area of approximately 15.4 million hectares. Karst areas are often important water sources, including underground rivers, which strategically meet human water needs and local ecosystems (Sari et al., 2019). The Maros-Pangkep Bantimurung Bulusaraung Karst area has a high limestone (CaCO₃) content and is spread throughout the region (Soma et al., 2021). The epikarst and endokarst characteristics of this region indicate its richness. The presence of subsurface water

discharge characterized by the presence of caves is known as spring density (Noperissa & Waspodo, 2018).

The underground river inside the Leang Lonrong cave flows through the mouth of the cave and has a stable water discharge throughout the year (Hayati, 2019). The availability of underground river water in Leang Lonrong Cave is the focus of research because of the importance of access to sustainable and good quality water sources for the local community and the sustainability of the karst ecosystem in Babul National Park. Estimating the availability of underground river water is an important step in sustainable water resource management (Agniy et al., 2017).

River flow discharge is one of the hydrological parameters that is very important for water resources management. Data and forecasting of river flow discharge is very important for the future, assuming the characteristics of the process remain the same. Because it is impossible for a river to have discharge population data that includes discharge data from start to finish. The processed discharge data is a periodic series, which is long-term data whose value shows movement over a long period of time and has an upward and downward tendency (Mayasari, D. 2017).

Autoregressive Integrated Moving Average (ARIMA) is a method introduced in 1970 by Box and Jenkins. ARIMA is a data analysis method that looks at past patterns and then creates a forecasting model (Nurissaidah et al., 2018). Time series forecasting analysis will be used to forecast this water availability. This forecasting is based on past data behavior, where the amount of data taken over several periods is used as a basis for making forecasts for future periods. Therefore, this analysis requires a large amount of information or data collected over a relatively long period of time. Autoregressive Integrated Moving Average (ARIMA), also known as Box-Jenkins, is a technique often used to perform time series forecasting analysis (Mboso, 2022).

The purpose of ARIMA is to generate time series processes (data) in which each event correlates with each other. Time series analysis is a statistical technique used to find data patterns in the past and use them to forecast future data patterns. The statistical software used for data processing in this study is Eviews software (econometrics views). As for the application of this water discharge, it can be analyzed with a partial differential equation model with different methods to provide insight into decision-making related to water resources management in the karst area, precisely in the Leang Lonrong Cave Area (Rifandi & Abdy, 2023). Water resources management of the community generally needs water to meet their daily needs, not only for domestic needs but also for the needs of the agricultural industry and animal husbandry. However, in karst areas, there is a limit on the amount of clean water that can be used to meet the needs of the population, and unstable water availability throughout the year is part of the problem.

To achieve this, the valuation of Leang Lonrong River water utilization for water availability involves the application of economic principles in analyzing the use, allocation,

and management of water resources. This can involve a study of the willingness to pay and the ability of the community to pay for water supply services to maintain and improve the water quality of the Leang Lonrong River by analyzing the preferences and payment desires of residents and tourist visitors by estimating the economic value they provide to the Leang Lonrong River water (Matondang & Suseno, 2020). There are several approaches that integrate economic principles with physics in order to understand and explain economic systems holistically. In this context, econophysical approaches are used to identify and model complex interactions between economic and physical variables that affect the availability of underground river water in karst caves (Ali, 2017).

The literature review underscores the significance of this topic by underscoring the importance of comprehending water discharge trends and the willingness to pay for water usage within environmental economic evaluations. For instance, (Hossain et al., 2022) stress the influence of precipitation on underground river water flow, while (Utami et al., 2024) delve into the impact of soil infiltration and alterations in soil physical characteristics on water discharge. Similarly, (NATH, n.d.) accentuates the necessity of non-market valuation methodologies, such as willingness to pay, in gauging the economic worth of environmental assets like water. The imperative to apply the study's findings stems from the necessity for efficient water resource management in the Leang Lonrong Cave Area. Insights into water discharge trends and the willingness to pay for water usage gleaned from the research can guide policy formulation and management tactics that strike a balance between the needs of tourists and local inhabitants while safeguarding the environment and upholding water quality.

Therefore, this study aims to estimate the availability of underground river water using the ARIMA Model Approach in the Leang Lonrong Karst Pangkep Cave Area of Bantimurung Bulusaraung National Park, as well as valuing the utilization of underground river water availability with an econophysical orientation at the location. It is hoped that the results of this study can help the government in planning effective water resources management and provide relevant information related to the economic value of underground river water utilization, which can be used in determining water tariff policies for sustainable management in the Leang Lonrong Cave area. The theoretical basis for the topic of daily water discharge analysis and valuation of underground river water utilization in the Leang Lonrong Cave Area lies in the principles of econophysics, which combines economic and physical concepts to analyze complex systems. This approach is particularly relevant in the context of water resource management, where understanding the dynamics of water discharge and the willingness of local residents to pay for its utilization is crucial for the sustainable management of these resources.

Research Methods

This study employs a quantitative descriptive survey research method to investigate water discharge patterns and the valuation of underground river water utilization in the Leang Lonrong Bantimurung Bulusaraung Tourism Area. Data collection was conducted in Panaikang Village, Minasatene District, Pangkajene Regency, and Islands. Daily water discharge data from 2010 to 2023 was obtained from the Pompengan Jeneberang River Basin Center (BBWS) as secondary data, while primary data on willingness to pay for underground river water usage was collected through research questionnaires distributed to respondents.

Data analysis involved several steps. For water discharge analysis, the data underwent stationary testing, followed by identification of appropriate ARIMA models, ARIMA testing, forecasting, and calculation of the mean absolute percentage error (MAPE). Valuation data analysis of underground river water utilization in Leang Lonrong Cave included calculating the elasticity coefficient, ratio value, and percentage elasticity.

To conduct the analyses, Microsoft Excel and Eviews 9 software were utilized for water discharge data analysis, while Microsoft Excel was employed for valuation data analysis of underground river water utilization in Leang Lonrong Cave. The research instruments were meticulously designed to ensure validity and reliability in capturing the necessary data for the study's objectives.

Results and Discussion

Research Results

Estimated Availability of Underground River Water in Leang Lonrong Cave Area Characteristics of Leang Lonrong Cave Area Based on Water Discharge

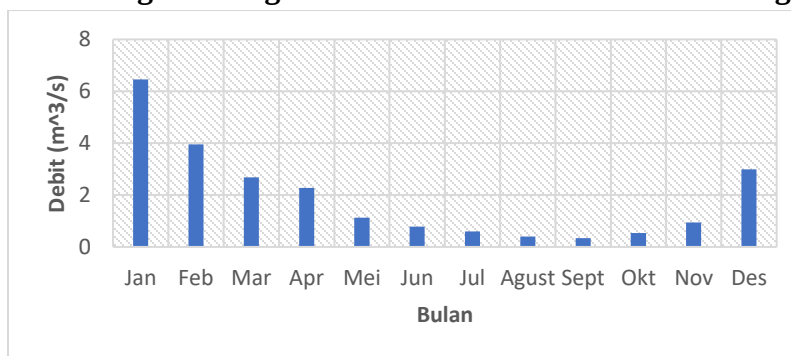


Figure 1.

Leang Lonrong River Water Discharge Profile 2010-2023

Based on The figure shows that for 14 years (2010-2023), the lowest water discharge occurred in September, which wa around $0.33 \text{ m}^3\text{s}^{-1}$ or $10.52 \text{ m}^3/\text{year}$, and the highest in January, which reached around 6.46 or $203.79 \text{ m}^3\text{s}^{-1}\text{m}^3/\text{year}$. It can also be seen that the water discharge decreases starting in July, August, September, and October. These months are marked by the dry season in the Leang Lonrong Cave Area. Water discharge begins to

enlarge in November around 0.94 or 29.56 $\text{m}^3\text{s}^{-1}\text{m}^3/\text{year}$. This situation lasted until April which was related to the rainy season in the Leang Lonrong Cave Area.

Tabel 1. Water Discharge Availability in 2010-2023

Bulan	Debit (m^3/s)													
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
January	9.14	14.02	6.84	4.8	3.49	2.51	1.03	2.41	0.99	19.3	5.5	6.2	4.17	9.8
February	3.99	11.3	4.13	1.77	1.26	2.7	1.71	1.75	0.91	4.2	4.5	0.8	1.46	14.8
March	2.7	6.99	2.69	3.37	1.42	4.22	1.31	1.74	0.82	4	2.3	2.4	1.07	2.6
April	2.24	4.4	1.99	4.76	1.14	2.49	1.08	2.32	1.59	1.7	2	1.6	0.83	3.7
May	1.28	2.06	0.87	1.17	0.55	0.81	0.78	2.19	1.53	0.9	1.3	0.7	0.63	1
June	1.28	0.76	0.53	0.82	0.37	0.35	0.21	1.56	1.6	0.7	1.5	0.6	0.45	0.3
July	1.47	0.22	0.18	0.78	0.18	0.17	0.17	0.83	1.61	0.7	0.6	0.3	0.48	0.7
August	1.75	0.2	0.16	0.41	0.09	0.13	0.07	0.34	1.25	0.2	0.4	0	0.52	0.1
September	2.1	0.19	0.15	0.16	0.07	0.09	0.06	0.2	1.02	0	0.1	0.1	0.33	0.1
October	3.36	0.18	0.14	0.15	0.08	0.08	0.35	0.37	1.13	0	0.1	0.1	1.34	0.1
November	6.91	0.19	0.15	0.32	0.09	0.08	1.01	0.11	1.52	0	0.3	1.2	1.04	0.2
Desember	9.07	1.14	1.02	2.04	1.01	0.49	0.72	0.82	0.99	1.6	13.4	5	3.9	0.6

Prediction of Leang Lonrong River Water Discharge Availability

Prediction using the ARIMA Model Approach

Prediction of Leang Lonrong River Water Discharge Data with ARIMA Method. The first step to predicting water discharge with the ARIMA model is the data stationary test and the determination of the best ARIMA model. According to (Rosita. et al, 2019) stationary assumptions are assumptions that must be met in predicting data. In this study, the data was stationary (probability lower than 0.05) with a differencing process of 1, which means shape, so the prediction model used is the ARIMA model (p, d, q) where $p = \text{AR}$, $d = 1$, $q = \text{MA}$.

In this study, temporary testing was carried out on the ARIMA model, namely the ARIMA model (1,1,1), (1,1,0), (0,1,1), (0,1,10). This came from assumptions that can be seen at the PAC and AC levels, which have at least 2 (two) stars read. Some of these models, which carry out significance tests, are feasible to use for prediction. The following are the results of the significance test of the provisional ARIMA model shown in the table, namely:

Table 2. Comparison of Probability Values in the ARIMA Model

No.	Model	Component	Probability
1	ARIMA (1,1,1)	AR 1	0,0000
		MA 1	0,9979
2	ARIMA (1,1,0)	AR 1	0,0610
3	ARIMA (0,1,1)	MA 1	0,0000
4	ARIMA (0,1,10)	MA 10	0,4392

The ARIMA model that is feasible to use has the lowest significant AR and MA terms (probability values smaller than 0.05). Based on the above data, a feasible ARIMA model is the ARIMA model (0,1,1) with a probability value of AR and MA terms smaller than 0.05. The ARIMA model (0,1,1) is then used to predict water discharge in the Leang Lonrong Cave Area in 2020-2023.

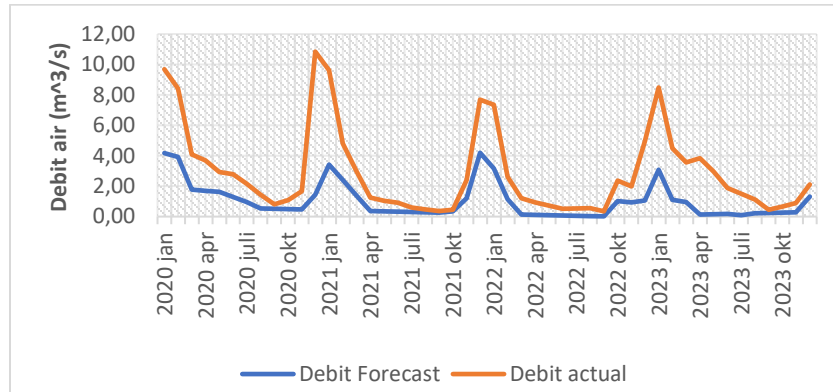


Figure 2.

Comparison Graph of Prediction Results with Observation Data for 2020-2023

Based on Figure 4.2, a comparison of prediction results with observation data for 2020-2023 shows that the ARIMA model (0,1,1) is able to predict the observation data for 2020-2023 well. Although, in general, there is a difference in value between the prediction results and the observation data, the predicted value tends to follow the pattern of movement of reality that occurs. Furthermore, the ARIMA model (0,1,1) is used to predict 7-year water discharge, namely from 2024 to 2030. To evaluate the suitability between the results of the observation discharge and the prediction results, a Mean Absolute Percentage Error (MAPE) analysis was obtained:

Table 3. MAPE forecasting results for 2024-2030

Month	Water Debit											
	2020			2021			2022			2023		
	Actual	Prediks	MAPE	Actual	Prediks	MAP	Actual	Prediks	MAP	Actual	Prediks	MAPE
1	5,5	4,17	0,24	6,2	3,42	0,45	4,17	3,17	0,24	9,8	3,07	0,69
2	4,5	3,93	0,13	3,8	2,39	0,37	2,46	3,15	-0,28	14,8	1,19	0,92
3	2,3	1,78	0,23	2,4	1,38	0,43	1,07	0,13	0,88	2,6	0,95	0,63
4	2,0	1,69	0,16	1,6	1,36	0,15	0,83	0,10	0,88	3,7	0,13	0,96
5	1,3	1,63	-0,25	0,7	0,34	0,51	0,63	0,08	0,87	1,0	0,16	0,84
6	1,5	1,29	0,14	0,6	0,32	0,47	0,45	0,06	0,87	0,3	0,17	0,43
7	1,2	0,96	0,20	0,3	0,29	0,03	0,48	0,04	0,92	0,7	0,10	0,86
8	0,9	0,53	0,41	0,2	0,17	0,15	0,52	0,03	0,94	0,1	0,13	-0,30
9	0,4	0,51	-0,28	0,1	0,15	-0,50	0,33	0,02	0,94	0,1	0,11	-0,10
10	0,6	0,48	0,20	0,1	0,13	-0,30	1,34	1,01	0,25	0,1	0,15	-0,50

11	1,2	0,46	0,62	1,2	1,21	-0,01	1,04	0,93	0,11	0,2	0,28	-0,40
12	9,4	1,44	0,85	5,0	4,19	0,16	3,9	1,05	0,73	0,6	0,43	0,28
Total			2,65			1,91			7,35			4,31
MAPE												0,337
MAPE (%)												33,7 %

Table 4.3 explains that the results obtained using MAPE in this study amounted to 33.7%; it can be interpreted as the result of a reduction between the actual value and the prediction that has been absolute, then divided by the actual value per each period, then summation of these results. The lower the MAPE value, the ability of the forecasting model used can be said to be good, and for MAPE, there is a range of values that can be used as measurement material about the ability of a forecasting model; the range of values can be seen in table 3.1. The results obtained from the MAPE method are 33.7% for evaluation calculations that are calculated using equations (3.1), and because of these results, the MAPE range ranges from 20-50%. It can be said that the MAPE results are good enough to have decent forecasting model capabilities, so the method used can be a reference to find predictions for several future time periods in water discharge in 2024-2030.

Tabel 4. Hasil Prediksi Debit air tahun 2024-2030

Months	Debit (m^3/s)							Average
	2024	2025	2026	2027	2028	2029	2030	
Januari	1,28	1,30	1,33	1,33	1,36	1,37	1,39	1,34
February	1,26	1,28	1,30	1,31	1,33	1,35	1,37	1,31
March	1,22	1,24	1,25	1,29	1,30	1,31	1,34	1,28
April	1,20	1,23	1,24	1,25	1,28	1,30	1,32	1,26
May	1,17	1,20	1,22	1,22	1,26	1,28	1,30	1,24
June	1,15	1,19	1,20	1,21	1,24	1,25	1,27	1,22
July	1,11	1,17	1,19	1,20	1,22	1,24	1,25	1,20
August	1,10	1,16	1,17	1,19	1,20	1,22	1,23	1,18
September	1,08	1,13	1,15	1,17	1,19	1,21	1,22	1,16
October	1,14	1,20	1,23	1,25	1,26	1,28	1,30	1,24
November	1,19	1,24	1,28	1,30	1,31	1,32	1,35	1,28
Desember	1,24	1,29	1,33	1,36	1,37	1,40	1,42	1,34

From the table above, predictions for 2024-2030 show that the Leang Lonrong Cave Area has the highest water discharge in December 2030 of 1.42 m^3/s or 44.79 $m^3/year$, while the lowest water discharge occurs in September 2024 at 1.08 m^3/s or 34.06 $m^3/year$.

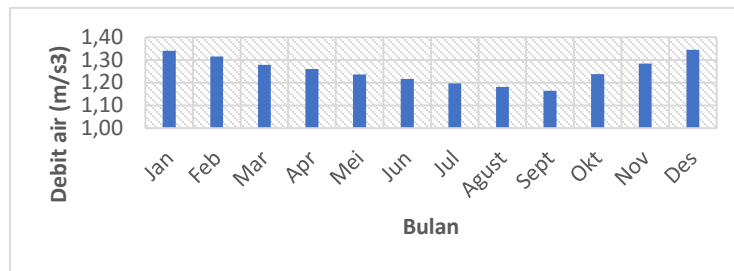


Figure 3.

Graph of Water Discharge Prediction Results in Leang Lonrong Cave Area in 2024 – 2030

Based on the graph above, the average water discharge prediction results for 2024-2030 show that when there is an increase or decrease in historical data, the prediction results depend on historical data. That is why the prediction results for 2024 to 2030 tend to have an up-and-down pattern. They follow historical data from previous years, which also experienced ups and downs, but that way, the sustainability of water availability can be achieved.

A steady rise in water discharge throughout the year indicates that the volume of flowing water continues to increase consistently throughout the period. As for the factors that cause the forecast chart to rise steadily:

1. Rainfall, according to Arsyad (2013), examined the discharge of underground river water in the Pangkep Karst area and how rainfall affects the availability of underground river water. High rainfall tends to increase the discharge of flowing water, but if the water discharge remains low despite high rainfall, this can be due to soil infiltration capacity being exceeded in intensive rains (Utami et al., 2024).
2. Soil Infiltration: Rain that falls in forming springs can respond quickly through the process of infiltration into groundwater and then form a rapid flow of groundwater as input from springs. Infiltration will decrease at the initial rate of a rain event (Muchtar & Abdullah, 2007). Low rainfall throughout the year can cause the soil to become dry and less able to absorb water properly. This can result in falling rainwater not being absorbed efficiently by the soil, resulting in more water flowing into the river and increasing water discharge (Utami et al., 2024).
3. Changes in the physical properties of the soil, Like hard or cracked soil due to drought, can also affect the soil's ability to absorb water. This can cause water discharge to continue to rise despite low rainfall (Utami et al., 2024). According to Rauf et al. (2015), soil density is influenced by the weight of soil content, where the smaller the weight value of soil content is, the lower the soil density will be, or the soil will have high fertility. Conversely, the denser the soil (the higher the weight of the content), the more conditioned the soil is to continue water or be penetrated by roots, affecting the increase in water discharge.

Water discharge modeling based on the application of finite difference methods

Solving Partial Differential Equations (PDE) in numerical methods generally uses the finite difference method. Replacing the existing derivative of the differential equation with finite difference discretization, the finite difference equation used to replace the second derivative in PDE, the equation will be discrete using the difference method to an explicit scheme by evaluating in space (i,j) (Julia, 2023). The finite difference method is one of the most popular and easy-to-use numerical methods in calculating approximations of derivatives of a function that can be analyzed using Microsoft Excel to be applied to water discharge.

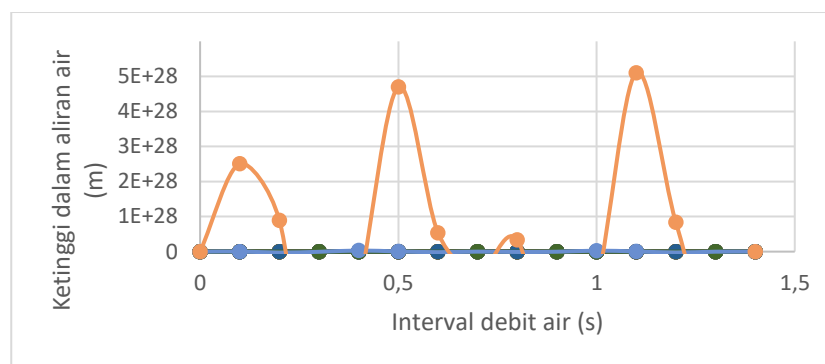


Figure 4.

Water discharge modeling graph based on finite difference method equation

Based on the interval graph above on the x-axis shows that the graph drops significantly at a larger water flow interval. This graph shape can be said to be a response to water flow that affects water discharge, where when water flow weakens, water discharge also falls. This can be caused by factors such as rainfall, evaporation, soil absorption, and others. As for the relationship of height in the water flow to water discharge, based on the graph, the height in the water flow affects the water discharge significantly. As the height of the water flow increases, the water discharge will also increase, and vice versa. This can be caused by factors such as soil pore capacity, soil permeability, and water table area in the river flow system.

Valuation of Leang Lonrong River Water Utilization

Environmental economic assessment of underground river water utilization involves a non-market valuation approach, which often uses the concept of Willingness to Pay (WTP). This approach involves assessing people's preferences for the quality of the surrounding environment. Using non-market valuation can provide an economic assessment of environmental goods, including water as a natural resource (Hasibuan, 2014).

Variables in economics are analogous to quantities in physics, where variables in economics are measurable concepts, and a ratio scale is used, as explained in principle I, that "Society is faced with sacrifices (People face tradeoffs)." This principle says that whenever we make an economic decision, we are faced with a choice that comes at the expense of other

options. When we choose something, we always lose something else. The law of conservation of energy can be used to explain this economic concept physically.

The willingness of residents to provide WTP utilization of Leang Lonrong River water

There were seven respondents who stated that they were willing to provide WTP in an effort to use clean water, which was transferred to a clean water management agency. However, there are also the remaining 32 respondents who are not willing to provide a number of WTP values for water quality management efforts. The respondents who are not willing to provide a number of WTP values have the reason that economic limitations or economies are less capable, so respondents are unwilling or unable to provide a number of WTP or WTP values equal to zero, along with other reasons.

a) Getting WTP Value

In this study, the value of the offer used to determine the WTP value of respondents was obtained through the open-ended question method. Through this method, respondents are given the freedom to state a number of values that are willing to be paid for clean water management efforts.

b) Calculating WTP Average Value

The alleged average WTP value of respondents is obtained based on the ratio of the amount of WTP value given by respondents to the total number of respondents who are willing to pay. The distribution of respondents' WTP values is shown in Table 4.7.

Table 5. WTP Average Value of Population

No	WTP	Number of Respondents	WTP × Number of Respondents
	(Rp)	(person)	(Rp)
1	30.000	4	120.000
2	50.000	2	100.000
3	75.000	1	75.000
Total		7	295.000

Based on the data above, the average WTP value of respondents was obtained at Rp 42,142.85 per month. The average WTP value illustrates that the community is willing to spend Rp 42,142.85 for each household per month, which can be used to cover the cost of clean water quality management efforts.

Visitors' willingness to provide WTP utilization of Leang Lonrong River water

Data collection was carried out by filling out a research questionnaire to visitors, and respondents obtained a total of 62 people from visitors on Sunday at Leang Lonrong Cave after the closure of tourist access due to bad weather conditions for the willingness of visitors to give WTP to contribute to maintaining the management of clean water quality of the Leang Lonrong River.

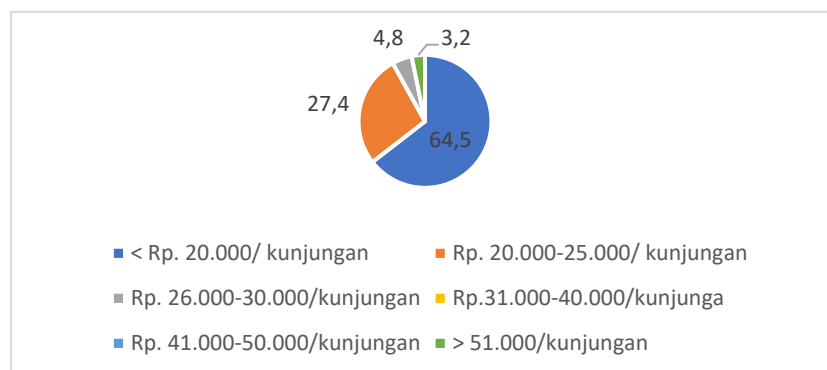


Figure 5.

Visitors' willingness to give WTP to contribute to maintaining water quality management in Leang Lonrong Cave

Based on the figure above, the alleged average WTP value of respondents is obtained based on the ratio of the number of WTP values given by respondents to the total number of respondents who are willing to pay. The distribution of WTP values given for contributions to maintaining water quality management in Leang Lonrong Cave to respondents is shown.

Table 6. WTP Average Value of Visitors

No	WTP (Rp)	Number of Respondents (Orang)	Percentage	WTP × Number of Respondents (Rp)
1	19.000	40	64,5	760.000
2	23.000	17	27,4	391. 000
3	28.000	3	4,8	84.000
4	52.000	2	3,2	104.000
Total		62	100	1.339.000
Obtained/visited				21.596,77

From Table 4.8, the average WTP value of respondents was obtained at Rp 21,596.77 per visit. The average value of WTP illustrates that visitors are willing to spend IDR 21,596.77 each time they visit this tourist spot, which can be used for the cost of maintaining the water quality management of the Leang Lonrong River.

Analogy of the Physical Approach to Economics

One possible analogy is the concept of potential. In physics, potential is the energy stored in a system, such as gravitational potential or electric potential. In the context of willingness to pay, potential can be thought of as financial "energy" stored in individuals or consumers. The level of willingness to pay a person can depend on how much financial "potential" he has and how much benefit or satisfaction is obtained from a product or service (Resmiyanto, 2014).

Water Discharge Modeling of Willingness to Pay

Elasticity analysis in modeling water discharge with willingness to pay is a method for measuring the responsiveness or sensitivity of willingness to pay to changes in water discharge.

1) Calculate elasticity coefficient $\partial Y/\partial X$

$$\text{Percentage change} = \frac{X_{\text{maksim}} - X_{\text{minimum}}}{X_{\text{minimum}}} \times 100\%$$

Table 7. Percentage change in the coefficient of elasticity

	Water Debit (∂X)	Willingness to pay	
		Population	Visitors
Percentage change	18,57	1,5	1,73

So, the coefficient of elasticity for the population:

$$\frac{\partial Y}{\partial X} = \frac{1,5}{18,57}$$

$$\frac{\partial Y}{\partial X} = 0.081$$

While the coefficient of elasticity for visitors:

$$\frac{\partial Y}{\partial X} = \frac{1,73}{18,57}$$

$$\frac{\partial Y}{\partial X} = 0.093$$

2) Calculate the ratio value $\left(\frac{x}{y}\right)$

$$\text{Ratio value} = \frac{\text{Maximum debit} + \text{minimum debit}}{\text{Willingness to pay high} + \text{willingness to pay low}}$$

Table 8. The result of calculating the ratio value

	Population	Visitors
Ratio Value	0,000065	0,000096

3) Calculating Percentage Elasticity

For Residents

$$E = \left(\frac{\partial Y}{\partial X} \right) \times \left(\frac{X}{Y} \right)$$

$$E = 0.081 \times 0,000065$$

$$E = 0.0000053$$

For Visitors

$$E = \left(\frac{\partial Y}{\partial X} \right) \times \left(\frac{X}{Y} \right)$$

$$E = 0.081 \times 0,000096$$

$$E = 0.0000078$$

Discussion

Estimation of River Water Availability in Leang Lonrong Cave Area

Water discharge characteristics

Graphical analysis of the average water discharge in the Leang Lonrong Cave Area can be seen in Figure 4.1 shows that for 13 years (2010-2023), the lowest water discharge occurred in September, which was $0.33 \text{ m}^3/\text{s}$ or $10.52 \text{ m}^3/\text{year}$, and the highest in January which reached $6.46 \text{ m}^3/\text{s}$ or $203.79 \text{ m}^3/\text{year}$. It can also be seen that the water discharge decreases starting in July, August, September, and October. These months are marked by the dry season in the Leang Lonrong Cave Area. Water discharge began to enlarge in November at around $0.94 \text{ m}^3/\text{s}$ or $29.54 \text{ m}^3/\text{year}$. This situation lasted until April, which was related to the rainy season in the Leang Lonrong Cave Area. The availability of underground river water discharge is very dependent on the rainy season in the Leang Lonrong Cave Area. However, based on the results of the data processing obtained are not in accordance with this theory because river water discharge can change depending on two conditions, namely first, the presence of rainfall (precipitation), and second, the occurrence of evapotranspiration from water bodies, soil, and plants. River discharge is never constant but always changes according to the climate and biophysical state of the watershed.

Prediction of Leang Lonrong River Water Discharge Availability

The stages in making predictions with the ARIMA model include stationary test data and determining the best ARIMA model. According to (Rosita. et al, 2019) stationary assumptions are assumptions that must be met in predicting data. Stationary data is a term that means that data is in equilibrium around a constant value over a certain time (Irma. et al., 2017). Then the determination of the best ARIMA model, according to (Nurissaidah. et al, 2018) and (Ahmad et al, 2018) are based on AR and MA terms that have significantly lowest (probability value smaller than 0.05). That is why the ARIMA model used in this study is the ARIMA model (0,1,1), where the probability value of AR and MA terms is smaller than 0.05. The results obtained from the MAPE method are 33.7% for evaluation calculations that are calculated using equations (3.1), and because of these results, the MAPE range ranges from 20-50%. It can be said that the results of this good cukum MAPE have decent forecasting model capabilities, so the method used can be a reference for determining predictions for several future time periods in 2024-2030 water discharge.

The results of water discharge predictions with the ARIMA model (0,1,1) for 2024-2030 tend to follow the pattern of movement of reality that occurs. According to (Tias et al, 2017) predictions with ARIMA assume that past patterns will continue into the future. When there is an increase or decrease in historical data, the prediction results depend on the historical data. That is why the prediction results for 2024 to 2030 tend to have an up-and-down pattern; they follow historical data from previous years, which also experienced ups and downs.

As for the application of partial differential equations using the finite difference method based on the analysis obtained through Microsoft Excel based on the figure, the graph for the interval on the x-axis shows that the graph drops significantly at a larger water flow interval. This graph shape can be said to be a response to water flow that affects water discharge, where when water flow weakens, water discharge also falls. This can be caused by factors such as rainfall, evaporation, soil absorption, and others. As for the relationship of height in the water flow to water discharge, based on the graph, the height in the water flow affects the water discharge significantly. As the height of the water flow increases, the water discharge will also increase, and vice versa. This can be caused by factors such as soil pore capacity, soil permeability, and water surface area in the river flow system.

Valuation of Leang Lonrong Cave Underground River Water Utilization

Based on the results of the Leang Lonrong River water utilization questionnaire, it was obtained that the dominant community utilizes river water for various purposes, both for the fulfillment of daily needs and for agriculture and animal husbandry. People use Leang Lonrong River water for toilets (bathing, washing, latrines), washing eating utensils, drinking, washing clothes, and use raw materials for drinking water, which are only used by people living around the Leang Lonrong River area where they are quite close to the river. Meanwhile, people who live outside the tourist area use bottled water as raw drinking water. In addition, Leang Lonrong River water is more widely used in agriculture and for the purposes of standard animals or livestock.

Leang Lonrong River still has visitors even in rainy conditions. However, when the river water flows fast, there are no visitors around the river; this is like what happened in January when the tourist destination Leang Lonrong was temporarily closed due to unfavorable weather conditions. Even so, Leang Lonrong River remains one of the tourist destinations chosen by the community as a place of recreation. This is the utilization of Leang Lonrong River water in the field of tourism.

Willingness to pay

The willingness of residents to provide WTP utilization of Leang Lonrong River water

The number of respondents was selected from residents who met on Saturday and were willing to fill out a questionnaire. As many as 32 respondents were interested in providing WTP for the use of underground river water. From the results of data collection regarding the willingness to provide WTP, there were seven respondents who expressed their willingness to provide WTP in an effort to use clean water, which was transferred to a clean water management agency. However, there are also the remaining 25 respondents who are not willing to provide a number of WTP values for efforts to manage the water quality of the Leang Lonrong River.

Of the seven respondents who are willing to provide WTP, willingness to pay is listed. The average WTP value of respondents amounted to Rp 42,142.85 per month. The average WTP value illustrates that the community is willing to spend Rp 42,142.85 for each

household per month, which can be used for the cost of efforts to improve the water quality of the Leang Lonrong River. Where according to the results of research conducted by Rindah (2023), Leang Lonrong River Water for public bathing purposes does not meet water quality according to quality standards. This is due to several parameters that do not meet the standards, namely the clarity parameter is an average of 0.136 meters in depth, and the UV index parameter is more than three at 11.00 WITA and 13.00 WITA. Measurement of this parameter was carried out in the field directly, and the value showed that the water of the Leang Lonrong River included very turbid waters to have low water productivity.

The respondents who are not willing to provide a number of WTP values have reasons for economic limitations or economies that are less able, so respondents are unwilling or unable to provide a number of WTP or WTP values equal to zero, along with other reasons. This is in accordance with the results of the analysis that income affects the willingness to pay (WTP).

Visitors' willingness to provide WTP utilization of Leang Lonrong River water

The number of respondents was selected from visitors who came on Sunday and were willing to fill out a questionnaire. As many as 62 respondents were interested in giving WTP to the use of underground river water.

From the results of data collection regarding the willingness to provide WTP, 62 respondents indicated that WTP contributed to improving the water quality management of the Leang Lonrong River. Of the 62 respondents who are willing to provide WTP, willingness to pay is listed in Table 4.7. obtained the average WTP value of respondents amounting to the contribution in maintaining the management of Leang Lonrong River water quality, visitors are willing to give WTP of Rp. 21,596.77 each time visitors visit this tourist spot, which can be used for contribution costs in maintaining the management of Leang Lonrong River water quality.

Analogy of the Econophysical Approach

One possible analogy is the concept of potential. In physics, potential is the energy stored in a system, such as gravitational potential or electric potential. In the context of willingness to pay, potential can be thought of as financial "energy" stored in individuals or consumers. The level of willingness to pay a person can depend on how much financial "potential" he has and how much benefit or satisfaction is obtained from a product or service (Resmiyanto, 2014).

The econophysical approach used in this study refers to Principle I, namely that society is faced with sacrifices (People face tradeoffs). In physics, this economic principle can be explained using the law of conservation of energy. Principle I shows that in situations with limited natural resources, such as low river water utilization, communities must make trade-offs or sacrifices in the allocation of these resources to prioritize their various interests.

Water Discharge Modeling with Willingness to Pay

Elasticity analysis in modeling water discharge with willingness to pay is a method to measure the responsiveness or sensitivity of willingness to pay to changes in water discharge. The relationship between water discharge has only a small impact on willingness to pay is based on the calculation of percentage elasticity where each resident and visitor has a percentage of elasticity smaller than one (<1). This suggests that willingness to pay tends to be unresponsive to percentage changes in water discharge.

In a case study of the economic valuation of groundwater resources, it was found that the Willingness to Pay (WTP) for increased water discharge to a willingness to pay indicates that communities are willing to pay more to increase water availability, reflecting the economic value given to the utilization of leading lonrong river water.

Conclusion

The study on daily water discharge analysis and valuation of underground river water utilization in the Leang Lonrong Cave Area provides valuable insights into the dynamics of water discharge patterns and the willingness of local residents to pay for water utilization. The analysis employed the ARIMA model to forecast water discharge patterns and found that the ARIMA model (0,1,1) was the most suitable for predicting water discharge, with a mean absolute percentage error (MAPE) of 33.7%. The study also utilized a willingness-to-pay approach to evaluate the valuation of underground river water utilization, where the average willingness-to-pay value for maintaining the management of Leang Lonrong river water quality was approximately IDR 21,596.77 per visit. The findings of this study have significant implications for the management of water resources in the Leang Lonrong Cave Area. Firstly, the ARIMA model (0,1,1) can be used as a reliable tool for predicting water discharge patterns, which is crucial for planning and managing water resources effectively. Secondly, the willingness-to-pay approach highlights the importance of considering the economic value of water utilization in environmental economic assessments. This approach can be used to inform policy decisions and management strategies that balance the needs of tourists and local residents with the need to protect the environment and maintain water quality. The study suggests several recommendations based on its findings. Firstly, integrating the ARIMA model (0,1,1) into the water resource management system of the Leang Lonrong Cave Area can improve the accuracy of water discharge predictions, aiding in more effective planning and resource management. Secondly, incorporating the willingness-to-pay approach into environmental economic assessments can offer a more holistic understanding of the economic value of water usage, informing policymakers' decisions regarding economic, social, and environmental factors. Thirdly, raising public awareness through education campaigns about water conservation and its economic importance can promote responsible water usage and sustainable tourism practices in the area. Additionally, developing sustainable water management strategies, such as water harvesting and efficient irrigation systems, is vital. Regular monitoring and evaluation of

water discharge patterns are also recommended to ensure the effectiveness of management strategies and responsiveness to environmental changes. Implementing these recommendations can foster sustainable management of water resources in the Leang Lonrong Cave Area, meeting the needs of both residents and tourists while safeguarding the environment.

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Nur Azizah Jaya, Muhammad Arsyad, Pariabti Palloan (2024)

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Advances in Social Humanities Research

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