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Water Availability in the Moayat River in Meeting Water Needs in Kotamobagu, North Sulawesi

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ABSTRACT

The Moayat River in Kotamobagu, North Sulawesi, plays an important role as a water source to meet the needs of the local community. However, water management in this area faces significant challenges due to seasonal discharge fluctuations, changes in land cover, and increasing water demand. **This study aims** to analyze the water availability of the Moayat River based on surface water conditions and current water demand assessments, future water demand projections, and water balance evaluations. **The results show** that current water availability is sufficient to meet domestic water needs. However, surface water conditions are influenced by climate change indicators, so that river discharge approaches the water demand threshold, thus creating a risk of water shortages, especially for irrigation. Over the past decade, forest cover in the catchment area has decreased, which has led to increased surface runoff and reduced water infiltration. **Based on these findings**, climate change in land cover greatly affects surface flow conditions so that an integrated management strategy is needed, including watershed rehabilitation, development of water storage infrastructure, and increasing water use efficiency, is essential to ensure the long-term sustainability of water supply from the Moayat River.

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1. INTRODUCTION

Water is essential for sustaining human life and ecosystems, supporting domestic, agricultural, and industrial needs, and maintaining environmental balance. In many tropical regions, such as Indonesia, water resources face increasing pressure due to population growth, urbanization, and changes in land use patterns. Kotamobagu, located in North Sulawesi, serves as a concrete example of an area facing these challenges [1]. As population growth and economic development drive water demand, effective water resource management has become a critical issue [2]. The Moayat River, a key water source in the region, plays a strategic role in meeting the needs of the local community and supporting other sectors [3].

Water resource management challenges are often linked to uneven spatial and temporal distribution. Rivers in tropical areas generally exhibit seasonal flow patterns strongly influenced by annual rainfall [4]. When rainfall is high, river discharge tends to be abundant, but during the dry season, discharge often declines drastically. This phenomenon complicates communities ability to optimally utilize water resources throughout the year [5]. Therefore, an in depth study of the Moayat River water availability is essential to ensure a sustainable water supply, especially during critical seasons.

Previous studies have highlighted the importance of the interaction between environmental factors and human activities in determining the sustainability of water resources [6]. Land cover changes, such as deforestation and urbanization, can exacerbate hydrological imbalances, causing increased surface runoff and reduced groundwater infiltration, leading to water loss [7]. Meanwhile, the development of water infrastructure, such as reservoirs and dams, plays a crucial role in stabilizing water supply during the dry season [8]. In the context of the Moayat River, these approaches offer effective solutions to address significant discharge fluctuations [9].

Kotamobagu, a rapidly developing region, is experiencing steady population growth, accompanied by an increase in water needs for domestic use, agricultural irrigation, and the expanding industrial sector, water demand in the region has increased by 20% over the past decade. However, this growth is not always matched by the capacity of the water supply, particularly during the dry season when the Moayat River discharge significantly declines [10].

Previous studies indicate that over 60% of water sources in this region come from rivers, including the Moayat River [11]. This high dependence on rivers emphasizes the importance of effective management to ensure water availability. High reliance on surface water requires an integrated management approach, combining land conservation, water infrastructure development, and efficient water use. These strategies are also relevant to the Moayat River context [12].

The Moayat River exhibits a seasonal flow pattern strongly influenced by rainfall [13]. Hydrological data show that annual rainfall in the Kotamobagu region ranges from 2,000 to 3,000 mm, with the peak rainy season occurring between November and April. The maximum discharge of the Moayat River is recorded from December to February, while the minimum discharge occurs from July to September [14]. These fluctuations create challenges in water supply management, especially during the dry season [15].

Changes in rainfall patterns due to climate change can exacerbate river flow fluctuations, increasing the risk of flooding during the rainy season and drought during the dry season and surface temperatures affect the hydrological conditions of a watershed [16]. In the context of the Moayat River, this underscores the need for long-term analysis to anticipate the impact of climate change on hydrological dynamics [17].

One key factor influencing water availability in the Moayat River is the condition of its catchment area. A healthy catchment area, with adequate vegetation cover, contributes to river flow stability by increasing water infiltration and reducing surface runoff [18]. Over time, catchment areas face pressure from deforestation for agriculture, settlements, and other economic activities, reducing the soils ability to absorb water [19].

Ecosystem based approaches, such as reforestation of catchment areas and forest protection, can improve water availability during dry seasons and reduce flooding risks in rainy seasons [20]. In the context of the Moayat River, rehabilitating the catchment area is an important step toward enhancing the sustainability of water resources [21].

Global climate change is impacting hydrological patterns, especially in tropical regions like Indonesia [22]. Rising global temperatures have altered rainfall patterns, with some areas experiencing higher rainfall intensity while others face reduced rainfall. In the context of the Moayat River, these changes have the potential to exacerbate river discharge fluctuations, increasing the risk of flooding and drought in certain seasons [23].

Climate change simulations using hydrological models can help identify long term risks to water availability. In the context of the Moayat River, similar analyses are needed to anticipate the impact of climate change on water supply. Effective water resource management requires an integrated approach that combines scientific analysis, government policies, and active community involvement. In many regions, infrastructure development such as reservoirs and dams has proven effective in reducing water supply fluctuations [24]. However, these developments must be balanced with land conservation and efficient water use.

Constructing small reservoirs in catchment areas can increase water storage capacity and reduce dependence on surface water flow. In the context of Kotamobagu, this approach can be applied to optimize the utilization of the Moayat River [25]. Based on literature reviews and conditions in the Kotamobagu area, this study focuses on the water availability of the Moayat River and its contribution to water resilience.

2. METHODOLOGY

This study conducted a hydrological analysis using rainfall data over a 14-year period (2009–2022) to evaluate the water availability of the Moayat River. The FJ Mock method was applied to determine river discharge based on rainfall conditions. Data for this study included rainfall and discharge measurements from local weather stations, population data from the Civil Registry Office, and land use mapping provided by local authorities [26].

2.1. Location Description

This study was conducted in the Moayat River Basin (DAS), located in Kotamobagu, North Sulawesi Province. The Moayat River Basin stretches over an area of 68 km^2, from the hilly upstream area to the downstream area with the distribution of land use as seen in Table 1.

Table 1. Land use of Moayat Watershed in 2022

Land Cover Type	Total Area (km^2)	Percentage (%)
Forest	0.431948	36.95
Mixed Gardens	0.368805	31.55
Rice Fields	0.956418	18.75
Savanah Grasslands	0.071826	6.14
Dryland Farming	0.095104	8.13
Shrubs	0.049909	4.26
Settlements	0.000244	0.05
Freshwater Ponds	0.000249	0.02
Rivers	0.00064	0.05

As shown in Figure 1, the map of the Moayat Watershed illustrates the study area topography and land cover types, providing a spatial context for analyzing water availability in relation to land use and geographic conditions.

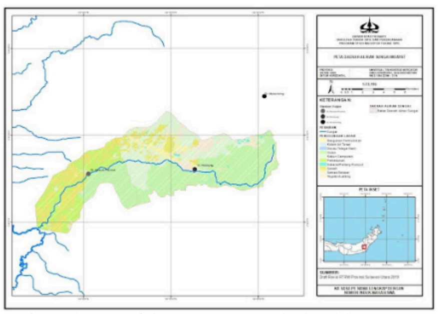

Figure 1. Map of the Moayat Watershed (DAS Moayat)

2.2. Data Collection

The data utilized in this research includes the following:

- **Rainfall and River Discharge Data:** Spanning the past 14 years, collected from three observation stations: Moayat Rain Station, Modayag Rain Station, and Modoinding Rain Station, provided by the River Basin Organization of Sulawesi I (Balai Wilayah Sungai Sulawesi I).
- **Discharge Data:** Covering the last 10 years, obtained from the Moayat measurement station under the same organization.

- **Population Data:** Sourced from the Civil Registry Office of Kotamobagu City.
- **Land Cover Data:** Derived from the 2022 updated Indonesian Digital Land Cover Database (Rupabumi Indonesia).

2.3. Data Analysis

The data in this study were processed using the FJ Mock method to understand the existing discharge conditions of the Moayat River and the climatology of the Moayat Watershed (DAS Moayat). It also aimed to identify the trends in the Moayat River discharge over 14 years (2009–2022) and assess the water availability of the Moayat River in meeting the needs of the community in Kotamobagu [27].

3. RESULT AND DISCUSSION

3.1. Rainfall Characteristics

In the recording of rainfall at Moayat Station, the characteristics of rainfall include maximum rainfall of 380.60 mm which occurred in July 2012, minimum rainfall of 13 mm which occurred in September 2009, while the average rainfall is 150.40 mm. The characteristics of rainfall indicate that the area is included in the moderate category. The Modayag Station, this area has rainfall characteristics including maximum rainfall of 383.58 mm in October 2016 and minimum rainfall of 12.62 mm in October 2015, while the average rainfall in the Modayag station area is 131.68 mm. At this station there is an anomaly in rainfall because the maximum and minimum conditions occur in the same month. The Modoinding Station, the characteristics of maximum rainfall that occurred were 357.93 mm in November 2009 and minimum rainfall of 0.85 mm in August 2015, while the average rainfall was 136.04 mm. The characteristics of rainfall for each station can be seen in the Figure 2.

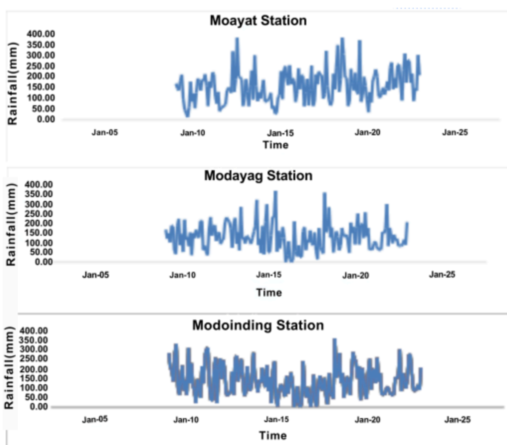

Figure 2. Monthly Rainfall Graph Based on Stations

As shown in Figure 2, annual rainfall data from Moayat, Modayag, and Modoinding stations show a clear seasonal pattern, with high rainfall between November and April, and a significant decrease from May to October. These fluctuations directly affect the water availability of the Moayat River, with higher rainfall causing increased river discharge during the rainy season. This is because the condition of rainfall intensity is influenced by the characteristics of a watershed, the characteristics of the watershed in the upstream part will be different from the conditions of the watershed in the middle and downstream parts so that they experience significant variations in rainfall, indicating the vulnerability of the area to seasonal changes [28].

3.2. Probability of Rainfall

In the analysis of rainfall probability in this study, the evaluation is based on baseline data from a 10-year period (2009–2019), which is compared with rainfall data from the years 2020, 2021, and 2022. The probability of change is observed based on both annual and monthly rainfall patterns. Based on the analysis, the average annual rainfall in the study area is approximately 2,008 mm. The year with the highest recorded rainfall was 2022, reaching 2,708 mm, while the lowest occurred in 2020, with only 1,452 mm. This fluctuation represents a significant variation, with a difference of up to 1,256 mm over the span of 14 years. These conditions indicate that rainfall intensity throughout the year experiences notable increases and decreases. Specifically, there was a decrease in rainfall in 2020 by 20.29%, followed by an increase of 44.02% in 2021, and a further increase of 68.54% in 2022.

Table 2. Comparison of Annual Rainfall

Year	Annual Rainfall (mm)	Percentage (%)
2009–2019	1471.92	Baseline
2020	1173.1	-20.29%
2021	2120.2	44.02%
2022	2480.8	68.54%

Monthly rainfall pattern analysis is carried out in the same way as the annual analysis, namely using baseline data which is then subjected to statistical analysis. The results of the monthly rainfall distribution analysis show uneven results. The highest average rainfall occurs in April at 188.31 mm, while the lowest average rainfall occurs in August at 99.00 mm. Furthermore, a comparison is made between the 2009–2019 rainfall and the monthly rainfall in 2020, 2021, and 2022 to identify whether there is an increase or decrease in rainfall. In general, there is a significant fluctuation in rainfall from year to year, especially in 2020, which showed a notable decrease in rainfall compared to the 2009–2019 period. Meanwhile, in 2021 and 2022, rainfall experienced a sharp increase in most months, with peaks observed in February and November 2022.

Table 3. Comparison of Monthly Rainfall

Month	2009–2019 (average)	2020 (mm)	2021 (mm)	2022 (mm)
January	165.73	35.10	143.50	231.70
February	145.47	127.50	177.50	307.50
March	167.67	191.82	137.60	172.20
April	188.31	150.26	244.00	276.00
May	171.82	92.13	265.70	273.50
June	140.14	76.48	142.50	171.70
July	160.79	108.93	193.00	213.50
August	99.00	15.43	149.50	87.60
September	102.67	24.58	253.60	145.50
October	126.57	51.68	257.00	134.40
November	139.26	94.79	171.80	300.50
December	133.73	74.82	90.10	206.50

3.3. Water Discharge at Moayat River

The water discharge of the Moayat River is strongly influenced by annual rainfall fluctuations, with clear seasonal variations. Generally, the highest discharge occurs during the rainy season, particularly from January to April, while the lowest discharge is observed during the dry season, especially from August to September [29].

The average monthly discharge during the observation period shows that the highest discharge occurred in February 2021 at 7.04 m^3/s, coinciding with high rainfall of 177.5 mm. Conversely, the lowest discharge occurred in October 2014, with 0.49 m^3/s, corresponding to the lowest rainfall of 34.42 mm.

The annual average discharge of the Moayat River directly correlates with rainfall, where each increase in monthly rainfall leads to a significant rise in discharge [30]. For instance, in February 2022, the discharge reached 4.48 m^3/s with a rainfall of 307.5 mm, reflecting the major contribution of surface runoff.

However, certain anomalies are noteworthy. High discharge in some months does not always correspond with high rainfall. For example, in March 2015, the discharge reached 2.14 m^3/s despite rainfall being only 127.29 mm. This could be influenced by factors such as groundwater contributions, runoff from upstream areas, or human activities that enhance river flow.

Low discharge during the dry season highlights the limited baseflow from groundwater infiltration. In August 2014, for instance, the discharge was just 0.50 m^3/s despite rainfall of 67.86 mm. This underscores the need for sustainable water resource management, particularly the protection of recharge areas and optimization of groundwater use [31].

Overall, the discharge of the Moayat River shows a high dependence on rainfall patterns. Therefore, shifts in rainfall patterns due to climate change could significantly affect water availability in the future [32].

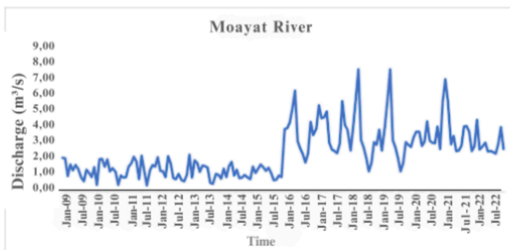

Figure 3. Graph of Average Monthly Discharge of the Moayat River (2009–2022)

3.4. Water balance of Moayat River

A comprehensive evaluation of the Moayat River water balance examines the relationship between water availability (river discharge) and demand (domestic and non domestic uses), comparing water needs with available discharge data.

3.4.1. Water needs

The calculation of water needs in Kotamobagu City takes into account the local population growth rate. The scope of the area used in this study was 33 villages, with an average population growth rate of 0.42%. The population growth projection used for 50 years assumes the same duration as the age of the building. The image below illustrates the condition of population growth in Kotamobagu City. Population projection is the first step to estimate future water needs.

The geometric method is used in this projection because it is able to describe a stable growth trend in urban areas. The projection results show that the population of Kotamobagu City will increase significantly in the next ten years. In 2025, the population is projected to reach 141,250 people and will continue to increase to 163,500 people in 2035. The area with the highest growth is Gogagoman Village, which reflects the level of urbanization and dominant economic activity in the area.

Domestic water needs are calculated based on the standard per capita water needs as regulated in the Indonesian National Standard (SNI) 19-6728.1-2002 concerning Drinking Water Supply System Planning, which is 150 liters/person/day. This standard covers the needs for household activities such as drinking, cooking, bathing, and washing, as well as for non-domestic needs based on the Regulation of the Minister of Public Works and Public Housing (PUPR) Number 27/PRT/M/2016 concerning Guidelines for the Preparation of Drinking Water Supply Systems.

Table 4. Water Needs in Kotamobagu City

Month	Water Discharge (m^3/s)	Water Needs (m^3/s)	Non-Domestic Needs (m^3/s)
Jan	3.36	0.22	0.02
Feb	4.11	0.22	0.02
Mar	4.12	0.22	0.02
Apr	3.58	0.22	0.02
May	2.99	0.22	0.02
Jun	3.00	0.22	0.02
Jul	4.04	0.22	0.02
Aug	3.11	0.22	0.02
Sep	3.28	0.22	0.02
Oct	3.25	0.22	0.02
Nov	4.02	0.22	0.02
Dec	2.64	0.22	0.02

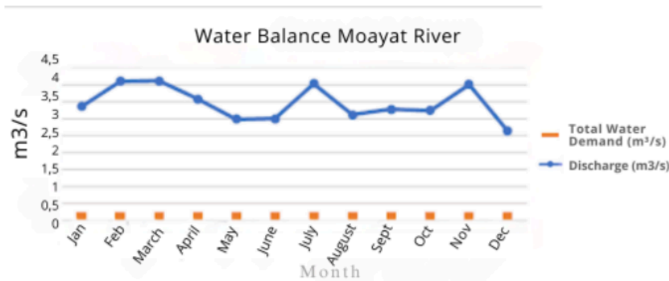

Figure 4. Water balance Moayat River

Based on the Table 4 above, it can be said that the availability of water in the Moayat River is surplus with domestic and non domestic water needs without the use of irrigation.

3.5. Water Availability Conditions Based on Scenarios

In order to assess the future capacity of the Moayat River in meeting water demands, scenario based projections were conducted. These scenarios simulate different levels of raw water allocation and utilization strategies to anticipate various conditions of water supply and demand over time. By evaluating multiple approaches, this analysis aims to identify the critical limits of water availability and propose the most sustainable management practices for long term resilience. Three scenarios are used to project water availability:

3.5.1. Scenario 1 (Raw water allocation 1.5 lps)

Scenario 1 is the allocation of raw water of 1500 lps to meet the need for raw water without utilizing irrigation with water sources from the Moayat River. Based on these conditions, the availability of water in S. Moayat can only meet the need for raw water until 2054. This can be seen in the Figure 5 below.

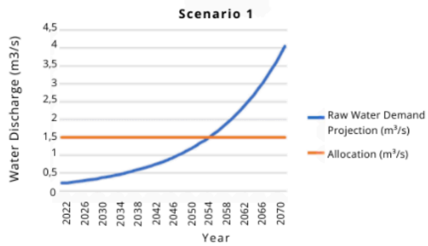

Figure 5. Scenario 1

3.5.2. Scenario 2 (Raw water allocation with irrigation utilization)

Scenario 2 allocates 1500 lps of raw water to meet raw water needs by utilizing irrigation with water sources from the Moayat River. Based on these conditions, the availability of water in S. Moayat can only meet raw water needs until 2038. This can be seen in the Figure 6 below.

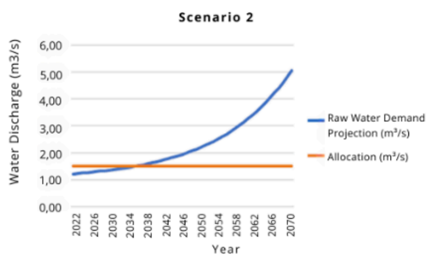

Figure 6. Scenario 2

3.5.3. Scenario 3 (Raw water allocation with 100% optimization)

Scenario 3 allocates 3000 lps of raw water to meet the raw water needs by utilizing irrigation with water sources from the Moayat River. This is based on the average discharge conditions of the Moayat River. Based on these conditions, the availability of water in the Moayat River can only meet the raw water needs until 2059. This can be seen in the Figure 7 below.

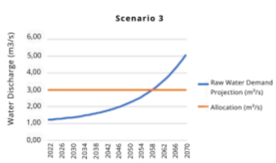

Figure 7. Scenario 3

4. MANAGERIAL IMPLICATIONS

Sustainable water supply from the Moayat River demands integrated watershed management, rehabilitation of upstream areas, and development of decentralized water storage facilities. Strengthening land conservation efforts, improving infiltration rates, and mitigating surface runoff are critical to address seasonal water shortages. Adoption of adaptive water governance, including irrigation efficiency improvements and real time hydrological monitoring, is essential to enhance water security under climate variability.

5. CONCLUSION

Based on the analysis of rainfall patterns and mainstay discharge in the Moayat River, an anomaly was identified between the FJ Mock analysis and the observed discharge data. The maximum discharge occurred between February and March, while the minimum discharge was recorded in May. Scenario analysis results showed that under Scenario 1, water availability can meet raw water needs until 2054; under Scenario 2, only until 2038; and under Scenario 3, until 2059. These findings highlight the vulnerability of the Moayat River to fluctuations in climate and water demand growth.

To address the risk of water shortages, strategic watershed management interventions are required. Implementation of river floodplain management, bioretention systems, and urban farming practices is recommended to enhance water infiltration, reduce surface runoff, and stabilize discharge. These solutions aim to optimize the hydrological balance of the Moayat Watershed, thus securing water availability for both domestic and non-domestic uses.

Future implications of this study emphasize the need for adaptive water management under changing climatic conditions. Continuous monitoring of hydrological patterns, investment in water storage infrastructure, and community engagement in sustainable water use practices will be crucial. Collaborative efforts among stakeholders will ensure long-term resilience and sustainability of water resources in Kotamobagu and its surrounding areas.

6. DECLARATIONS

6.1. About Authors

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6.2. Author Contributions

Conceptualization: MA; Methodology: EK, BE and DP; Software: MA and DP; Validation: BE and DP; Formal Analysis: BE and EK; Investigation: EK, BE, and DP; Resources: MA; Data Curation: DP; Writing Original Draft Preparation: MA, EK, BE, and DP; Writing Review and Editing: MA, BE, and DP; Visualization: MA; All authors, MA, EK, BE, and DP, have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

6.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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Water Availability in the Moayat River in Meeting Water Needs in Kotamobagu, North Sulawesi

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ABSTRACT

The Moayat River in Kotamobagu, North Sulawesi, plays an important role as a water source to meet the needs of the local community. However, water management in this area faces significant challenges due to seasonal discharge fluctuations, changes in land cover, and increasing water demand. **This study aims** to analyze the water availability of the Moayat River based on surface water conditions and current water demand assessments, future water demand projections, and water balance evaluations. **The results show** that current water availability is sufficient to meet domestic water needs. However, surface water conditions are influenced by climate change indicators, so that river discharge approaches the water demand threshold, thus creating a risk of water shortages, especially for irrigation. Over the past decade, forest cover in the catchment area has decreased, which has led to increased surface runoff and reduced water infiltration. **Based on these findings**, climate change in land cover greatly affects surface flow conditions so that an integrated management strategy is needed, including watershed rehabilitation, development of water storage infrastructure, and increasing water use efficiency, is essential to ensure the long-term sustainability of water supply from the Moayat River.

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1. INTRODUCTION

Water is essential for sustaining human life and ecosystems, supporting domestic, agricultural, and industrial needs, and maintaining environmental balance. In many tropical regions, such as Indonesia, water resources face increasing pressure due to population growth, urbanization, and changes in land use patterns. Kotamobagu, located in North Sulawesi, serves as a concrete example of an area facing these challenges [1]. As population growth and economic development drive water demand, effective water resource management has become a critical issue [2]. The Moayat River, a key water source in the region, plays a strategic role in meeting the needs of the local community and supporting other sectors [3].

Water resource management challenges are often linked to uneven spatial and temporal distribution. Rivers in tropical areas generally exhibit seasonal flow patterns strongly influenced by annual rainfall [4]. When rainfall is high, river discharge tends to be abundant, but during the dry season, discharge often declines drastically. This phenomenon complicates communities ability to optimally utilize water resources throughout the year [5]. Therefore, an in depth study of the Moayat River water availability is essential to ensure a sustainable water supply, especially during critical seasons.

Previous studies have highlighted the importance of the interaction between environmental factors and human activities in determining the sustainability of water resources [6]. Land cover changes, such as deforestation and urbanization, can exacerbate hydrological imbalances, causing increased surface runoff and reduced groundwater infiltration, leading to water loss [7]. Meanwhile, the development of water infrastructure, such as reservoirs and dams, plays a crucial role in stabilizing water supply during the dry season [8]. In the context of the Moayat River, these approaches offer effective solutions to address significant discharge fluctuations [9].

Kotamobagu, a rapidly developing region, is experiencing steady population growth, accompanied by an increase in water needs for domestic use, agricultural irrigation, and the expanding industrial sector, water demand in the region has increased by 20% over the past decade. However, this growth is not always matched by the capacity of the water supply, particularly during the dry season when the Moayat River discharge significantly declines [10].

Previous studies indicate that over 60% of water sources in this region come from rivers, including the Moayat River [11]. This high dependence on rivers emphasizes the importance of effective management to ensure water availability. High reliance on surface water requires an integrated management approach, combining land conservation, water infrastructure development, and efficient water use. These strategies are also relevant to the Moayat River context [12].

The Moayat River exhibits a seasonal flow pattern strongly influenced by rainfall [13]. Hydrological data show that annual rainfall in the Kotamobagu region ranges from 2,000 to 3,000 mm, with the peak rainy season occurring between November and April. The maximum discharge of the Moayat River is recorded from December to February, while the minimum discharge occurs from July to September [14]. These fluctuations create challenges in water supply management, especially during the dry season [15].

Changes in rainfall patterns due to climate change can exacerbate river flow fluctuations, increasing the risk of flooding during the rainy season and drought during the dry season and surface temperatures affect the hydrological conditions of a watershed [16]. In the context of the Moayat River, this underscores the need for long-term analysis to anticipate the impact of climate change on hydrological dynamics [17].

One key factor influencing water availability in the Moayat River is the condition of its catchment area. A healthy catchment area, with adequate vegetation cover, contributes to river flow stability by increasing water infiltration and reducing surface runoff [18]. Over time, catchment areas face pressure from deforestation for agriculture, settlements, and other economic activities, reducing the soils ability to absorb water [19].

Ecosystem based approaches, such as reforestation of catchment areas and forest protection, can improve water availability during dry seasons and reduce flooding risks in rainy seasons [20]. In the context of the Moayat River, rehabilitating the catchment area is an important step toward enhancing the sustainability of water resources [21].

Global climate change is impacting hydrological patterns, especially in tropical regions like Indonesia [22]. Rising global temperatures have altered rainfall patterns, with some areas experiencing higher rainfall intensity while others face reduced rainfall. In the context of the Moayat River, these changes have the potential to exacerbate river discharge fluctuations, increasing the risk of flooding and drought in certain seasons [23].

Climate change simulations using hydrological models can help identify long term risks to water availability. In the context of the Moayat River, similar analyses are needed to anticipate the impact of climate change on water supply. Effective water resource management requires an integrated approach that combines scientific analysis, government policies, and active community involvement. In many regions, infrastructure development such as reservoirs and dams has proven effective in reducing water supply fluctuations [24]. However, these developments must be balanced with land conservation and efficient water use.

Constructing small reservoirs in catchment areas can increase water storage capacity and reduce dependence on surface water flow. In the context of Kotamobagu, this approach can be applied to optimize the utilization of the Moayat River [25]. Based on literature reviews and conditions in the Kotamobagu area, this study focuses on the water availability of the Moayat River and its contribution to water resilience.

2. METHODOLOGY

This study conducted a hydrological analysis using rainfall data over a 14-year period (2009–2022) to evaluate the water availability of the Moayat River. The FJ Mock method was applied to determine river discharge based on rainfall conditions. Data for this study included rainfall and discharge measurements from local weather stations, population data from the Civil Registry Office, and land use mapping provided by local authorities [26].

2.1. Location Description

This study was conducted in the Moayat River Basin (DAS), located in Kotamobagu, North Sulawesi Province. The Moayat River Basin stretches over an area of 68 km^2, from the hilly upstream area to the downstream area with the distribution of land use as seen in Table 1.

Table 1. Land use of Moayat Watershed in 2022

Land Cover Type	Total Area (km²)	Percentage (%)
Forest	0.431948	36.95
Mixed Gardens	0.368805	31.55
Rice Fields	0.956418	18.75
Savanah Grasslands	0.071826	6.14
Dryland Farming	0.095104	8.13
Shrubs	0.049909	4.26
Settlements	0.000244	0.05
Freshwater Ponds	0.000249	0.02
Rivers	0.00064	0.05

As shown in Figure 1, the map of the Moayat Watershed illustrates the study area topography and land cover types, providing a spatial context for analyzing water availability in relation to land use and geographic conditions.

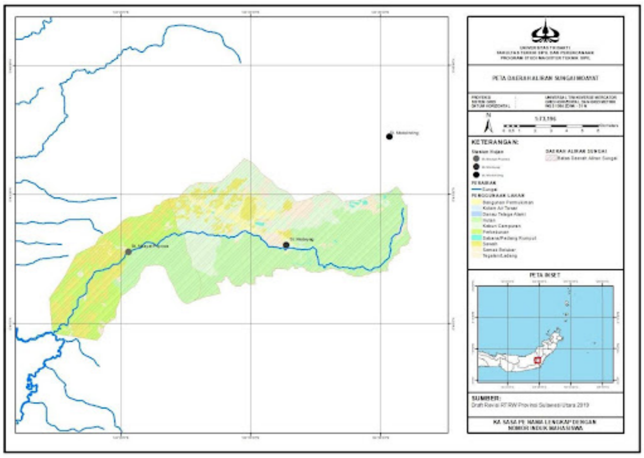

Figure 1. Map of the Moayat Watershed (DAS Moayat)

2.2. Data Collection

The data utilized in this research includes the following:

- **Rainfall and River Discharge Data:** Spanning the past 14 years, collected from three observation stations: Moayat Rain Station, Modayag Rain Station, and Modoinding Rain Station, provided by the River Basin Organization of Sulawesi I (Balai Wilayah Sungai Sulawesi I).
- **Discharge Data:** Covering the last 10 years, obtained from the Moayat measurement station under the same organization.

- **Population Data:** Sourced from the Civil Registry Office of Kotamobagu City.
- **Land Cover Data:** Derived from the 2022 updated Indonesian Digital Land Cover Database (Rupabumi Indonesia).

2.3. Data Analysis

The data in this study were processed using the FJ Mock method to understand the existing discharge conditions of the Moayat River and the climatology of the Moayat Watershed (DAS Moayat). It also aimed to identify the trends in the Moayat River discharge over 14 years (2009–2022) and assess the water availability of the Moayat River in meeting the needs of the community in Kotamobagu [27].

3. RESULT AND DISCUSSION

3.1. Rainfall Characteristics

In the recording of rainfall at Moayat Station, the characteristics of rainfall include maximum rainfall of 380.60 mm which occurred in July 2012, minimum rainfall of 13 mm which occurred in September 2009, while the average rainfall is 150.40 mm. The characteristics of rainfall indicate that the area is included in the moderate category. The Modayag Station, this area has rainfall characteristics including maximum rainfall of 383.58 mm in October 2016 and minimum rainfall of 12.62 mm in October 2015, while the average rainfall in the Modayag station area is 131.68 mm. At this station there is an anomaly in rainfall because the maximum and minimum conditions occur in the same month. The Modoinding Station, the characteristics of maximum rainfall that occurred were 357.93 mm in November 2009 and minimum rainfall of 0.85 mm in August 2015, while the average rainfall was 136.04 mm. The characteristics of rainfall for each station can be seen in the Figure 2.

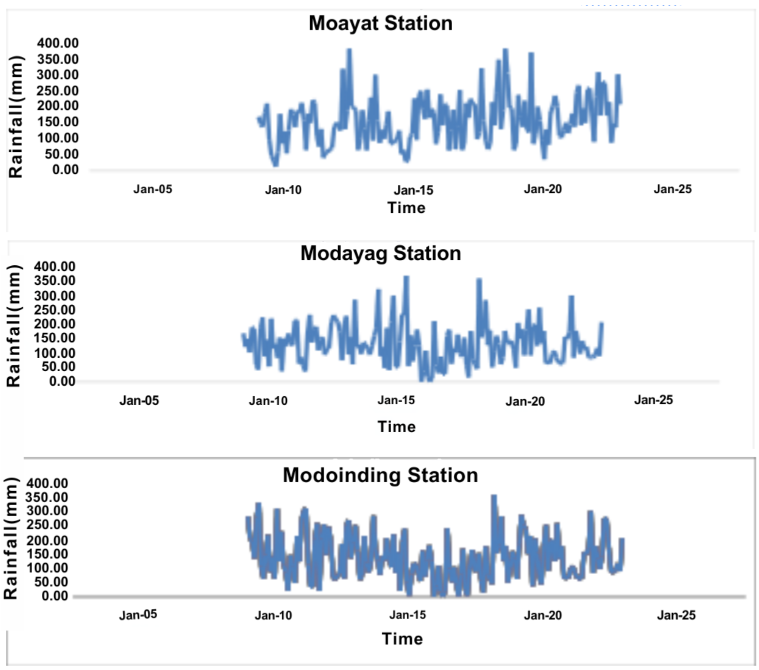

Figure 2. Monthly Rainfall Graph Based on Stations

As shown in Figure 2, annual rainfall data from Moayat, Modayag, and Modoinding stations show a clear seasonal pattern, with high rainfall between November and April, and a significant decrease from May to October. These fluctuations directly affect the water availability of the Moayat River, with higher rainfall causing increased river discharge during the rainy season. This is because the condition of rainfall intensity is influenced by the characteristics of a watershed, the characteristics of the watershed in the upstream part will be different from the conditions of the watershed in the middle and downstream parts so that they experience significant variations in rainfall, indicating the vulnerability of the area to seasonal changes [28].

3.2. Probability of Rainfall

In the analysis of rainfall probability in this study, the evaluation is based on baseline data from a 10-year period (2009–2019), which is compared with rainfall data from the years 2020, 2021, and 2022. The probability of change is observed based on both annual and monthly rainfall patterns. Based on the analysis, the average annual rainfall in the study area is approximately 2,008 mm. The year with the highest recorded rainfall was 2022, reaching 2,708 mm, while the lowest occurred in 2020, with only 1,452 mm. This fluctuation represents a significant variation, with a difference of up to 1,256 mm over the span of 14 years. These conditions indicate that rainfall intensity throughout the year experiences notable increases and decreases. Specifically, there was a decrease in rainfall in 2020 by 20.29%, followed by an increase of 44.02% in 2021, and a further increase of 68.54% in 2022.

Table 2. Comparison of Annual Rainfall

Year	Annual Rainfall (mm)	Percentage (%)
2009–2019	1471.92	Baseline
2020	1173.1	-20.29%
2021	2120.2	44.02%
2022	2480.8	68.54%

Monthly rainfall pattern analysis is carried out in the same way as the annual analysis, namely using baseline data which is then subjected to statistical analysis. The results of the monthly rainfall distribution analysis show uneven results. The highest average rainfall occurs in April at 188.31 mm, while the lowest average rainfall occurs in August at 99.00 mm. Furthermore, a comparison is made between the 2009–2019 rainfall and the monthly rainfall in 2020, 2021, and 2022 to identify whether there is an increase or decrease in rainfall. In general, there is a significant fluctuation in rainfall from year to year, especially in 2020, which showed a notable decrease in rainfall compared to the 2009–2019 period. Meanwhile, in 2021 and 2022, rainfall experienced a sharp increase in most months, with peaks observed in February and November 2022.

Table 3. Comparison of Monthly Rainfall

Month	2009–2019 (average)	2020 (mm)	2021 (mm)	2022 (mm)
January	165.73	35.10	143.50	231.70
February	145.47	127.50	177.50	307.50
March	167.67	191.82	137.60	172.20
April	188.31	150.26	244.00	276.00
May	171.82	92.13	265.70	273.50
June	140.14	76.48	142.50	171.70
July	160.79	108.93	193.00	213.50
August	99.00	15.43	149.50	87.60
September	102.67	24.58	253.60	145.50
October	126.57	51.68	257.00	134.40
November	139.26	94.79	171.80	300.50
December	133.73	74.82	90.10	206.50

3.3. Water Discharge at Moayat River

The water discharge of the Moayat River is strongly influenced by annual rainfall fluctuations, with clear seasonal variations. Generally, the highest discharge occurs during the rainy season, particularly from January to April, while the lowest discharge is observed during the dry season, especially from August to September [29].

The average monthly discharge during the observation period shows that the highest discharge occurred in February 2021 at 7.04 m^3/s, coinciding with high rainfall of 177.5 mm. Conversely, the lowest discharge occurred in October 2014, with 0.49 m^3/s, corresponding to the lowest rainfall of 34.42 mm.

The annual average discharge of the Moayat River directly correlates with rainfall, where each increase in monthly rainfall leads to a significant rise in discharge [30]. For instance, in February 2022, the discharge reached 4.48 m^3/s with a rainfall of 307.5 mm, reflecting the major contribution of surface runoff.

However, certain anomalies are noteworthy. High discharge in some months does not always correspond with high rainfall. For example, in March 2015, the discharge reached 2.14 m^3/s despite rainfall being only 127.29 mm. This could be influenced by factors such as groundwater contributions, runoff from upstream areas, or human activities that enhance river flow.

Low discharge during the dry season highlights the limited baseflow from groundwater infiltration. In August 2014, for instance, the discharge was just 0.50 m^3/s despite rainfall of 67.86 mm. This underscores the need for sustainable water resource management, particularly the protection of recharge areas and optimization of groundwater use [31].

Overall, the discharge of the Moayat River shows a high dependence on rainfall patterns. Therefore, shifts in rainfall patterns due to climate change could significantly affect water availability in the future [32].

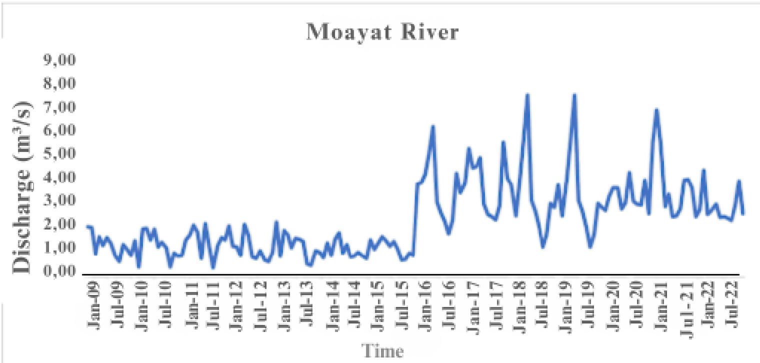

Figure 3. Graph of Average Monthly Discharge of the Moayat River (2009–2022)

3.4. Water balance of Moayat River

A comprehensive evaluation of the Moayat River water balance examines the relationship between water availability (river discharge) and demand (domestic and non domestic uses), comparing water needs with available discharge data.

3.4.1. Water needs

The calculation of water needs in Kotamobagu City takes into account the local population growth rate. The scope of the area used in this study was 33 villages, with an average population growth rate of 0.42%. The population growth projection used for 50 years assumes the same duration as the age of the building. The image below illustrates the condition of population growth in Kotamobagu City. Population projection is the first step to estimate future water needs.

The geometric method is used in this projection because it is able to describe a stable growth trend in urban areas. The projection results show that the population of Kotamobagu City will increase significantly in the next ten years. In 2025, the population is projected to reach 141,250 people and will continue to increase to 163,500 people in 2035. The area with the highest growth is Gogagoman Village, which reflects the level of urbanization and dominant economic activity in the area.

Domestic water needs are calculated based on the standard per capita water needs as regulated in the Indonesian National Standard (SNI) 19-6728.1-2002 concerning Drinking Water Supply System Planning, which is 150 liters/person/day. This standard covers the needs for household activities such as drinking, cooking, bathing, and washing, as well as for non-domestic needs based on the Regulation of the Minister of Public Works and Public Housing (PUPR) Number 27/PRT/M/2016 concerning Guidelines for the Preparation of Drinking Water Supply Systems.

Table 4. Water Needs in Kotamobagu City

Month	Water Discharge (m^3/s)	Water Needs (m^3/s)	Non-Domestic Needs (m^3/s)
Jan	3.36	0.22	0.02
Feb	4.11	0.22	0.02
Mar	4.12	0.22	0.02
Apr	3.58	0.22	0.02
May	2.99	0.22	0.02
Jun	3.00	0.22	0.02
Jul	4.04	0.22	0.02
Aug	3.11	0.22	0.02
Sep	3.28	0.22	0.02
Oct	3.25	0.22	0.02
Nov	4.02	0.22	0.02
Dec	2.64	0.22	0.02

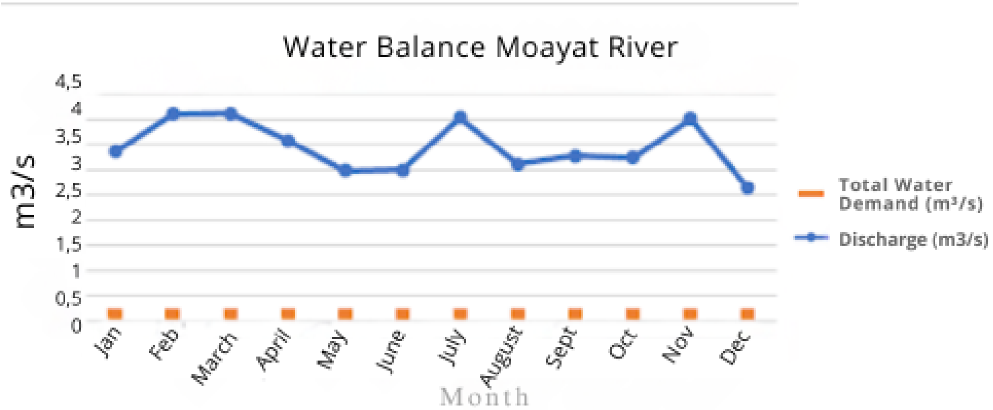

Figure 4. Water balance Moayat River

Based on the Table 4 above, it can be said that the availability of water in the Moayat River is surplus with domestic and non domestic water needs without the use of irrigation.

3.5. Water Availability Conditions Based on Scenarios

In order to assess the future capacity of the Moayat River in meeting water demands, scenario based projections were conducted. These scenarios simulate different levels of raw water allocation and utilization strategies to anticipate various conditions of water supply and demand over time. By evaluating multiple approaches, this analysis aims to identify the critical limits of water availability and propose the most sustainable management practices for long term resilience. Three scenarios are used to project water availability:

3.5.1. Scenario 1 (Raw water allocation 1.5 lps)

Scenario 1 is the allocation of raw water of 1500 lps to meet the need for raw water without utilizing irrigation with water sources from the Moayat River. Based on these conditions, the availability of water in S. Moayat can only meet the need for raw water until 2054. This can be seen in the Figure 5 below.

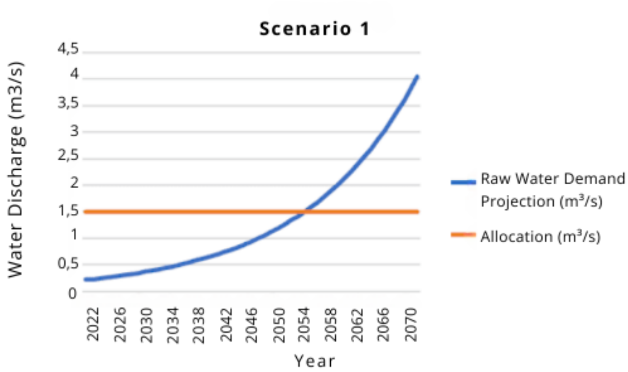

Figure 5. Scenario 1

3.5.2. Scenario 2 (Raw water allocation with irrigation utilization)

Scenario 2 allocates 1500 lps of raw water to meet raw water needs by utilizing irrigation with water sources from the Moayat River. Based on these conditions, the availability of water in S. Moayat can only meet raw water needs until 2038. This can be seen in the Figure 6 below.

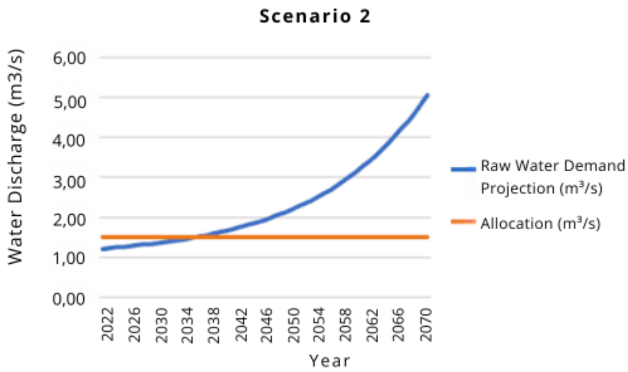

Figure 6. Scenario 2

3.5.3. Scenario 3 (Raw water allocation with 100% optimization)

Scenario 3 allocates 3000 lps of raw water to meet the raw water needs by utilizing irrigation with water sources from the Moayat River. This is based on the average discharge conditions of the Moayat River. Based on these conditions, the availability of water in the Moayat River can only meet the raw water needs until 2059. This can be seen in the Figure 7 below.

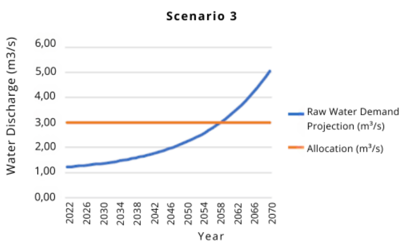

Figure 7. Scenario 3

4. MANAGERIAL IMPLICATIONS

Sustainable water supply from the Moayat River demands integrated watershed management, rehabilitation of upstream areas, and development of decentralized water storage facilities. Strengthening land conservation efforts, improving infiltration rates, and mitigating surface runoff are critical to address seasonal water shortages. Adoption of adaptive water governance, including irrigation efficiency improvements and real time hydrological monitoring, is essential to enhance water security under climate variability.

5. CONCLUSION

Based on the analysis of rainfall patterns and mainstay discharge in the Moayat River, an anomaly was identified between the FJ Mock analysis and the observed discharge data. The maximum discharge occurred between February and March, while the minimum discharge was recorded in May. Scenario analysis results showed that under Scenario 1, water availability can meet raw water needs until 2054; under Scenario 2, only until 2038; and under Scenario 3, until 2059. These findings highlight the vulnerability of the Moayat River to fluctuations in climate and water demand growth.

To address the risk of water shortages, strategic watershed management interventions are required. Implementation of river floodplain management, bioretention systems, and urban farming practices is recommended to enhance water infiltration, reduce surface runoff, and stabilize discharge. These solutions aim to optimize the hydrological balance of the Moayat Watershed, thus securing water availability for both domestic and non-domestic uses.

Future implications of this study emphasize the need for adaptive water management under changing climatic conditions. Continuous monitoring of hydrological patterns, investment in water storage infrastructure, and community engagement in sustainable water use practices will be crucial. Collaborative efforts among stakeholders will ensure long-term resilience and sustainability of water resources in Kotamobagu and its surrounding areas.

6. DECLARATIONS

6.1. About Authors

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6.2. Author Contributions

Conceptualization: MA; Methodology: EK, BE and DP; Software: MA and DP; Validation: BE and DP; Formal Analysis: BE and EK; Investigation: EK, BE, and DP; Resources: MA; Data Curation: DP; Writing Original Draft Preparation: MA, EK, BE, and DP; Writing Review and Editing: MA, BE, and DP; Visualization: MA; All authors, MA, EK, BE, and DP, have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

6.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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