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Trend Analysis and Forecasting of Water Releases from Angat Water Reservoir through Simple Linear Regression

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Abstract*: Actual Water Releases Forecasting Model Using Weka. Figure 8 shows the 10-fold cross-validation technique used in this study to forecast the Actual Water Releases. The said technique provides a more reliable estimate of the model's performance than a single train-test split, as it uses multiple splits of the data. Sunshine, or solar radiation, can indirectly affect water releases in Angat Water Reservoir through its impact on temperature, evaporation, and water demand. Sunshine can heat the surface of the reservoir, causing the water temperature to rise. The study is focused on providing a validated set of simple linear regression models in forecasting actual and approved water releases through temperature, sunshine and rainfall as factors. The study aimed to provide a validated set of forecasting models of water allocation and actual releases in Angat Reservoir with temperature, sunshine and rainfall as factors using simple linear regression. Simple linear regression is a valuable statistical technique that can be used in trend analysis and forecasting of water releases from the Angat Water Reservoir. By identifying the relationship between the variables, simple linear regression can help to forecast water releases.*

Keywords: Angat Water Reservoir, Forecasting, Simple Linear Regression, Water Releases

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1. Introduction

Water is a critical resource that is essential for various human activities, including agriculture, industry, and domestic use. In many parts of the world, including the Philippines, water scarcity is a pressing issue that needs to be addressed. The Angat Reservoir is a significant source of water supply for Metro Manila and nearby provinces. Therefore, analyzing the trends and predicting the water allocation and actual releases from the reservoir is crucial to ensure a sustainable water supply for the region. Trend analysis is a statistical technique that helps to identify patterns and trends in data over a specified period. This analysis can help to identify the factors that influence water releases and provide insights into how these factors may change in the future [1].

To conduct trend analysis on approved water releases and actual water releases from the Angat Reservoir, data from the past several years can be used. Approved water release refers to the amount of water that had been approved for release by NIA. Actual releases refer to the amount of water that is released from the reservoir to meet the allocated water demand. Simple Linear Regression can help to identify the relationship between temperature, rainfall and sunshine and water releases, both approved and actual and predict the need for future water releases. Using the insights gained from trend analysis, predictions can be made about future water allocation and actual releases from the Angat Reservoir. These predictions can help to identify potential water shortages or surpluses and plan for water conservation measures [2].

Simple linear regression is a statistical technique that is commonly used in trend analysis and prediction of approved and actual water releases. In this study, the researcher explored the use of linear regression in trend analysis and forecasting of approved and actual water releases from the Angat Water Reservoir [3].

Using the equation, y = mx + b, where y represents the dependent variables (approved and actual water releases), x represents the independent variable (temperature, sunshine and rainfall), m represents the slope of the line (the change in actual releases for each unit change in temperature, sunshine and rainfall and b represents the intercept (the value of the water releases when the other parameters are zero) [4]. Using this equation, forecasts can be made about the need for future water releases based on changes in temperature, rainfall, and sunshine.

Simple linear regression can also help to identify the factors that influence water releases. By analyzing the slope of the line, it is possible to identify how changes in temperature, sunshine and rainfall can affect actual releases. This information can be used to identify potential water shortages or surpluses and plan for water conservation measures. Simple linear regression is a valuable statistical technique that can be used in trend analysis and forecasting of water releases from the Angat Water Reservoir [5]. By identifying the relationship between the variables, simple linear regression can help to forecast water releases. This information can be used to plan for potential water shortages or surpluses and take proactive measures to mitigate their impact. Additionally, simple linear regression can help to identify the factors that influence water availability and consumption, which can help to optimize the use of water resources and promote water conservation measures.

A. Statement of the Problem

The study aimed to provide a validated set of forecasting models of water allocation and actual releases in Angat Reservoir with temperature, sunshine and rainfall as factors using simple linear regression. 2

Specifically, this study aimed to answer the following:

1. What is the demographic profile of the Angat Dam Water Reservoir in terms of the following:
   a. Temperature
   b. Sunshine
   c. Rainfall
   d. Approved Water Releases
   e. Actual Water Releases
2. How to use simple linear regression in forecasting Actual and Approved Water Releases in Angat Dam Reservoir?
3. How to evaluate the accuracy of the developed forecasting models?

B. Scope and Limitations of the Study

The study is focused on providing a validated set of simple linear regression models in forecasting actual and approved water releases through temperature, sunshine and rainfall as factors. First, the researcher described the Angat Water Reservoir in terms of temperature, sunshine and rainfall as parameters and as well as the actual and approved releases for the past 11 years. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) has a weather station located near Angat Water Reservoir in Bustos, Bulacan. The weather station is called the PAGASA Bustos Synoptic Station, and it provides regular updates on weather conditions in the area. The data from the said station on factors such as temperature, rainfall, and sunshine were considered in this study. The said reports detailed the temperature, rainfall, and sunshine from 2012 to 2022. The approved and actual water releases reports from 2012 to 2022 came from the National Irrigation Administration. The Angat Water Reservoir will be described in terms of the temperature, rainfall and sunshine as well as approved and actual water releases reports from 2012 to 2022.

Weka version 3.8.6 was used to generate the forecasting models for the Approved and Actual Water Releases (weka. classifiers. functions); and simple Linear Regression was used. The simple linear regression models provided by Weka were generated to determine the initial weight for the temperature, rainfall and sunshine parameters.

Percentage Error (%Error), Correlation Coefficient (CC), Mean Absolute Error (MAE), Relative Absolute Error (RAE) and Root Mean Square Error (RMSE), Relative Squared Error (RSE) were used to evaluate the accuracy of the forecasting models.

The study is limited to the data sets from PAGASA Bustos Synoptic Station and NIA. Temperature, Rainfall and Sunshine are the data sets from the former while Approved and Actual Releases were provided by the latter. These data sets covered only the period between 2012 and 2022.

C. Conceptual Framework

The researcher used the conceptual framework below in conducting the study. It was anchored on The Knowledge Discovery Databases (KDD) model.

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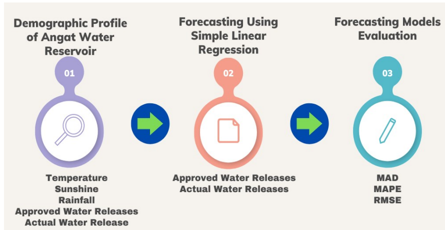

Figure 1: Conceptual Framework

As depicted in figure 1, the researcher analyzed the trends in the gathered data sets through a demographic profile of the Angat Water Reservoir. The said profile describes and analyzes the data sets using temperature, sunshine, rainfall, approved and actual water releases of Angat Water Reservoir covering the years from 2012 to 2022. Simple linear regression was used in forecasting the Approved and Actual Water Releases by using the relationship between the dependent and independent variables to make forecasts about future values of the dependent variable. In this case the independent variables are temperature, sunshine and rainfall while the dependent variables are water releases. The forecasting models were evaluated using Percentage Error (%Error), Correlation Coefficient (CC), Mean Absolute Error (MAE), Relative Absolute Error (RAE) and Root Mean Square Error (RMSE), Relative Squared Error (RSE) were used to evaluate the accuracy of the forecasting models.

2. Materials and Methods

The data sets from PAGASA Bustos Synoptic Station and NIA were used to describe Actual and Approved Water Releases through graphs. Changes in temperature, sunshine and rainfall over the past 11 years were noted as well as the water releases variations were presented. Using Weka 3.8.6, the simple linear regression models were determined. Running the data sets in Weka was necessary to determine the initial weight for computation of the simple linear regression implementation.

Using temperature, rainfall, and sunshine as independent variables and water releases as dependent variables, the simple linear regression models for forecasting the actual and approved water releases were generated. Simple Linear Regression determines the relationship between two different variables, called the dependent and independent variables. When the relative relationship between the two variables is calculated, a linear regression model to forecast the water releases could be formulated. $y = bx + a$ is the formula for a linear regression. The "y" is the value to forecast, the "b" is the slope of the regression line, the "x" is the value of the independent value, and the "a" represents the y-intercept. The regression equation simply describes the relationship between the dependent variable (y) and the independent variable (x) [6].

3. Results and Discussions

The following section presents the results of analyzing the historical data on temperature, sunshine and rainfall as well as approved and actual water releases towards the development of various forecasting models using simple linear regression.

A. Demographic Profile

Data on the reports from PAGASA on temperature sunshine and rainfall from 2012 to 2022 are presented in the next section. The actual and approved water releases reports from 2012 to 2022 from NIA were also used to describe the Angat Water Reservoir.

Table 1 shows the historical data sets of the dependent and independent variables used in this study. The recorded daily temperature, rainfall and sunshine were summed up to get the monthly and then the yearly average values of each of the said parameters. I1 to I3 represents the independent variables of temperature, rainfall, and sunshine respectively for the 11-year periods of 2012 to 2022. Columns D1 and D2 represent the dependent variables which are the approved and actual water releases from 2012 to 2022. The recorded daily water releases, both approved and actual, were summed up to get the monthly and then the yearly average values of each of the said dependent variables.

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Year	I1	I2	I3	D1	D2
2012	31.04	155.55	5.83	27.18	41.63
2013	30.89	239.74	5.53	32.86	36.92
2014	32.12	133.58	6.64	36.66	37.61
2015	30.83	203.33	5.42	19.77	21.98
2016	31.35	219.78	5.83	22.68	26.63
2017	31.44	182.05	5.91	25.25	27.16
2018	31.23	140.90	6.33	36.57	48.99
2019	31.45	181.70	7.01	28.09	29.26
2020	32.04	157.56	6.33	27.50	24.47
2021	32.03	144.23	6.19	23.04	30.83
2022	31.77	229.74	6.29	30.75	31.46

Table 1: Angat Water Reservoir Demographics

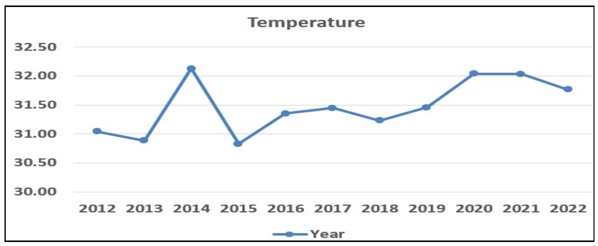

Figure 2: Changes in Temperature

Figure 2 depicts the changes in temperature in the location of Angat Water Reservoir as recorded by PAGASA Bustos Synoptic Station. Temperature can have several effects on water releases in Angat Water Reservoir. Higher temperatures can cause more water to evaporate from the surface of the reservoir. This means that more water needs to be released to compensate for the loss of water due to evaporation. Higher temperatures can increase the demand for water for irrigation, drinking, and other purposes. This means that more water needs to be released from the reservoir to meet the demand. Temperature can also impact the amount and timing of rainfall. Higher temperatures can cause more intense rainfall events, which can result in more water flowing into the reservoir and potentially requiring higher releases. Temperature can impact the quality of the water in the reservoir, which can affect the amount of water that can be released. Higher temperatures can promote the growth of harmful algae blooms, which can make the water unsafe for release.

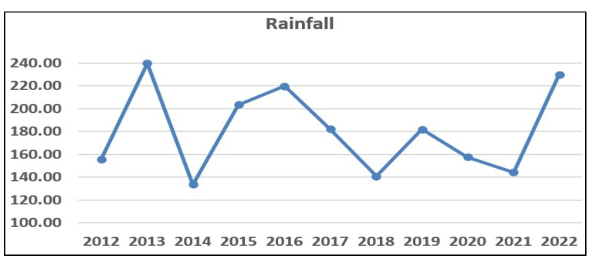

Figure 3: Changes in Rainfall

Figure 3 shows the changes in rainfall in the location of Angat Water Reservoir as recorded by PAGASA Bustos Synoptic Station. Rainfall is the primary source of water that enters the reservoir, and its volume and intensity can vary significantly depending on the weather conditions in the area. Heavy rainfall can result in large amounts of water flowing into the reservoir, which may require increased water releases to prevent the reservoir from overflowing. Heavy rainfall can quickly fill up the reservoir, resulting in a higher storage level and potentially requiring increased water releases to maintain a safe level. Rainfall can also impact the demand for water in the area. If there is heavy rainfall, there may be less demand for water for irrigation, drinking, and other purposes, which could reduce the need for water releases. Moreover, a lack of rainfall can lead to drought conditions, which can result in lower inflow into the reservoir and reduced storage levels. In these cases, water releases may need to be reduced to conserve water and maintain a safe.

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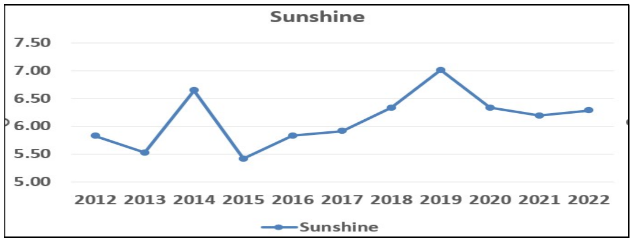

Figure 4: Changes in Sunshine

Figure 4 shows the changes in sunshine in the location of Angat Water Reservoir as recorded by PAGASA Bustos Synoptic Station from 2012 to 2022. Sunshine, or solar radiation, can indirectly affect water releases in Angat Water Reservoir through its impact on temperature, evaporation, and water demand. Sunshine can heat the surface of the reservoir, causing the water temperature to rise. This can result in higher evaporation rates, which can reduce the overall water volume in the reservoir and potentially require increased water releases to maintain a safe level. Higher levels of sunshine can increase evaporation rates, which can reduce the water volume in the reservoir and potentially require increased water releases. Sunshine can also impact the demand for water in the area. During hot and dry weather conditions, there may be an increased demand for water for irrigation, drinking, and other purposes, which could increase the need for water releases from the reservoir. While sunshine itself does not directly affect water releases in Angat Water Reservoir, it can impact other factors such as temperature, evaporation, and water demand, which can in turn impact water releases.

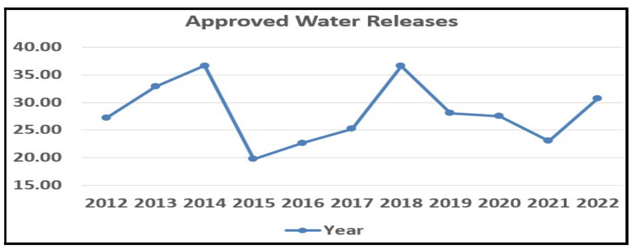

Figure 5: Approved Water Releases for the Past 11 Years

Figure 5 shows the Approved Water Releases in cubic meters per day (m^3/d) from the records of NIA [7]. The National Irrigation Administration (NIA) is responsible for managing and overseeing the use of water resources in the Philippines, including the Angat Water Reservoir. NIA is tasked with ensuring that water releases are allocated and approved from the reservoir in a fair, equitable, and sustainable manner, taking into account the needs of various stakeholders including farmers, households, industries, and the environment. NIA approves water releases from the Angat Water Reservoir to ensure that there is enough water available to meet the demand for irrigation, domestic, and industrial use, while also ensuring that the water level in the reservoir remains at a safe and sustainable level [8]. The approval process typically involves an assessment of the water level in the reservoir, the anticipated demand for water, and the weather conditions in the area. NIA also coordinates with other government agencies and stakeholders to ensure that water releases are aligned with broader water management objectives, such as mitigating the impacts of drought, protecting water quality, and maintaining the ecological health of rivers and other water bodies.

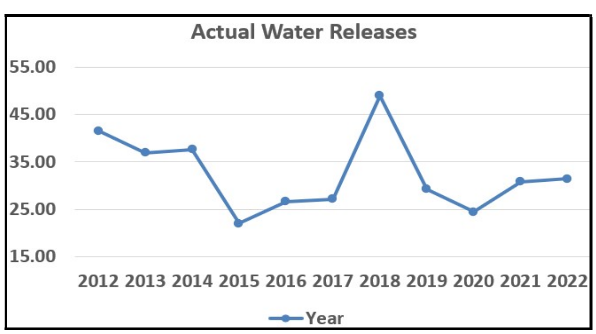

Figure 6: Actual Water Releases for the Past 11 Years

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Figure 6 shows the Actual Water Releases in cubic meters per day (m^3/d) from the records of NIA. The actual water releases from the reservoir help to ensure that there is enough water available to meet the demand for irrigation, domestic, and industrial use in the area. By monitoring and adjusting the water releases as needed, water managers can help to prevent water shortages and ensure that water is allocated and distributed fairly and efficiently. The actual water releases from the reservoir can also help to manage flood risk in the surrounding areas. By releasing water from the reservoir in a controlled manner during periods of heavy rainfall, water managers can help to prevent flooding and minimize damage to property and infrastructure. The actual water releases from the reservoir can also help to maintain the ecological health of the surrounding rivers and other water bodies. By releasing water in a manner that mimics natural flow patterns, water managers can help to support the health of aquatic ecosystems and the species that depend on them. The actual water releases from the reservoir can also provide important information for reservoir management. By monitoring the volume and timing of water releases, water managers can track changes in reservoir levels, predict future water availability, and make informed decisions about water allocation and use.

B. Simple Linear Regression

For the forecasting models using simple linear regression, the data sets regarding the dependent and independent variables from 2012 to 2022 were used as training data sets in Weka 3.8. The training data sets for the Approved and Actual Water Releases were saved as .CSV files and were ran using the Simple Linear Regression in in Weka 3.8.6.

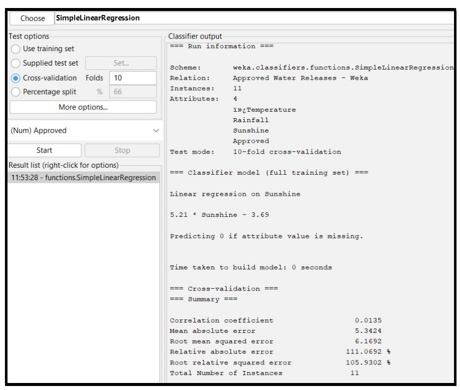

Figure 7: Approved Water Releases Forecasting Model Using Weka

As seen in Figure 7, 10-fold cross-validation was used. It is a technique used in machine learning to evaluate the performance of a forecasting model. In Weka, 10-fold cross-validation involves dividing the available data into 10 equally-sized subsets, or folds. The model is then trained on 9 of these folds and tested on the remaining fold. This process is repeated 10 times, with each of the 10 folds used as the testing set once. As shown in Figure 7, Weka 3.8.6 provided sets of slopes (b) for every input (x) and y-intercept value used in the computation of the Simple Linear Regression model.

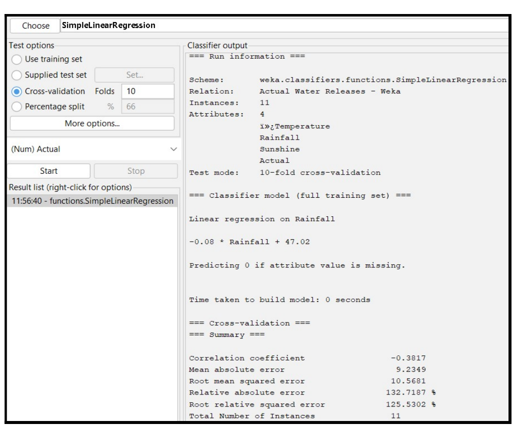

Figure 8: Actual Water Releases Forecasting Model Using Weka

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Figure 8 shows the 10-fold cross-validation technique used in this study to forecast the Actual Water Releases. The said technique provides a more reliable estimate of the model's performance than a single train-test split, as it uses multiple splits of the data. It makes efficient use of the available data, as it uses all of the data for training and testing.

E2 fx =0.08*B2+47.02

	A	B	C	D	E
1	Temperature	Rainfall	Sunshine	Actual	Forecast
2	31.04	155.55	5.83	41.63	59.46
3	30.89	239.74	5.53	36.92	66.20
4	32.12	133.58	6.64	37.61	57.71
5	30.83	203.33	5.42	21.98	63.29
6	31.35	219.78	5.83	26.63	64.60
7	31.44	182.05	5.91	27.16	61.58
8	31.23	140.9	6.33	48.99	58.29
9	31.45	181.7	7.01	29.26	61.56
10	32.04	157.56	6.33	24.47	59.62
11	32.03	144.23	6.19	30.83	58.56
12	31.77	229.74	6.29	31.46	65.40

Figure 9: Simple Linear Computation Using Excel

As shown in Figure 9, to compute for the forecast of a particular year, Y = bx+a. b0* I1 + b1* I1 + …bn*In + a. The process is repeated for all the inputs and slopes and the y-intercept (a) for all the years under study. Excel was used for computing the forecasts for both the Actual and Approved Water Releases.

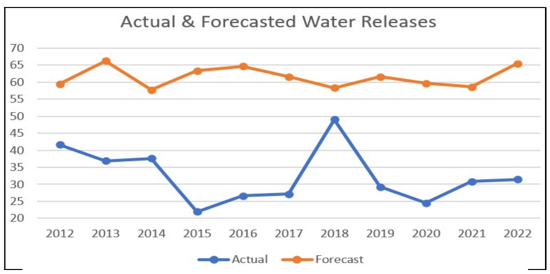

Figure 10 Simple Linear Computation Using Excel

Figure 10 shows the actual and forecasted water releases from 2012 to 2022. It was noted that the recorded actual releases in the Angat Water Reservoir did not intercept at any point with the forecasted values. This implicates a significant difference between the two sets of values.

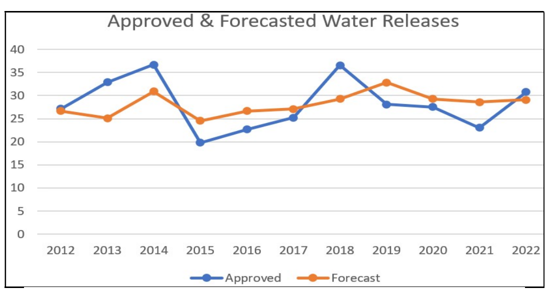

Figure 11: Simple Linear Computation Using Excel

As shown in Figure 11, there are many points when the Approved and Forecasted values intercepted in the graph. This implicates that there are values between the two data under investigation which are meeting or almost similar at some point.

C. Evaluation of Accuracy

Table 2 shows the error rates of the simple linear regression models developed in this study. Error rate were computed using the formula of:

> ABS (Forecasted_WaterReleases – Actual_WaterReleases) / Actual_WaterReleases * 100. It is percentage of error of the absolute value of the researcher's forecasted water releases against the recorded water releases by NIA.

In this study, FM1 represents the Approved Water Releases while FM2 is for the Actual Water Releases. From the years 2012 to 2022, it was only once (2018) when FMS performed better than FM1 in terms of forecasting accuracy.

Year	FM1	%Error	FM2	%Error	Lowest
2012	26.68	1.82	59.46	42.84	FM1
2013	25.12	23.55	66.20	79.30	FM1
2014	30.90	15.70	57.71	53.43	FM1
2015	24.55	24.17	63.29	187.93	FM1
2016	26.68	17.66	64.60	142.59	FM1
2017	27.10	7.33	61.58	126.75	FM1
2018	29.29	19.91	58.29	18.99	FM2
2019	32.83	16.88	61.56	110.38	FM1
2020	29.29	6.51	59.62	143.66	FM1
2021	28.56	23.96	58.56	89.94	FM1
2022	29.08	5.43	65.40	107.88	FM1

Table 2: Percentage Error Summary

Table 3 supported the results of the previous table with regards to which forecasting model is better. As indicated in Table 3, FM1 outperformed FM2 in terms of the mentioned criteria in evaluating the accuracy of the two (2) forecasting models.

Criteria	FM1	FM2	Lowest
CC	0.0135	-0.3817	FM2
MAE	5.3424	9.2349	FM1
RMSE	6.1692	10.5681	FM1
RAE	111.0692%	132.7187%	FM1
RRSE	105.9302%	125.5301%	FM1

Table 3: Forecasting Models Evaluation Summary

4. Conclusion

Water scarcity is a pressing issue in many parts of the world, including the Philippines, where the Angat Reservoir is a crucial source of water supply for Metro Manila and nearby provinces. To ensure a sustainable water supply, trend analysis is needed to identify the factors that influence water releases. Simple linear regression is a statistical technique that can be used to analyze the data and predict water releases based on temperature, sunshine and rainfall. The equation $y = mx + b$ is used to identify the changes in actual water releases for each unit change in temperature, sunshine and rainfall. By analyzing the slope of the line, it is possible to identify how changes in temperature, sunshine and rainfall can affect water releases and plan for water conservation measures. Simple linear regression is a valuable tool for predicting water releases from the Angat Reservoir and preparing for potential water shortages or surpluses. This study aimed to use simple linear regression to forecast water allocation and actual releases in the Angat Reservoir. To do this, the researcher first described the Angat Water Reservoir in terms of temperature, sunshine, and rainfall, and gathered data from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and the National Irrigation Administration. The researcher then used Weka version 3.8.6 to generate forecasting models, which were evaluated using Percentage Error (%Error), Correlation Coefficient (CC), Mean Absolute Error (MAE), Relative Absolute Error (RAE) and Root Mean Square Error (RMSE), and Relative Squared Error (RSE). The simple linear regression models developed used temperature, sunshine, and rainfall as independent variables, and water releases as the dependent variable. The results of the study showed that simple linear regression can be an effective tool for forecasting water allocation and consumption in the Angat Reservoir. This study provides data on temperature, rainfall, sunshine, approved and actual water releases from 2012-2022 from the PAGASA Bustos Synoptic Station and the NIA. Temperature, rainfall, and sunshine are the independent variables, and the approved and actual water releases are the dependent variables. Higher temperatures can cause more water to evaporate, increase the demand for

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water, and impact the amount and timing of rainfall. Higher temperatures can also affect the quality of the water in the reservoir. Rainfall is the primary source of water that enters the reservoir and heavy rainfall can require increased water releases. Sunshine can indirectly affect water releases by impacting temperature, evaporation, and water demand. The NIA is responsible for managing and overseeing the use of water resources and approving water releases from the Angat Water Reservoir to meet the demand while also keeping the water level at a safe and sustainable level. Water releases from the NIA reservoir are an important factor in managing water availability, flood risk, and the health of aquatic ecosystems. To ensure water resources are managed efficiently, water managers must be able to accurately forecast water releases. To do this, simple linear regression models can be used with training data sets to predict future water releases. Weka 3.8.6 is a machine learning software that can be used to train forecasting models using the Simple Linear Regression algorithm. The training data sets for Approved and Actual Water Releases are saved as .CSV files and run with 10-fold cross-validation, which is a technique used to evaluate the performance of a forecasting model. By monitoring and adjusting water releases as needed, water managers can help to manage water resources effectively, reducing the risk of water shortages or floods.

This study recommends the use of other forecasting techniques to build models and compare the results with existing studies such as this. Also, other parameters aside from temperature, sunshine and rainfall may also be considered. It is further recommended to look into other water reservoir with data sets for temperature, sunshine and rainfall considered such as similar in this study.

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