FORECASTING THE WATER CONSUMPTION IN THE CITY OF MATI WITH TIME SERIES ANALYSIS

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ABSTRACT: *Water has always been associated with life; hence, efficient and appropriate prediction is ultimately needed for future water consumption. In this study, the seasonal ARIMA model was utilized in forecasting water consumption in the City of Mati using the monthly consumption in cubic meters (CBM) from January 2006 to July 2021. Specifically, this piece of endeavor is anchored to the time-series models as it looks at past patterns of data and attempts to predict the future based on the underlying patterns contained within those data. Upon diagnostic checking with the use of AIC, SBC, and MAPE; the ARIMA* $(0, 1, 1)\times(0, 0, 2)_{12}$ *was found to be the best-fit model to do the forecasting. The result showed an increase of approximately 4.12% in the average annual water consumption. And it further revealed that there will be a nearly 15.48% increase in water consumption for the year 2021 vis-à-vis year 2023.*

Keywords: ARIMA Model; forecasting; City of Mati; time series analysis; water consumption

I. INTRODUCTION

Water is undeniably a source of life and is even associated with the existence of human and animal beings [1]. In developing counties, water quality is really a pressing problem which is also associated to poverty and various health concerns [2, 3, 4].

At the outset of 2020, the Coronavirus Disease (COVID-19) erupted and became a major concern when it was announced by WHO as a pandemic. Its drastic impact has been very noticeable in almost all sectors of society [5]. In this context, as the governments respond to a variety of effects from the pandemic, the water sector will play a significantly crucial role in the control, recovery, and rebuilding phases [6]. This role encompasses the extensiveness and depth of water resource management's different realms and specializations [7].

The Philippines is a developing country that has an enormous water resource indispensable for its improvements that include farming and other livelihood industries [8, 9]. Nonetheless, the country's freshwater ecosystem has always been confronted with threatening difficulties due to pollution which sometimes resulted in the increasing costs of safe and potable water [10]. Moreover, based on the study conducted by World Resources Institute (WRI), the Philippines is predicted to experience extreme water shortage by the year 2040 which will adversely affect the economy [11, 12]. Hence, the water quality, supply, and usage had been provided with attention, especially in relation to the availability of potable water [13].

Davao Oriental is one of the 81 provinces of the Philippines which is home to seven major rivers and fifteen identified waterfalls in the province with the Aliwagwag Falls as the most well-known [14]. The capital of the province is the City of Mati whose population as of 2015 reached 141,141 and the projected population for 2020 is 147,547 [15]. There are two private water system associations and a quasi-government water district known as Mati Water District that has been supplying water in the major parts of the City [16].

Population growth, urbanization, industrialization, and improved living standards have led to increased demand for drinking water in urban areas [17]. According to Billings & Jones [18], forecasting water consumption could supply a basis for operational, tactical, and strategic decision-making and can help improve the performance of water distribution systems by anticipating consumption values. Forecasting models generally facilitate understanding water consumption behavior [19], besides helping the development of water-saving strategies [20], energy, and adequate destination for effluents [21]. In addition, understanding and managing water, in an urban context, is considered a critical factor for achieving sustainability [22].

Forecasting monthly water consumption is important for the efficient operation and management of an existing water supply system [23]. Furthermore, water demand can be seen as a dynamic system and requires mathematical modeling [23]. As stated by Donkor et al. [24], there is a series of forecasting methods, and choosing one directly depends on the quantity and quality of the data, desired forecast horizon, and the availability of time and resources. Employing methods for modeling time series is quite widespread as there are two advantages: (i) the methods are simpler than the others and they are based on the premise that historical behavioral trends regarding series are maintained with time [25]; (ii) they are direct methods, forecasting without considering other external variables that quite often can be complex and uncertain [26].

The objective of this study primarily aims to evaluate water consumption forecast models in the City of Mati using the series analysis. The significance of this study arises from its application in monthly water consumption forecasts, easily replicated in any location.

II. METHODS

Research Design

This study is utilizing a quantitative forecasting method. This method is based on mathematical (quantitative) models and is objective in nature which relies heavily on mathematical computations. Specifically, this piece of endeavor is anchored to the time-series models as it looks at past patterns of data and attempts to predict the future based on the underlying patterns contained within those data. Moreover, the simple moving average is also employed since this uses an average of a specified number of the most recent observations, with each observation receiving the same emphasis (weight).

Data and Collection

The data herein are quantitative, inasmuch as this study is using the monthly water consumption in cubic meters (CBM) from January 2006 up to July 2021. These data are the water consumption in the City of Mati as recorded by the Mati Water District, a quasi-government agency that supplies the water demand in the major parts of the City.

Statistical Tools and Analysis

This study paper would be analyzed and presented in accordance to the approach of George Box and Gwilym Jenkins in ARIMA Modeling. The Box-Jenkins approach to modeling ARIMA processes was described in a highly influential book by statisticians George Box and Gwilym Jenkins in 1970. An ARIMA process is a mathematical model used for forecasting. Box-Jenkins modeling involves identifying an appropriate ARIMA process, fitting it to the data, and then using the fitted model for forecasting. One of the attractive features of the Box-Jenkins approach to forecasting is that ARIMA processes are a very rich class of possible models and it is usually possible to find a process that provides an adequate description of the data [27]. The overall time series analysis and forecasting processes would include the (a) preparation of data for model building, that is, making these data stationary; (b) identification of the model type; (c) estimation of the parameters; and, (d) forecasting the future values.

III. RESULTS

Time Series Plot of the Water Consumption in the City of Mati

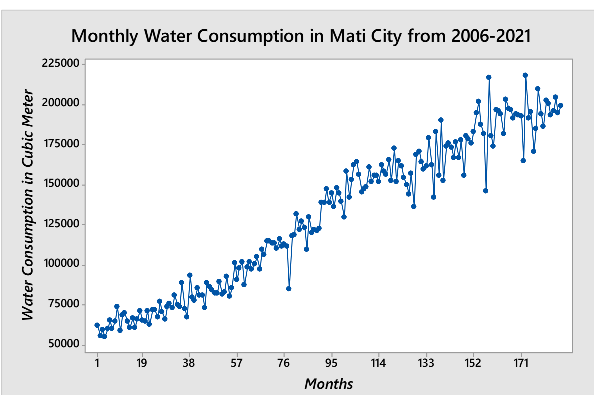

Figure 1. Time Series Plot of the Water Consumption in the City of Mati from June 2006 to July 2021.

Shown in figure 1 are the data on monthly water consumption in the City of Mati. The x-axis (horizontal line) represents the 187-month period of consumption of the province from June 2006 to July 2021, while the y-axis (vertical line) denotes the water consumption in cubic meters.

It can be observed from the time series plot of the data a clear ascending trend as well as a periodically sinusoidal, wave-like, or seasonal pattern. When the time series is showing a trend, then such data are said to be nonstationary. Because the data were nonstationary, they needed to be transformed using differencing in order to achieve stationarity and proceed to ARIMA. To utilize ARIMA modeling, either a stationary time series or a time series that transforms into stationary after one or more differencing of the data is required [28].

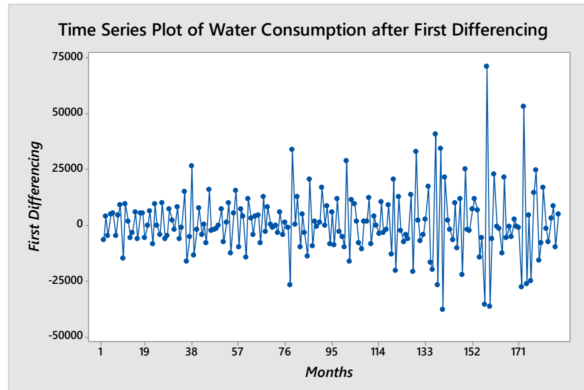

Figure 2. Time Series Plot of the Water Consumption in the City of Mati from June 2006 to July 2021 after first differencing.

Figure 2 displays the first-differenced time series plot of the monthly water consumption. By examining the plot, it can be observed that there was no trend formed and that the variance has become stable with the mean somehow converging to zero. This entailed that the data were now stationary.

Model Identification

With the application of the rules in model identification, it followed that the possible models are ARIMA (0, 1, 3)×(0, 0, 2)$_{12}$, ARIMA (0, 1, 2)×(0, 0, 2)$_{12}$, ARIMA (0, 1, 1)×(0, 0, 2)$_{12}$, ARIMA (1, 1, 1)×(0, 0, 2)$_{12}$, and ARIMA (1, 1, 2)×(0, 0, 2)$_{12}$. Displayed in Table 1 is the parameter estimation of the five identified models with corresponding coefficients, standard error of the coefficients, t-statistics, and the p-value. It can be depicted that only three of these models showed statistically significant parameters having p-values that are lesser than the chosen α-level, 0.05. Hence, these models have the qualities to fit the original data and to forecast future values.

Diagnostic Checking

In choosing the final model to forecast the monthly water consumption, the three models having significant parameters are being compared based on the Akaike Information Criterion (AIC) and Schwarz's Bayesian Criterion (SBC) and their Mean Absolute Percentage Error (MAPE). As shown in Table 1, ARIMA (0, 1, 1) × (0, 0, 2)12 had lesser AIC and SBC values with 8.94743 and 7.95179, respectively, compared to the AIC and SBC values of the other two models. In terms of their MAPE, the three models had very tolerable errors in the forecasts, but it is still the second model which had shown to have the least errors with just almost 4.75%.

Table 1. Akaike information criterion (AIC), Schwartz Bayesian Criterion (SBC), and Mean Absolute Percentage Error (MAPE) of the four identified ARIMA Models

Models	AIC	SBC	MAPE
ARIMA $(0, 1, 2)\times(0, 0, 2)_{12}$	8.97	7.97	4.87
ARIMA $(0, 1, 1)\times(0, 0, 2)_{12}$	8.95	7.95	4.75
ARIMA $(1, 1, 1)\times(0, 0, 2)_{12}$	9.02	8.02	4.91

Since the ARIMA $(0,1,1)\times(0, 0, 2)_{12}$ has been found as the best fitting among the three identified models, we shall then proceed to the comparison of the generated forecasts based on the partial data with known original observations as shown on figure 3. This is done by utilizing the consumption data from June 2006 to December 2019 and trying to backwardly forecast the next nineteen months (January 2020 to July 2021) using the candidate model. This is the most common and effective measure of the reliability of the model.

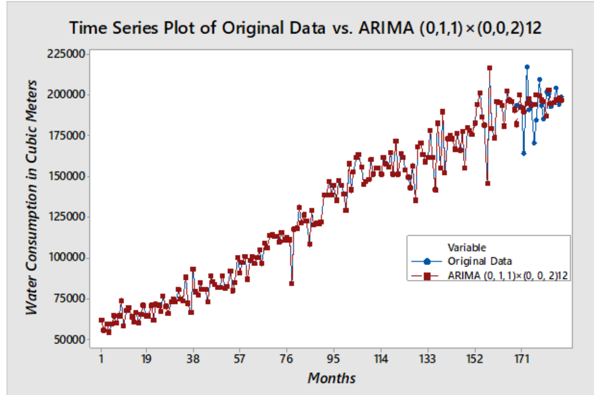

Figure 3. Time series plot of the actual water consumption from June 2006 to July 2021 versus Backward Forecast values from January 2020 to July 2021 using ARIMA $(0, 1, 1) \times (0, 0, 2)_{12}$

Table 2. Forecast values from January 2022 to December 2025 using the ARIMA $(0, 1, 1) \times (0, 0, 2)_{12}$

Month	Year			
	2022	2023	2024	2025
January	203838.4038	212859.1529	221768.9847	230803.6723
February	204257.4332	213038.5344	222521.8754	231556.5629
March	203491.7832	214841.9944	223274.766	232309.4536
April	209289.0116	214979.9469	224027.6566	233062.3442
May	205383.1424	215142.5133	224780.5473	233815.2348
June	207597.7965	216302.7432	225533.4379	234568.1255
July	205490.9342	217251.6409	226286.3285	235321.0161
August	207403.6097	218004.5316	227039.2192	236073.9067
September	211389.3664	218757.4222	227792.1098	236826.7974
October	210210.1564	219510.3128	228545.0004	237579.688
November	209981.1046	220263.2035	229297.891	238332.5786
December	213172.0238	221016.0941	230050.7817	239085.4693
Average	*207625.3972*	*216830.6742*	*225909.8832*	*234944.5708*

Forecast Values of the Water Consumption from January 2022 to December 2025

With an aid of the statistical software, the final model ARIMA $(0, 1, 1) \times (0, 0, 2)_{12}$ was utilized in forecasting the water consumption in a cubic meter of the City of Mati for 48 months (4 years) from January 2022 to December 2025. This is presented in table 2.

DISCUSSION

Water consumption is undeniably increasing, and this phenomenon is something to be expected as a consequence of growing population, industrialization, technological deployment, and urbanization. With this, forecasting the consumption in a certain area is indispensable in order to ensure that there would be enough supply to be utilized in the near future [29].

Results show that water consumption really depicted seasonality since there were those peak seasons when the industry and the community would consume much. In fact, consumption is most closely associated various factors such as climate, demographics, and even with political and administrative factors [30].

While there have been various studies wherein different models have been employed for the prediction of water consumption both in long terms and short terms, the autoregressive moving average (ARIMA) models have been widely used in different countries [31-33]. And in this study, the seasonal ARIMA models were identified to have significant parameters and were proven to predict the water consumption in the City of Mati. This was substantiated by Akaike Information Criterion (AIC), and the mean absolute percentage error (MAPE). This then indicated that the identified ARIMA models have the capacity to be utilized in the prediction process especially in forecasting the period observed in monthly data [28].

There were five possible models identified which were ARIMA $(0, 1, 3)\times(0, 0, 2)_{12}$, ARIMA $(0, 1, 2)\times(0, 0, 2)_{12}$, ARIMA $(0, 1, 1)\times(0, 0, 2)_{12}$, ARIMA $(1, 1, 1)\times(0, 0, 2)_{12}$, and ARIMA $(1, 1, 2)\times(0, 0, 2)_{12}$. And upon diagnosing the models through the AIC, BIC, and MAPE, it was found that ARIMA $(0, 1, 1)\times(0, 0, 2)_{12}$ performed well among the six.

Hence, the ARIMA $(0, 1, 1)\times(0, 0, 2)_{12}$ model was utilized in order to forecast the water consumption in the next 48 months. This result showed an increase of approximately 4.12% in the average annual water consumption. And it further revealed that there will be a nearly 15.48% increase in water consumption for the year 2021 vis-à-vis year 2023. This result is in consonance with the findings of previous studies [9, 11], which have remarked that the water demand in the Philippines will increase in the next few years. Further, it was also highlighted that projections on water availability indicate that water stress will worsen in the future, brought about by limited supply amidst higher demand and worsening water quality [8].

This study further showed that ARIMA is still fitting to forecast water consumption, showing a relatively small mean absolute percentage error.

In summary, the water consumption in the City of Mati was modeled using the autoregressive integrated moving average or ARIMA through time series analysis and following the Box and Jenkins framework. This study was able to provide a prediction of 48-month (4 years) consumption of the City by utilizing historical data from January 2006 to July 2021. Such data were acquired from the Mati City Water District. It was found that ARIMA fits to forecast the water consumption of the City.

CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

In this study, ARIMA was found to be fit for performing the research objectives. It had been shown as well that the ARIMA model was appropriate in predicting the water consumption in the City of Mati.

The forecasted values showed that there would be an average annual increase rate of approximately 4.12% from 2022 to 2025; and a 15.48% rate of increase from 2021 to 2025. This is expectedly equivalent to an annual increase of 9,106.39 cubic meters.

As for its implication to the City's economy, the outcomes endorsed that more households and other industrial infrastructures would really give a significant increase to the total water consumption. Therefore, the City Water District needs to look for sources and further prepare for the increase in water demand in the next few years so as to continuously supply the needs of the population of the entire place. There is then a need to have thorough planning in the distribution of water sources, and conduct seminars to the consumers for them to have proper utilization of water and avoid any shortages.

Lastly, researchers can conduct a similar investigation focusing on the various factors affecting the increase, and on the effects of this on the consumers. They could also employ hybrid models with machine learning, in order to strengthen the projected data and further minimize the errors.

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