TIME SERIES MODEL OF WATER LEVEL FLUCTUATION IN MAHAKANADARAWA TANK

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Supervisor's name: Dr. Panduka Neluwala

Signature of the supervisor: Date:2022-07-01

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ABSTRACT

This research concludes an attempt to forecast water level changes using the best-fitted model of Mahakanadarawa tank by using Box and Jenkins methodology of univariate Auto-Regressive Integrated Moving Average (ARIMA) model. Data from 2010 to 2019 was analyzed and predicted values for the next 12 months were calculated. SARIMA (1, 1, 1) $(1, 1, 1)_{12}$ was identified as the tentative model, and Finally, the best-fitting models (0, 1, 1) (0, 1, 1)12) were discovered of water level fluctuations of Mahakanadarawa tank. Forecasted values were used to decide on the supply of water. Two major purposes were considered. Drinking water requirements and water for cultivation were focused.

Keywords- ARIMA, water level, forecasting

Table of Content

List of Figures

List of Tables

List of Abbreviations

ACF- Auto Correlation Function

PACF- Partial Auto Correlation Function

MA- Moving Average

SMA- Seasonal Moving Average

AR- Auto-Regressive

SAR- Seasonal Auto-Regressive

SARIMA- Seasonal Auto-Regressive Integrated Moving Average Model

1 CHAPTER 1 – INTRODUCTION

Mahakanadarawa Tank is approximately 6.5 kilometers from the Mihintale town center. In this region, this is the largest tank. In this location, water level fluctuations have a direct impact on crops.

The Rambewa Municipality is the capital and administrative center of the Rambewa Region, which includes Mihintale, Kebithigollewa, Horovipathana, and Medawachchiya. It has a population of 162,046 people, with 86,239 males and 75,807 females, respectively. Since 2000, the population has increased by over 81 percent. In terms of water delivery in the municipality, the National Water Supply and Drainage Board has been successful in correcting many of the issues reported in 2007, when more than 60% of the population lacked access to safe drinking water and sanitation. Very old machines, broken down hand pumps, and other equipment have been replaced or rebuilt in the municipality for effective water production and delivery. Agricultural agriculture employs the bulk of the Municipality's residents (about 65 percent). In the municipality, traditional cutlass and hoe technology are extensively used in agricultural production. Mechanized farming has a low acceptance rate, and other agricultural-related technologies have an even lower adoption rate. Because there are no irrigation systems, farming is exclusively rain-fed, resulting in low production. Access routes to farming centers are likewise weak, making product marketing difficult. These factors, combined with the lack of storage facilities, resulted in considerable post-harvest losses. Therefore, using my site experience and ability of land preparations of farmers, we need to change the traditional "YALA, MAHA" seasons without sticking to the relevant months like May to August YALA season and September to next year March MAHA season. To show these results I could be able to used my forecasted water levels for upcoming year and proposed new seasons for land preparations and give some conditions to limited the issuing of water instead of land preparations. It was more effective decision to manage tank water for agricultural work as well as domestic purposes throughout the year.

2 CHAPTER 2- LITERATURE REVIEW

The change in water level is the most important hydrological factor in reservoirs. Water level fluctuations are linked to rainfall patterns, which cause reservoirs to fill up. There is also less demand for water for agricultural uses at this time. The water level begins to fall with the start of the dry season when inflow is negligible to non-existent, and the resulting demand for cultivation. The purpose of a literature review is to gain an understanding of the existing research and debates relevant to a particular topic or area of study, and to present that knowledge in the form of a written report. In my research several research topics were relevance to my findings as follow.

The effect of changing water levels on fish output is becoming more apparent (Welcomme, 1970; Martin et al., 1981; Beam, 1983; Miranda et al., 1984; Henderson, 1985; De Silva, 1985b, 1986). Reservoir fishery management should emphasize research on water level manipulation and its effects on fish populations, according to Bernacsek (1984) and Hall (1985). In this data set, they have analyzed and validated with another separate reservoir. Then they have been identified same factors were affected for the fish population like water level, inflow and outflow capacity

Perennial Reservoirs: Perennial reservoirs have a lot of annual water level variations. Water level variations in different reservoirs tend to expose littoral zones to varying degrees. The extent of the exposed region differs from reservoir to reservoir, which could affect the recruitment pattern of the fishery. In general, even modest changes in the water level in Sri Lankan reservoirs due to significant changes in their capacity can have a significant impact.Perennial reservoirs, as its name suggests, store water all year. Some of the smaller and older primary reservoirs, such as the Tissawewa (234 ha) and Yodawewa (488 ha) in the southeastern half of the island, may completely dry up in especially dry years. Normally dry months were reported every year July to September in my study area as my experienced. So it not highly effect for water level but some kind of effect is there. When we consider the large date set it can be neglected. Only little lakes remained in the center of these two reservoirs in August-September 1984. The implications of such reservoir drying on flora and fauna, as well as fish productivity, are little understood.

3 CHAPTER 3- MATERIALS AND METHODS

3.1 Data Collection

For this study, water level fluctuation of Mahakanadarawa tank was considered and 120 monthly water level fluctuation data was brought for the period from 2010 to 2019 from the Department of Irrigation Engineering Mihintale & Research & development center at Anuradhapura National Water Supply & drainage board. A minimum of 50 observations is recommended for constructing a decent autoregressive integrated moving average (ARIMA) model (Wei 1990). The maximum water level was recorded between November and February, according to monthly water level data. The maximum water level of the tank is in the range of 15 – 21 feet. The data of water demand for both cultivation and drinking were considered.

3.2 Time series modeling

A time series is a set of observations made in a specific order over some time. The included data are ordered concerning time. The successive observations are usually expected to be dependent. Time series modeling includes the steps of identifying a tentative model, fitting the model, and verifying the model. To fit a model, at least 50 observations are needed. Before developing the ARIMA model the time series is checked for stationary. The major assumption in the time-series analysis is that the underlying series is stationary.

3.3 ACF & PACF

The autocorrelation function (ACF) and partial autocorrelation function (PACF) are useful tools for determining the model type and the order of the process. The ACFs and PACFs are calculated for k = 1, 2, 3, …, K, for more consistent model identification. For a given time series of Z1; Z2; ...; Zn, pk samppkCF is dpked by:

$pk = kkk$ is It is known as the sample correlogram because it is plotted against k in the graph.

3.4 Seasonal ARIMA model: SARIMA (p, d, q) (P, D, Q) s

Non-seasonal and seasonal components are included in ARIMA models. The typical non-seasonal ARIMA model is AR to order p and MA to order q, and it acts on the dth difference of the time series; consequently, an ARIMA model is classified by three parameters (p, d, and q) that can have zero or positive integral values. The ARIMA model has been generalized to deal with seasonality, and a general multiplicative seasonal ARIMA model, also known as a seasonal ARIMA model, has been defined. . ARIMA (P, D, Q) s is the general mixed seasonal model used in this study. Where p denotes the order of the AR process, P denotes the order of the seasonal AR process, q denotes the order of the MA process, Q denotes the order of the seasonal MA process, s denotes the span of seasonality, d - # of differencing, D - # of seasonal differencing. ARIMA (p, d, q) (P, D, Q) S is the seasonal ARIMA model, where (p, d, q) is the non-seasonal component of the model and (P, D, Q) is the seasonal part of the model with seasonality. S This can be expressed as:

$\phi p\ (B)\ \Phi P\ (Bs)\ Wt = \theta q\ (Bs)\ \boldsymbol{\vartheta} Q\ (B) Zt$ (Equation 1)

$\phi p\ (B) = 1 - \alpha 1B1 - \alpha 2B2 - \ldots\ldots.. - \alpha pBp$ (Equation 2)

$\Phi P\ (B) = 1 - \alpha 1Bs - \alpha 2B2s - \ldots\ldots.. - \alpha pBps$ (Equation 3)

$\Theta q\ (B) = 1 + \beta 1B1 + \beta 1B2 + \ldots\ldots\ldots + \beta 1Bq$ (Equation 4)

$\boldsymbol{\vartheta} Q\ (B) = 1 + \beta 1Bs + \beta 2B2s + \ldots\ldots\ldots + \beta qBqs$ (Equation 5)

Where, ϕp (B) and ΦP (B) are polynomials of order p and q, respectively; θq (Bs) and $\boldsymbol{\vartheta} Q$ (B) are the polynomials in Bs of degrees P and Q respectively. The non-seasonal and seasonal difference components are designated by:

$W_t = \nabla 112\ X_t$ (Equation 6)

3.5 Box- Jenkins Methodology

In the Box-Jenkins approach, there are four processes to consider while building a linear model: identifying basic model requirements, estimating model parameters, diagnostic evaluation of model appropriateness, and forecasting future realizations.

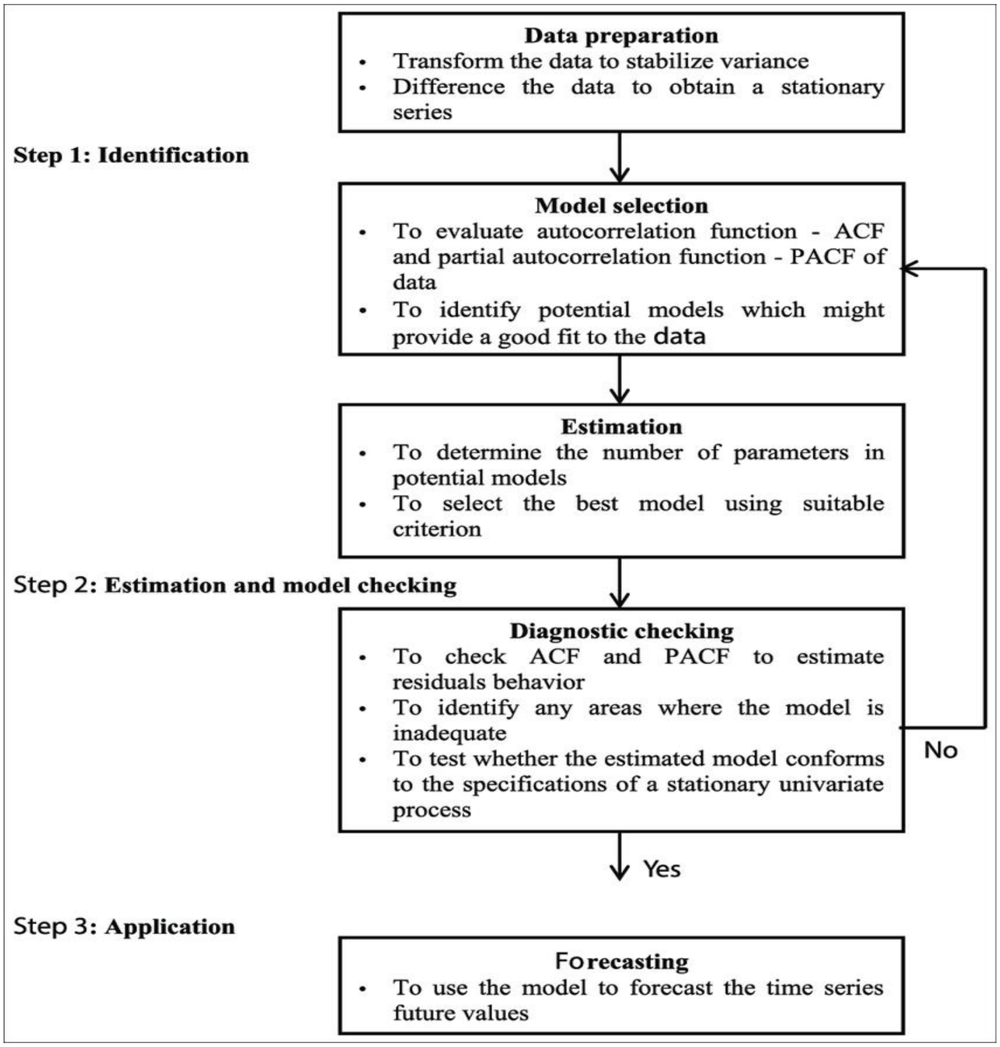


Figure 3. 1: Box- Jenkins Methodology

3.6 Model selection

Model selection is to determine the autoregressive (AR) terms and moving average (MA) terms that are most fitted to the time series data. Consideration of distribution patterns of ACF and PACF assists in identifying the tentative model. The seasonal components and non-seasonal components are identified there.

4 CHAPTER 4- RESULT & DISCUSSION

The monthly water level fluctuation from January 2010 to December 2019 is shown in table 4.1. In the last ten years, the water level of the Mahakanadarawa tank varied from a low of 0 to a high of 21.8 feet. The seasonal length is 12. As shown in Figure 4.1, the time series of water level fluctuation showed a non-stationary time series. A small increasing trend and seasonal variation are shown in figure 4.1. Therefore, the series is seemed to be non-stationary. As a result, it's critical to use first-order trend difference and first-order seasonal difference to stabilize data on water level fluctuations.

Table 4.1: Monthly water level (in feet) of Mahakanadarawa Tank

Month	Year									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Jan	13.4	19.2	13.4	18.3	10.7	20.9	21	4.8	10.4	20.8
Feb	11.4	19.4	13.5	17	11.1	20.3	20.2	3.9	10.4	20.7
March	9.2	16.9	12.2	17.2	11.2	20.5	19.6	3.3	10.2	20.5
April	10.8	16.6	15.3	16.9	12.4	20.3	17.8	5.1	11.5	18.8
May	15.1	16.3	11.4	15.1	20.1	21.2	18.9	6.7	12.9	17.7
Jun	12.9	12.5	3.3	13.2	18.5	20	20.1	7	14.7	15.1
Jul	11.1	7.3	1	10	15.3	17.8	17.4	6.5	12.9	11.9
August	8.5	1.4	0.01	6.5	12.3	16.7	15.3	5.7	10.7	10.5
September	7.6	0	0	5.6	11.9	16.2	13.7	6.7	7.4	10.2
October	11.8	0	6.3	3.8	13.1	17.6	12.3	6.8	13.5	17.4
November	13.6	3.6	18.3	6.2	18.2	21.6	9.4	7.8	21	21.3
December	19.4	12.6	18.9	9	21.8	21.5	7.2	9.8	21.2	21.7
Total	270.6	239.41	252.41	315.4	411.2	427.5	267	230.9	363.4	206.6

Figure 4.2 depicts the modified time series. The graphs of ACF and PACF are drawn considering the altered time series to estimate important parameters of the SARIMA

model (p, d, q and P, D, Q) (Fig. 4.3 & Fig. 4.4). The tentative model is thus recognized as SARIMA (1, 1, 1) (1, 1, 1)12. The sufficiency is then double-checked using Ljung-Box values.

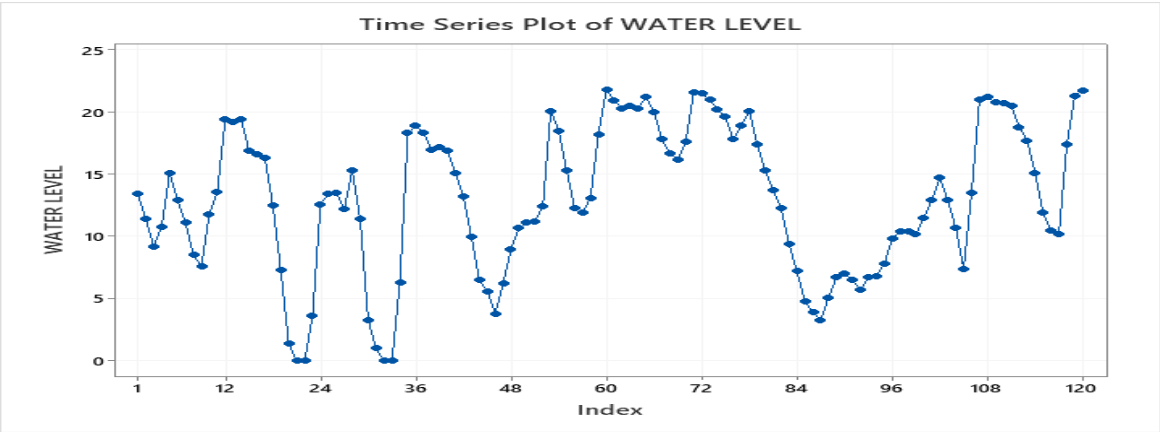


Figure 4. 1: Mahakanadarawa Tank monthly water level time series plot

Time series plot shows seasonal pattern and slightly increasing trend. So data series not stationary.

4.1.1 Autocorrelations

Lag	ACF	T	LBQ
1	0.867135	9.50	92.51
2	0.630606	4.37	141.84
3	0.405933	2.45	162.46
4	0.247186	1.42	170.17
5	0.141910	0.80	172.74
6	0.085104	0.48	173.67
7	0.057911	0.33	174.10
8	0.046215	0.26	174.38
9	0.089118	0.50	175.43
10	0.174050	0.97	179.46
11	0.244542	1.36	187.49
12	0.226596	1.24	194.45
24	- 0.102356	- 0.49	273.53

The T values are slightly decreasing at lag 1, 2 & 3. So it is clear that series is not stationary. At LAG(seasonal lag=1, 2) 12 & 24, T values are slightly decreased as well.

Partial Autocorrelations

Lag	PACF	T
1	0.867135	9.50
2	-0.489029	-5.36
3	0.083473	0.91
4	0.055745	0.61
5	-0.062019	-0.68
6	0.067505	0.74
7	-0.015149	-0.17
8	0.001701	0.02
9	0.273855	3.00
10	0.040444	0.44
11	-0.070312	-0.77
12	-0.213572	-2.34
24	0.024553	0.27

In the PACF, T values are slightly decreased. At LAG(seasonal lag=1, 2) 12 & 24, T values are slightly decreased as well. So, it is clear that series is not stationary. Therefore, differencing is done to data series.

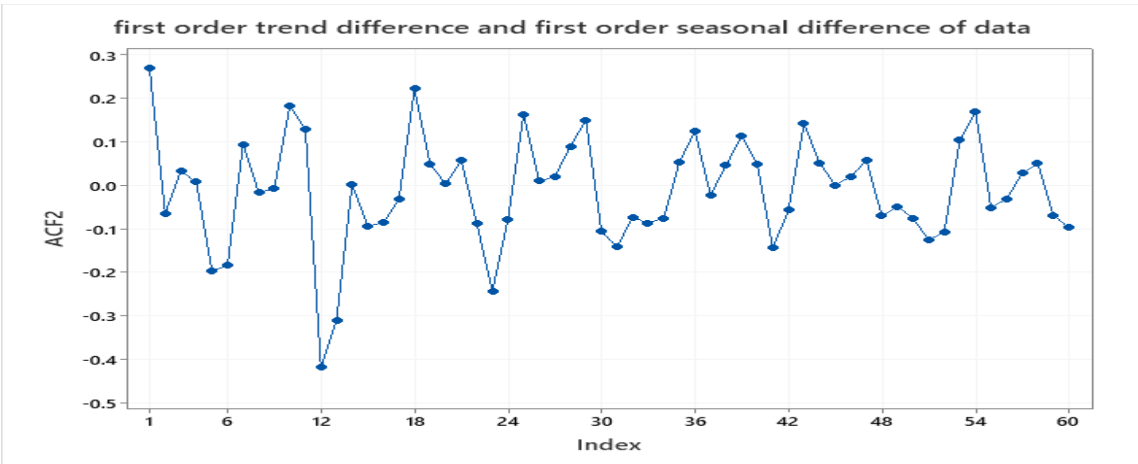


Figure 4. 2: First order trend difference and first-order seasonal difference of data

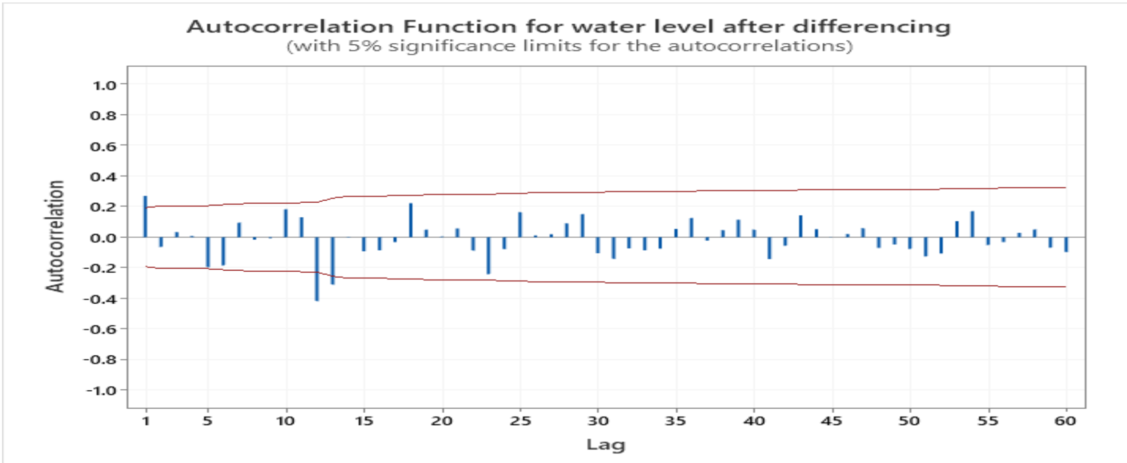


Figure 4. 3: ACF for water level differencing

4.1.2 Autocorrelations

Lag	ACF	T	LBQ
1	0.269221	2.78	7.97
2	-0.063408	-0.61	8.42
3	0.033072	0.32	8.54
4	0.008583	0.08	8.55
5	-0.195655	-1.88	12.93
6	-0.183488	-1.71	16.82
7	0.095006	0.86	17.87
8	-0.015971	-0.14	17.90
9	-0.006499	-0.06	17.91
10	0.183095	1.65	21.94
11	0.129492	1.14	23.97
12	-0.416598	-3.62	45.28
24	-0.077315	-0.54	76.50
36	0.124887	0.82	95.62

48	-0.069704	-0.44	108.81
60	-0.096324	-0.59	129.83

Here, the T values are dramatically changed. So it can be considered that the series is stationary.

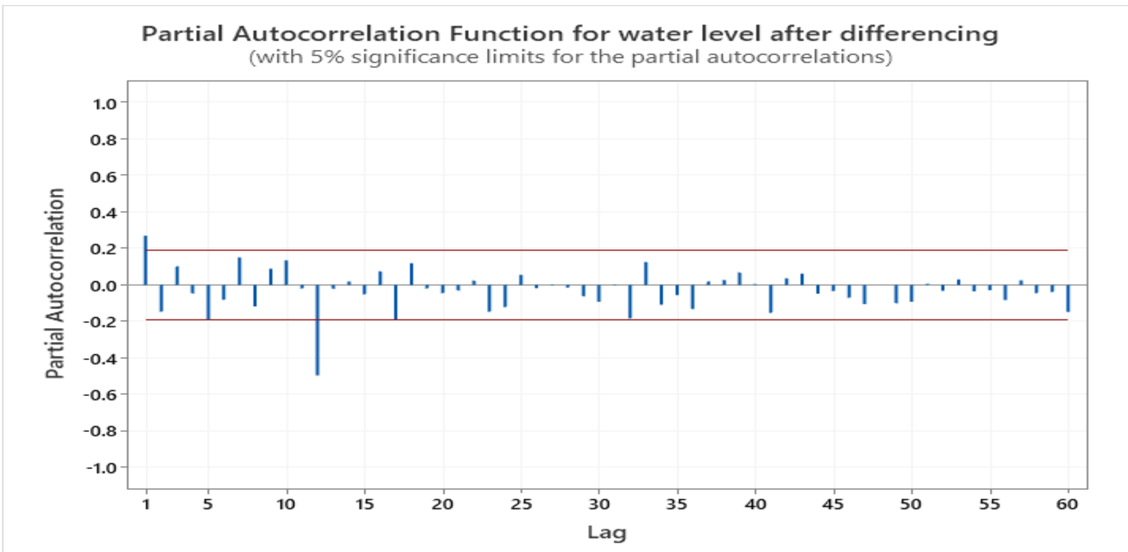


Figure 4. 4: PACF for water level differencing

4.1.3 Partial Autocorrelations

Lag	PACF	T
1	0.269221	2.78
2	-0.146507	-1.52
3	0.101460	1.05
4	-0.045318	-0.47
5	-0.192722	-1.99
6	-0.080207	-0.83
7	0.150610	1.56

8	-0.116963	-1.21
9	0.088752	0.92
10	0.135307	1.40
11	-0.018367	-0.19
12	-0.494191	-5.11
24	-0.120862	-1.25
36	-0.132410	-1.37
48	-0.000494	-0.01
60	-0.146861	-1.52

Here, the T values are dramatically changed. So it can be considered that the series is stationary. In addition, in both PACF and ACF graphs, it is cut off at lag 1 in the seasonal area and non-seasonal area.

From the above ACF and PACF graphs, the tentative model is determined. From ACF, q=1, Q=1, D=1 and from PACF, p=1, P=1, d=1.

So the tentative model is SARIMA(1,1,1)(1,1,1)12.

This model' s accuracy is checked using final estimates of parameters.

4.1.4 Final Estimates of Parameters

Type	**Coef**	**SE Coef**	**T-Value**	**P-Value**
AR 1	0.064	0.335	0.19	0.849
SAR 12	0.006	0.127	0.05	0.963
MA 1	-0.239	0.326	-0.73	0.466
SMA 12	0.8673	0.0962	9.01	0.000
Constant	0.0240	0.0651	0.37	0.714

Since, P value of all parameters are greater than 0.05, it is concluded that all parameters are significant. Therefore one AR term and one SAR term is reduced by one.

4.1.5 Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag	**12**	**24**	**36**	**48**
Chi-Square	19.46	35.22	51.12	61.61
DF	7	19	31	43
P-Value	0.007	0.013	0.013	0.033

As P-values are less than 0.05, it is determined that residuals are not random.

Therefore, the new model is taken as SARIMA (0, 1, 1) (0, 1, 1)12. The relevant parameters checked for this model.

Table 4.2 shows the estimation of SARIMA model parameters as well as the outcomes of the tests. Figure 4.5 shows the ACF and PACF of the residual series of SARIMA (0, 1, 1) (0, 1, 1)12. Autocorrelations and partial autocorrelations were suggested by the ACF and PACF of residuals, which cut off at lag zero. The residuals did not reject H0 in this case. The findings of the L-young Box test indicate that autocorrelation coefficients are not statistically different from zero. All parameters are significant. SARIMA (0, 1, 1) (0, 1, $1)_{12}$ model fitted the data reasonably well. The Correlation Matrix of the Estimated Parameters indicates that parameter redundancy does not exist. The normality of residuals is checked (Figure 4.6). The normal probability plot indicates that residuals are normally distributed.

Table 4.2: Final Estimates of Parameters

Type	**Coef**	**SE Coef**	**T-Value**	**P-Value**
MA 1	-0.2945	0.0941	-3.13	0.002
SMA 12	0.8663	0.0731	11.85	0

As p values < 0.05 all parameters are significant.

Table 4.3: Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

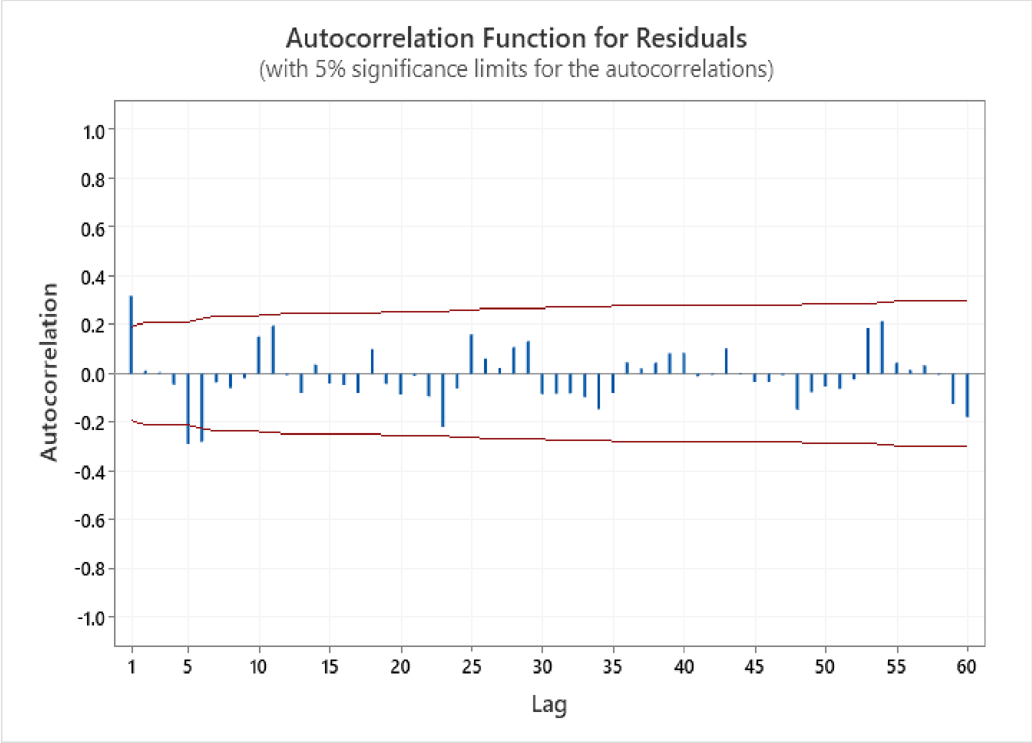
Lag	**12**	**24**	**36**	**48**
Chi-Square	19.35	34.71	50.45	60.94
DF	10	22	34	46
P-Value	0.056	0.092	0.054	0.069

Differencing: 1 regular, 1 seasonal of order 12

Number of observations: Original series 120, after differencing 107

Table 4.4: Correlation Matrix of the Estimated Parameters

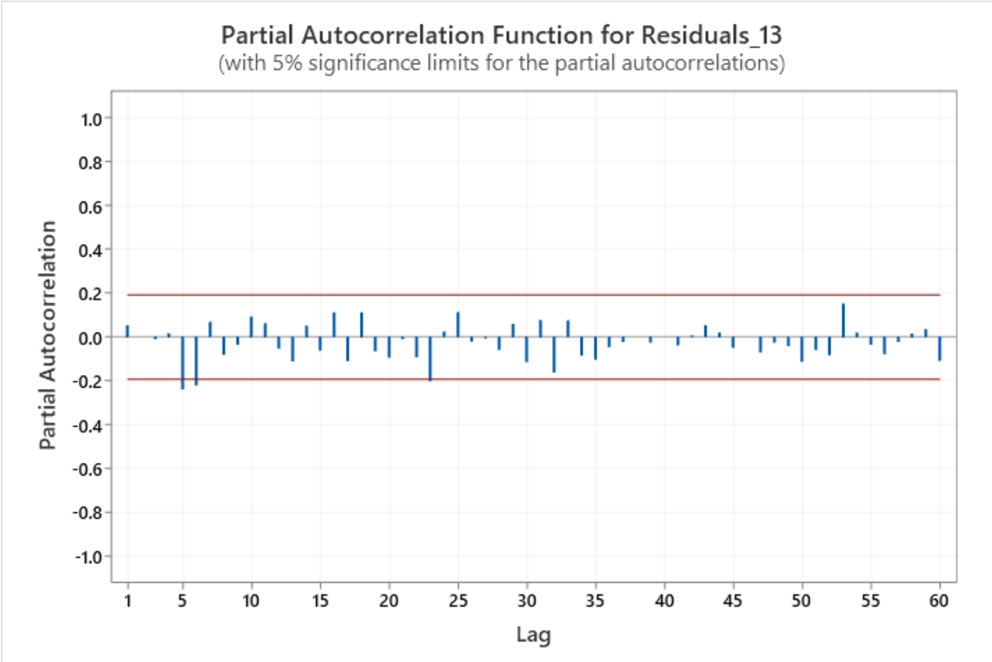
	1
2	**-0.0629**



4.1.6 Autocorrelations for residuals

Table 4.5: ACF values for residuals

Lag	ACF	T	LBQ
1	0.318461	3.29	11.16
2	0.011854	0.11	11.17
3	0.005016	0.05	11.18
4	-0.046514	-0.44	11.42
5	-0.288250	-2.71	20.92
6	-0.279198	-2.46	29.92
7	-0.036492	-0.31	30.08
8	-0.059390	-0.50	30.50
9	-0.019094	-0.16	30.54
10	0.150211	1.25	33.25
11	0.196608	1.62	37.95
12	-0.006030	-0.05	37.95
13	-0.079785	-0.64	38.74
14	0.036862	0.29	38.91
15	-0.040656	-0.32	39.12
16	-0.047578	-0.38	39.41
17	-0.079054	-0.63	40.22
18	0.100196	0.80	41.54
19	-0.042836	-0.34	41.78
20	-0.085363	-0.67	42.76
21	-0.009156	-0.07	42.77
22	-0.093221	-0.73	43.96
23	-0.219642	-1.72	50.66
24	-0.060728	-0.46	51.18



4.1.7 Partial Autocorrelations for residuals

Table 4.6: PACF values for residuals

Lag	PACF	T
1	0.054386	0.56
2	-0.001010	-0.01
3	-0.010193	-0.11
4	0.017688	0.18
5	-0.238542	-2.47
6	-0.220614	-2.28
7	0.069224	0.72
8	-0.081613	-0.84
9	-0.034481	-0.36
10	0.093565	0.97
11	0.063718	0.66
12	-0.052794	-0.55
13	-0.110875	-1.15

14	0.052459	0.54
15	-0.062379	-0.65
16	0.112267	1.16
17	-0.109680	-1.13
18	0.112984	1.17
19	-0.065623	-0.68
20	-0.093438	-0.97
21	-0.009909	-0.10
22	-0.092155	-0.95
23	-0.201684	-2.09
24	0.025660	0.27

Figure 4. 5: ACF and PACF for Residuals

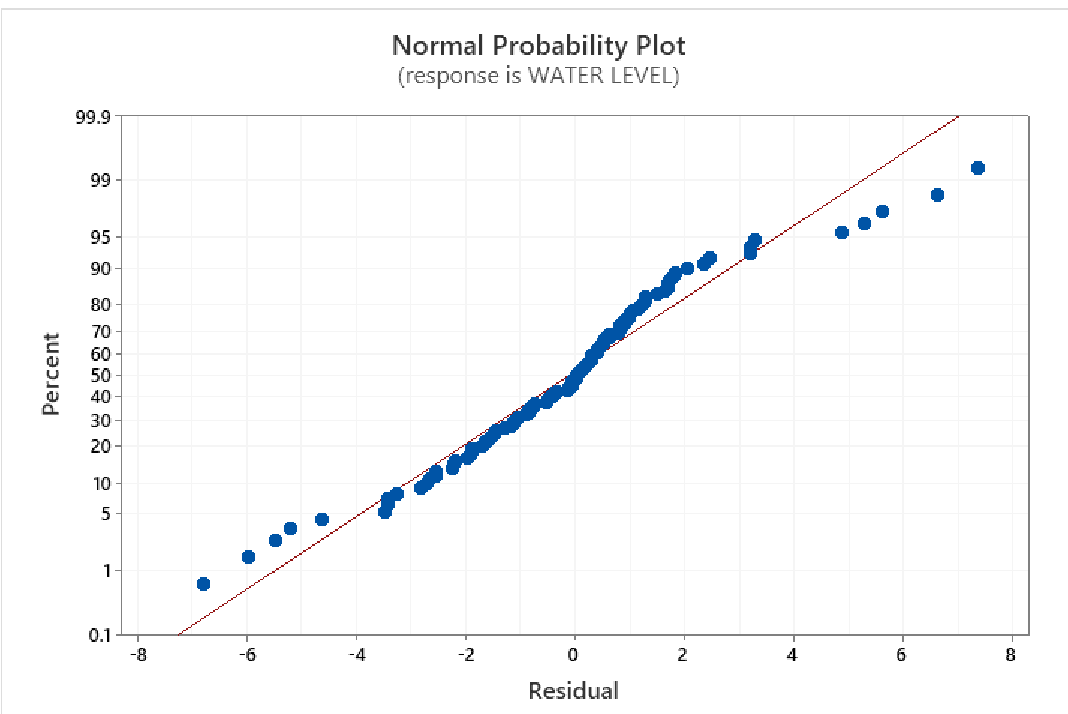


Figure 4. 6: Normal probability plot of residuals

4.1.8 Forecasting

Table 4.1.1 1: Forecasted Water Level for Next Year

Month	**Water Level (feet)**
Jan	21.14
Feb	20.71
March	20.13
April	20.55
May	21.53
Jun	20.29
Jul	17.82
August	15.63
September	14.60
October	17.44
November	21.44
December	23.25

Table 4.1.1 2: Forecasted water level with a tank capacity

Month	Forecasted Water Level (feet)	Forecasted Water Level (m)	Capacity	
			ACFT	m3
Jan	21.14	6.442826606	21666	26714178
Feb	20.71	6.311177435	21330	26299890
March	20.13	6.137122546	20266	24987978
April	20.55	6.263759312	21666	26714178
May	21.53	6.563483312	21666	26714178
Jun	20.29	6.184100155	20532	25315956
Jul	17.82	5.432117085	16375	20190375
August	15.63	4.76414679	13250	16337250
September	14.60	4.450558595	12086	14902038
October	17.44	5.314778035	15880	19580040
November	21.44	6.533920319	21666	26714178
December	23.25	7.085238022	21666	26714178

Table 4.1.1 3: Water demand

Water Demand(m3)	Rest water(m3)	Rest water after cultivation(m3)	Rest water(If 5 acft is given for Maha
564000	26150178	10398603	3647928
564000	25735890	9984315	3233640
564000	24423978	8672403	1921728
564000	26150178	3647928	
564000	26150178	3647928	
564000	24751956	2249706	
564000	19626375	-2875875	
564000	15773250	-6729000	
564000	14338038	-1413537	-8164212
564000	19016040	3264465	-3486210
564000	26150178	10398603	3647928
564000	26150178	10398603	3647928

4.2 Discussion

SARIMA (1, 1, 1) $(1, 1, 1)_{12}$is identified as the tentative model. Then the model adequacy was checked for SARIMA (1, 1, 1) $(1, 1, 1)_{12}$. The p-values of the Ljung-Box table do not satisfy the necessary conditions for residual randomness. Then it was modified as SARIMA (0, 1, 1) $(0, 1, 1)_{12}$ using residuals and Ljung- Box. This model satisfied all the conditions of an adequate model. So forecasting can be done by using SARIMA (0, 1, 1) $(0, 1, 1)_{12}$.

5 CONCLUSION AND RECOMMENDATION

Statistical analysis of Mahakanadarawa tank water level fluctuations is highly beneficial in determining water requirements for agricultural and potable water. This is an example of a Decision Support System (DSS). These are always vital in supporting policy decisions about water supply for Yala and Maha Kanna, the ability to deliver water for Maha Kanna land preparations, the ability to offer drinking water all year, and so on. The statistical technique makes it possible to provide to estimate the forecast with practical precession well in advance. Time series analysis for forecasting is regarded as a useful practice to predict future values considering previously observed values.

5.1.1 CONCLUSIONS

Following conclusions are determined through the time series analysis and forecasting.

As the final model, SARIMA (0, 1, 1) $(0, 1, 1)_{12}$ was determined. Forecasting was done using this model.

The water level of the Mahakanadarawa tank for the next 12 months was forecasted. The relevant tank capacities were considered. It seemed that water levels from July to October were smaller than in other months. Therefore, the ability to supply water may be challenged.

Forecasted results showed that drinking water requirements can be fulfilled throughout the year. In Yala Kanna, water can be given only first 3 months of Yala Kanna and there will be a lack of water in the next 2 months. It seems that the suitable period of land preparations are first 3 months of Yala Kanna (April, May, and June).

In Maha Kanna, there will be a water shortage in the first month of Maha Kanna (September).

Supplying water for the rest months of Maha Kanna will not be an issue. If water is given for both land preparation and cultivation of Maha Kanna, there will be a shortage of water in September and October.

5.1.2 Recommendations

The people need to fulfill the water requirement of cultivation in July, August, and September. When considering the drinking water requirement, no issue in providing drinking water throughout the year. As the suitable periods for land preparations, April, May, and June can be recommended. In the case of Maha Kanna, rainwater must be used in September and also in October, if water is given for both land preparation and cultivation.

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