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ANALYZING TREND, CHANGE POINTS AND FORECASTING OF HYDROPOWER GENERATION USING ARIMA IN THE MAJOR SOUTH ASIAN COUNTRIES

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Abstract

This study investigates hydropower generation across major South Asian countries, namely Bangladesh, Pakistan, and Sri Lanka. The paper focused on exploring through descriptive statistics, employing change points, homogeneity tests, and the Mann-Kendall Trend Test, alongside Sen's Slope analysis, the study evaluates the trends in hydropower generation. Additionally, ARIMA models are applied to the data, optimizing parameters (p, d, q) to identify the most suitable model. Utilizing ACF and PACF plots and considering AIC and BIC for model selection, the study forecasts hydropower generation (TWh) for major SAARC nations. This comprehensive analysis contributes to understanding the dynamics of hydropower generation in South Asia and facilitates informed decision-making in energy policy and planning.

Index Terms: ARIMA, Change Points, Homogeneity Test, Hydropower Generation, South Asian Countries, Trend Analysis.

1. INTRODUCTION

Hydropower generation plays a pivotal role in shaping the energy landscape of major South Asian countries, including Bangladesh, Pakistan, and Sri Lanka. As burgeoning economies with rapidly growing populations, these nations face the dual challenge of meeting escalating energy demands while addressing environmental concerns. Against this backdrop, hydropower emerges as a significant component of their energy portfolios, offering a renewable and relatively clean source of electricity. The South Asian region boasts abundant water resources, making it conducive to the development of hydroelectric projects. Consequently, hydropower plays a crucial role in bolstering energy security and fostering economic development across Bangladesh, Pakistan, and Sri Lanka.

Initially, the researchers explored the various sustainability and renewability issues that society has been facing over the past couple of decades and also discussed the potential of large hydropower to be considered sustainable "[1]". Another study provided a well explanation of how hydroelectric power could take part to the global energy challenges. The authors also discussed the various factors that affect the development of hydroelectric power plants. Although the global potential of hydropower has increased, countries are expected to experience a decrease in its production due to climate change

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"[2]". Analyzing the environmental impacts of large and small hydropower projects. The results indicated that large hydropower projects had lower environmental impacts than their counterparts could be affected by various factors and considered when implementing renewable energy policies "[3]".

The authors focused on the importance of enhancing cross-border electricity trade and the development of hydropower in South Asia. The development of hydroelectric power in South Asia could increase by almost three times over the next couple of decades if the region can establish a free flow of electricity across its borders. It also suggested that a carbon tax could help boost the region's power generation capacity "[4]". Further, the studies analyzed the types of renewable energy include wind, solar, biomass, and small hydropower that could be used in Pakistan.

The study also found that the weight distribution of wind and solar energy in Pakistan is similar to that of commercial potential. In addition, wind power was ideal for the generation of green hydrogen. The study revealed that these two energy sources are good for the country's efforts in developing green hydrogen "[5]". The researchers provided a list of potential opportunities for the country's hydropower industry. These include improving the country's supply-supply gap, securing energy security, and addressing climate change. Despite the various issues that have been identified in the country's hydropower industry, the study showed a promising source of cheap, clean, and secure energy "[6]".

The practical way of using ANNs to predict the energy potential of a new hydropower plant. They selected the various inputs needed for the model's prediction, such as the reservoir capacity, monthly inflows, and irrigation releases. This method can be used for reconnaissance studies as it provides a quick and accurate estimate of the energy potential of an irrigation dam "[7]".

The present study focuses on understanding the hydropower generation of major South Asian countries such as Bangladesh, Pakistan and Sri Lanka. The year-wise time series data was collected during 1965 – 2021 and for Bangladesh, the duration is from 1971 – 2021. Focusing on exploring the hydropower generation, its trends and change points are vital elements to know the necessity of the countries. There is a need to forecasts the hydropower generation of these major south Asian countries to reach the targets and achieving clean energy goals.

2. STATISTICAL ANALYSIS AND RESULTS

Descriptive statistics such as Mean, Standard Deviation (SD), Skewness and Kurtosis of the hydropower generation of major south Asian countries (Bangladesh, Pakistan and Sri Lanka). The annual hydro power generation is considered in the study and to know the current consumption status in the country.

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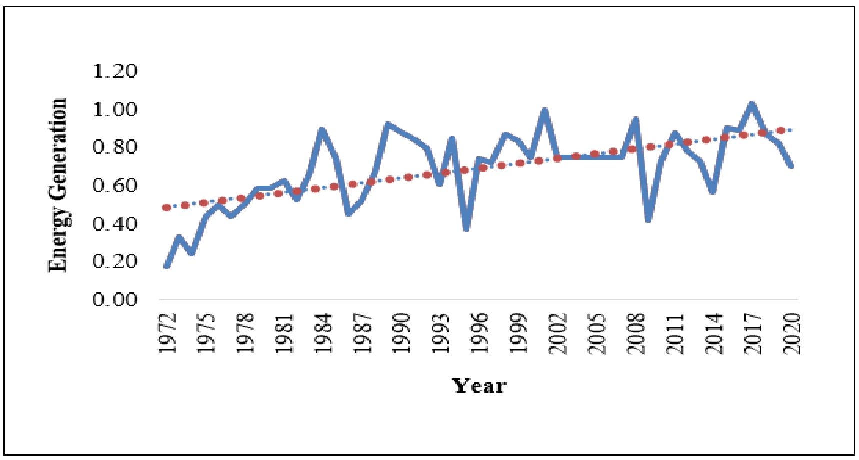
2.1 Descriptive Statistics

Table 1: Descriptive Statistics of Hydropower Generation (Twh)

SAARC Countries	Mean	SD	Skewness	Kurtosis
Bangladesh	0.6894	0.1966	-0.6688	-0.0498
Pakistan	19.997	9.8911	0.0085	-1.0594
Sri Lanka	3.1959	1.5133	0.2898	-0.3048

Table 1 summarizes the descriptive statistics of hydropower generation of SAARC countries. The mean values with standard deviations of Bangladesh (0.6894 ± 0.1966), Pakistan (19.997 ± 9.8911) and Sri Lanka (3.1959 ± 1.5133) are given in the table. The distribution of hydropower generation of Pakistan and Sri Lanka are identified as positively skewed (0.0085 and 0.2898) and for Bangladesh is negatively skewed (-0.6688). All calculated values of kurtosis are identified as negative nature and data follows a platykurtic distribution. There is a consistent growth of hydropower observed for Pakistan and Sri Lanka and decline observed for Bangladesh. The initial trends of hydropower generation of Bangladesh, Pakistan and Sri Lanka are represented in the Fig.1, 2, and 3.



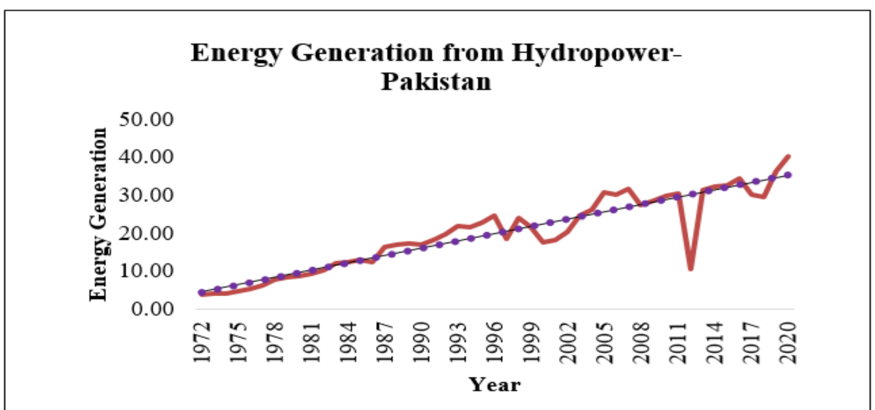


Fig. 2. Energy Generation from Hydropower of Pakistan

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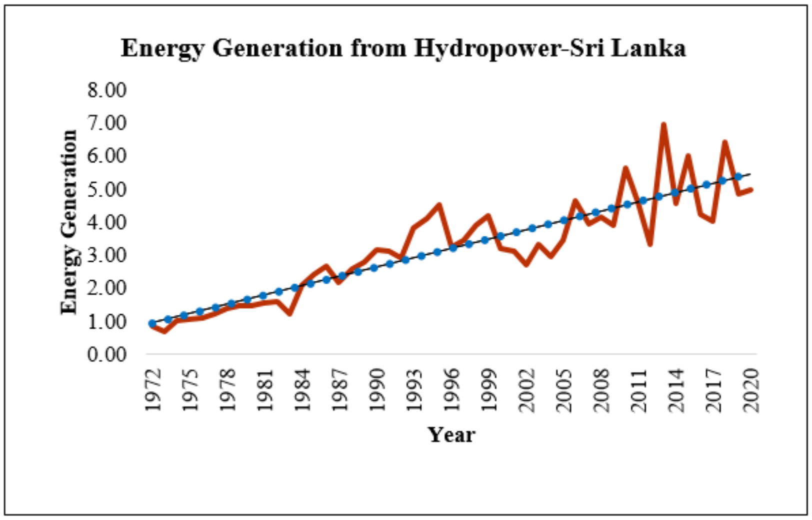

2.2 Tests of Homogeneity of Hydropower Generation in SAARC countries

Table 2: Results of Homogeneity Tests of Hydropower Generation in SAARC Countries

SAARC Countries	PT		SNHT		BT	
	Sig.	Change Point	Sig.	Change Point	Sig.	Change Point
Bangladesh	1%	1988	1%	1982	1%	1988
Pakistan	1%	1991	1%	1991	1%	1991
Sri Lanka	1%	1992	1%	1989	1%	1992

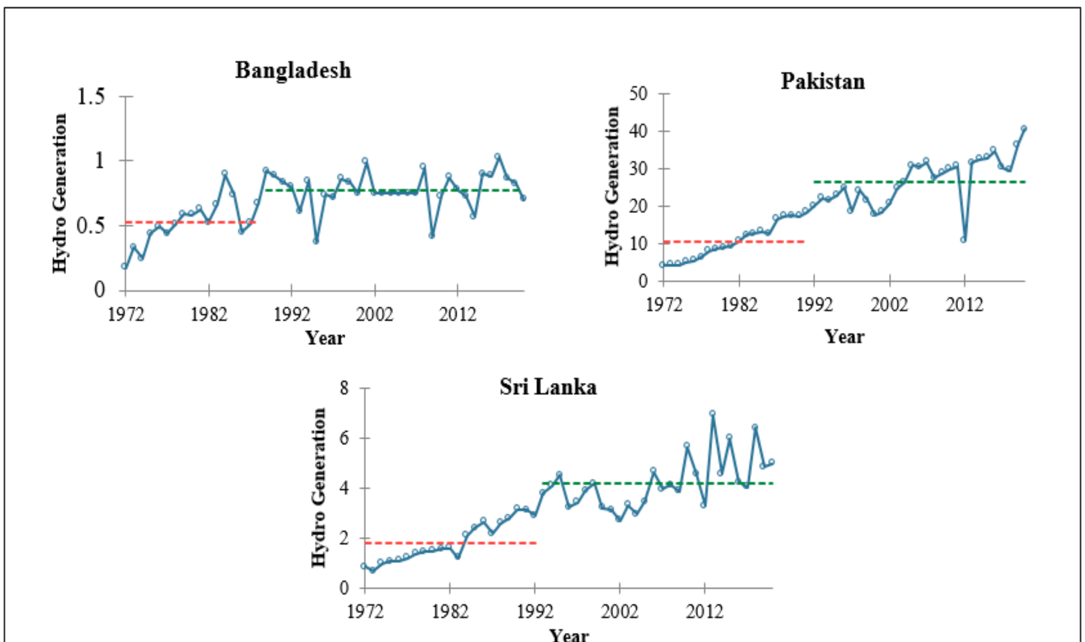

Fig. 4. Captured Change Points in SAARC Countries

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Table 2 summarizes the homogeneity tests such as SNH, Buishand's and Pettitt's tests have been conducted to notice the change point of hydropower generation of SAARC countries (Bangladesh, Pakistan and Sri Lanka). From the above table 2 and fig. 4, the homogeneity tests are revealed that the hydropower generation data of SAARC countries exhibits inhomogeneous pattern. Which means that, the time series data have abrupt change, which is identified during the period 1972 to 2020, country wise, by the tests of SNH and Buishand's test. Bangladesh data represents 1988 is a significant break point from the methods of Pettit's test and Buishand's test. The identified change points for the countries Pakistan and Sri Lanka are 1991 and 1992. In the view of three SAARC countries, it is clear that the change is occurred between the period is 1988 to 1992.

After studying the homogeneity of data, the entire time series (1972-2020) is considered into three time periods. The three time periods represented by the Period-I (before shift), Period-II (after shift) and whole time series is Period-III (1972-2020). Now the trend analysis can perform based on three periods, it gives a clear idea about how the trends are changed time to time. In this stage the most familiar method to analyse the trends of long-term data is MK test is taken into consideration and tried to apply for hydropower generation data. The results are presented in table 3.

2.3 Trend and Slope Estimation of Hydropower Generation of SAARC countries

Table 3: Mann-Kendall Trend Test and Sen's Slope Estimator Results of Hydropower Generation in SAARC Countries

SAARC Countries	Time Periods	MK statistic	Sen's Slope	Sig.
Bangladesh	1972-1988	0.632	0.030	0.000
	1989-2020	-0.010	0.000	0.948
	1972-2020	0.435	45.199	0.0001
Pakistan	1972-1991	0.958	1.212	0.0001
	1992-2020	0.576	1.200	0.0001
	1972-2020	0.830	1.378	0.0001
Sri Lanka	1972-1992	0.886	7.929	0.0001
	1993-2020	0.386	4.526	0.004
	1972-2020	0.770	8.694	0.0001

Table 3 exhibits the trend analysis based on period wise and whole-time series with reference to country wise hydropower generation data. This study discovered interesting increasing trends in hydropower generation data of four SAARC countries on an annual time scale. Eleven out of the twelve MK test values are statistically significant at 95% confidence and the growth rates of generation of hydropower are in raising pattern. From the Sen's slope estimator results, the average growth rates are calculated. From the above analysis the highest average growth rate in Sri Lanka with 7.929/year and the lowest average growth rate in Bangladesh with 0.030/year in the period-I, respectively. On the basis of the period-II, the significant rate of change of maximum and minimum growth rates are identified in the countries Sri Lanka and Pakistan with magnitude of trends are 4.526/year and 1.2/year. The results of the period-III exhibit the highest upward trend value in Bangladesh are captured and their trend values are 45.199/year.

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The other observation is the magnitude of the trend has declined from the period-I to the period-II in the countries Pakistan and Sri Lanka. However, Bangladesh generates a good amount of power is observed from long term data (1972 to 2020).

2.4 ARIMA Models on Hydropower Generation of SAARC Countries

The chapter also covers ARIMA models on hydropower generation data of Bangladesh, Pakistan and Sri Lanka. In this study, ACF and PACF plots generated to identify the correlations and choosing the lags in the hydropower generation data. Next step is to perform various ARIMA models to suit the particular data and detect the best among the models. Further the study focused on predicting the next ten years of hydropower generation data by using best ARIMA model.

2.4.1 Bangladesh

2.4.1.1 ACF and PACF of Hydropower Generation in Bangladesh

In ARIMA model, ACF plot indicates the correlations of models with its own lags of hydropower generation data and PACF also suggest the drastic decrease from initial values. It is observed that ACF cuts off after lag 2 and PACF cuts off after the lag 1 represented in fig. 5. Suggested the different models of ARIMA (0,1,0) to ARIMA (2,1,2).

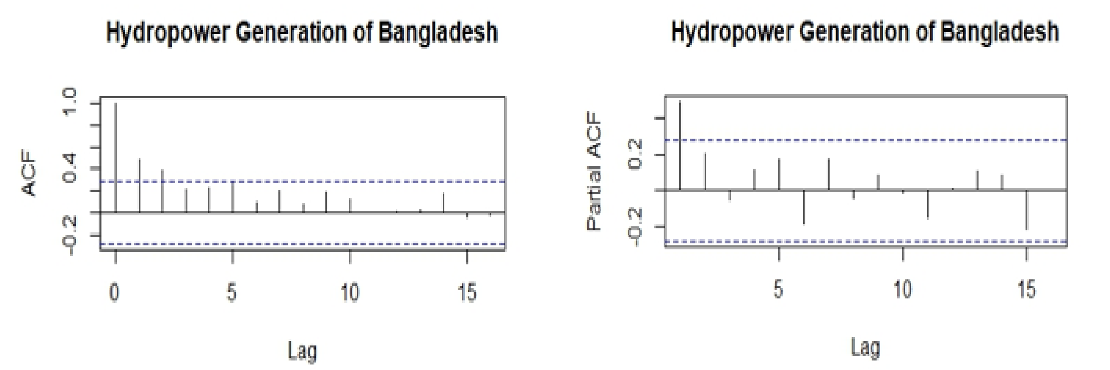

Fig. 5. ACF and PACF Plots of Hydropower Generation in Bangladesh

2.4.1.2 ARIMA Models for Hydropower Generation of Bangladesh

The ARIMA models of various (p, d, q) values applied on hydropower generation data of Bangladesh and fitted models with and without drift obtained along AIC values. The various models were represented in the Table – 4 and the best fitted model with lowest AIC and BIC values were presented in Table 5.

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Table 4: ARIMA Models with Different (P, D, Q) Values

ARIMA Model		AIC Value
ARIMA (2,1,2) with drift	:	-31.88094
ARIMA (0,1,0) with drift	:	-22.21429
ARIMA (1,1,0) with drift	:	-30.04163
ARIMA (0,1,1) with drift	:	-37.09894
ARIMA (0,1,0)	:	-24.0448
ARIMA (1,1,1) with drift	:	-35.55761
ARIMA (0,1,2) with drift	:	-35.49528
ARIMA (1,1,2) with drift	:	-33.56933
ARIMA (0,1,1)	:	-36.52928

Table 5: Selection of Best Model for Bangladesh

Country	Best Model	AIC	BIC
Bangladesh	ARIMA (0,1,1) with drift	-37.1	-31.49

Further, the study forecasted the hydropower generation of Bangladesh for the next ten years and observed that there is a minute exponential growth in the same. The forecasted values in shown the table 6 and represented forecasted portion with the past time years in the figure – 6. The overall forecasts from the ARIMA model (0, 1, 1) depicts that the country need more focus on hydropower generation and make policy decisions accordingly to improve the same.

Table 6: Predicted Values of Hydropower Generation of Bangladesh

Forecasting Year (Bangladesh)	Values (in TWh)
2021	0.8530
2022	0.8637
2023	0.8744
2024	0.8851
2025	0.8958
2026	0.9065
2027	0.9171
2028	0.9278
2029	0.9385
2030	0.9492

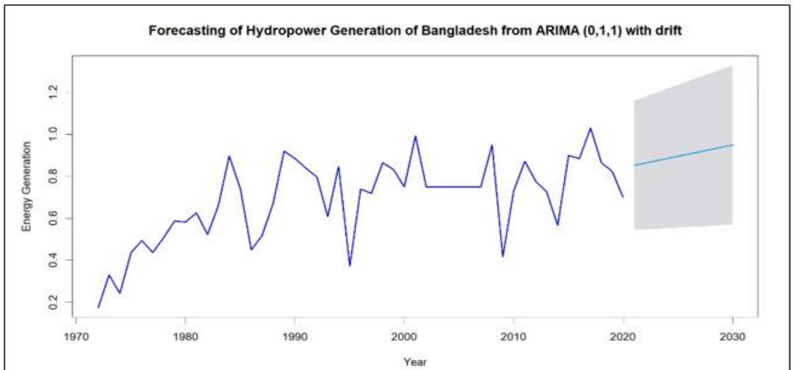

Fig. 6. Predicted values of Hydropower Generation of Bangladesh

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2.4.2 Pakistan

2.4.2.1 ACF and PACF of Hydropower Generation in Pakistan

In the initial steps of ARIMA model, ACF and PACF values are providing the correlations among the its own values and values are exponentially decreasing, obtained stationarity at lag 14. The PACF values cuts off after lag 1 surprisingly. Both ACF and PACF are represented in Figure – 7.

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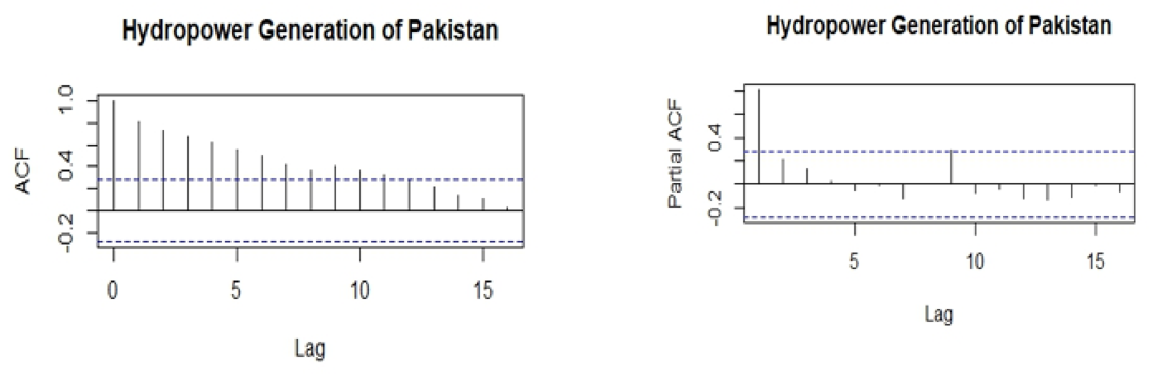

Figure 7. ACF and PACF Plots of Hydropower Generation in Pakistan

2.4.2 .2 ARIMA Models for Hydropower Generation of Pakistan

Models with (p, d, q) values were employed on the hydropower generation of Pakistan and obtained the fitted models with and without drifts along with AIC values. The models were represented in Table – 7 and the best fitted model with lowest AIC and BIC values were presented in Table – 8.

Table 7: ARIMA Models with different (p, d, q) Values

Table 8: Selection of Best Model

Country	Best Model	AIC	BIC
Pakistan	ARIMA (2,1,0) with drift	281.86	289.35

After selecting best fitted ARIMA model, the study extended to forecast the next ten-year values so that country can plan the improving stages and take the decision in enhancing the production of the hydropower generation. The same represented in the table 9 and fig. 8.

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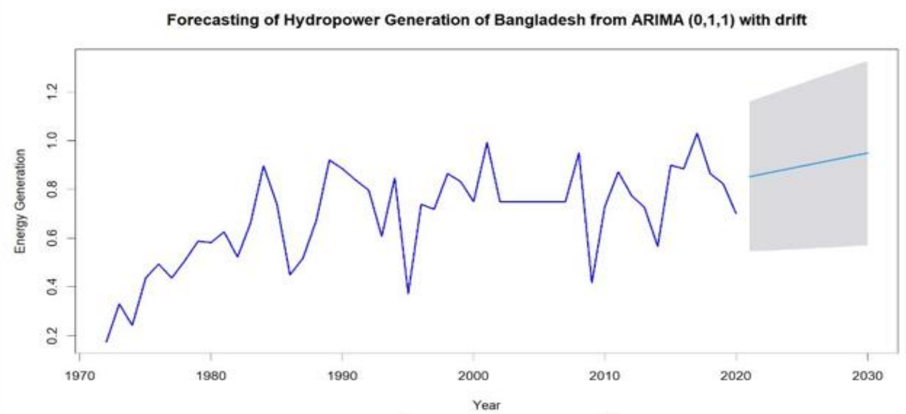

Fig. 8. Selection of Best Model

Table 9: Predicted Values of Hydropower Generation of Bangladesh

Forecasting Year (Pakistan)	Values (in TWh)
2021	37.6710
2022	39.2566
2023	40.3979
2024	40.6564
2025	41.4941
2026	42.2634
2027	42.9147
2028	43.6458
2029	44.3666
2030	45.0715

2.4.3 Sri Lanka

2.4.3.1 ACF and PACF of Hydropower Generation in Sri Lanka

The ACF and PACF plots indicates the correlations of the models with its own lags of hydropower generation of Sri Lanka and PACF gives the suggestive models for the fitting shown in fig. 9.

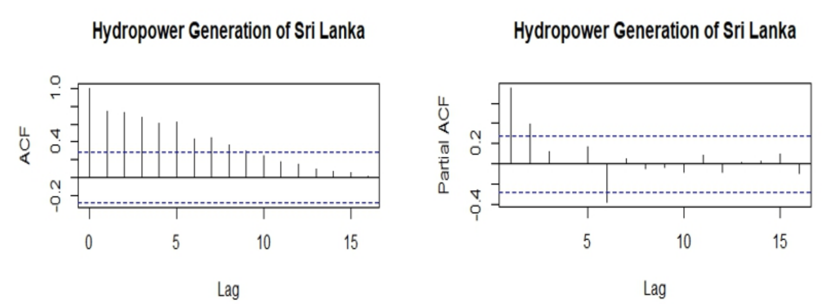

Fig. 9. ACF and PACF Plots of Hydropower Generation in Sri Lanka

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2.4.3.2 ARIMA Model Results of Hydropower Generation of Sri Lanka

The ARIMA models with (p, d, q) values obtained with AIC values in Table 10 and selection of best model with lower AIC and BIC values in Table 11. Further the study, forecasted the next ten years to know the status of hydropower generation in Sri Lanka are presented in Table 12 and displayed the same in Fig. 10.

Table 10: ARIMA Models with different (p, d, q) values

ARIMA Model		AIC Value
ARIMA (2,1,2) with drift	:	115.3978
ARIMA (0,1,0) with drift	:	138.3538
ARIMA (1,1,0) with drift	:	122.144
ARIMA (0,1,1) with drift	:	Inf
ARIMA (0,1,0)	:	136.7216
ARIMA (1,1,2) with drift	:	113.9178
ARIMA (0,1,2) with drift	:	112.1898
ARIMA (0,1,3) with drift	:	113.6034
ARIMA (1,1,1) with drift	:	112.5555
ARIMA (1,1,3) with drift	:	113.47
ARIMA (0,1,2)	:	115.0915

Table 11: Selection of Best Model

Country	Best Model	AIC	BIC
Sri Lanka	ARIMA (0,1,2) with drift	112.19	119.67

Table 12: Predicted Values of Hydropower Generation of Sri Lanka

Forecasting Year (Sri Lanka)	Values (in TWh)
2021	5.4338
2022	5.4108
2023	5.5039
2024	5.5970
2025	5.6902
2026	5.7833
2027	5.8764
2028	5.9696
2029	6.0627
2030	6.1558

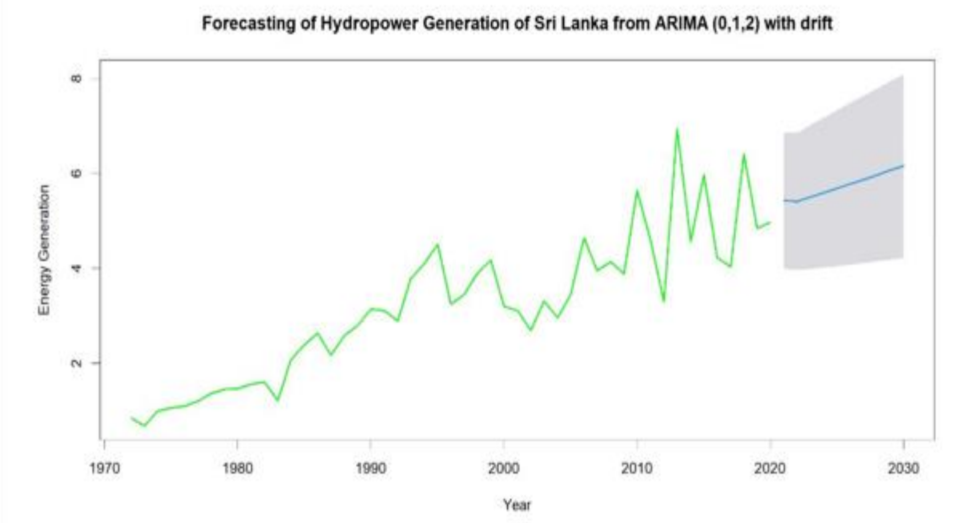

Fig. 10. Forecasting of Hydropower Generation of Sri Lanka

CONCLUSION

Hydroelectric power or simply hydropower is one of the oldest and an affordable way to generate electricity from water. Renewable energies production is need of the hour for the present-day situation in the world, such energy can be generated by one of the best sources is hydropower. The monitoring of such hydropower trends is vital in the South Asian countries such as Bangladesh, Pakistan and Sri Lanka. Trend analysis has been conducted on annual hydropower generations of SAARC countries after the verification of homogeneity of data.

The homogeneity tests captured the significant change points to all SAARC countries at various time periods which lies between the periods of 1988 to 1992. The MK test results indicated that the magnitude of trend values is in raising pattern in all SAARC countries. However, from period-II, the performance of hydropower generation is good and the raise of trends in Sri Lanka high than the other countries.

Renewable energy production is considered essential in today's modern world, and one of the major sources of such energy is hydropower. As, the time series model building with ARIMA method was very popular in most of the fields, the study also focused on predicting the hydropower generation in major SAARC countries such as Bangladesh, Pakistan and Sri Lanka.

Based on the forecasting results, it may be concluded that ARIMA model could be successfully used for forecasting hydropower Generation of these countries for the immediate subsequent years. The study helps to understand the generation of hydropower which is essential for country's future energy requirements.

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