Proceedings of the Pakistan Academy of Sciences:
A. Physical and Computational Sciences 56 (3): 27-36 (2019)

ISSN: 2518-4245 (print), 2518-4253 (online)

Pakistan Academy of Sciences

Research Article

Forecasting Buffalo Population of Pakistan using Autoregressive Integrated Moving Average (ARIMA) Time Series Models

Muhammad Qasim[1], Muhammad Amin[2*], Muhammad Nauman Akram[2], Talha Omer[1], and Fiaz Hussain[3]

[1]Department of Economics, Finance and Statistics, Jönköping University, Sweden
[2]Department of Statistics, University of Sargodha, Pakistan
[3]Department of Animal Nutrition, University of Veterinary and Animal Sciences, Lahore, Pakistan

Abstract: Livestock plays a vital role in Pakistan's economy. Buffalo is the primary source of milk and meat, which is a basic need for human health. So, there is a need to forecast the buffalo population of Pakistan. The main objective of the current study is to determine an appropriate empirical model for forecasting buffalo population of Pakistan to assess its future trend up to the year 2030. We apply different Autoregressive Integrated Moving Average (ARIMA) models on the buffalo population-based on fifty-years' time-series dataset. Different model selection criteria are used to test the reliability of the ARIMA models. Based on these criteria, we perceive that ARIMA (1, 0, 0) is a more suitable model. Moreover, we also test the fitted model assumptions, such as normality and independence, to find out more accurate forecasted values. This study revealed that the buffalo population expected to increase 30% up to the year 2030 under the assumption that there is no irregular trend can be encountered during forecasted years.

Keywords: Autoregressive Integrated Moving Average (ARIMA), Buffalo, Estimated Root Mean Square Error (ERMSE), Time Series Model.

1. INTRODUCTION

The agriculture sector is the cornerstone of the economy of developing countries like Pakistan. It is the second largest sector and contributing about 21% of the national Gross Domestic Product (GDP). However, only livestock is contributing to the share of 58.92 percent to overall agriculture GDP [1]. Livestock is the fastest growing sub-sectors in developing countries in the last few decades and it is still increasing continuously. Continue growing of livestock and their productivity will fulfil the demands of meat, milk, and eggs of increasing human population [2]. Buffalo population is estimated at177 million head in the world and out of these about 170 million head presents in Asia (more than 95%) [3].

Pakistan has a unique environment and geographical location for a good adaptation of buffalo which is the cause of contributing a big percentage of livestock and ranked as the 2nd largest population of buffalo in the world [1]. The national herd consists of 29.9 million buffalo. The buffalo (Bubalus bubalis) is an important contributor to milk, meat and leather production in many developing countries like Pakistan and play a vital role in export. Pakistan is the world's 3rd largest producer of milk, generating approximately 43,562 million tons of milk and 1,601 million tons of beef which obtained from livestock. They were mainly used to produce meat and milk [4, 5]. The meat of buffalo has a unique taste which is exported to various foreign countries especially Arabian countries including the Kingdom of Saudi Arabia

Received: May 2019; Accepted: September 2019
*Corresponding Author: Muhammad Amin <muhammad.amin@uos.edu.pk>

(KSA), Kuwait, United Arab Emirates (UAE), Oman, Qatar, and Bahrain. Moreover, Pakistan exports live animals and meat and earn around US$ 13.95 million from its exports. Buffalo milk has high-fat contents about 6 to 8.5 percent and preferred by consumers over cow milk. Due to better fat contents and consumers' preference its price is high in South Asian milk markets [4, 5, 6]. But, the rapid increase in population, urbanization and per capita consumption of meat and milk, a massive increase in the demand for livestock and their products for developing countries [7]. According to the recent statistic, at least 1.3 billion employs are associated with the livestock sector globally and directly support about 600 million poor smallholder farmers [8]. This is continuously increasing the demand of meat and about 56 percent increase in meat export as compared to the previous year's [1].

Some research studies have been carried out under different countries of the world for forecasting the livestock population using statistical models. Thornton [9] reviewed recent trends of the livestock population and future scenarios in Kenya and found that due to an increase in human population and urbanization, the demand of livestock and their products will also be increased. Ahmed et al. [10] predicting the milk production of Pakistan by using time series Autoregressive Integrated Moving Average (ARIMA) (1, 1, 1) model for estimation. They suggested that recent development in the dairy sector will help to increase milk production. So, there is a need for a comprehensive policy of development to increase the strength of dairy and livestock to fulfil the demand for milk and other products. Ayyub et al. [1] predicted meat production and its price and future perspective in Pakistan. In their study, they used ARIMA models and found that ARIMA (4, 2, 4) is most suitable for forecasting purposes. They concluded that meat and its price would increase continuously for a local consumer in Pakistan in future. Pasha and Hayat [11] discussed the present situation of buffalo production and forecasted the buffalo population for the future. In their finding, they indicated a huge gap between demand and supply in the market and this gap would be increased in future, since buffalo is used for various purposes, milk, meat and mechanical power to human. Suresh et al. [12] designed a study regarding forecasting of livestock population and its feed resources in India. Higher-order autoregressive models were used to enhance the efficient forecasting models for livestock feed resources. They forecasted livestock population feed and crop based on 40 years' historical data of livestock production, crop production and land use. Hossain and Hassan [13] carried out a study about the forecasting of milk and meat production in Bangladesh. They used five different growth models (linear, exponential, cubic, quadratic, and compound model) for forecasting purpose. They concluded that the milk, meat, and egg production would be increased if the current growth rate of Bangladesh economy remains the same. Nouman et al. [14] carried out a study about forecasting of beef and total livestock production of Pakistan up to 2020 by using time series ARIMA model (0, 1, 1).

In his study, he found that beef and livestock demand will be increased in future while supply will not rise with the same ratio of demand because of lack of availability of advanced technology in reproduction and poor feedings plan in Pakistan. Mgaya [24] studied that the potential for improvement of animal feed as the market opportunity for the dairy farmer by forecast utilization of livestock manufactured goods such as eggs, milk, chicken and cow meat. He showed that the consumption of all livestock products (such as meat, milk and eggs) is expected to increase as the population and income growth using ARIMA time series models. Nimbalkar et al [25] studied the trend of trade of sheep and goat meat. They forecasted the sheep and goat meat export for years 2019 to 2023 using ARIMA time series model. Recently, Deshmukh and Paramasivam [26] forecasted the milk production based on the time series model by using a secondary dataset from the year 1961 to 2012. They used ARIMA and vector auto regression models and found that ARIMA (1, 1, 1) is an appropriate model for predicting milk production. The literature indicated that no researcher gives the idea of livestock population forecasting in Pakistan to meet the challenges in the future. Therefore, literature motivates us to continue the current research work.

The main aim of this study is to forecast the buffalo population to meet the challenges of increasing demands of meat, milk and other livestock products for the human population that continuously increasing. The rest of the article is structured as follows: Section 2 defines the nature of data, time series modelling and choice of an appropriate model. In Section 3, the forecasting results are presented. The results are discussed in Section 4. Finally, the concluding remarks and future challenging with buffalo production are stated in Section 5.

2. MATERIALS AND METHODS

2.1 Data

The livestock is the sub-sector of agriculture that contains buffalo population and offers significant employment and livelihood opportunities, especially for the rural areas. This study is supported by secondary time series data from 1961-2017 of buffalo population in Pakistan. To attain the objective of the study, a secondary time series data of the buffalo population is collected from the different publications of Pakistan such as bureau of statistics and Pakistan economic survey.

2.2 Time Series Models

Different existing time series models are used to conquer the objective of the current study. The best-fitted model is selected based on different performance criteria. For this purpose, we used time-series data from 1961-2010 for model fitting. While the time-series data from 2011-2017 are used for comparison of forecasted in our selected model with the actual buffalo population. This study is based on a linear time series model which was given by Box and Jenkins [15] for forecasting buffalo population in Pakistan to meet the challenges in advance. ARIMA is an important class of forecasting time series model. The general form of the ARIMA (p, d, q) model using log-polynomials can be written as:

$$\left(1-\sum_{j=1}^{p}\emptyset_j L_j\right)(1-L)^d Y_T=\left(1+\sum_{i=1}^{q}\vartheta_i L_i\right)\epsilon_T,$$

where p, d, and q are three non-negative integer parameters which can be defined as “p=is the order of autoregressive”, “d=is the order of differencing” and “q=is the order of moving average model”. If the integrated parts (d) reduce to zero then, ARIMA (p, d=0, q) reduce to ARMIA (p, q). Different forms of the ARIMA models are illustrated by Amin et al. [16] and these are presented in Table 1.

Further more, the order of p and q for the ARIMA model is identified by Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF), respectively. Moreover, the value of d is determined when the series becomes stationary.

Table 1. Different ways of the time series ARIMA models for forecasting Buffalo population of Pakistan.

Sr. No.	Model's Name	Mathematical Form of the Model
1	ARIMA (0, 1, 1) =IAM (1, 1) through constant(μ)	$Y_T=\mu_o+Y_{T-1}+\epsilon_T+\mu_1\ \epsilon_{T-1}$
2	ARIMA (0, 1, 2) through constant(μ)	$Y_T=\mu_o+Y_{T-1}+\epsilon_T-\mu_1\epsilon_{T-1}-\mu_2\epsilon_{T-2}$
3	ARIMA (1, 1, 1) through constant(μ)	$Y_T=\mu_o+(1+\emptyset)Y_{T-1}+\emptyset Y_{T-2}+\epsilon_T-\mu_1\ \epsilon_{T-1}$
4	ARIMA (0, 2, 2) through constant(μ)	$Y_T=\mu_o+2Y_{T-1}-Y_{T-1}+\epsilon_T-\mu_1\epsilon_{T-1}-\mu_2\epsilon_{T-2}$
5	ARIMA (0, 1, 1) =IAM (1, 1)	$Y_T=Y_{T-1}+\epsilon_T+\mu_1\epsilon_{T-1}$
6	ARIMA (1, 1, 1)	$Y_T=(1+\emptyset)Y_{T-1}+\emptyset Y_{T-2}+\epsilon_T-\mu_1\epsilon_{T-1}$
7	ARIMA (0, 2, 2)	$Y_T=2Y_{T-1}-Y_{T-2}+\epsilon_T-\mu_1\epsilon_{T-1}-\mu_2\epsilon_{T-2}$
8	Linear Trend	$Y_T=\alpha+\epsilon_T+\mu_1\epsilon_{T-1}$
9	Random walk with drift	$Y_T=\mu_o+Y_{T-1}+\epsilon_T$
10	Simple exponential smoothing	$Y_T=\alpha Y_T+(1-\alpha)\ Y_{T-1}$

2.3 Time Series Model Selection Criteria

Model selection is considered to be important for more accurate and reliable forecasting. The selection of the model is based on the model selection criteria. Most common listed criteria are Akaike Information Criteria (AIC) and Schwarz Bayesian Information Criteria (SBIC). However, the order of the ARIMA (p, d, q) model is also determined through AIC and SBIC. A time series model that has minimum AIC and SBIC are assumed best-fitted model [17]. The parameters of the time series models are estimated using the maximum likelihood estimation method.

2.4 Time Series Model Diagnostics

Different diagnostics methods are used to ensure whether the model fitted properly or not. The firstly, the diagnostic method is used to draw the time series plot of residual. Secondly, we verified the identification of normality of the well fitted time series model by using the Periodogram under the confidence interval bound between 95% and 99% and normal probability. At the third step, the autocorrelation of the fitted time series model by utilizing the Box-Pierce test and Runs test. Finally, ACF and PACF are used for detection of autocorrelation in the residual.

2.5 Forecasting Accuracy Assessment Procedures

After selecting the suitable model, the next step is to check the accuracy of forecasted values of the selected time series to find reliable forecasts. Various methods are available in the literature to assess the accuracy of the forecasted values of the selected model. These procedures include Estimated Mean Error (EME), Estimated Mean Percentage Error (EMPE), Estimated Root Mean Square Error (ERMSR) and Estimated Mean Absolute Percentage Error (EMAPE). The mathematical form of these measures is given in Table 2.

3. RESULTS

Time series model can be fitted to attain the objective of the reliable forecast. In this article, some novel time series models are fitted on buffalo population data of Pakistan. For attaining more accuracy and reliability multiple time series models are fitted and tested based on different statistical measures.

3.1 Buffalo Population Forecasting Based On 1960-2010 Time Series Data

Different time series models (a-q) are fitted on the buffalo population using time series data 1961-2010 and results are set out in Table.3.

Fitness of the best model is assessed by considering the AIC criteria. The AIC criteria revealed that ARIMA (1, 0, 0) shows the minimum value than other time series models. So ARIMA (1, 0, 0) is the suitable model for forecasting the buffalo population of Pakistan. Table 3 includes the results to verify the assumptions of the fitted time series model. We selected the best model m since it has minimum AIC, HQC and SBIC. All the performance criteria also verified by m (ARIMA (1, 0, 0)) model. While none of the other models found statistically significant to a 95% confidence interval and the model m is undoubtedly the adequate model for forecasting the buffalo population of Pakistan. The summary of model coefficients of ARIMA (1, 0, 0) is demonstrated in Table 4.

Table 2. Performance criteria methods for forecasted values.

Method's Name	Mathematical Form	Notation's Meaning
ERMSE	$\frac{\sum_{T=1}^{n} \epsilon_T^2}{n}$	ϵ is the regression residual Y_T is the time series considered response T denotes the time taking integers $PE_T = \left(\frac{Y_T - F_T}{Y_T}\right) \times 100$ where F_T is the forecasted value for time *T*.
EMAPE	$\frac{\sum_{T=1}^{n} \lvert PE_T \rvert}{n}$	
EME	$\frac{\sum_{T=1}^{n} \epsilon_T}{n}$	
EMAE	$\frac{\sum_{T=1}^{n} \lvert \epsilon_T \rvert}{n}$	
EMPE	$\frac{\sum_{T=1}^{n} PE_T}{n}$	

3.2 Execution of Important Model Assumptions

Reliable forecasting of buffalo population can be possible if the selected model can fulfil all model assumptions. A model is considered a good one if the model residuals belong to the normal distribution, not auto correlated and not heteroscedastic. Table 5 indicated that ARIMA (1, 0, 0) model residuals are independent and not auto correlated which can be confirmed in the ACF plot (Fig. 1) and PACF plot (Fig. 2).

For checking these assumptions three tests have been run to check the randomness of runs. The first median test counts the number of runs above or below the median. The random number sequence is usually called white noise, as it contains equal contribution at various frequencies. The P-value of

Table 3. Model selection for forecasting Buffalo population of Pakistan.

Model	ERMSE	EMAE	EMAPE	EME	EMPE	AIC	HQC	SBIC	RUNS	RUNM	AUTO	MEAN	VAR
(a)	0.639	0.490	2.887	0.461	2.625	-0.895	-0.895	-0.895	OK	***	OK	***	OK
(b)	0.447	0.294	2.202	0.000	-0.700	-1.570	-1.555	-1.532	OK	***	OK	***	OK
(c)	6.864	5.932	42.230	0.000	-18.416	3.893	3.907	3.931	***	***	***	***	***
(d)	1.678	1.349	10.347	0.000	0.196	1.115	1.144	1.192	***	***	***	OK	OK
(e)	0.491	0.344	2.456	0.000	-0.130	-1.303	-1.259	-1.188	***	***	***	**	OK
(f)	0.697	0.565	4.247	0.053	-0.147	-0.643	-0.614	-0.566	***	***	***	***	***
(g)	6.141	5.007	32.078	1.088	-6.244	3.710	3.739	3.786	***	***	***	***	***
(h)	0.883	0.703	4.005	0.693	3.911	-0.208	-0.194	-0.170	OK	***	**	***	*
(i)	0.639	0.480	2.830	0.452	2.573	-0.855	-0.840	-0.817	OK	***	OK	***	*
(j)	0.419	0.199	1.448	0.078	0.574	-1.701	-1.686	-1.662	OK	*	OK	OK	*
(k)	0.410	0.173	1.176	0.083	0.453	-1.701	-1.672	-1.625	OK	**	OK	OK	*
(l)	0.445	0.232	1.637	0.012	0.087	-1.578	-1.564	-1.540	OK	***	OK	OK	**
(m)	0.390	0.163	1.289	-0.002	-0.266	-1.843	-1.828	-1.804	OK	OK	OK	OK	*
(n)	0.393	0.171	1.366	-0.014	-0.360	-1.787	-1.758	-1.710	OK	OK	OK	OK	*
(o)	0.394	0.163	1.279	0.007	-0.214	-1.780	-1.751	-1.704	OK	**	OK	OK	*
(p)	0.403	0.149	1.071	0.039	0.313	-1.739	-1.710	-1.663	OK	OK	OK	OK	*
(q)	0.400	0.169	1.346	-0.002	-0.296	-1.715	-1.671	-1.600	OK	**	OK	*	*

(a) Random walk *(b)* Random walk with drift = 0.461224 *(c)* Constant mean = 16.2 *(d)* Linear trend = 4.54971 + 0.456874 t *(e)* Quadratic trend = 8.28604 + 0.0257593 t + 0.00845323 t^2 *(f)* Exponential trend = exp (1.97113 + 0.0285218 t) *(g)* S-curve trend = exp (2.82076 + -1.3594 /t) *(h)* Simple moving average of 2 terms (i) Simple exponential smoothing with alpha = 0.9999 *(j)* Brown's linear exp. smoothing with alpha = 0.5119 *(k)* Holt's linear exp. smoothing with alpha = 0.8934 and beta = 0.1737 *(l)* Brown's quadratic exp. smoothing with alpha = 0.3195 *(m)* ARIMA (1,0,0) *(n)* ARIMA (1,0,1) *(o)* ARIMA (2,0,0) *(p)* ARIMA (1,1,1) *(q)* ARIMA (1,0,2).

RMSE (Root Mean Squared Error)
RUNS (Test for excessive runs up and down)
RUNM (Test for excessive runs above and below median)
AUTO (Box-Pierce test for excessive autocorrelation)
MEAN (Test for difference in mean 1st half to 2nd half)
VAR (Test for difference in variance 1st half to 2nd half)
OK = not significant ($p >= 0.05$)
* = marginally significant ($0.01 < p <= 0.05$)
** = significant ($0.001 < p <= 0.01$)
*** = highly significant ($p <= 0.001$)

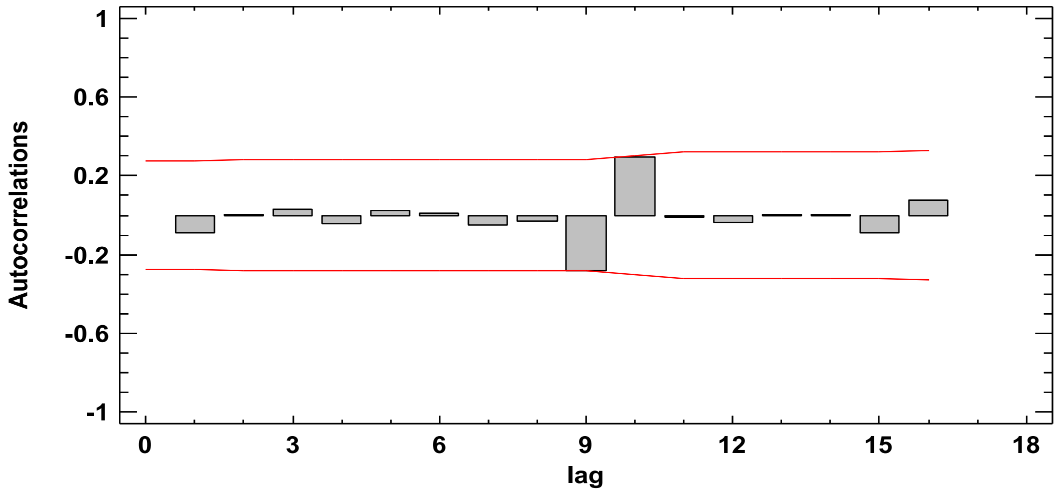

Fig. 1. Autocorrelation plot of ARIMA (1, 0, 0) model.

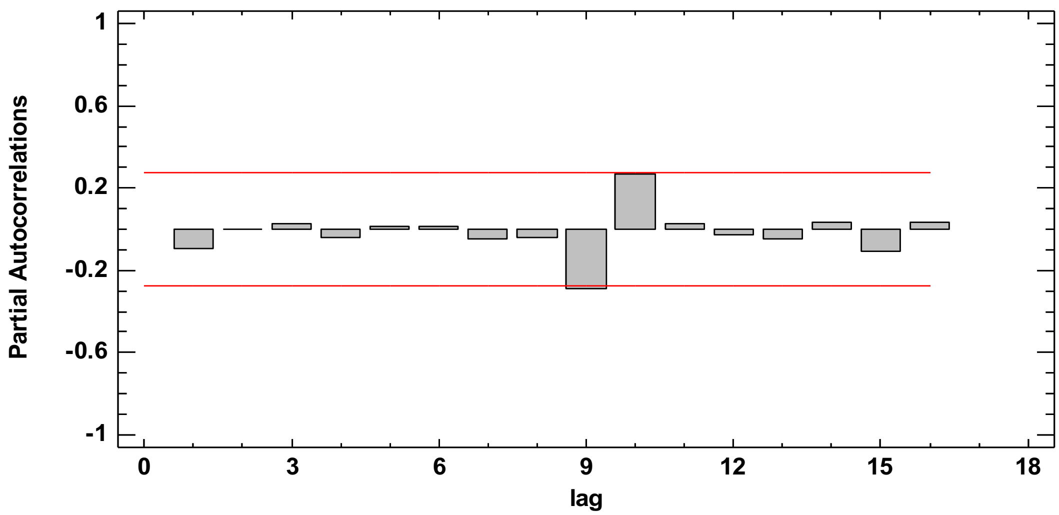

Fig. 2. Partial autocorrelation plot of ARIMA (1, 0, 0) model.

all run tests shows the non-significance result for the null hypotheses that the residuals are random at a 5% significance level. The second test notes the rise and fall of the sequence. The number of rise and fall counted 33 as compared to an expected value of 32. The P-value is greater than 0.05 which shows that we cannot reject the null hypothesis "The series is random". The third test is based on the sum of the square of autocorrelation. The similar result is evidently noted from the third test. Furthermore, the Periodogram is used for checking the normality assumption. Fig. 3 indicates the normality of residuals of the ARIMA (1, 0, 0) model.

After checking all the assumptions and significance of ARIMA (1, 0, 0) model, the next step is to forecast the buffalo production. One step ahead forecasted values and residuals for buffalo population for the period 2011-2018 based on the ARIMA (1, 0, 0) model is presented in Table 6. Furthermore, it can be seen that how well the forecasted values matched with the actual value as the forecast depends on statistical data formulation. Thus, it is an appropriate forecast and assumed that there is no change in environmental conditions.

Now, we forecasted the buffalo population (millions) from 2019 to 2030 based on selected time series model i.e. ARIMA (1, 0, 0) and the results are provided in Table 7. We can also observe that the buffalo population expected to be 39.67 million in 2019. The buffalo population is expected to be

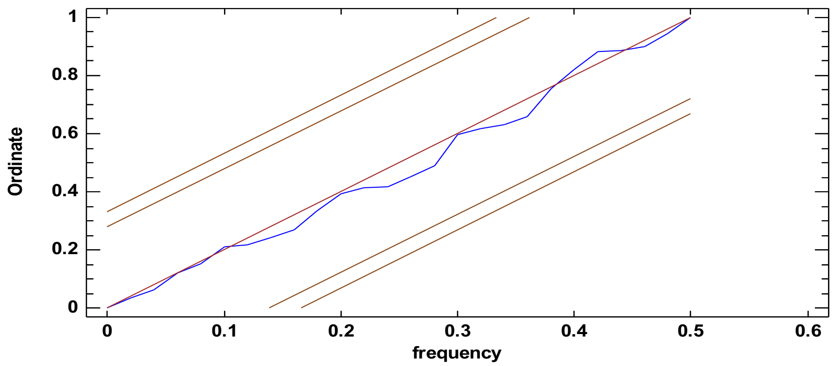

Fig. 3. Periodogram of the ARIMA (1, 0, 0) time series model.

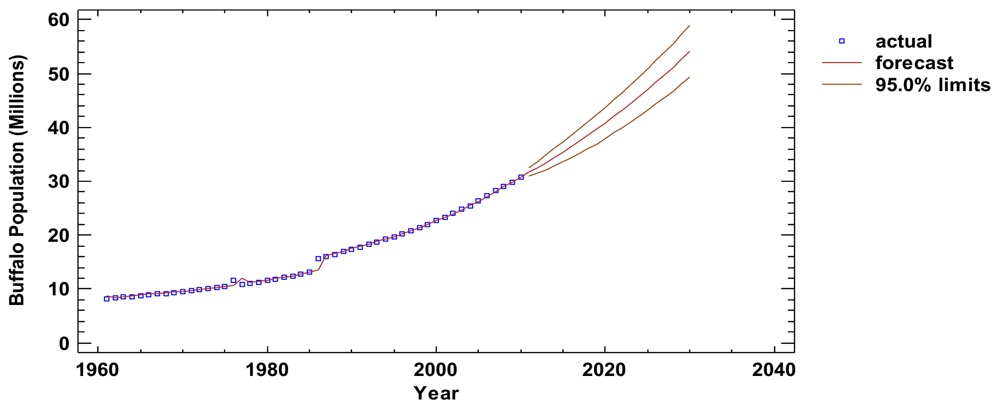

Fig. 4. Forecasting plot for predicting buffalo population.

Table 4. Estimated coefficient summary of ARIMA (1, 0, 0) Model

Parameter	Estimate	Standard Error	t- statistic	P-value
AR(1)	1.02854	0.00322571	318.856	0.0000

Table 5. Test for Autocorrelation and Randomness

Test	Test Statistic	P-value	Expected Number of Runs	P-value
Runs above and below the median	1.00021	0.317208	26	0.0000
Runs up and down	1.53747	0.124178	33	
Box-Pierce Test	9.85226	0.828929	--	

Table 6. One step ahead forecasts and residuals for Buffalo Population (Millions) data (1961-2010).

Years	Actual	Forecasted	Residual
2011	31.7	31.68	0.0211
2012	32.7	32.58	0.1171
2013	33.7	33.51	0.1874
2014	34.6	34.47	0.1311
2015	35.6	35.45	0.1475
2016	36.6	36.46	0.1359
2017	37.7	37.50	0.1954
2018	38.8	38.57	0.2252

Table 7. Yearly Buffalo population forecasts (Millions).

Years	Forecast	95 % Lower Confidence Limit	95 % Upper Confidence Limit
2019	39.6756	36.9876	42.3636
2020	40.8077	37.9306	43.6848
2021	41.9722	38.9077	45.0367
2022	43.1699	39.9189	46.4209
2023	44.4018	40.9644	47.8391
2024	45.6688	42.0448	49.2928
2025	46.9719	43.1604	50.7835
2026	48.3123	44.3119	52.3127
2027	49.6909	45.5000	53.8818
2028	51.1088	46.7254	55.4923
2029	52.5672	47.9889	57.1456
2030	54.0673	49.2914	58.8431

increased gradually. This gradual increase in buffalo population indicated that buffalo population of Pakistan would become 54.07 million in 2030 with the assumption that there is no epidemic disease which results in a decrease in buffalo population due to mortality of the diseases.

4. DISCUSSION

The study presented here forecasted the production of buffalo using ARIMA modelling. As Buffalo is called a "black gold" of Pakistan. As it plays a crucial role to raise the economy by providing different food items. Bilal et al. [18] highlighted in their study that buffalo contributes approximately 68% of the total milk production in Pakistan. Because of the large fat ratio in buffalo milk, it is the most preferable species. While certain constraints act as a brake to yet greater output. These may include, long calving interval, late age of maturity and silent heat. These are the general problems which may affect the production of buffalo. These problems can be solved through efficient monitoring. They pointed out some points to raise the production with a little touch to exotic buffaloes and recommendations are given to produce more. As in our study, the result indicates that the production of buffalo is increasing with an increase in the time period. Findings of our research are similar to previous studies of [19, 20], estimation of the genetic parameters of Nili-Ravi buffaloes which include lactation length, milk yield and dry period. For this, data on 9003 lactation records of Nili-Ravi buffaloes from four different herds in Punjab, Pakistan were used. A model with all possible relationships was used to estimate the variance. The estimates based on 305 days for milk yield, total milk yield, lactation length and dry period were 35%, 36%, 22% and 9%. The low percentage of all production traits indicates that this was due to ecological settings and non-additive genetic effects.

Furthermore, economic evaluation of the production of buffalo in different regions of Bangladesh as noted by Islam et al. [21] which is consistent with our results. Dostain et al. [22] investigated the future planning of livestock management in Baluchistan using time-series analysis. Box and Jenkins ARIMA models and regression models were used for forecasting the production of livestock. The findings of the Baluchistan study coincided the results of our study. The results of our findings showed that the population of buffalo is expected to be increased gradually. This increase in the buffalo population indicates that the expected population would become 54.07 million in 2030. These findings were also supported by Hamid et al. [23] in their study which investigated the production of buffalo in Bangladesh and compared it with the South Asian Association for Regional Cooperation (SAARC) countries.

5. CONCLUSIONS

The increase in the buffalo population is the basic need to meet the nation's requirements of food. For this purpose, forecasting is a crucial method which helps us to tackle all the upcoming situations in advance. By getting motivation from the contemporary idea given by Prime Minister Imran Khan to the nation that the halal meat market was worth more than 2000 Billion US$. Though, Pakistan does not have a significant contribution to this market. Buffalo production forecast enables us to decide to contribute to this market to boost the country economy in the future. In this study, we applied different time series models based on buffalo time-series data from the years 1960 to 2010. After applying time series models on the buffalo population, AIC and SBIC are used to select the appropriate model. The AIC and SBIC criteria gave the best model i.e. ARIMA (1, 0, 0) as it gets the lowest value of AIC criteria. ARIMA (1, 0, 0) time series model fulfills all the assumptions; normality of the residuals of the fitted time series model, no autocorrelation in residuals, and heteroscedasticity of the residual term. Based on ARIMA (1, 0, 0) model, we have found that the buffalo production will rise approximately 30% from the year 2018 to the year 2030 under the assumption that there is no irregular trend can be encountered in these years. This technique can be applied to find out the trends and forecast of the other animal population.

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