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Trend Analysis and Forecasting of Salt Demand and Production in Bangladesh

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Abstract: Salt is a strategic commodity in Bangladesh, contributing significantly to food security, industrial development, and coastal livelihoods. This study aims to analyze the long-term trend of salt demand and production in Bangladesh and to forecast future growth patterns. Secondary data covering the period 2000-2024 were collected from the Bangladesh Small and Cottage Industries Corporation, while relevant climatic information was obtained from the Bangladesh Meteorological Department. Trend analysis was performed using linear, quadratic, cubic, and exponential growth models. Model performance was evaluated using R^2, AIC, MAE, and MAPE criteria. The findings reveal a consistent upward trend in both salt demand and production, with the cubic growth model providing the best fit. Based on this growth model, salt demand for 2024-2025 is forecasted at 27.56 million tons (CI: 25.69-29.42), rising steadily to 44.75 million tons by 2030-2031. Similarly, salt production is projected to grow from 25.16 million tons in 2024-2025 to 45.13 million tons by 2030-2031. The study provides empirical evidence to support strategic planning and sustainable development of the salt sector in Bangladesh.

Keywords: Salt production; Demand trend; Growth modeling; Forecasting; Bangladesh.

INTRODUCTION

Salt, chemically known as sodium chloride (NaCl), is an essential mineral widely used for human consumption, food preservation, livestock feeding, fisheries, and numerous industrial applications (Chudy et al., 2025). Due to its indispensable role in daily life and industrial processes, salt is considered a strategic commodity in many countries, including Bangladesh. From the former age, salt has been a vital commodity used not only for preserving food but also as a method of trade and as a currency (Williams, 2009). Salt cannot be substituted. It is utilized in industry, fisheries, and animals in addition to being used in human diet. Planned salt production started in the country from 1961 through BCIC under the Ministry of Industry as a government initiative (TBS Report, 2023).

As salt is an essential commodity, the expansion and development of the salt business is very important, just like the expansion and development of other sectors. Under the help of the Ministry of Industry, Bangladesh Small and Cottage industries Corporation (BSCIC) is serving as a patron of the salt industry. Salt production is an ancient industry begun in the coastal zone of Bangladesh mostly in Chittagong and Cox's bazar districts. Generally, the period from November to May is considered as the salt production season but as a reason of high salinity of the sea water more salt is produced between the month of March, April and mid-May. The country's total demand for crude salt, according to the government's newly released salt strategy for the years 2022 to 2026, is expected to be 30.48 lakh tones and its aim is expanding the local salt industry through using modern technologies and environment-friendly production process (NEWAGE, 2026). In coastal areas with easy access to seawater, Salt producers use solar evaporation to obtain salt that involves collecting seawater in tiny saltpans and letting it dry off in the heat of the sun. After that, the remaining salt is gathered and dried (Doyle et al., 2010). Most of the dry season determines how much sea salt is produced by evaporation. Farmers can produce more salt when the dry season is longer (Hossain et al., 2006). The majority of

Bangladesh's coastal cities are located on the banks of rivers in low-lying tidal zones, with an average elevation of 1.0 to 1.5 meters above sea level. Cyclonic storms linked to tidal floods have a significant effect on livelihoods and infrastructure. Due to inadequate infrastructure, coastal cities are unsafe and unable to support the coastal population, despite being their ultimate haven during extreme storms (Rahman et al., 2015). Salt production plays a crucial role in the local economies of Bangladesh, providing livelihoods and contributing to food security.

Today's world population is increasing day by day. Also, the population of Bangladesh has increased in proportion to its size and is on the rise. The current government is taking various steps to meet the salt demand of this growing population. Not only the demand for salt but also the demand for workplaces and accommodation are increasing which the government is making every effort to meet. It is very important to see how much salt production is currently being done in Bangladesh or how much it is helping to meet the current salt demand of Bangladesh. Increasing the production of this crude salt production can meet the country's demand as well as play a special role in earning foreign exchange which is very noticeable in other countries. It is very important to look at what factors are causing the production of salt to fail or what factors are disrupting the production of crude salt. Because provision of adequate space for saltpans, raising of sufficient number of farmers and proper management and management of their marketing are necessary. By addressing these issues, the government will be able to fill the gaps that Bangladesh has and will be able to increase employment and improve the production and salt production sector of Bangladesh. Through this study, it will be tried to find out at what rate the amount of crude salt is increasing, what steps should be taken by the government and what kind of support and measures should be taken by the crude salt farmers needs to be taken, so that salt production can be successfully done both in nationally and internationally. Therefore, the objective of this study is to analyze the long-term trends of salt demand and production in Bangladesh and to forecast future levels using appropriate statistical growth models.

MATERIALS AND METHODS

Source of Data

The study was conducted using secondary time-series data on salt production and national demand in Bangladesh covering the period from 2000 to 2024. The data were collected from the Bangladesh Small and Cottage Industries Corporation (BSCIC), which is the principal authority responsible for monitoring and managing the salt sector in Bangladesh. The collected data were used to analyze historical trends, estimate growth rates, and forecast the future potential of salt production and demand in Bangladesh.

Descriptive Analysis

Descriptive analysis is an essential preliminary step in trend analysis, as it facilitates the organization, summarization, and interpretation of data before applying advanced statistical techniques. It provides an overall understanding of the dataset, identifies underlying patterns, and ensures that the data are suitable for subsequent modeling.

In this study, summary statistics such as mean, standard deviation, minimum, and maximum values were computed to describe the central tendency and dispersion of salt production and demand over the study period.

The coefficient of variation (CV) was used to measure the relative variability of the data. The CV is defined as the ratio of the standard deviation to the mean and is usually expressed as a percentage:

$$CV = \frac{s}{\bar{x}} \times 100$$

where s represents the standard deviation and $\bar{x}$ represents the mean.

A smaller CV indicates greater homogeneity or consistency in the data, whereas a larger CV reflects higher variability relative to the mean. The CV is particularly useful when comparing variability across variables measured on different scales.

Trend Analysis

Trend analysis is a statistical technique used to identify and examine systematic patterns in time-series data. It helps determine the direction (increasing or decreasing) and magnitude of changes in variables over time. In this study, trend analysis was employed to assess the long-term movement of salt demand and production in Bangladesh.

Time-series data were analyzed to estimate the underlying trend component, separating it from short-term fluctuations. Trend analysis enables the estimation of growth or declines rates and supports forecasting future values based on historical patterns.

Growth Modeling

Growth modeling aims to analyze the trajectory of variables over time and to identify the pattern of change. It provides insight into the dynamics of growth and helps explain whether the change is constant, accelerating, or decelerating. Growth models are generally classified into two broad categories: (i) Linear growth models, where the rate of change is constant over time, and (ii) Nonlinear growth models, where the rate of change varies over time and may accelerate or decelerate. Nonlinear growth models include exponential, quadratic, cubic, logarithmic, and sigmoid functional forms. In this study, four deterministic growth models were considered to determine which specification best fits the data on salt demand and production. These models are: (i) Linear model, (ii) Exponential model, (iii) Quadratic model, and (iv) Cubic model. The general functional forms of these models are presented in Table 1.

It can be observed that the growth rates of the linear and exponential models are independent of time in terms of structural specification, whereas the growth rates of the quadratic and cubic models vary over time due to the presence of higher-order time terms.

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Combining forecasts from different growth models can sometimes improve predictive accuracy (Hassan et al., 2011). Therefore, model comparison criteria were applied to identify the most appropriate specification for the dataset.

Best Model Selection Criteria

A variety of models can be used for analysis. However, not every model works well with the available data. A few factors help determine which model best fits the given data. Model selection criteria are used to determine which model is the best. Model selection criteria are the standards by which the best model for the available data is chosen. The best model among several models is chosen using a variety of model selection criteria and used for further research or predictions. For time series data analysis, several kinds of model selection criteria are employed. Among them, R^2, adjusted R^2, Akaike InformationCriterion (AIC), Bayesian Information Criterion (BIC), MAPE (Mean Absolute Percentage Error), MAD (Mean Absolute Deviation), MSD (Mean Squared Deviation), and RMSE (Root Mean Square Error) are most commonly applied (Mamun et al., 2021). The models taken into consideration for this study were calculated using Bangladesh's yearly salt production and its demand from 2000 to 2024. In this study, the best fitted model for forecasting and for revealing the growth patterns of the salt production was found using all of the model selection criteria. The lowest values of MAPE, MAD, MSD and the higher values of R^2 and adjusted R^2 are used to interpret the model selection criterion (Hossain et al., 2013).

RESULTS AND DISCUSSIONS

Trend Analysis of Salt Production and Demand

The trend analysis indicates a clear and sustained upward movement in both salt production and demand in Bangladesh over the study period (2000–2024). As shown in Figure 1, production exhibits a generally increasing pattern with moderate year-to-year fluctuations, whereas demand follows a comparatively smoother and more stable upward trajectory. Throughout most of the observed period, salt production remained higher than domestic demand, suggesting a favorable supply position in the national market. However, the gap between production and demand varies across years, reflecting the influence of climatic conditions, policy interventions, and market dynamics. In particular, noticeable increases in production are observed in the later years of the study period, corresponding with technological improvements, government support measures, and favorable weather conditions.

Table 1: Functional Forms of Growth Models and Corresponding Growth Rates

Model's Name	Model	Growth rate formula (individual)	Notation
Linear	$Y = \alpha + \beta t + \varepsilon$	$\frac{\beta}{Y_t} \times 100$	Y = dependent variable (time series data) t = time variable ε = error or residual α, β, γ and δ are called the coefficients of the corresponding models.
Exponential	$Y = \alpha e^{\beta t \varepsilon}$	$\beta \times 100$	
Quadratic	$Y = \alpha + \beta t + \gamma t^2 + \varepsilon$	$\frac{\beta + 2\gamma t}{Y_t} \times 100$	
Cubic	$Y = \alpha + \beta t + \gamma t^2 + \gamma t^3 + \varepsilon$	$\frac{\beta + 2\gamma t + 3\delta t^2}{Y_t} \times 100$	

Import levels (where present) appear relatively small compared to total domestic production, indicating that Bangladesh largely relies on local salt production to meet national demand (Mamun et al., 2014). Temporary imports in certain years may be attributed to short-term supply shortages caused by adverse climatic events or market imbalances.

Overall, the upward trend in both production and demand reflects the expanding domestic market and growing industrial requirements. The pattern suggests that the salt sector has experienced progressive development over time, although production demonstrates greater variability than demand due to its dependence on environmental and seasonal factors (Hossain et al., 2006).

Descriptive Analysis of Production and Demand (2000–2024)

A detailed scenario analysis of salt production and demand is presented in Table 2, summarizing the mean, standard deviation (SD), and coefficient of variation (CV) for six sub-periods spanning from 2000 to 2024.

The analysis reveals a steady increase in both production and demand, with notable fluctuations. Salt production shows the lowest variability (CV = 11.19%) during 2000–2004, indicating a period of stability, while the highest variability (CV = 24.48%) occurred in 2008–2012, reflecting production challenges during that time. In the most recent period (2020–2024), production reached its peak mean value (20.385 million tons) with moderate variability (CV = 17.69%), suggesting improved but not fully stable production systems. On the other hand, demand demonstrates a consistent upward trajectory, with the lowest variability (CV = 1.38%) during 2000–2004, indicating a highly predictable demand in the early years. The highest variability in demand (CV = 5.96%) occurred in 2016–2020, potentially due to changes in consumption patterns or industrial requirements. By 2020–2024, demand reached its highest mean value (23.7675 million tons), with

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Table 2: Scenario Analysis of Salt Production and Demand

	Demand		
Year	Mean	SD	CV (%)
2000-2004	9.0025	.12500	**1.38%**
2004-2008	11.8850	.37890	3.18%
2008-2012	13.5975	.58323	4.28%
2012-2016	16.0050	.72945	4.55%
2016-2020	17.0075	1.01431	**5.96%**
2020-2024	**23.7675**	1.14494	**4.81%**
	Production		
Year	Mean	SD	CV (%)
2000-2004	8.7100	.97540	**11.19%**
2004-2008	11.9125	2.78005	23.33%
2008-2012	12.9625	3.17369	**24.48%**
2012-2016	15.5600	1.99975	12.85%
2016-2020	15.6275	1.93796	12.40%
2020-2024	**20.3850**	3.60661	**17.69%**

fluctuations slightly reduced (CV = 4.81%). This data highlights the growing importance of salt in the economy while reflecting challenges in balancing production variability with increasing and stable demand.

Best model selection to forecast the Production and Demand of Salt Production

Table 3 presents the performance metrics of four growth models (Linear, Exponential, Quadratic, and Cubic) applied to analyze and forecast salt production and demand. The models were evaluated using standard statistical metrics, including R^2, Adjusted R^2, AIC (Akaike Information Criterion), RMSE (Root Mean Square Error), MAPE (Mean Absolute Percentage Error), and MAD (Mean Absolute Deviation). The Cubic model consistently outperformed the other models across all key metrics.

For salt production, the cubic model yields the lowest MAD (1.864), MSD (4.466), MSE (5.359), RMSE (2.315), MAPE (14.275), and AIC (114.025), along with the highest adjusted R^2 value of 0.716, indicating a strong fit to the data. Similarly, for salt demand, the cubic model achieves the lowest MAD (0.618), MSD (0.718), MSE (0.861), RMSE (0.928), MAPE (4.235), and AIC (70.145), with the highest adjusted R^2 value of 0.962, suggesting near-perfect accuracy in capturing the demand trend. Figures 2 and 3 for both production and demand visually illustrate the superior accuracy of the cubic model in predicting the observed values, reflecting a more precise fit to the data compared to linear, exponential, and quadratic models. The cubic model's consistent performance across these metrics makes it the most reliable tool for forecasting future trends in salt production and demand in Bangladesh.

Table 3: Criteria for selecting best fitted model of salt production and demand

	Model	**Fitted trend equation**	**Accuracy measures**						
			MAD	MSD	MSE	RMSE	MAPE	Adjusted R^2	AIC
Production	Linear	Y = 7.82634 + 0.50933t	2.012	5.683	5.683	2.49	14.446	0.672	115.81
	Exponential	$Y = 8.665233.e^{1.0375\,t}$	1.965	5.422	5.915	2.432	14.039	0.688	114.529
	Quadratic	$Y = 9.08208 + 0.21954t + 0.01159t^2$	1.991	5.438	6.215	2.493	14.478	0.671	116.75
	Cubic	$Y=14.1929+17.2721t+2.4274t^2 + 4.8296t^3$	1.864	4.466	5.359	2.315	14.275	0.716	114.025
	Model	Fitted trend equation	Accuracy measures						
			MAD	MSD	MSE	RMSE	MAPE	Adjusted R^2	AIC
Demand	Linear	Y = 7.09507+0.64926t	1.031	1.77	1.77	1.389	6.38	0.916	87.809
	Exponential	$Y = 8.35364.e^{1.0452t}$	0.821	1.131	1.234	1.111	5.242	0.955	76.735
	Quadratic	$Y = 9.083725 + 0.1903t + 0.018357t^2$	0.887	1.154	1.319	1.148	6.008	0.942	79.547
	Cubic	$Y=15.2108+22.0175t+3.8441t^2 + 3.2363t^3$	0.618	0.718	0.861	0.928	4.235	0.962	70.145

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For salt production, the cubic model is represented by the equation:

$$Y = 14.1929 + 17.2721t + 2.4274t^2 + 4.8296t^3$$

In this equation, Y represents the salt production, and t represents time. The intercept of 14.1929 indicates the initial level of salt production when t = 0. The linear term (17.2721t) shows that salt production increases at a rate of 17.2721 units for each unit of time. The quadratic term ($2.4274t^2$) indicates a slight acceleration or deceleration in production growth as time progresses, and the cubic term ($4.8296t^3$) introduces an additional layer of complexity, showing that the rate of change in production itself accelerates or decelerates over time, capturing any inflection points or more dynamic shifts in production trends.

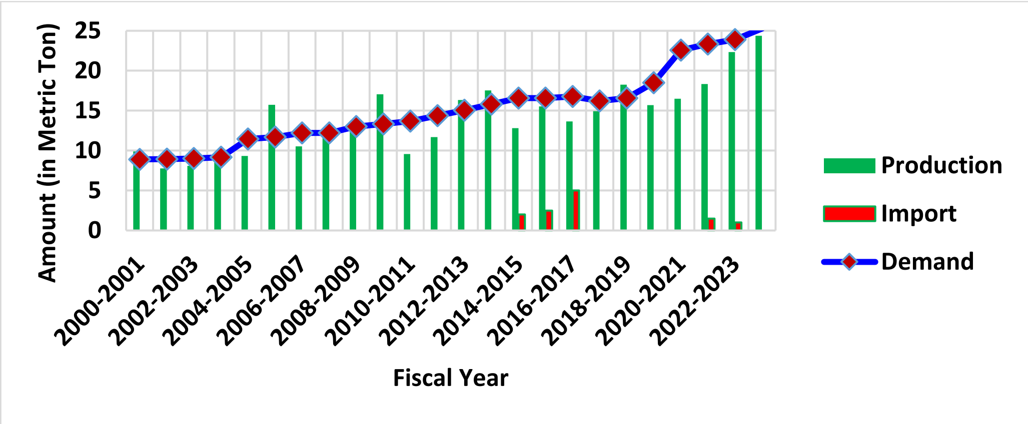


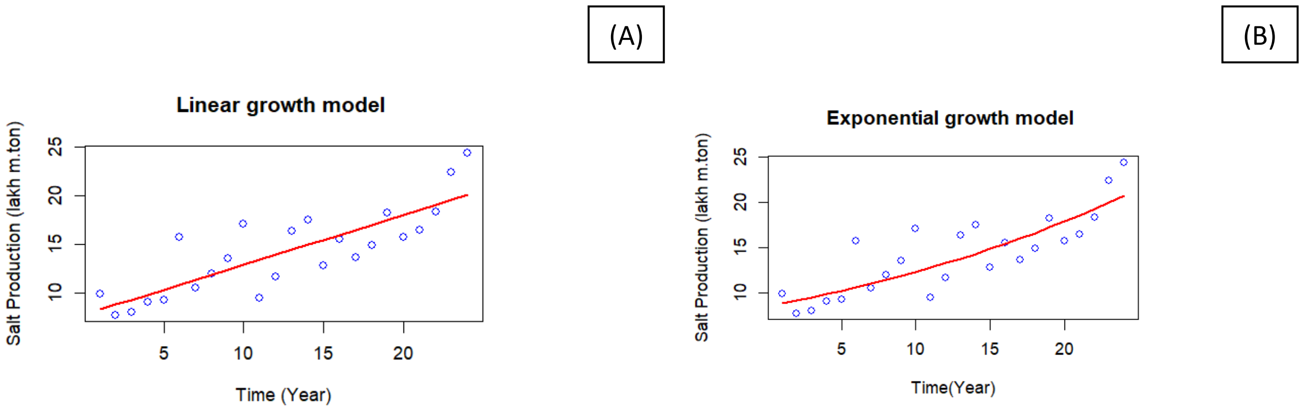
Figure 1: Trend and patterns of salt demand production and import data in Bangladesh

For salt demand, the cubic model is given by the equation:

$$\boldsymbol{Y = 15.2108 + 22.0175t + 3.8441t^2 + 3.2363t^3}$$

Here, Y represents the salt demand, and t again represents time. The intercept of 15.2108 reflects the initial level of demand at time t = 0. The linear term (22.0175t) indicates that salt demand increases at a rate of 22.0175 units per unit of time. The quadratic term ($3.8441t^2$) suggests that the rate of demand growth either accelerates or decelerates as time goes on, while the cubic term ($3.2363t^3$) adds a further level of complexity to the model, accounting for more nuanced changes in the growth rate of salt demand, possibly indicating periods of faster or slower growth.

Both equations highlight the non-linear relationship between time and the respective variables (production and demand), and by incorporating cubic terms, the models offer a more precise fit, better capturing the actual patterns of growth over time. These models can be used to predict future trends in both production and demand, providing insights into how these factors evolve.



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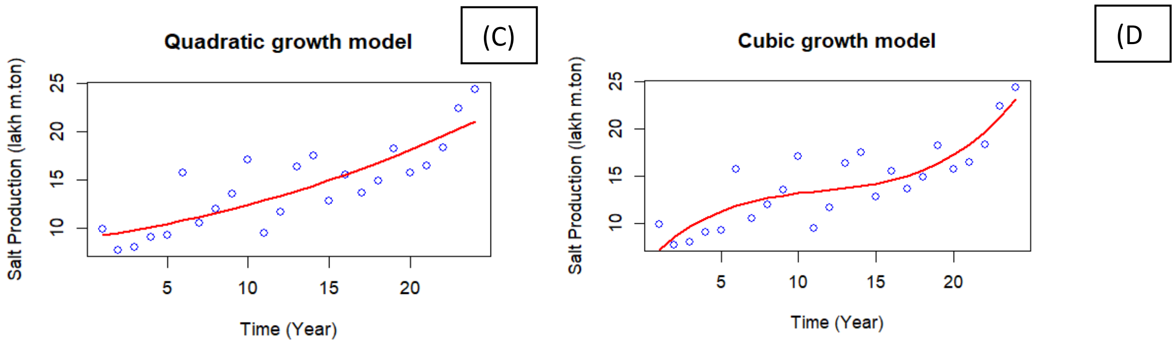

Figure 2: Predictive model for salt production

Forecasting salt production and demand for next seven years

Table 4 presents the forecasted values for salt production and demand in Bangladesh for the years 2024 to 2031, based on the cubic growth model. The forecast includes lower and upper limits for each year, as well as the length of the confidence intervals (CI).

For salt demand, the forecast for 2024-2025 is 27.56 million tons, with a lower limit of 25.69 million tons and an upper limit of 29.42 million tons. Over the next seven years, demand is expected to increase steadily, reaching 44.75 million tons by 2030-2031. The length of the confidence interval for demand grows from 3.73 in the first forecast year to 15.66 in the last, indicating greater uncertainty in the forecast as time progresses.

Table 4: Forecasting salt production and demand based on cubic growth

Model	Description	Forecast year						
		2024-2025	2025-2026	2026-2027	2027-2028	2028-2029	2029-2030	2030-2031
Demand (MT) (Cubic)	Lower limit	25.69	27.26	28.94	30.74	32.66	34.72	36.92
	Forecast	27.56	29.76	32.21	34.92	37.90	41.17	44.75
	Upper limit	29.42	32.26	35.48	39.10	43.14	47.63	52.58
	Length of CI	3.73	5.00	6.54	8.36	10.48	12.91	15.66
Production (MT) (Cubic)	Lower limit	20.51	21.35	22.18	23.01	23.85	24.71	25.59
	Forecast	25.16	27.58	30.33	33.44	36.93	40.82	45.13
	Upper limit	29.81	33.82	38.49	43.88	50.00	56.92	64.67
	Length of CI	9.3	12.47	16.31	20.87	25.29	32.21	39.08

Similarly, salt production is forecasted to grow from 25.16 million tons in 2024-2025 to 45.13 million tons in 2030-2031. The lower and upper limits for production show an increasing range of variation, from 20.51 million tons to 29.81 million tons in the first year, up to 25.59 million tons to 64.67 million tons in the final forecast year. The length of the confidence interval for production increases significantly, from 9.3 in the first forecast year to 39.08 in the last, reflecting the growing uncertainty in long-term projections.

The data suggests that while the short-term forecasts for both demand and production are relatively precise, the accuracy of the predictions decreases as the time horizon extends. If current growth trends persist, salt demand and production in Bangladesh are projected to reach 44.75 million tons and 45.13 million tons, respectively, by 2030-2031. However, the increasing length of the confidence intervals underscores the growing uncertainty associated with these long-term forecasts.

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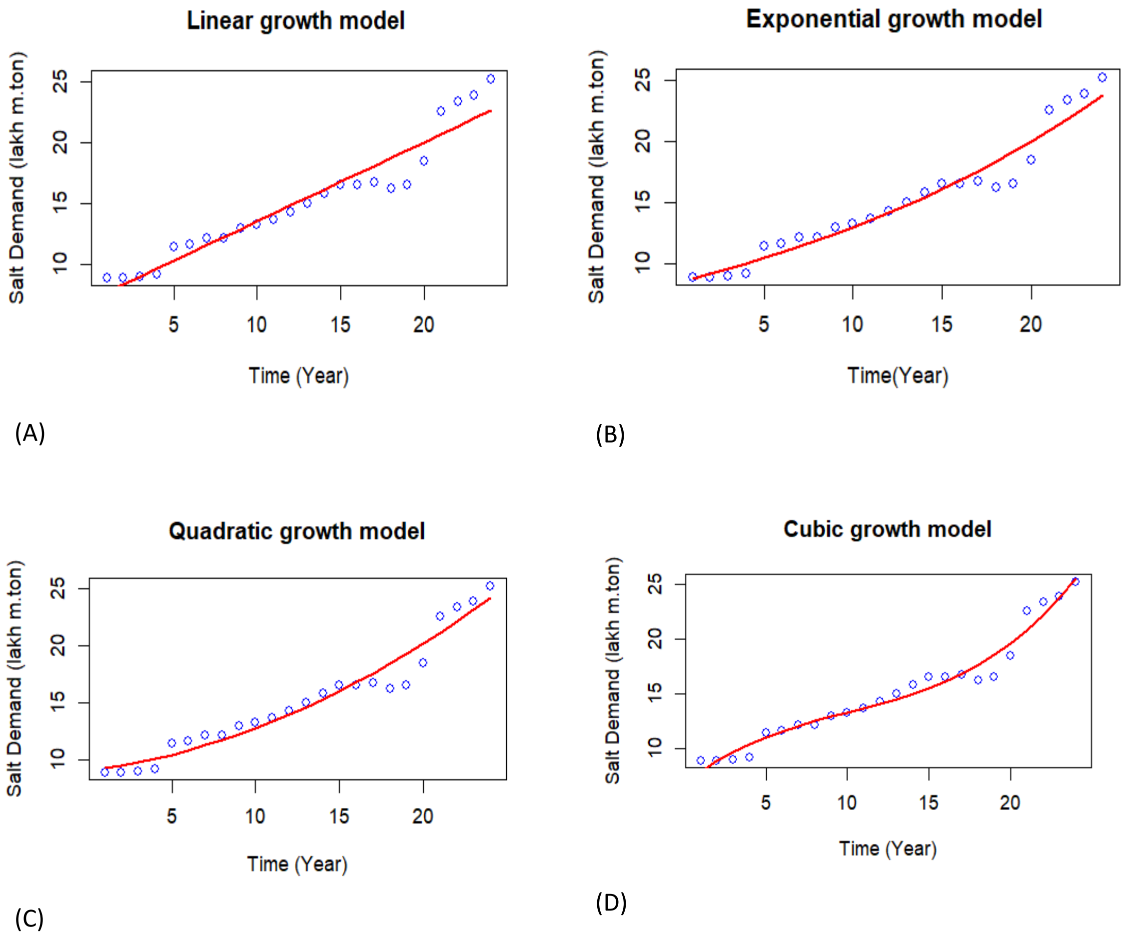

Figure 3: Predictive model for demand of salt

CONCLUSION

This study analyzed the trends and growth rates of salt production and demand in Bangladesh, focusing on four growth models, linear, exponential, quadratic, and cubic. The results revealed a consistent upward trend in both salt production and demand, with production consistently exceeding demand. This gap has remained stable over the years, although production has exhibited more variability than demand. The cubic model outperformed the other models in capturing these trends, as indicated by the lowest values of MAD, MSD, MSE, RMSE, MAPE, and AIC, along with the highest adjusted R^2, making it the most accurate and reliable model for forecasting.

The forecasting results for the next seven years, based on the cubic growth model, project significant growth in both salt production and demand. For salt demand, the forecast for 2030-2031 is 44.75 million tons, while production is expected to reach 45.13 million tons. These forecasts suggest continued growth in the salt industry, with demand and production both showing increasing trends. The length of the confidence intervals for these forecasts indicates relatively low uncertainty for the short-term, highlighting the cubic model's capability to provide accurate predictions in the near future. Overall, the cubic model proves to be an effective tool for forecasting salt production and demand in Bangladesh, offering a more precise fit to the historical data compared to other models. The study's findings emphasize that short-term forecasts, such as those for the coming years, are expected to be more reliable, with growth rates continuing to accelerate in the near future. It makes the cubic model a valuable tool for decision-making and planning in the salt industry.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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