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Statistical Forecasting of Cereal Grain Used in Livestock and Fisheries Feed of Nepal

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ABSTRACT

Cereal grains play a central role in Nepal's food security, serving as major inputs for human consumption as well as livestock and fisheries feed systems. Rapid growth in livestock and aquaculture has intensified pressure on cereal supplies, raising concerns about the long-term balance between food and feed uses. This study examines trends, growth patterns, and future requirements of foodgrains in Nepal using annual time-series data on cereal production, human consumption, livestock feed, fisheries feed, and total foodgrain requirements. Data were obtained from official publications of the Government of Nepal for the period 2007–2022. The analysis employs descriptive statistics, growth rate analysis, correlation analysis, linear and log-linear trend models, and exponential smoothing (Holt) methods for short- to medium-term forecasting. Results indicate that total foodgrain production has increased steadily, but at a slower pace than aggregate demand driven mainly by livestock and rapidly expanding fisheries feed requirements. Feedgrain use in fisheries exhibits the highest compound annual growth rate, reflecting the dynamic expansion of aquaculture. Strong positive correlations are observed between livestock feed demand and total foodgrain requirement, while foodgrain use for human consumption shows a strong negative association with feed demand, highlighting growing competition between food and feed uses. Forecast comparisons suggest that simple trend-based and Holt exponential smoothing models provide reliable projections under limited data conditions, with the Holt model performing particularly well for fisheries feed demand. The findings underscore the need for an integrated food–feed policy framework in Nepal, emphasizing improvements in cereal productivity, feed efficiency, forage-based systems, and sustainable livestock and fisheries development to ensure long-term food and nutritional security.

Keywords: Cereal Crops, Forecasting, Fishery, Livestock, Statistical, Utilization.

1. Introduction

Cereal crops are fundamental to food security, serving as primary sources of nutrition for both humans and livestock. Their cultivation across multiple seasons not only helps mitigate hunger but also ensures the provision of essential nutrients required for healthy growth and development. Nepal's varied topography and climatic conditions create a unique environment that supports diverse agricultural practices, enhancing the productivity and sustainability of cereal crop farming. Cereal crops provide approximately 65% of the protein and energy consumed by livestock, fish, and people in Nepal, underscoring their critical role in national nutrition and food security. According to the Government of Nepal (2022) Economic Survey, the contribution of the agricultural sector to GDP has been declining, with an estimated 24.1 % share in fiscal year 2022/23 compared to 24.7 % in the previous year, reflecting a long-term downward trend in agriculture's share of total GDP. To reverse this trend and strengthen the economic contribution of food crops, it is essential to enhance the efficiency and effectiveness of agricultural practices. Improving productivity through modern techniques and sustainable farming methods could help balance the demands of food and feed, ensuring long-term food security and economic stability. This study aims to analyze the statistical patterns and trends of cereal crop production to gain a deeper understanding of how Nepal utilizes its food crops. With its diverse topography and climate, Nepal relies heavily on agriculture as the primary source of food production (Shrestha et al., 2020). Although a wide variety of food crops are cultivated across the country, current production levels remain insufficient to satisfy the growing food demand of its population. Addressing this gap is essential for ensuring food security and sustainable agricultural development in Nepal.

Time-series analysis of agricultural production and demand is widely used to examine long-term structural changes, growth dynamics, and variability in the food sector, particularly in developing countries where data availability is limited. When the number of annual observations is small, descriptive and trend-based approaches are considered statistically appropriate and policy-relevant (Gujarati and Porter, 2009). Graphical analysis using line plots provides an initial understanding of underlying trends, turning points, and fluctuations in agricultural production and demand over time. Visual inspection of time-series data is an essential step in identifying structural patterns before formal modeling, especially in short time series (Chatfield, 2004). Year-to-year growth rates are commonly employed in agricultural economics to assess temporal changes in production and consumption. Growth rate analysis helps capture periods of acceleration and deceleration and facilitates comparison across different variables and time periods (Debertin, 2012). To analyze long-term trends, deterministic trend models are employed. Linear trend models are appropriate when variables change at a constant absolute rate over time, while log-linear models are preferred when growth occurs at a constant proportional rate. The coefficients obtained from log-linear specifications provide direct estimates of compound annual growth rates, which are widely used in agricultural growth analysis (Gujarati and Porter, 2009).

2. Methodology

The cereal crop production data such as paddy, maize, wheat, millet, and barley were used for data analysis. As a variety of cereal crops were used in livestock feed consumption patterns, ruminants were not considered fully dependent on concentrate diets; rather, one-third of the total dry matter (DM) intake was assumed to be fulfilled from concentrate diets. The sources of data were the Statistical Information and Economic Survey of the Government of Nepal, based on the latest publication for the fiscal year 2022/23.

Due to the dependency of livestock on diverse feed sources, livestock were assumed to depend on both forage- and concentrate-based diets. The total dry matter requirement of livestock through concentrate-based diets was calculated based on the total number of livestock in the country and their standard dry matter requirements successively from 2007 to 2022 (O'Brien et al., 2018).

The consumption amount of feed was converted into animal units (AU) using the standard formula:

$$AU = \sum_{i=1}^{n} N_i \times AU_i \tag{2.1}$$

where N_i denotes the number of animals in the i-th livestock category, AU_i represents the animal unit conversion factor for the i-th livestock category, and n is the total number of livestock categories.

Table 1: Animal Unit (AU) Conversion Factors Used in Nepal

Livestock type	AU factor
Cattle (adult)	1.00
Buffalo (adult)	1.25
Sheep	0.10
Goat	0.10
Pig	0.30
Poultry	0.01

The cereal grain requirement for fish was calculated using a 2.5 conversion ratio, where 15% cereal was used in feed-making practices for the current level of fish production.

So, the study uses annual time-series data on foodgrain production, consumption, and requirements in Nepal. The variables include total foodgrain production, foodgrain used for human consumption, foodgrain used as feed for livestock and fisheries, and total foodgrain requirement. The data are observed annually. Given the limited number of observations, the analysis emphasizes descriptive statistics, growth analysis, trend estimation, and smoothing techniques.

As a preliminary step, line plots are used to visualize the temporal behavior of each variable. Graphical trend analysis helps identify long-term movement, structural changes, and volatility in agricultural time series and is particularly useful when the number of observations is limited (Pradhan and Koirala, 2024).

The year-to-year growth rate measures the percentage change in a variable between two consecutive periods and is widely used in agricultural growth studies (Debertin, 2012). The growth rate is computed as:

$$g_t = \left(\frac{Y_t - Y_{t-1}}{Y_{t-1}}\right) \times 100 \tag{2.2}$$

where Y_t denotes the value of the variable in year t and Y_{t-1} represents its value in the previous year.

The mean provides a measure of central tendency, while the standard deviation captures absolute dispersion. These are calculated as:

$$\bar{Y} = \frac{1}{n}\sum_{t=1}^{n} Y_t \tag{2.3}$$

$$SD = \sqrt{\frac{1}{n-1}\sum_{t=1}^{n}(Y_t - \bar{Y})^2} \tag{2.4}$$

To assess relative variability and production instability, the coefficient of variation (CV) is used (Pradhan, 2023):

$$CV = \frac{SD}{\bar{Y}} \times 100 \tag{2.5}$$

A higher CV indicates greater variability and instability in the variable under consideration.

Correlation analysis is employed to examine the degree of linear association between different foodgrain variables. The Pearson correlation coefficient is calculated as (Pradhan, 2023):

$$r_{XY} = \frac{\sum(X_t - \bar{X})(Y_t - \bar{Y})}{\sqrt{\sum(X_t - \bar{X})^2 \sum(Y_t - \bar{Y})^2}} \tag{2.6}$$

The correlation coefficient ranges between -1 and $+1$, indicating the strength and direction of the linear relationship.

To examine long-term changes in foodgrain production and demand, a linear trend model is estimated. This model assumes a constant absolute change over time and is specified as (Gujarati and Porter, 2009):

$$Y_t = \alpha + \beta t + \varepsilon_t \tag{2.7}$$

where t represents time, α is the intercept, β measures the average annual change, and ε_t is the error term.

When growth occurs at a constant proportional rate, a log-linear trend model is more appropriate. The model is expressed as:

$$\ln(Y_t) = \alpha + \beta t + \varepsilon_t \tag{2.8}$$

In this specification, the coefficient β approximates the compound annual growth rate (CAGR). The percentage growth rate is obtained as:

$$Growth\ Rate(\%) = (e^{\beta} - 1) \times 100 \tag{2.9}$$

Log-linear models are widely used in agricultural economics to estimate growth rates due to their interpretability and robustness (Gujarati and Porter, 2009).

To generate short- to medium-term projections, exponential smoothing methods are employed. Simple exponential smoothing assigns exponentially decreasing weights to past observations and is defined by (Hyndman and Athanasopoulos, 2021):

$$\hat{Y}_t = \alpha Y_t + (1-\alpha)\hat{Y}_{t-1} \tag{2.10}$$

where $\hat{Y}_t$ is the smoothed value at time t and α ($0 < \alpha < 1$) is the smoothing parameter.

For series exhibiting a trend, Holt's linear exponential smoothing method is used:

$$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + T_{t-1}) \tag{2.11}$$

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1} \tag{2.12}$$

$$\hat{Y}_{t+h} = L_t + hT_t \tag{2.13}$$

where L_t is the level component, T_t is the trend component, α and β are smoothing parameters, and h denotes the forecast horizon.

Given the short annual time series and the policy-oriented nature of the study, the combination of descriptive statistics, growth analysis, trend models, and exponential smoothing provides a robust and interpretable framework. These methods are well suited for identifying structural patterns and generating plausible projections without imposing strong statistical assumptions required by complex time-series models. However to compare the best method the following three error analysis has been done (Upadhyay and Pradhan, 2023).

Root Mean Square Error (RMSE) is defined as:

$$\text{RMSE} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2} \tag{2.14}$$

Maximum Absolute Error (MaxAE) is given by:

$$\text{MaxAE} = \max|y_t - \hat{y}_t| \tag{2.15}$$

Maximum Absolute Percentage Error (MAPE) is calculated as:

$$\text{MAPE} = \max\left(\frac{|y_t - \hat{y}_t|}{y_t}\right) \times 100 \tag{2.16}$$

3. Result

Trends in Foodgrain Production and Feed Demand

Figure 1 illustrates the trends in foodgrain production, consumption, and requirement in Nepal over the study period. Feedgrain use for fisheries exhibits a strong and consistent upward trend, with a noticeable acceleration in recent years, reflecting the rapid expansion of the aquaculture sector. In contrast, feedgrain consumption for livestock shows a generally increasing pattern but with a pronounced temporary decline around the later years, followed by a sharp recovery, indicating short-term disruptions and subsequent adjustment in livestock feed demand.

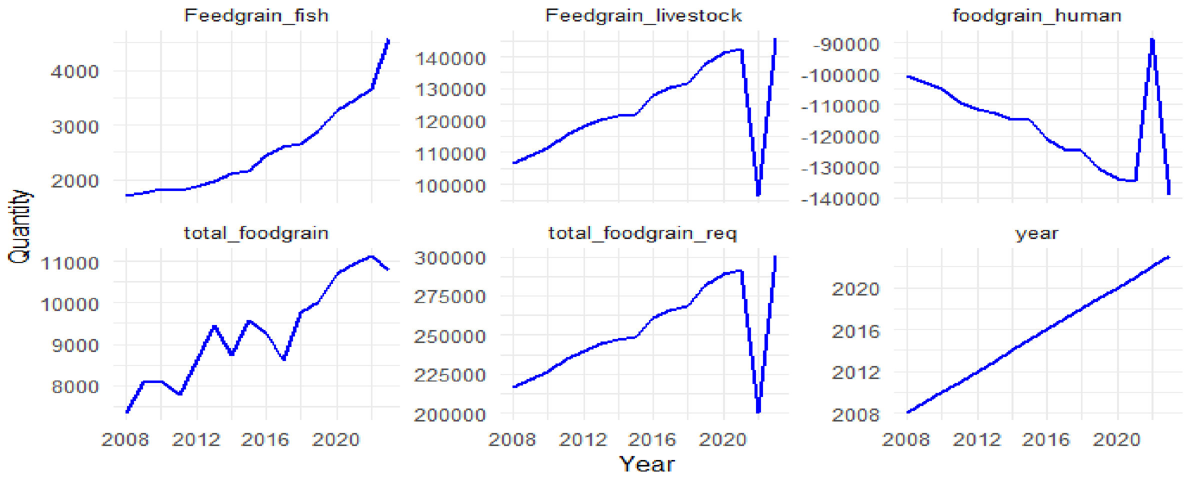

Figure 1: Trends of Human, Livestock & Fisheries Feed in Nepal

Foodgrain use for human consumption displays a declining trend over time, suggesting a gradual shift of cereals away from direct human use toward feed purposes. This downward movement is interrupted by a brief spike in the later period, which may reflect short-term market or policy-induced fluctuations. Total foodgrain production demonstrates a moderate upward trend with some year-to-year variability, indicating gradual improvement in production capacity alongside persistent instability.

Total foodgrain requirement shows a strong increasing trajectory, closely mirroring trends in livestock and fisheries feed demand, with a noticeable dip followed by a sharp rise in the final years. Overall, the figure highlights widening pressure on Nepal's foodgrain system, driven primarily by rising feed demand rather than growth in foodgrain production.

Descriptive Statistics of Human, Livestock & Fisheries Feed in Nepal

Table 2 presents the descriptive statistics of major foodgrain variables in Nepal. The average total foodgrain production during the study period was 9,300.73 thousand metric tons, with a coefficient of variation (CV) of 12.82%, indicating moderate variability over time. Feedgrain consumption for livestock recorded a substantially higher mean of 123,584.70 metric tons and relatively lower variability (CV = 11.41%), reflecting its stable and increasing demand. In contrast, feedgrain use in fisheries showed the highest variability (CV = 32.70%), suggesting rapid expansion and structural changes in fish feed requirements. Total foodgrain requirement exhibited a mean value of 252,258.90 metric tons with a CV of 11.56%, indicating consistent growth in aggregate demand.

Table 2: Descriptive Statistics of Human, Livestock & Fisheries Feed in Nepal

Variable	Mean (MT)	SD	CV (%)
Total Foodgrain	9,300.73	1,192.17	12.82
Feedgrain (Livestock)	123,584.70	14,101.61	11.41
Feedgrain (Fish)	2,544.79	832.14	32.70
Foodgrain (Human Consumption)	116,828.70	13,960.38	11.95
Total Foodgrain Requirement	252,258.90	29,153.22	11.56

Year to Year Growth Rates of Human, Livestock & Fisheries feed in Nepal

Figure 2 shows noticeable year-to-year fluctuations in the growth rates of foodgrain production, consumption, and requirements in Nepal. Feedgrain use in fisheries records mostly positive and often high growth rates, indicating the rapid expansion of the fisheries sector, though with considerable instability across years. Feedgrain consumption for livestock remains relatively stable for most of the period but experiences a sharp decline in one year, followed by a strong recovery, suggesting the presence of short-term shocks and subsequent adjustment. Foodgrain use for human consumption also shows moderate growth in many years, interrupted by a pronounced contraction toward the end of the period, reflecting increasing pressure from competing feed demands.

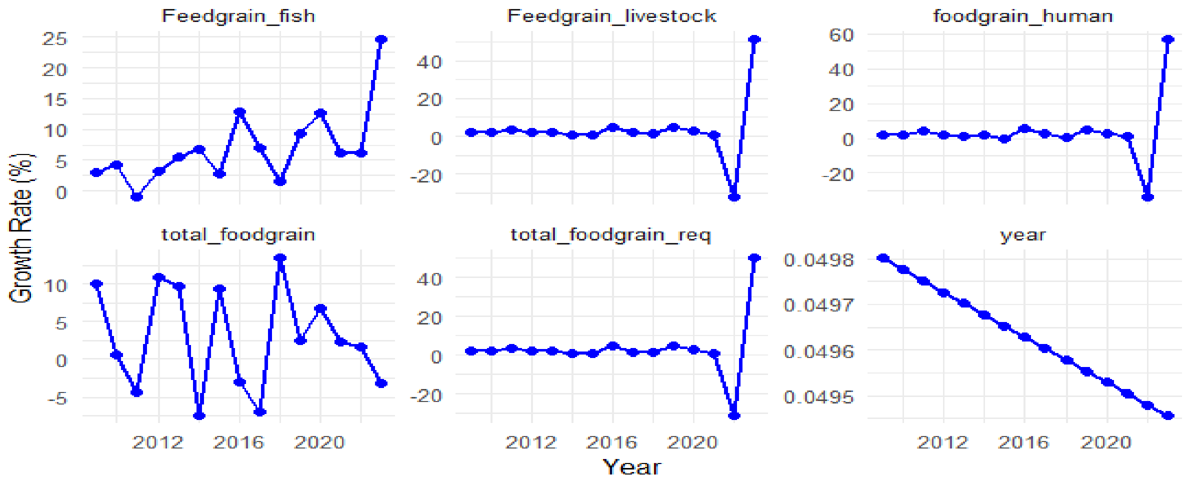

Figure 2: Year to Year Growth Rates of Human, Livestock & Fisheries Feed in Nepal

Total foodgrain production exhibits alternating phases of positive and negative growth, highlighting persistent production instability despite overall progress. In contrast, total foodgrain requirement shows generally steady growth but with an extreme drop and rebound in the final years, largely driven by fluctuations in livestock and fisheries feed demand. Overall, the figure highlights that variability in feed demand—rather than production—plays a dominant role in shaping changes in Nepal's foodgrain system over time.

Correlation among Human, Livestock & Fisheries Feed in Nepal

The correlation structure among foodgrain variables is reported in Table 3. Total foodgrain production shows a strong positive correlation with feedgrain use in fisheries (r = 0.868) and total foodgrain requirement (r = 0.547), implying that increases in production are closely associated with rising feed demand. Feedgrain use for livestock is almost perfectly correlated with total foodgrain requirement (r = 0.999), highlighting livestock feed as the dominant driver of aggregate foodgrain demand. Conversely, foodgrain used for human consumption is strongly and negatively correlated with livestock feedgrain (r = -0.999) and total foodgrain requirement (r = -0.997), indicating increasing competition between feed and food uses over time. All major variables also exhibit strong correlations with time, confirming upward trends.

Table 3: Correlation Matrix of Foodgrain Variables

Variable	TFG	FGL	FGF)	FGH	TFG
Total Foodgrain	1.000	0.514	0.868	-0.486	0.547
Feedgrain (Livestock)	0.514	1.000	0.551	-0.999	0.999
Feedgrain (Fish)	0.868	0.551	1.000	-0.542	0.590
Foodgrain (Human)	-0.486	-0.999	-0.542	1.000	-0.997
Total Foodgrain Req.	0.547	0.999	0.590	-0.997	1.000
Year	0.936	0.605	0.936	-0.587	0.639

Compound Annual Growth Rate of Human, Livestock & Fisheries Feed in Nepal

Table 4 reports the compound annual growth rates (CAGR) of foodgrain variables. Total foodgrain production grew at an annual rate of 2.57%, while feedgrain consumption for livestock increased at a relatively lower rate of 1.39%. Feedgrain demand for fisheries expanded rapidly, recording the highest growth rate of 6.38% per annum, reflecting the fast-growing aquaculture sector in Nepal. Total foodgrain requirement increased at an annual rate of 1.49%, indicating sustained pressure on cereal supplies.

Table 4: Compound Annual Growth Rates (CAGR) of of Human, Livestock & Fisheries Feed in Nepal

Variable	CAGR (%)
Total Foodgrain	2.57
Feedgrain (Livestock)	1.39
Feedgrain (Fish)	6.38
Total Foodgrain Requirement	1.49

Linear Trend of Livestock & Fisheries Feed in Nepal

The results of linear trend estimation are presented in Table 5. All trend coefficients are positive and statistically significant at conventional levels. Total foodgrain production increased by an average of 234.38 thousand metric tons per year (p ¡ 0.01). Feedgrain consumption for livestock rose annually by 1,793.30 metric tons ($p < 0.05$), while feedgrain use in fisheries increased by 163.60 metric tons per year ($p < 0.01$). Total foodgrain requirement exhibited the largest absolute increase, growing by 3,913.78 metric tons annually ($p < 0.01$), reinforcing concerns regarding long-term food and feed balance.

Table 5: Linear Trend Coefficients (Slope) for Foodgrain Variables

Variable	Slope	Std. Error	t-value	p-value
Total Foodgrain	234.38	23.56	9.95	0.0000
Feedgrain (Livestock)	1,793.30	630.03	2.85	0.0129
Feedgrain (Fish)	163.60	16.44	9.95	0.0000
Total Foodgrain Requirement	3,913.78	1,258.64	3.11	0.0077

Holt Model to Forecast Livestock & Fisheries Feed in Nepal

Table 6 summarizes the Holt exponential smoothing model estimates. The final level and trend components indicate continued upward trajectories for all variables. Feedgrain demand for fisheries displays relatively higher smoothing parameters (α = 0.506, β = 0.506), suggesting stronger short-term fluctuations and responsiveness to recent changes. In contrast, livestock feedgrain and total foodgrain production exhibit lower smoothing parameters, implying more stable long-term trends.

Table 6: Holt Model Coefficients (Level and Trend) for Foodgrain Variables

Variable	Alpha	Beta	Final Level	Final Trend
Total Foodgrain	0.000	0.000	10,975.09	213.86
Feedgrain (Livestock)	0.002	0.000	137,558.24	1,893.73
Feedgrain (Fish)	0.506	0.506	4,266.42	568.95
Total Foodgrain Requirement	0.027	0.027	289,685.02	3,194.06

Comparing Models

Forecast accuracy measures comparing linear, log-linear, and Holt models are presented in Table 7. For total foodgrain production, the log-linear model performs marginally better in terms of RMSE and MAPE. In the case of livestock feedgrain demand, all three models show comparable performance, with slightly lower errors for the linear model. For fisheries feedgrain demand, the Holt model clearly outperforms the linear and log-linear models, recording the lowest RMSE (184.93), MAPE (4.43%), and MaxAE (613.08). For total foodgrain requirement, the Holt model achieves the lowest MAPE, indicating superior short-term forecasting accuracy.

Table 7: Forecast Accuracy Comparison across Linear, Log-Linear, and Holt Models

Variable	Metric	Linear	Log-Linear	Holt
Total Foodgrain	RMSE	412.08	405.93	423.32
	MAPE	3.61	3.55	3.69
	MaxAE	1,082.12	1,018.87	1,078.13
Feedgrain (Livestock)	RMSE	10,539.53	10,605.70	10,893.82
	MAPE	4.96	5.30	5.21
	MaxAE	38,279.24	37,420.97	39,410.51
Feedgrain (Fish)	RMSE	317.27	253.43	184.93
	MAPE	9.75	6.27	4.43
	MaxAE	916.71	860.47	613.08
Total Foodgrain Requirement	RMSE	21,018.70	21,150.62	22,941.83
	MAPE	4.74	5.07	4.50
	MaxAE	76,192.97	74,614.60	88,851.05

Overall, the results reveal a consistent upward trend in foodgrain demand driven primarily by livestock and rapidly expanding fisheries feed requirements, with important implications for future food and feed security in Nepal.

4. Discussion

The findings of this study reveal a persistent and structurally driven increase in foodgrain demand in Nepal, primarily fueled by livestock and fisheries feed requirements. Although total foodgrain production has shown a statistically significant upward trend, the growth rate of production remains insufficient relative to the rapidly expanding demand for feed, particularly from the fisheries sector. This imbalance has important implications for national food security and agricultural policy.

The moderate variability observed in total foodgrain production aligns with earlier studies highlighting Nepal's vulnerability to climatic variability, fragmented landholdings, and limited adoption of modern agricultural technologies (Shrestha et al., 2020). While production growth of 2.57% per annum appears encouraging, it is increasingly offset by rising feed demand, indicating that gains in productivity alone may not be adequate without structural transformation in the agri-food system.

Livestock feedgrain consumption emerged as the dominant contributor to total foodgrain requirement, as evidenced by its near-perfect correlation with aggregate demand. This finding is consistent with O'Brien et al. (2018), who emphasize that expanding livestock populations significantly intensify pressure on cereal-based feed systems. Nepal's livestock sector, although crucial for rural livelihoods, continues to rely heavily on cereal-based concentrates due to limited availability of improved forage, pasture management, and balanced ration technologies. This underscores the need for policy interventions promoting forage diversification, feed efficiency, and alternative feed resources.

The most striking result is the exceptionally high growth rate of feedgrain use in fisheries (6.38% CAGR). This reflects the rapid commercialization and intensification of aquaculture in Nepal over the past decade. While fisheries development aligns with national objectives for income generation and nutrition improvement, the heavy dependence on cereal-based feeds poses sustainability concerns. Similar patterns have been observed in other developing countries, where aquaculture expansion increases competition between food and feed uses of cereals (Debertin, 2012). Policy measures encouraging improved feed conversion ratios, use of non-cereal feed ingredients, and locally formulated feeds are therefore essential to mitigate future cereal demand pressures.

The negative correlation between foodgrain use for human consumption and feedgrain demand indicates a growing trade-off between food and feed utilization. This structural shift raises concerns for food availability and affordability, particularly for low-income households. As noted by Hazell (1982) and Ray (1983), rising variability and competition in food systems can exacerbate food insecurity if not addressed through coordinated policy responses. Nepal's current food security strategies must therefore integrate feed demand dynamics rather than treating food and livestock sectors independently.

The forecasting results further suggest that simple trend-based and smoothing models provide reliable short- to medium-term projections, given Nepal's limited time-series data. The superior performance of the Holt model for fisheries feed demand highlights the sector's dynamic nature and sensitivity to recent growth trends (Hyndman and Athanasopoulos, 2021). These projections can serve as practical planning tools for policymakers, particularly for estimating future cereal requirements and designing buffer stock and import strategies.

Overall, the results support the need for a holistic and integrated food–feed policy framework in Nepal. Increasing cereal productivity through climate-resilient varieties, improving feed efficiency in livestock and fisheries, promoting forage-based systems, and strengthening data-driven planning are critical for balancing food and feed demands. Without such coordinated interventions, the widening gap between foodgrain production and total requirement may pose serious risks to Nepal's long-term food and nutritional security.

5. Conclusion

This study examined the trends, growth patterns, and future requirements of foodgrains used for food, livestock, and fisheries in Nepal using time-series analysis and forecasting techniques. The results indicate that while total foodgrain production in Nepal has increased steadily over time, the growth in aggregate foodgrain requirement driven mainly by livestock and rapidly expanding fisheries feed demand poses increasing pressure on the national cereal supply system (MoALD, Government of Nepal, 2024).

The findings reveal that livestock feedgrain consumption is the principal determinant of total foodgrain demand, whereas fisheries feed demand is growing at a substantially faster rate. The strong negative relationship between foodgrain use for human consumption and feedgrain demand highlights an emerging competition between food and feed uses of cereals. This structural shift underscores the importance of integrating feed demand considerations into national food security planning.

Forecasting results suggest that trend-based and exponential smoothing models provide reliable short- to medium-term projections under limited data conditions. In particular, the Holt model performs well for fisheries feed demand, reflecting the dynamic growth of the aquaculture sector. These projections offer valuable inputs for policymakers in estimating future cereal requirements and designing evidence-based interventions.

Overall, the study emphasizes the need for a holistic food–feed policy framework in Nepal. Enhancing cereal productivity alone may not be sufficient to meet rising demand unless accompanied by improvements in feed efficiency, promotion of forage- and non-cereal-based feed resources, and sustainable livestock and fisheries development strategies. Strengthening data systems and adopting integrated planning approaches will be crucial to ensuring long-term food and nutritional security in Nepal.

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