Advances in Bioresearch
Adv. Biores., Vol 16 (5) September 2025: 110-117

Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.16.5.110117

Advances in Bioresearch

ORIGINAL ARTICLE

Analysis of Trends in Area, Production, Productivity and Export Performance of Mango in India

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ABSTRACT
The present study aimed to analyze the trends in area, production, and productivity, as well as the export performance of mango (Mangifera indica L.) in India from 1994 to 2023. The study period was divided into four sub-periods: 1994–2003, 2004–2013, 2014–2023, and the overall period of 1994–2023. Utilized secondary data from Indiastat and APEDA. The objectives were (1) Analyzed trends in mango cultivation area, production, and productivity from 1994 to 2023 and (2) to assess the export performance of mangoes. To achieve these objectives, parametric trend models and the Markov chain approach were applied. Cubic trend model identified as best statistical model for future projections on basis of goodness-of-fit criteria, such as R^2. Overall, Mango area and production showed long-term positive growth. The mango productivity declined between 1994 and 2004, After 2004, productivity improves, between 2010 and 2023, productivity remained stable The Markov chain approach used to evaluate transition probabilities for mango markets. The results revealed that Qatar, Singapore, and Nepal were stable export markets in both quantity and value terms, while the UAE, United Kingdom, USA, Kuwait, Canada, Oman, and others were unstable.
Keywords: *Export, R^2, Parametric trend models, Markov chain approach, Linear programming*

Received 10.05.2025 Revised 01.07.2025 Accepted 21.09.2025

How to cite this article:
Sandeep G, R.R. Kushwaha, Sachin Kumar V, Mahima P N and Harshit M. Analysis of Trends in Area, Production, Productivity and Export Performance of Mango in India. Adv. Biores., Vol 16 (5) September 2025:110-117.

INTRODUCTION

Horticulture is an agricultural field that studies the art and science of cultivating fruits, vegetables, flowers, and other cultivable crops. The horticulture industry plays an essential part in the economic development of local people by raising income and creating jobs [11]. The growth in the production of fruits and vegetables is critical nowadays due to the increase in demand caused by the rapid increase in population, which has been accelerated by the rise in people's income levels and the resulting changes in consumption patterns. Fruits play a special significance in developing nations like India, both economically and socially, for boosting income and nutritional condition, particularly among rural populations [2]. In a world full of exotic fruits, one exquisite delicacy stands out: mangoes. This tropical jewel, known as the "king of fruits," has captured the hearts and palates of people all around the world. The seduction of mangos is apparent, from their alluring scent to their beautiful golden skin. This delightful fruit is a wonderful natural gem since it not only tastes great but also has several health benefits. The mango has a long history dating back thousands of years, with its roots in South Asia. It is one of the world's earliest cultivated fruits, dating back to 4,000 BCE. Mangoes are treasured for their divine flavour and mythological importance, and they have been included into various historical legends and cultural practices around the globe [3]. The mango, Mangifera indica L, belongs to the Anacardiaceae family and is one of the world's most significant tropical and subtropical fruits, available both fresh and processed. It is known as the "king of fruits" because of its high nutritional content, delicious flavour, appealing smell, and health-promoting properties. It is a tasty, unusual, and nutritious fruit that provides vitamins A and B to humans. Many languages refer to it as the mother of all tropical fruits, and it is India's

national fruit. People are often concerned that mango is a fruit for everyone, with everyone devouring it, whether from a poor or wealthy neighbourhood. Mango is healthy and a good source of carotene as compared to other fruits. A 100-gram edible chunk of mango contains around 1,990 mcg of beta-carotene (vitamin A), which is significantly greater than the same in other fruits [8]. India's primary mango-producing states include Andhra Pradesh, Uttar Pradesh, Maharashtra, Karnataka, Bihar, Gujarat, West Bengal, Orissa, Kerala, and Tamil Nadu. Uttar Pradesh leads in mango production, followed by Andhra Pradesh. India is the world's greatest mango grower, with hundreds of different types each with its own particular taste, shape, and size. Most Indian mango cultivars require certain eco-geographic conditions for optimal development and output. Mango is even the national fruit of India and is grown mostly for edible fruit in the country [5].

Objectives of the Study

As such with the above pretext it is proposed to undertake a study "Trend in Area, Production, Productivity and Export Performance of Mango in India" with the following objectives.

1. To analyse the Trend in Area, Production and Productivity of Mango in India.
2. To Estimate the Export Performance of Mango in India.

MATERIAL AND METHODS

The data of study for a period of 30 years (1994 to 2023) of India and period was divided into four sub-periods: 1994–2003, 2004–2013, 2014–2023, and the overall period of 1994–2023. pertaining to Area ('000 Hectare), Production ('000 MT) and Productivity (in Kg/Hectare) of Mango were collected from the official website of indiastat.com [13]. In order to examine the nature of change and degree of relationship in area, production and productivity of mango in India, various linear and non-linear statistical models were worked out and to analyse the export performance of mango in India Markov chain analysis was used.

The linear and non-linear regression models for the crop characteristics i.e., Area, Production and Productivity of mango in India are estimated by fitting the following functions

Parametric Trend Model: Model can be described as a means of presenting a process/system. Statistical model generally traces the path of the process along with its statistical properties and implications. In the present context we are interested in studying the path and nature of the series under our preview through different models which are briefly given here:

Linear Model: The equation of Linear model is given by $Y_t = a + bt$

Quadratic Model: The equation of Quadratic Model is given by $Y_t = a + bt + ct2$

The quadratic model can be used to model a series which "takes off" or a series which "dampens".

Cubic Model: The equation of cubic model is given by $Y_t = a + bt + ct^2 + dt^3$

Compound Model: The equation of compound model is given by $Y_t = ab^t$

Logarithmic Model: The equation of logarithmic model is given by $Y_t = a + b \ln (t)$

Exponential Model: The equation of exponential model is given by $Y_t = ae^{bt}$ (or),

$\ln(Y_t) = \ln (a) + b_t$

Growth Model: The equation of growth model is given by $\ln Y_t = \text{Exp}(a+b_t)$ (or) $\text{In}(Y_t) = a+b_t$

Where Yt is the value of the series at time t and a, b, c and d are the parameters.

The models fitted to the time series data of area, production and productivity are linear, logarithmic, quadratic, cubic, compound, growth, power and exponential [5, 7]**.**

Markov Chain Analysis

Period of Study: Country wise export data (in quantity and value terms) for the period 2014 to 2023 was collected from Ministry of commerce & industry and APEDA.

Nature and sources of data: The time series data were collected from secondary sources pertaining to export of Indian mango to major other importing countries.

Analytical Framework: The changes in India's exports of mango to major importing countries was analysed by employing the Markov chain model which captures the net effect changes in exports over the period. The estimate of the transitional probability matrix P is a basic component of Markov Chain Analysis. The chance that exports will eventually shift from nation "i" to country "j" is indicated by the components Pij of the matrix P. The likelihood that a nation's export share would be maintained is shown by the diagonal members of the matrix. Stated differently, the importing country's level of allegiance to a certain country's exports may be determined by analyzing the diagonal components of the transitional probability matrix. The row parts show the likelihood of trade loss due to rival nations, while the column elements show the likelihood of trade gain from other rival nations [1, 6, 9-12].

Markov chain analysis

$$E_{jt} = \sum_{i=1} E_{it-1} P_{ij} + e_{jt} \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where,
E_{jt} = export from India to the j^{th} country in the year t,
E_{it-1} = exports of i^{th} country during the year t-1.
P*ij* = probability that exports were shift from i^{th} country to j^{th} country
e_{jt} = error term which is statistically independent of E_{it-1}
n = the number of importing countries and
t = number of years considered for the analysis
The transitional probabilities P_{ij} which can be arranged in a (c*r) matrix have the following properties.

$$0 \leq P_{ij} \leq 1$$

$$\sum_{i=1}^{n} P_{ij} = 1 \text{ for all } i$$

The advantages of Markov models are that they are completely general, and the generated sequences appear to be a sample of real-world usage as long as the model captures operational behaviour. Another advantage is that the model is based on a formal stochastic process, which has an analytical theory. Through this analysis, we can be able to identify which country will be having more retention of imports from India [4].

RESULT AND DISCUSSION

Various linear and non-linear models were used to study the trend in area, production, and productivity of the mango crop in India during the study period. Based on the maximum of adjusted R^2 criteria, the cubic model was found to be a suitable model for fitting and projecting future values on area, production, and productivity of the mango crop.

Trends in Area

The data reported in Table No. 1 for area under mango crop shows that the cubic model had the highest R^2 value of 0.93. The cubic model was shown to be the best trend equation for predicting future mango crop area. The model is substantial, and it shows that the long-term trend is positive, with continuous expansion and stabilisation. The fitted cubic model is provided by

$$Y_t = 1014+101.98(t)-1.34(t^2)-0.02(t^3)$$

$$[R^2 = 0.93]$$

Table No. 1 Parametric values of fitted linear and non-linear models for area of mango in India

Model Summary and Parameter Estimates						
Equation	**R^2**	**Significance**	**constant (a)**	**b1**	**b2**	**b3**
Linear	0.77	0.00	1371.8	41.20		
Exponential	0.76	0.00	1384	0.02		
Logarithmic	0.84	0.00	897.44	447.26		
Cubic	**0.93**	**0.00**	**1014**	**101.98**	**-1.34**	**-0.02**
Quadratic	0.92	0.00	976.97	115.24	-2.39	
compound	0.76	0.00	1284	1.02		
Growth	0.76	0.00	733.1	0.02		

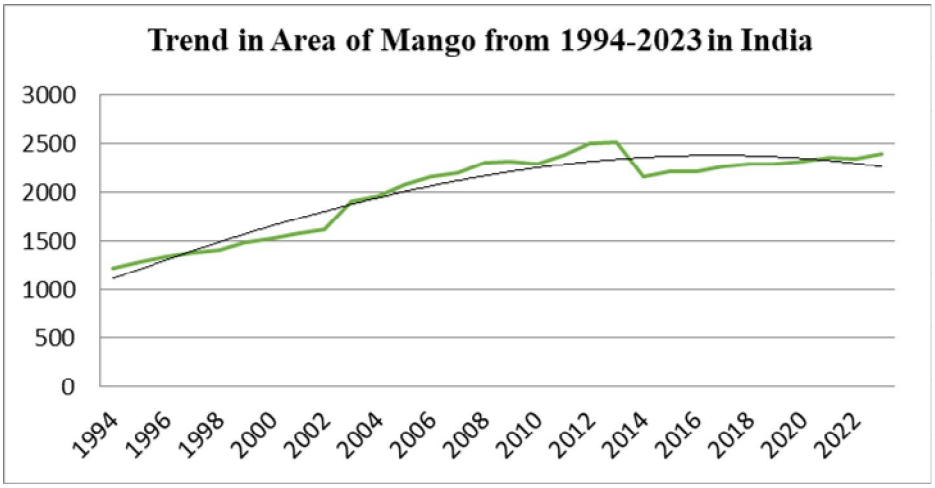


Fig. No. 1 Trend in Area of Mango from 1994-2023 in India

Figure 1 depicts a consistent rise in mango area in India from 1994 to 2012. A decrease occurred between 2013 and 2015, indicating a temporary setback. The agriculture area rebounded after 2016, and it stayed constant until 2023. This demonstrates perseverance in mango growing despite previous setbacks.

Trends in Production

The presented Table No. 2 shows that for mango crop production, the maximum R^2 value is 0.973 for the cubic model. The cubic model was shown to be the best trend equation for predicting future mango production. The model is substantial, as it has been seen that mango output has been increasing over time. The fitted cubic model is provided by

$$Y_t = 11591-650.63(t)+79.452(t^2)-1.5608(t^3)$$

$$R^2 = 0.973$$

Table No. 2 Parametric values of fitted linear and non-linear models for Production of mango in India

Model Summary and Parameter Estimates						
Equation	**R^2**	**Significance**	**constant (a)**	**b1**	**b2**	**b3**
Linear	0.928	0.00	7899	477.3		
Exponential	0.930	0.00	8992.4	0.0317		
Logarithmic	0.673	0.00	4821.4	4209.5		
Cubic	**0.973**	**0.00**	**11591**	**-650.63**	**79.452**	**-1.5608**
Quadratic	0.939	0.00	9035.9	264.14	6.8761	
compound	0.930	0.00	8741	1.032		
Growth	0.931	0.00	5359.1	0.032		

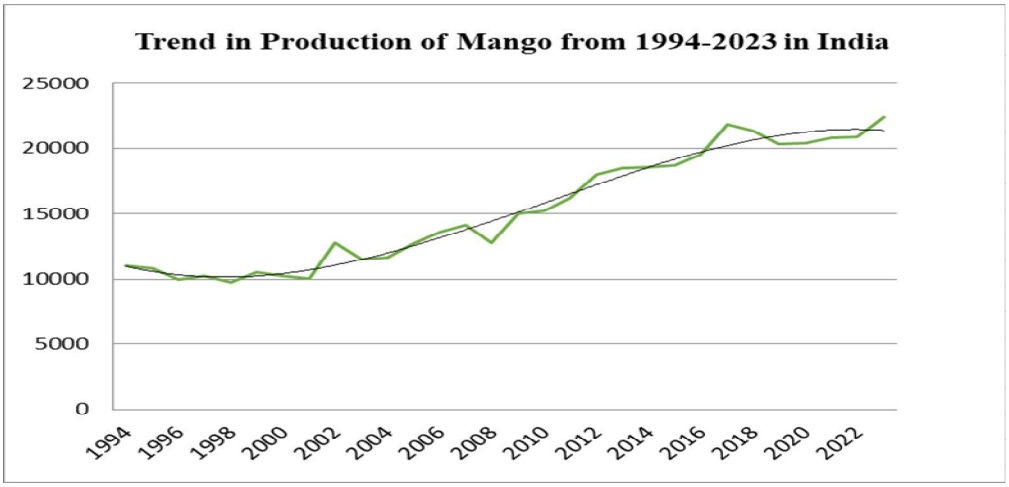


Fig. No. 2 Trend in Production of Mango from 1994-2023 in India

Figure 2 indicates a large growth in mango output in India over time. Fluctuations occurred between 2002 and 2008, with a strong increase after 2010 owing to improved farming methods. After 2018, output increased consistently, showing stability. Improved irrigation and orchard growth helped fuel this trend.

Trends in Productivity

Table No.3 presents the productivity statistics for the mango crop. The cubic model was determined to be the best trend equation for predicting future mango crop productivity. The model is noteworthy, as it has been noted that the fitted cubic model is provided by.

$$Y_t = 9835-801.4(t)+51.786(t^2)-0.8557(t^3)$$

$$[R^2 = 0.8266]$$

Table No. 3 Parametric values of fitted linear and non-linear models for Productivity of mango in India

Model Summary and Parameter Estimates						
Equation	**R^2**	**Significance**	**constant (a)**	**b1**	**b2**	**b3**
Linear	0.2631	0.00	6451.2	71.989		
Exponential	0.2393	0.00	6479.5	0.0092		
Logarithmic	0.0411	0.00	6833.7	294.67		
Cubic	**0.8266**	**0.00**	**9835**	**-801.4**	**51.786**	**-0.8557**
Quadratic	0.6994	0.00	8434.4	-299.87	11.995	
compound	0.2392	0.00	5480	1.009		
Growth	0.2395	0.00	6445	0.009		

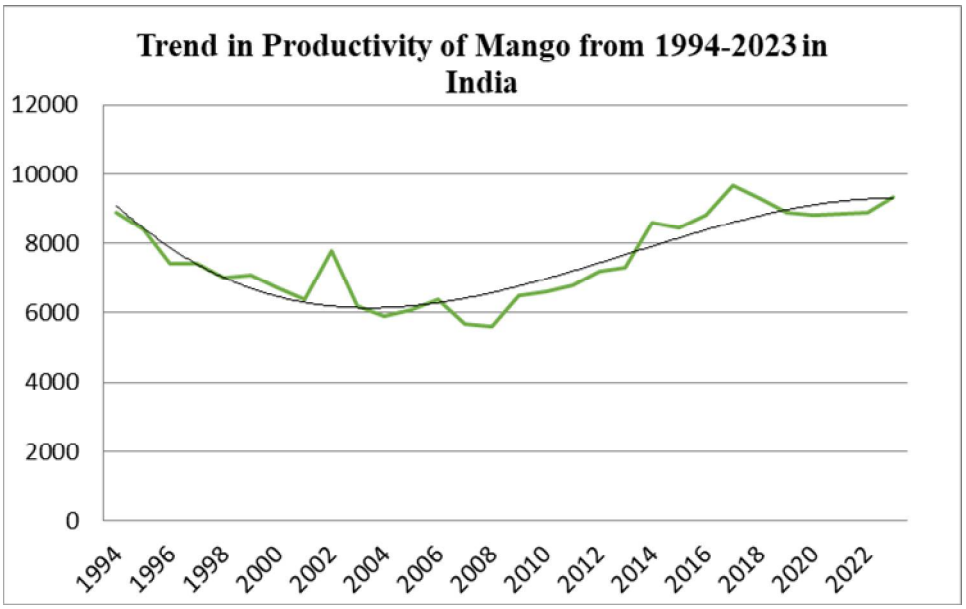


Fig. No. 3 Trend in Productivity of Mango from 1994-2023 in India

Figure 3 shows a reduction in mango productivity from 1994 to 2004, which might be attributed to ageing orchards and inefficient farming practices. After 2004, productivity began to rise, thanks to improved agricultural practices and pest control. Following 2010, there was a steady growth, which corresponded to increasing total production. Between 2016 and 2023, productivity remained steady, owing to improved land utilisation and yield efficiency. Overall, innovations in farming methods have helped to maintain production increases.

Direction of Mango export in quantity from India (2014 to 2023)

India is well-known for its fruit production around the world. India is home to more than 40 percent of the world's mango plantations. Mango production was concentrated in Uttar Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Bihar, Gujarat, Maharashtra, Kerala and Orissa in India. It was reasonable to analyse the flow of Indian mango trade to various importing country by estimating the transitional probability matrix inside the Markov chain framework by LINGO software, it was possible to study the direction of trade of Indian mango to various importing countries. It demonstrates the commitment of an importing nation to a specific nation's exports. Annual mango export data from APEDA for the years 2014 to 2023 were utilized to examine trade trends and changes in the export pattern of Indian mangoes. UAE, UK, USA, Kuwait, Qatar Canada, Oman, Nepal, Singapore were major importing countries. The remaining significant imported countries were categorized as others. The exports during the 10years study period were examined using the Markov chain analysis method. A general overview of the change in trade direction over ten years by presenting the transitional probability of Indian mango exports to various destinations is given in table no. 4

Table No 4. Transition Probability matrix of Mango export in quantity from India (2014 to 2023)

Country	UAE	UK	USA	Kuwait	Qatar	Canada	Oman	Nepal	Singapore	Other
UAE	0.0000	0.0000	0.6573	0.0000	0.0000	0.0000	0.3447	0.0000	0.0000	0.0000
United Kingdom	0.1791	0.0000	0.0944	0.0000	0.0000	0.1280	0.1026	0.1754	0.2185	0.1065
USA	0.2717	0.0000	0.0000	0.2302	0.0631	0.0243	0.3228	0.0585	0.0343	0.0000
Kuwait	0.0756	0.0000	0.0000	0.0000	0.2835	0.0000	0.0462	0.0706	0.2626	0.2622
Qatar	0.0000	0.0000	0.0000	0.0499	0.3704	0.0000	0.0923	0.2086	0.1540	0.1241
Canada	0.0000	0.1868	0.1772	0.0000	0.1696	0.0000	0.2004	0.0000	0.1518	0.1144
Oman	0.3272	0.1338	0.0512	0.1066	0.0000	0.0545	0.0000	0.1530	0.0000	0.1707
Nepal	0.0000	0.4325	0.0919	0.0000	0.0000	0.1173	0.2039	0.1545	0.0000	0.0000
Singapore	0.1575	0.1258	0.0000	0.0000	0.1322	0.1169	0.0000	0.1692	0.2990	0.0000
Other	0.0000	0.3320	0.1198	0.1861	0.2438	0.1216	0.0000	0.0000	0.0000	0.0000

The diagonal value in a transitional probability matrix provides the information on the probability of retention of the trade. Furthermore, the row elements indicate the probability of loss in trade on account of competing countries. The column elements indicate the probability of gain of import from other competing countries. Qatar was the largest importer of Indian Mango. It held a share of about 37.04 percent of mango export during the entire study period. It is gained 28.35 percent share from Kuwait, 24.38 percent share from others, 16.96 percent share from Canada and 13.22 percent share from Singapore. Also, it lost its 20.86, 15.40, 12.41, 9.23 and 4.99 percent share to Nepal, Singapore, Others, Oman and Kuwait respectively. Singapore retained its 29.90 percent share. It is gained 26.26, 21.85, 15.40, 15.18 and 3.43 percent share from Kuwait, United Kingdom, Qatar, Canada and USA respectively. It lost 16.92, 15.75, 13.22, 12.58 and 11.69 percent share to Nepal, UAE, Qatar, United Kingdom and Canada respectively. Nepal retained its 15.45 percent share. It is gained 20.86, 17.54, 16.92, 15.30, 7.06 and 5.85 percent share from Qatar, United Kingdom, Singapore, Oman Kuwait and USA respectively. It lost 43.25, 20.39, 11.73 and 9.19 percent share to United Kingdom, Oman, Canada and USA respectively. Furthermore, the result depicts that in quantity term UAE, United Kingdom, USA, Kuwait, Canada, Oman and Others retained none of its share. Qatar, Singapore and Nepal were the stable market and UAE, United Kingdom, USA, Kuwait, Canada, Oman and Others were Unstable Market. The probable reason may be that these countries are importing Mango from another region.

Table No 5. Transition Probability matrix of Mango export in value from India (2014 to 2023)

Country	UAE	UK	USA	Kuwait	Qatar	Canada	Oman	Nepal	Singapore	Other
UAE	0.0000	0.0000	0.2550	0.0000	0.0000	0.2505	0.4966	0.0000	0.0000	0.0000
United Kingdom	0.1105	0.0000	0.0711	0.0000	0.0000	0.1113	0.0000	0.3869	0.0000	0.3242
USA	0.0958	0.1070	0.0000	0.1122	0.1093	0.0000	0.5044	0.0582	0.0113	0.0000
Kuwait	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2934	0.4849	0.0000	0.2266
Qatar	0.2169	0.0000	0.0000	0.2133	0.2089	0.0000	0.0000	0.0761	0.0000	0.2850
Canada	0.1613	0.0536	0.0000	0.0532	0.2887	0.0000	0.1812	0.1562	0.0583	0.0456
Oman	0.0611	0.0000	0.1681	0.1834	0.1611	0.1681	0.0000	0.1258	0.0472	0.0832
Nepal	0.0000	0.0578	0.0192	0.0534	0.0448	0.1715	0.2594	0.2640	0.0558	0.0777
Singapore	0.0551	0.1631	0.1942	0.1563	0.0000	0.1942	0.0462	0.0504	0.1425	0.0000
Other	0.0000	0.0531	0.2667	0.0484	0.2055	0.2668	0.1154	0.0000	0.0409	0.0000

In value term Nepal was the largest importer of Mango. It retained about 26.40 percent share of mango during the entire study period. Furthermore, Nepal lost to 25.94, 17.15, 7.77, 5.78, 5.58, 5.34, 4.48 and 1.92 percent share to Oman, Canada, Others, United Kingdom, Singapore, Kuwait, Qatar and USA respectively whereas it future gained 48.49 percent share from Kuwait, 38.69 percent share from United Kingdom, 15.62 percent share from Canada, 7.61 percent share from Qatar, 12.58 percent share from Oman 5. 82 percent share from USA and 5.04 percent share from Singapore respectively (Table No. 5). The result indicates that in value term Nepal, Qatar and Singapore are stable market and UAE, United Kingdom, USA, Kuwait, Canada, Oman and Other are unstable market. UAE lost majority share of 49.66, 25.50 and 25.05 percent to Oman, Canada and USA respectively whereas future gained from 21.69, 16.13, 11.05, 9.58, 6.11 and 5.51 percent share from Qatar, Canada, United Kingdom, USA, Oman and Singapore. United Kingdom lost its 38.69 32.42, 11.13, 11.05 and 7.11 percent share to Nepal, Others, Canada, UAE and USA respectively whereas future gained from Singapore (16.31 %), USA (10.70 %), Nepal (5.78%),

Canada (5.36%) and others (5.31%) respectively. USA lost its 50.44, 11.22, 10.93, 10.70, 9.58 and 5.82 percent share to Oman, Kuwait, Qatar, United Kingdom, UAE and Nepal respectively whereas future gained from others (26.67%), UAE (25.50%), Singapore (19.42%), Oman (16.81%), United Kingdom (7.11%) and Nepal (1.92%) respectively. Kuwait lost its 48.49, 29.34 and 22.66 percent share to Nepal, Oman and Others respectively whereas future gained from Qatar (21.33%), Oman (18.34%), Singapore (15.63%), USA (11.22 %) Nepal (5.34%), Canada (5.32%) and Others (4.84%) respectively. Canada lost its 28.87, 18.12, 16.13, 15.62, 5.83, 5.36, 5.32, and 4.56 percent share to Qatar, Oman, UAE, Nepal, Singapore, United Kingdom, Kuwait and Others respectively whereas future gained from others (26.68%), UAE (25.05%), Singapore (19.42%), Nepal (17.15%), Oman (16.81%) and United Kingdom (11.13%) respectively. Oman lost its 18.34, 16.81, 16.81, 16.11, 12.58, 8.32, 6.11 and 4.72 percent share to Kuwait, USA, Canada, Qatar, Nepal, Others, UAE and Singapore respectively whereas future gained from USA (50.44%), UAE (49.66%), Kuwait (29.34%), Nepal (25.94%), Canada (18.12%), Others (11.54%) and Singapore (4.62%) respectively.

Other country which includes Bahrain, New Zealand, Bangladesh, Japan, Australia, South Africa etc. These countries future gained from United Kingdom (32.42%), Qatar (28.50%), Kuwait (22.66%), Oman (8.32 %), Nepal (7.77%) and Canada (4.56%) whereas it lost from Canada (26.68%), USA (26.67%), Qatar (20.55%), Oman (11.54%), United Kingdom (5.31%), Kuwait (4.84%) and Singapore (4.09%) respectively.

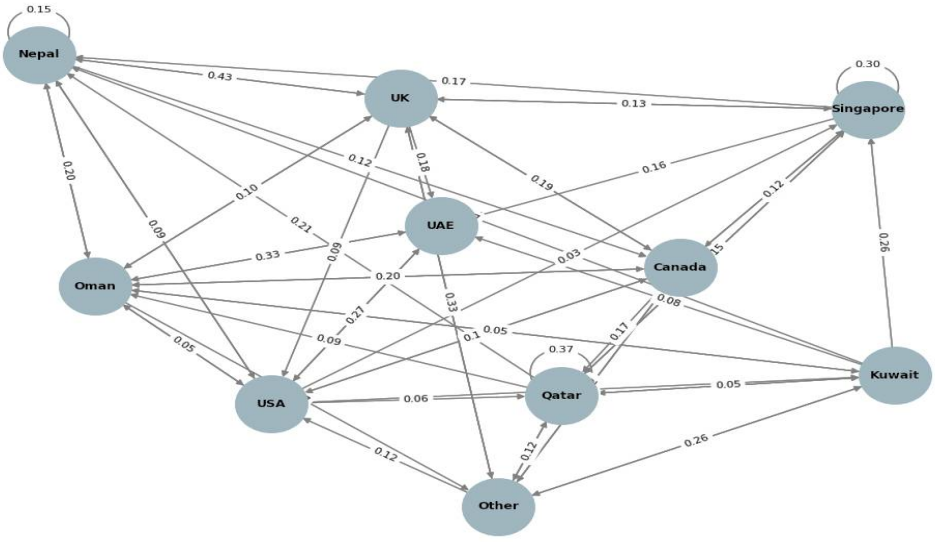
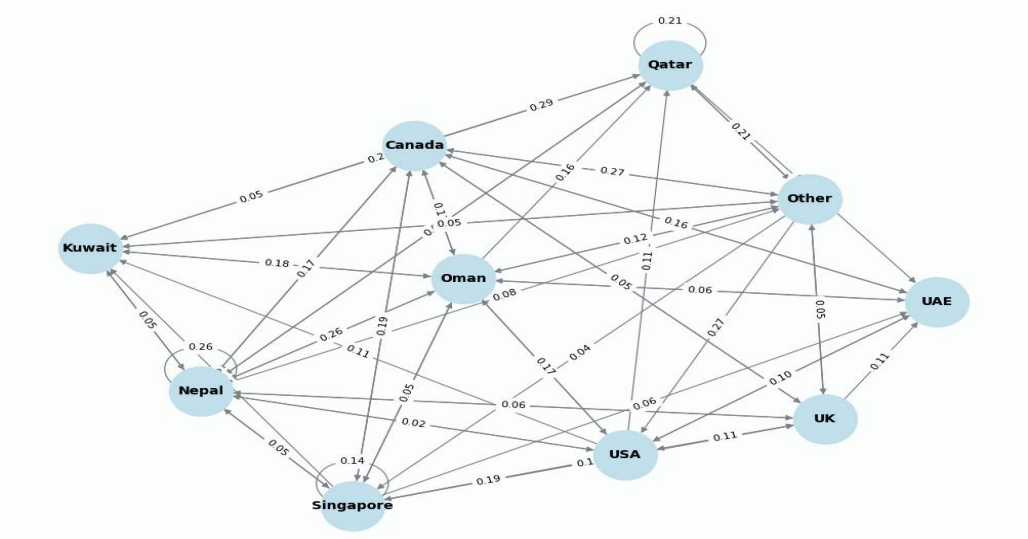


Figure 4 Directional Graph of Mango export in quantity from India

Figure 5 Directional Graph of Mango export in value from India



CONCLUSION

The mango, sometimes referred to as the peach of the tropics, are the national tree of Bangladesh and the national fruit of India, Pakistan, and the Philippines. It is the source of half of all tropical fruits produced worldwide. Despite challenges including urbanisation, climate change, and economic reasons, India's mango production has increased thanks to modern farming practices, research and improved access to inputs, knowledge exchange, and government initiatives. The demand for Indian mangoes on both domestic and international markets has also contributed to this rise. The results of this investigation led to the conclusion that based on goodness-of-fit criteria like R^2, the cubic trend model was the best statistical model for future projections. Overall, there was long-term beneficial expansion in the mango area and output. Between 1994 and 2004, the productivity of mangoes decreased. Productivity increases after 2004. From 2010 until 2023, productivity stayed constant. Mango market transition probability is assessed using the Markov chain technique. The findings showed that whereas the UAE, UK, USA, Kuwait, Canada, Oman, and other countries were unstable export markets, Qatar, Singapore, and Nepal were stable in terms of both quantity and value.

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