Potato J (2026) 53 (1): 64-70

POTATO TRADE DYNAMICS IN INDIA: A MARKOV CHAIN ANALYSIS

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ABSTRACT: An attempt has been made in this paper to study direction of trade of Indian potato. The study is based on secondary data collected for the periods 2003-04 to 2022-23 on area, production and productivity of potato in India and period 2014-15 to 2023-24 on destination-wise export of potato from India. Besides simple tabular analysis, compound growth rates (CGRs), Coppock's instability index and Markov Chain analysis were used to derive the inferences of the study. In India, area, production and productivity of potato have registered positive and significant growth rate of 2.80, 4.83 and 1.97 per cent per annum, respectively. This clearly indicates that the production of potato in India increased due to area expansion followed by yield improvement. The instability index in area, production and productivity was 4.91, 8.85 and 6.86 per cent, respectively which may be considered relatively low. It was further found that Nepal was the most stable country among major importers of Indian potato as reflected by its high probability of retention (78%). All other countries (Oman, Malaysia, Sri Lanka and UAE) had zero probability of retention, hence are most unstable.

KEYWORDS: Compound Growth Rate, Coppock's Instability Index, Markov Chain Analysis

INTRODUCTION

Agricultural sector is playing an important role in linking Indian farmers to ultimate consumers in the domestic and international markets. Indian agricultural sector is playing an important role in supplying sufficient food to meet the food demand for fast growing population of the country, raw materials for agro-based industry, export surplus and employment opportunity to 42.60 percent population in the country.

The share of agriculture and allied sector to India's total gross value added (Rs 452081.8 billion) at current price was 21.10 per cent in 2022-23 (Agricultural statistics at a glance, 2023). India's agricultural sector has gone to a remarkable transformation from food-deficit to the exportable surplus generation after meeting the domestic requirements of the fast-growing population of the country (Singh and Sain, 2003). India is blessed with 15 agro-climatic zones, 141 million ha of net cropping area, a diverse group of the population, and their internal demand for food which is supported by 48.9% of the working population in agriculture (Panigrahy and Kalamkar, 2024). Horticulture occupies only 5.6 percent of gross cropped area of the country but contributes about 25 per cent to agriculture GDP of India (Goyal *et al*., 2020)

At global level potato is one of the most important crops as it is produced in almost every corner of the world. Its production at world level reached at 374.7 million tonnes

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covering 17.78 million hectare and 21.06 t/ha yield during the year 2022 (FAO, 2022). Export of Indian potato has increased from almost 166 thousand tonnes to around 442 thousand tonenes in the year 2022 which signifies the importance of the crop at global level. Nepal has always been the best export destination for export of potato from India as it has ranked number one in term of the total quantity exported from India. India is the second largest producer of potato after China with a total production of 56.17 mt contributing around 15 per cent of total global production (FAO, 2022). In India, five major potato producing states *viz*. Uttar Pradesh, West Bengal, Bihar, Gujrat, Madhya Pradesh, together produce about four-fifth of total production in the country. And most of potato in India (85-90%) is produced during rabi season. In *kharif* season it is cultivated in Karnataka, Maharashtra, Himachal Pradesh and Uttarakhand. (Pant *et al*., 2020).

Despite a leading role of the nation in potato area, production and productivity, the same have been fluctuating from one year to another. A very few studies have been conducted in the recent years which describes the growth and instability in potato. Moreover, a very rare studies calculated the growth and instability of potato at national level. Additionally, there is a lack of literature to analyze the direction of trade of potato from India. Although a sufficient literature is available for the other fruits and vegetable. Moreover, the majority of current research tends to be predominantly descriptive and fails to sufficiently reflect the evolving dynamics of export markets over time. In this regard, employing a Markov Chain methodology to analyze trade direction offers a more rigorous and scientific framework, facilitating a better comprehension of transitional probabilities and the stability of export markets. This method allows for the identification of both loyal and emerging markets, thus providing more profound insights into the structural transformations within India's potato trade.

The present study tries to fill the gap to analyze the trends in area, production and productivity of potato in India over a period of last 20 years. Further this study tries to find the direction of trade of potato from India. India is the second largest producer of potato at global level whereas it ranks 10th in term of global export which enhances the importance to study the direction of trade of Indian potatoes.

MATERIAL AND METHODS

The study is based on secondary data on area, production, productivity, export quantity and export earnings of potato from India. The data were collected from different published sources such as; APEDA, Indiastat and FAO for the periods 2003-04 to 2023-24. The timeframe from 2014–15 to 2023–24 was chosen for the analysis of exports due to the presence of reliable and up-to-date data, which accurately represents the prevailing trade patterns and developing trends in the export of potatoes from India.

Growth rate analysis

Compound growth rates (CGR) were calculated to find out trend in area, production and productivity of potato in India for the period of last 20 years *i.e.* 2003-04 to 2022-23. The compound growth rates were computed using the exponential function of the form:

$$Y_t = ab^t u_t$$

$$\text{Log } Y_t = \text{Log } a + t \text{ Log } b + \text{Log } u_t$$

Where,

Y_t = Area/production/productivity/export of potato in year 't'

t = Time elements which take the value 1, 2, 3, …..,n

a = Intercept

b = Regression coefficient

u_t = Error term

Compound growth rates were worked out as follow:

Compound growth rate (r) = (antilog b-1) ×100

The standard error of the growth rate was estimated and tested for its significance with 't' statistic.

Instability – Coppock's instability index

A number of statistical measures are available in literature to measure the instability index. Coppock (1962), MacBean (1966), Massel (1970), Weber and Sievers (1985), Singh and Byerlee (1990), Cuddy and Della Valle (1978) and Wasim (1997) have made use of different techniques of measuring instability index. In this study, the instability was estimated using Coppock's instability index (Coppock, 1962). Coppock's instability index is a close approximation of the average year to year per cent variation adjusted for trend. The estimated form is given below:

$$CII = \left[(Antilog)\sqrt{Vlog - 1}\right] x100$$

Where:

$$V\log = \frac{1}{N-1}\sum\left(\log X_{t+1} - \log X_t - M\right)^2$$

$$M = \frac{1}{N-1}\sum\left(\log X_{t+1} - \log X_t\right)$$

N = Number of years

X = Value of parameter

M = Arithmetic mean of the differences between logs of X_t, X_{t+I} and X_{t+2}, etc.

Markov chain model

The major potato importing countries from India are Nepal, Oman, Malaysia, Sri Lanka and U Arab Emirates. Annual export data of potato were used for analyzing the direction of trade and changing pattern of Indian potato export. The trade directions of Indian potato exports were analyzed using the first order Markov chain approach. The Markov Chain methodology is especially effective for examining trade dynamics, as it summarizes the probabilistic transitions and variations in export shares across various importing nations over time. Additionally, it aids in evaluating the stability and retention ability of export markets. The lingo software was adopted to study the transition probability matrix. Central to Markov chain analysis is the estimation of the transitional probability matrix 'P' whose elements, P_{ij} indicate the probability of exports switching from country 'i' to country 'j' over time. The diagonal element P_{ij} where i=j, measures the probability of a country retaining its market share or in other words, the loyalty of an importing country to a particular country's exports. Annual export data for period 2014-15 to 2023-24 were used to analyze the direction of trade and changing pattern of Indian potato export. In this context, major potato importing countries *viz.*, Nepal, Oman, Malaysia, Sri Lanka and U Arab Emirates, remaining countries clubbed as other countries. The average exports to a particular country were considered to be a random variable which depends only on the past exports to that country, which can be denoted algebraically as

$$E_{jt} = \sum_{i=0}^{n} E_{t-1} * P_j + e_j$$

Where,

E_{jt} = exports 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} = the probability that exports will shift from i^{th} country to j^{th} country

e_{jt} = the error term which is statistically independent of E_{it-1}

n = the number of importing countries

The transitional probabilities P_{ij}, which can be arranged in a (c x n) matrix, have the following properties:

$$\sum_{i=1}^{n} P_{ij} = 1 \text{ and } 0 \le P_j \le 1 = 1,$$

Thus, the expected export share of each country during period 't' is obtained by

multiplying the exports to these countries in the previous period (t-1) with the transitional probability matrix.

RESULTS AND DISCUSSION

Trends in area, production, productivity of potato in India

The trend in area, production and productivity of potato in India is shown in Table 1 and Figures 1 to 3. The table shows that the area under potato was 1289.2 thousand ha during 2003-04 which increased to 2332.2 thousand ha during 2022-23 registering an increase by 4.04 per cent per annum, the average yield increased from 17.9 MT/hectare during 2003-04 to 25.8 MT/hectare during 2022-23 registering an increase by 2.21 per cent per annum. Due to positive growth in area as well productivity, the total production of potato in India which was 23060 thousand MT in 2003-04 increased to 60142 thousand MT in 2022-23 registering an annual increase of 8.04 per cent.

The figures 1 to 3 depicts that during the last 20 years, area, production and productivity of potato crop in India registered an annual

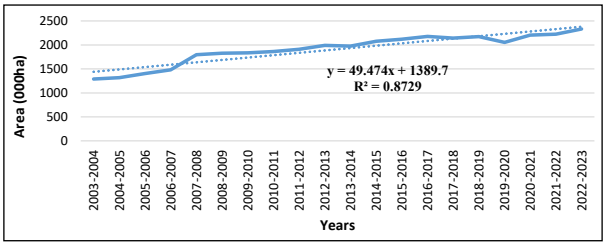

Fig. 1. Trends in area of potato in India

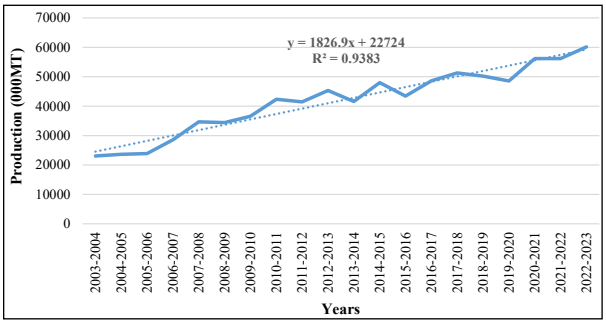

Fig. 2. Trends in production of potato in India

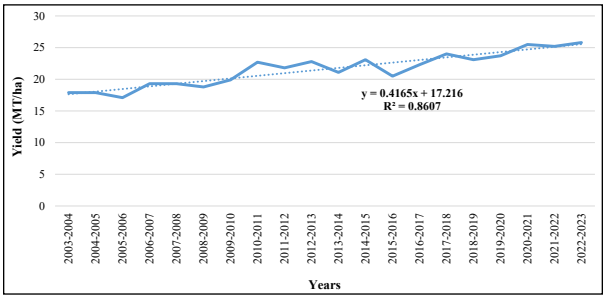

Fig. 3. Trends in productivity of potato in India

Table 1. Trends in area, production and productivity of potato in India

Year	Area (000 Hectare)	Production (000 MT)	Productivity (In MT/ Hectare)
2003-2004	1289.2	23060	17.9
2004-2005	1318.5	23631	17.9
2005-2006	1401.4	23905	17.1
2006-2007	1482.3	28600	19.3
2007-2008	1795.0	34658	19.3
2008-2009	1828.3	34391	18.8
2009-2010	1835.3	36577	19.9
2010-2011	1863.2	42339	22.7
2011-2012	1907.0	41483	21.8
2012-2013	1992.2	45344	22.8
2013-2014	1973.2	41555	21.1
2014-2015	2075.9	48009	23.1
2015-2016	2117.0	43417	20.5
2016-2017	2179.0	48605	22.3
2017-2018	2142.0	51310	24.0
2018-2019	2173.0	50190	23.1
2019-2020	2051.0	48562	23.7
2020-2021	2203.0	56173	25.5
2021-2022	2225.7	56176	25.2
2022-2023	2332.2	60142	25.8
Average	1909.22	41906.35	21.59
Annual % age change	4.04	8.04	2.21
CAGR	2.80**	4.83**	1.97**
Instability	4.91	8.85	6.86

Note: **Significant at 1 per cent probability level

increase at the rate of 49.47 thousand ha, 1827 thousand tonnes and productivity 0.41 MT/ha, respectively. The yearly compound growth rates reveals that the increase in production (4.83%) was mainly contributed to the expansion of area (2.80%) and yield (1.97%) under potato. This implies that although technological advancements have had an impact, the growth area remains a significant factor, underscoring the potential for additional productivity improvements through better varieties and management techniques.

The instability in area, production and productivity was 4.91, 8.85 and 6.86 percent, respectively.—The comparatively greater instability in production, when contrasted with area and yield, indicate the susceptibility to external factors such as variations in weather and fluctuations in the market. This highlights the necessity for stabilization policies, which may encompass enhanced storage infrastructure and mechanisms for price support.

Destination of potato export from India in 2023-24

The destination-wise export country-wise percentage share in total quantity and total value of potato and for the year 2023-24 is presented in Table 2. It is evident from the table that total potato export in 2023-24 was 500.54 thousand tonnes with the total export value of ₹83261.48 lakh. It is also clear from the table that in terms of quantity exported, Nepal with 47.33 percent share was the highest importer followed by Oman (8.74%), Malaysia (3.49%), Sri Lanka (2.88%) and UAE (2.67%). In terms of export earnings also, Nepal with 30.76 percent share of total export value from India topped the list. Oman (12.42%) stood at 2nd place followed by Malaysia (5.23%), Sri Lanka (3.97%) and UAE (3.86%), etc.

Table 2. Destination-wise export of potato from India to major importing countries, 2023- 24.

Sr. No.	Country	Quantity (MT)	% in total quantity	Value (₹ Lakh)	% in total value
1	Nepal	236883.43	47.33	25611.73	30.76
2	Oman	43739.00	8.74	10340.61	12.42
3	Malaysia	17473.48	3.49	4358.35	5.23
4	Sri Lanka	14417.95	2.88	3309.34	3.97
5	U Arab Emts	13381.61	2.67	3215.76	3.86
6	Others	162715.71	32.51	33514.05	40.32
	Total	500541.25	100.00	83261.48	100.00

Note: Export values are at constant prices: base year - 2011-2012

The predominance of Nepal as a significant export destination reflects a considerable market concentration, potentially rendering Indian exports vulnerable to regional demand fluctuations. Consequently, it is crucial to diversify into alternative markets to mitigate dependency and strengthen export resilience.

Direction of trade of Indian potato export

The knowledge of changing export trade across the destinations is of paramount importance. The Markov chain analysis was employed to study the structural changes in export proportion of Indian potato to the major destinations. The transitional probability matrix was computed for export of potato. The Transitional probability Matrix revealed a broad indication of changes in the direction of export of potato from India for the study period (2014-15 to 2023-24). The transitional probability matrix was obtained for the study period by using the actual proportion of exports to different importing countries. This matrix explains the changing direction of trade among the importing countries.

The row elements in a matrix indicate the probability of loss in trade on account of competing countries. The column elements

indicate the probability of gain in trade from other competing countries. The transitional probability matrix for Indian potato exports is presented in Table 3 which gives a broad indication of change in direction of potato trade for the study period (2014-15 to 2023-24). The top five importing countries considered for the study were Nepal, Oman, Malaysia, Sri Lanka and U Arab Emts. The exports to other than these countries were pooled under the broad head "Others".

The table indicates the probability matrix ~~indicates that~~ during the current period (2023-24) which reveals that Nepal is the most stable market amongst the studied markets as it has retained to the extent of about 78 per cent of its share. On the other hand, 5 per cent of its share was lost to Oman, 5 percent to Sri Lanka and 8 percent to 'Others'. The transition probabilities indicate considerable volatility across the majority of markets, with the exception of Nepal, which points to a lack of strong market retention in alternative destinations. This observation implies restricted long-term trade relationships and possible competitiveness challenges within these markets. The complete shifts in market shares observed for countries like Oman, Malaysia, Sri Lanka, and the UAE indicate unstable trade connections, which may be attributed to factors such as price competitiveness, variations in quality, or evolving import preferences.

The other countries could retain only 16 percent, losing its share to the extent of 55 per cent to Nepal, 13 percent to Oman and gaining 8 per cent from Nepal. The major gainers among importers of Indian potato during the reference period were Nepal, Oman and 'Others'. Nepal and Oman gained 100 percent share from Sri Lanka and UAE, respectively. Other countries gained 100 percent share from Oman and Malaysia.

Thus, transitional probability matrix presented in the Table 3 indicated that Nepal was the most stable country among major importers of Indian potato as reflected by its high probability of retention (78%). All other countries (Oman, Malaysia, Sri Lanka and UAE) had zero probability of retention, hence are most unstable.

From a policy point of view, the results underline the importance of encouraging export diversification strategies by investigating new markets outside of conventional destinations such as Nepal. Furthermore, enhancing supply chain efficiency, quality standards, and trade agreements can facilitate better market retention. Additionally, reinforcing cold storage infrastructure and export-oriented value chains can further mitigate instability and enhance competitiveness in global markets.

CONCLUSION

The research indicates a notable and significant increase in the area, production,

Table 3. Transitional Probability Matrix of Indian potato exports (2014-24)

Destination	Nepal	Oman	Malaysia	Sri Lanka	U Arab Emts	Others
Nepal	**0.78448**	0.04729	0.02363	0.04660	0.01455	0.08345
Oman	0	**0**	0	0	0	1
Malaysia	0	0	**0**	0	0	1
Sri Lanka	1	0	0	**0**	0	0
U Arab Emts	0	1	0	0	**0**	0
Others	0.55435	0.13905	0.09203	0	0.05456	**0.15994**

and productivity of potatoes in India, accompanied by relatively low instability levels. The trade analysis shows that Nepal is the most stable export destination, characterized by a high retention probability of 78 percent, whereas other markets demonstrate considerable instability. The concentration of exports in a limited number of countries underscores the risks associated with market dependence. From a policy point of view, it is essential to encourage export diversification by investigating new and emerging markets. Enhancing supply chain infrastructure, elevating quality standards, and boosting competitiveness can contribute to stabilizing current markets and expanding India's footprint in the global potato trade.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the author.

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(MS Received : February 19, 2025; Accepted : May 21, 2026)