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Millets in India: Evaluating the Current Scenario, Emerging Trends, Export Dynamics and Future Prospects

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SUMMARY

This study explores the evolving trends and future prospects of millets globally and within India, while also shedding light on the export dynamics of millets from India to importing countries. Globally, millet production has significantly declined from 1961 to 2022, with Asia remaining the primary contributor despite diminishing trends. In contrast, Africa has experienced growth in production due to expanded cultivation areas. In India, between 2000 and 2022, the cultivation area for small millets, jowar, bajra and ragi consistently declined, with compound annual growth rates (CAGR) of -5.60 per cent, -4.30 per cent, -1.70 per cent and -2.20 per cent, respectively. While the production of small millets and jowar experienced a decline, bajra production exhibited modest growth, increasing at an average rate of 1.6 per cent per annum. Nevertheless, productivity for these millets has improved, indicating better yields. Markov chain analysis highlights Bangladesh as the most reliable importer of Indian millet, maintaining a 96.85 per cent share, followed by the UAE at 51.29 per cent. Despite ongoing promotional efforts, significant challenges continue to hinder millet cultivation. This study underscores the need for strategic enhancements in export markets, productivity improvements and comprehensive outreach initiatives. By raising awareness and engaging consumers, the study aims to support the revival of millet cultivation and boost its trade in India.

Keywords: Millets; Markov chain model; Millet trade; Growth rate etc.

1. INTRODUCTION

Hidden hunger, a widespread yet often underestimated issue, deprives billions of people globally, particularly in India. It arises from diets overly reliant on cereals and lacking nutritional diversity, thereby jeopardizing health and hindering progress toward sustainable development goals (Sreekala *et al.*, 2023). The changing climate, depletion of natural resources and increasing incidence of malnutrition across the globe necessitate the identification and utilization of alternate crops suited to sustainable food production systems (Devi *et al.*, 2024). Millets, recognized as a valuable food source, are emerging as a promising solution to address these challenges (FAO, 2020). They are known as Nutri-cereals and offer a sustainable option due to their adaptability to climate change and exceptional nutritional benefits (GoI, 2023). Millets are most popular in developing regions, like India and Africa, where food and nutritional security are major challenges (McDonough *et al.*, 2000). Total world millet production was 30.86 million tonnes with an area of around 29.85 million hectares (FAOSTAT, 2023). India is the largest producer of millet, having a global share of about 40 per cent, followed by Niger (USDA, 2023). Increasing the cultivation of coarse cereals like millets and sorghum can boost nutrition, enhance climate resilience, reduce greenhouse gas emissions, and lower water and energy demand, all while maintaining calorie production (Saxsena *et al.*, 2018). Millets also require less water, fertilizer, and pesticides compared to wheat and rice, making them more sustainable. However, a significant issue is the global decline in millet cropping areas (Gowri and Shivakumar, 2020). The decline in millet cultivation is attributed to competition from more profitable crops like wheat and cash crops during the late colonial period, shifting dietary preferences toward processed

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foods and government policies favoring other crops through subsidies (Siddiqui, 2015).

However, a significant turnaround has occurred in recent years as governments have recognized the value of millets, particularly in light of their declining production and shrinking cultivation areas. This decline has prompted a renewed focus on promoting millets as a sustainable alternative. In this context, 2023 was celebrated as the "International Year of Millets" to raise awareness of their health benefits, encourage increased production and consumption, and emphasize their role in addressing food security, climate change adaptation, and sustainable agriculture (Sreekala *et al.*, 2023). Millets are also gaining recognition as a potential export commodity, offering significant economic benefits. In the fiscal year 2022-23, India exported 169.04 million metric tonnes of millets, which generated approximately ₹608.03 crores in revenue (APEDA, 2023). Despite various initiatives to boost millet cultivation and exports, significant challenges persist. Notably, there is a lack of comprehensive analysis of long-term trends and instability in the area, production, productivity, and export performance of millets in India. Although India plays a pivotal role in the global millet trade, with the potential to reduce the trade deficit, the evolving dynamics of millet cultivation and export remain underexplored.

Several studies have effectively employed statistical models particularly Markov chain analysis to examine export dynamics in agricultural commodities (Joshi *et al.*, 2015; HC and Srivastava, 2020; Chetia *et al.*, 2022; Swarnalatha *et al.*, 2024). These models are valuable for analyzing transitional behaviors over time, such as shifts in export performance across markets. However, their application to millet exports has been limited, despite the crop's growing importance in sustainable agriculture and trade. Therefore, the present study employed Markov chain analysis to assess the dynamics of India's millet exports by estimating the probabilities of market retention and shifts among major importing countries over time. This method provides a robust framework for capturing the stability and direction of export flows. Combined with a trend analysis of area, production and productivity, the study offers evidence-based insights to support strategic planning and improve the sustainability and global competitiveness of India's millet sector.

2. METHODOLOGY

In this study, secondary data from diverse sources, including FAOSTAT, INDIASTAT, and the Ministry of Agriculture and Farmer's Welfare, was collected. To analyze the data, several statistical tools were employed, including the Compound Annual Growth Rate (CAGR), Coefficient of Variation (CV), Cuddy-Della Valle Index, Percentage Change Method and Markov Chain analysis. These tools were chosen for their effectiveness in assessing trends, variability, and the export scenario in the data. These methods are described as follows:

1) Compound annual growth rate

The compound annual growth rate (CAGR) shows the rate of growth in particular period of time. The CAGR has been calculated using following equation:

$$\mathbf{Y_t = ae^{bt} + u}$$

Where,

Y_t = Area/Production, t = Time period, a = Intercept, b = Slope, u= Error term

2) Coefficient of variation

The coefficient of variation represents the ratio of the standard deviation to the mean and it is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from one another.

$$\textbf{Coefficient of variation} = \sigma/\bar{u} * 100$$

σ = Standard deviation

$\bar{u}$ = Mean

3) Cuddy-Della Valle (Instability index)

Instability index is a simple analytical technique to find out the fluctuation or instability in any time series data. This method corrects the coefficient of variation, if data are scattered around the negative or positive trend line.

The **Cuddy-Della Valle Index** is given follows

$$I = CV * (1-R^2)^{0.5}$$

CV = Coefficient of variation

R^2 = Corrected coefficient of determination of the log linear trend function that fits the time series

4) Per cent change in selected parameters

Per cent change has been estimated for comparison of area production and productivity scenario between two time periods. This is given by formula as given below:

$$\text{Per cent change} = \frac{X_1 - X_2}{X_2} \times 100$$

Where,

X_1= value of parameter under the current year

X_2= value of parameter under the previous year

5) Markov chain analysis

A critical component of the present study involves the application of Markov chain analysis to examine the dynamic behavior of India's millet export patterns across major destination markets. The Markov chain model is particularly appropriate in this context, as it assumes that the future state of a system depends solely on its current state and not on the sequence of events that preceded it an assumption known as the Markov property. At the core of this analysis is the estimation of the transition probability matrix, denoted as P. Each element P_{ij} in this matrix represents the probability that millet exports will transition from country 'i' to country 'j' over a specified time period. The diagonal elements 'P_{ii}' indicate the probability that an importing country will retain its share of imports from India in the subsequent period. These values are interpreted as a measure of market retention or loyalty. In contrast, the off-diagonal elements capture the likelihood of export share shifting from one importing country to another. These transition probabilities provide insights into the volatility, diversification, or concentration of export destinations. Millets exports in any period depended solely on previous exports, expressed algebraically by Eq. (1):

$$E_{jt} = \sum_{i=1}^{r} E_{it-1} P_{ij} + e_{jt} \tag{1}$$

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} = 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 = Number of importing countries

Transitional probability matrix (T) was estimated using linear programming (LP) framework adopted in the method called minimization of Mean Absolute Deviation (MAD). The MAD method used in the analysis was given in Eq. 2:

$$\text{Min, } OP^* + Ie \tag{2}$$

Subject to:

$$X P^* + V = Y \; GP^* = 1$$

$$P^* \geq 0$$

Where,

P^* = Vector of the probabilities, O = Vector of Zeroes, I = Dimensional vectors of areas

e =Vector of absolute errors, Y = The proportion of Indian export to each country,

V = Vector of errors, X = Block diagonal matrix of lagged values of y

G = Grouping matrix to add row elements of P in P^* to unity

3. RESULTS AND DISCUSSIONS

Trends in the area, production and productivity of millets across major global regions

Over the span of 61 years, from 1961 to 2022, the global millet cultivation area witnessed a significant decrease of 31.22 percent, declining from 43.40 million hectares to 29.85 million hectares, as shown in Table 1. While America and Oceania maintained relatively stable cultivation areas, Asia and Europe experienced notable declines. Despite being the largest contributor to millet cultivation, Asia had a substantial reduction of 7.61 million hectares in its cultivation area. This decline is attributed to factors such as diminishing crop diversity,

Table 1. Trends in the area under millet cultivation in major global regions

Region	Area (million hectares)		Change	
	1961	2022	Quantum (million hectares)	Per Cent (%)
Africa	11.42	19.03	7.61	66.63
America	0.29	0.21	-0.08	-27.58
Asia	27.78	10.31	-17.47	62.88
Europe	3.86	0.25	-3.61	93.52
Oceania	0.03	0.04	0.01	33.33
World	43.4	29.85	-13.55	31.22

Data *Source:* **FAOSTAT (2023) and the data excludes 'sorghum'** heavy reliance on rice and maize, reduced profitability in farming, the impact of the Green Revolution and associated government policies in various Asian countries. In contrast, Africa has significantly increased its millet cultivation area by 66.63 per cent, rising from 11.42 million hectares to 19.09 million hectares. This growth reflects a transition from water-intensive crops like maize to more climate-resilient millets and sorghum. Despite the overall decline in global millet cultivation, Asia continues to hold the largest share of global millet production.

The status of millet production across various regions is presented in Table 2. The decline in millet production across Asia, including India, can be attributed to several factors such as a decrease in the area under millet cultivation, adverse climatic conditions, agricultural policies and changing market demands (Pouchepparadjou *et al.*, 2023; Sendhil *et al.*, 2023). In Europe, there was a significant reduction of 84.98 per cent in millet production, dropping from 2.73 million tonnes to 0.41 million tonnes. However, globally, millet production increased by 20.03 per cent, rising from 25.71 million tonnes to 30.86 million tonnes, highlighting dynamic shifts in regional contributions. There have been notable fluctuations in productivity levels over the years, as shown in Table 3. Despite Europe's relatively low share in millet cultivation, the adoption of modern agricultural practices has significantly boosted its productivity, rising from 0.7 MT/MHA in 1961 to 1.64 MT/MHA in 2022. Similarly, Asia experienced a substantial increase in productivity, growing by 163.14 per cent from 0.57 MT/MHA in 1961 to 1.50 MT/MHA in 2022. Africa also had a 33.33 per cent rise in productivity, reaching 0.76 MT/MHA by 2022, though this increase lagged behind the growth in cultivation area due to low-input strategies and ineffective agricultural systems. Oceania's productivity grew by 35 per cent, from 1.00 MT/MHA in 1961 to 1.25 MT/MHA in 2022. Globally, millet productivity increased by 74.57 percent, from 0.59 MT/MHA in 1961 to 1.03 MT/MHA in 2022, reflecting diverse regional trends and advancements over the period.

Table 2. Trends in millet production across major global regions

Region	Production (million tonnes)		Change	
	1961	2022	Quantum (million tonnes)	Per Cent (%)
Africa	6.59	14.6	8.01	121.54
Americas	0.37	0.22	-0.15	40.54
Asia	15.99	15.58	-0.41	2.56
Europe	2.73	0.41	-2.32	84.98
Oceania	0.03	0.05	0.02	66.66
World	25.71	30.86	5.15	20.03

Data *Source:* **FAOSTAT (2023) and the data excludes 'sorghum'**

Table 3. Trends in millet productivity across major global regions

Region	Productivity (million tonnes/million hectare)		Change	
	1961	2022	Quantum	Per Cent (%)
Africa	0.57	0.76	0.19	33.33
Americas	1.27	1.04	-0.23	-18.11
Asia	0.57	1.5	0.93	163.15
Europe	0.7	1.64	0.94	134.28
Oceania	1.00	1.25	0.25	25.00
World	0.59	1.03	0.44	74.57

Data *Source:* **FAOSTAT (2023) and the data excludes 'sorghum'**

3.1 Scenario of millets in India

Small millets

From 2000-01 to 2022-23, the cultivation of small millets in India exhibited significant fluctuations. The area dedicated to small millets decreased from 1,424 thousand hectares in 2000-01 to 429 thousand hectares in 2021-22, reflecting a compound annual growth rate (CAGR) of -5.60 per cent. Similarly, production fell from 587 thousand MT to 384 thousand MT, with a CAGR of -2.1 per cent. Despite this decline in area and production, productivity improved, rising from 0.41 thousand tonnes per thousand hectares to 0.85 thousand tonnes per thousand hectares, with a CAGR of 3.7 per cent. The instability indices for area, production and productivity were 7.22, 11.36, and 10.55 per cent respectively, indicating considerable variability.

The reduction in the cultivation area can be attributed to farmers shifting their focus towards cereals, pulses and cash crops. The decline in production is primarily due to the transition to more profitable crops. However, productivity has shown a positive trend, driven by the development and adoption of high-yielding varieties, pest and disease-resistant crops and improved cultivation practices. These advancements have contributed to better yields despite the overall decrease in area and production. Similar research findings have been reported by Dwivedi *et al.*, 2024, and Kumar *et al.*, 2022, in their studies on small millets.

Table 4. Growth rate of area, production and productivity of small millets in India

Year	Area (Thousand Hectares)	Production (Thousand Tonnes)	Productivity (Thousand Tonnes/ Thousand Hectare)
2000-2001	1424	587	0.41
2001-2002	1311	577	0.44
2002-2003	1201	459	0.38
2003-2004	1191	564	0.47
2004-2005	1101	478	0.43
2005-2006	1064	472	0.44
2006-2007	1010	480	0.47
2007-2008	1039	551	0.53
2008-2009	905	445	0.49
2009-2010	831	382	0.45
2010-2011	800	442	0.55
2011-2012	798	452	0.56
2012-2013	754	436	0.57
2013-2014	682	430	0.63
2014-2015	590	386	0.65
2015-2016	650	391	0.60
2016-2017	619	442	0.71
2017-2018	546	439	0.80
2018-2019	454	333	0.73
2019-2020	458	371	0.81
2020-2021	444	347	0.78
2021-2022	429	367	0.85
2022-2023	-	384	-
Mean	831.86	444.13	0.57
Standard Deviation	300.50	72.11	0.14
CV	36.12	16.23	25.12
CAGR(%)	-5.6*** (-0.002)	-2.1*** (-0.003)	3.7*** (-0.002)
R^2	0.98	0.71	0.92
Instability	7.22	11.36	10.55

*** ,**,*** Denotes significance at 0.01,0.05,0.001 levels of probability**

Table 5. Growth rate of area, production and productivity of Bajra in India

Year	Area (Thousand Hectares)	Production (Thousand Tonnes)	Productivity (Thousand Tonnes/Thousand Hectare)
2000-2001	9829	6759	0.68
2001-2002	9529	8284	0.86
2002-2003	7827	4776	0.61
2003-2004	10612	12109	1.14
2004-2005	9233	7931	0.85
2005-2006	9581	7684	0.8
2006-2007	9508	8424	0.88
2007-2008	9571	9970	1.04
2008-2009	8753	8887	1.01
2009-2010	8904	6506	0.73
2010-2011	9612	10370	1.07
2011-2012	8777	10276	1.17
2012-2013	7297	8742	1.19
2013-2014	7811	9250	1.18
2014-2015	7318	9184	1.25
2015-2016	7129	8067	1.13
2016-2017	7459	9730	1.3
2017-2018	7481	9209	1.23
2018-2019	7105	8664	1.21
2019-2020	7543	10363	1.37
2020-2021	7652	10863	1.41
2021-2022	6841	9781	1.42
2022-2023	-	11431	-
Mean	8426	9011.34	1.06
Standard Deviation	2006.16	1658.25	0.23
CV	23.80916	18.409	22.24
CAGR(%)	-1.7*** (-0.003)	1.6** (-0.006)	3.2*** (-0.005)
R^2	0.66	0.50	0.70
Instability	23.09	12.88	6.672

*** ,**,*** Denotes significance at 0.01,0.05,0.001 levels of probability**

From 2000-01 to 2022-23, India's bajra cultivation revealed notable trends. The area under cultivation initially was 9,829 thousand hectares in 2000-01, peaked at 10,612 thousand hectares in 2003-04, and then decreased to 6,841 thousand hectares by 2021-22. During this period, production fluctuated, reached its highest point at 12,109 thousand tonnes in 2003-04, and recorded 11,431 thousand tonnes in 2022-23. Productivity, however, showed a steady improvement, rising from 0.68 to 1.42 thousand tonnes per thousand hectares. The compound annual growth rates (CAGR) demonstrate that while the area under cultivation declined at a rate of -1.7 per cent per annum, production and productivity grew at rates of 1.6 per cent and 3.2 per cent per annum, respectively. The coefficient of variation (CV) for area, production and productivity was 23.81 per cent, 18.41 per cent, and 22.24 per cent, respectively, reflecting substantial variability. Instability indices further highlighted this variability, with values of 23.09 per cent for area, 12.88 per cent for production, and 6.67 per cent for productivity. The greatest instability was observed in the area under cultivation. This data reflects a trend where increased productivity has compensated for a reduction in cultivated area, leading to overall growth in bajra production efficiency.

Table 6. Growth rate of area, production and productivity of Jowar in India

Year	Area	Production	Productivity
	(Thousand Hectares)	(Thousand Tonnes)	(Thousand Tonnes/ Thousand Hectare)
2000-2001	9856	7529	0.76
2001-2002	9795	7557	0.77
2002-2003	9300	7012	0.75
2003-2004	9331	6681	0.71
2004-2005	9092	7244	0.79
2005-2006	8667	7630	0.88
2006-2007	8473	7151	0.84
2007-2008	7764	7926	1.02
2008-2009	7531	7246	0.96
2009-2010	7787	6698	0.86
2010-2011	7382	7003	0.94
2011-2012	6245	5979	0.95
2012-2013	6214	5282	0.85
2013-2014	5793	5542	0.95
2014-2015	6161	5445	0.88
2015-2016	6077	4238	0.69
2016-2017	5624	4568	0.81
2017-2018	5024	4803	0.95
2018-2019	4093	3475	0.84
2019-2020	4824	4772	0.98
2020-2021	4378	4812	1.09
2021-2022	3801	4151	1.09
Mean	6964.18	6033.81	0.88
Standard Deviation	1926.2	1360.1	0.11
CV	27.65	22.54	12.85
CAGR(%)	-4.3*** (-0.002)	-3.2*** (-0.004)	1.1* (-0.004)
R^2	0.95	0.78	0.32
Instability	8.84	13.52	10.78

*** ,**,*** Denotes significance at 0.01,0.05,0.001 levels of probability**

The analysis of jowar cultivation, production, and productivity in India from 2000-01 to 2021-22 reveals significant trends. The area dedicated to jowar cultivation has sharply declined from 9,856 thousand hectares to 3,801 thousand hectares, reflecting a Compound Annual Growth Rate (CAGR) of -4.3 per cent. This substantial reduction indicates a shift away from jowar, likely driven by changes in agricultural practices, market demands and government policies. Alongside this decrease in area, jowar production has also fallen by -3.2 per cent over the same period, suggesting a reduced emphasis on jowar as a major crop. Despite these declines in both cultivation area and production, there has been a positive trend in jowar productivity. Productivity has increased from 0.76 thousand tonnes per thousand hectares to 0.85 thousand

Table 7. Growth rate of area, production and productivity of Ragi in India

Year	Area	Production	Productivity
	(Thousand Hectares)	(Thousand Tonnes)	(Thousand Tonnes/ Thousand Hectare)
2000-2001	1759	2732	1.55
2001-2002	1647	2375	1.44
2002-2003	1415	1316	0.93
2003-2004	1666	1966	1.18
2004-2005	1553	2432	1.56
2005-2006	1534	2354	1.53
2006-2007	1177	1444	1.22
2007-2008	1387	2152	1.55
2008-2009	1381	2040	1.47
2009-2010	1268	1888	1.48
2010-2011	1286	2193	1.7
2011-2012	1176	1929	1.64
2012-2013	1131	1574	1.39
2013-2014	1194	1983	1.66
2014-2015	1208	2061	1.7
2015-2016	1138	1822	1.6
2016-2017	1016	1385	1.36
2017-2018	1194	1985	1.66
2018-2019	891	1239	1.39
2019-2020	1004	1755	1.74
2020-2021	1159	1998	1.72
2021-2022	1218	1701	1.39
2022-2023	-	1691	-
Mean	1291	1913.696	1.49
Standard Deviation	227.72	375.02	0.2
CV	17.63904	19.59664	13.4
CAGR(%)	-2.2*** (-0.003)	-1.3*** (-0.006)	1*** (-0.005)
R^2	0.70	0.40	0.45
Instability	12.86	19.19	12.19

,**, Denotes significance at 0.01, 0.05, 0.001 levels of probability**

tonnes per thousand hectares, with a CAGR of 1.1 per cent. This increase in productivity highlights successful adoption of improved seed varieties and advancements in agricultural techniques, which have helped to offset some of the adverse effects of declining cultivation and production. A study conducted by Charankumar *et al.* (2024) reported similar findings, further supporting the observed trends in bajra cultivation.

India experienced a notable decline in both ragi production and cultivation area from 2000-01 to 2022-23, as detailed in Table-7. The annual growth rates for production and area were -1.3 per cent and -2.2 per cent, respectively. Despite this decline, ragi productivity showed a modest increase of 1.00 per cent. This positive trend is attributed to favorable market prices and ragi's adaptability to dry regions, which have encouraged farmers to grow more ragi. The instability indices for area, production, and productivity were 12.86 per cent, 19.19 per cent, and 12.19 per cent, respectively. The reduction in cultivation area is primarily due to the shift towards more competitive crops like paddy, pulses, and vegetables, and the classification of ragi as a lower-value crop compared to other millets. Similar results were found by Amin *et al.*, 2017; Bellundagi *et al.*, 2016; Vennila and Murthy, 2021 concluding that most of the cultivated land was dominated by cereal crops.

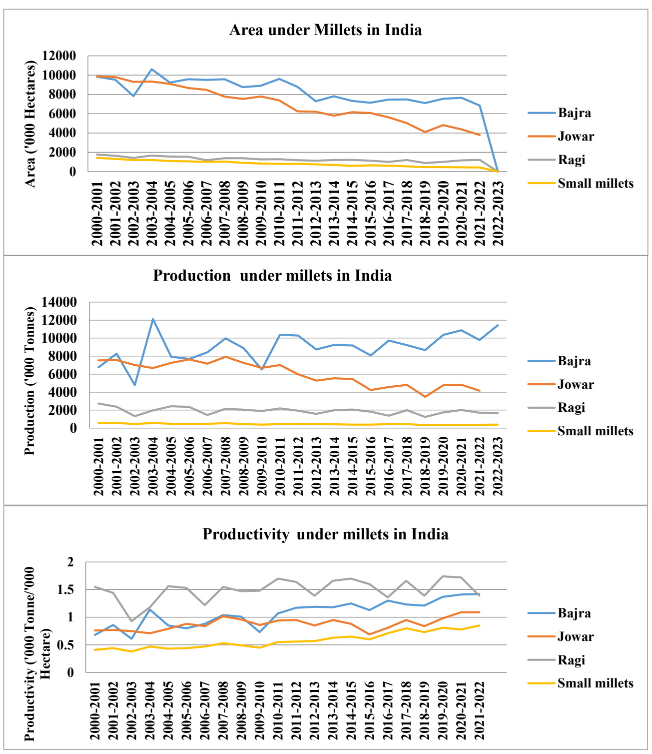

Fig. .1 Trends of area, production and productivity of millets in India

3.2 Stability Analysis of Indian Millet Export

Markov chain analysis

The changing scenario of millet exports from India was analyzed using the Traditional Probability Matrix (TPM), which utilized actual export data to various importing countries. This matrix elucidates the shifting directions of trade among millet-importing countries. Markov chain analysis was applied to data spanning from 2013-14 to 2022-23, allowing for predictions from 2023-24 to 2027-28. The Transitional Probability Matrix, as shown in Table 9 and Fig. 2, provides a comprehensive overview of the changes in the direction of millet exports from India during the study period. The row elements in the transitional probability matrix indicate the extent of trade loss due to competition from other countries. The column elements reflect the probability of gaining trade volume from competing countries. The diagonal elements represent the likelihood of retaining the previous year's trade volume for each respective country. The major eight importers of millets from India include the UAE, Saudi Arabia, Nepal, Bangladesh, Japan, Libya, Germany and the USA. Among these key importers, Bangladesh stands out as the most stable impoter, consistently retaining 96.85 per cent of its share. Following closely is UAE, maintaining 51.29 per cent of its share, while Saudi Arabia and Nepal exhibit moderate stability with retention rates of 36.73 per cent and 36.61 per cent respectively. However, Germany showed relatively lower probability retention at 21.81 per cent. The analysis further highlights significant shifts in market shares. Japan and USA experience a complete loss of share, with Saudi Arabia and Nepal emerging as the recipients. Nepal, in particular, loses 56.02 per cent of its share to UAE, while Germany faces a reduction of 34.27 per cent and 43.92 per cent in its shares to Nepal and USA respectively. These findings underscore the dynamic nature of millet exports from India, with some importers demonstrating resilience while others experience substantial shifts in their market presence.

Table 10 presents a comparison between actual millet exports and predicted values from India to major importing nations from 2013-14 to 2022-23. Market share projections for millets to major importing countries were computed up to 2027-28 using transitional probability matrix, providing a detailed forecast of future trends. Throughout the examined period, there is a discernible upward trend in millet

Table 9. Transitional probability matrix of millet exports from India during 2013-14 to 2022-23

Export Destination	UAE	Saudi Arabia	Nepal	Bangladesh	Japan	U S A	Germany	Libya
UAE	0.5129	0.2726	0.0024	0.0424	0.0712	0.0000	0.0000	0.0985
Saudi Arab	0.0908	0.3673	0.1370	0.0000	0.1890	0.0649	0.0986	0.0524
Nepal	0.5602	0.0000	0.3661	0.0000	0.0000	0.0000	0.0000	0.0736
Bangladesh	0.0000	0.0000	0.0209	0.9685	0.0000	0.0107	0.0000	0.0000
Japan	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U S A	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Germany	0.0000	0.0000	0.3427	0.0000	0.0000	0.4392	0.2181	0.0000
Libya	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000

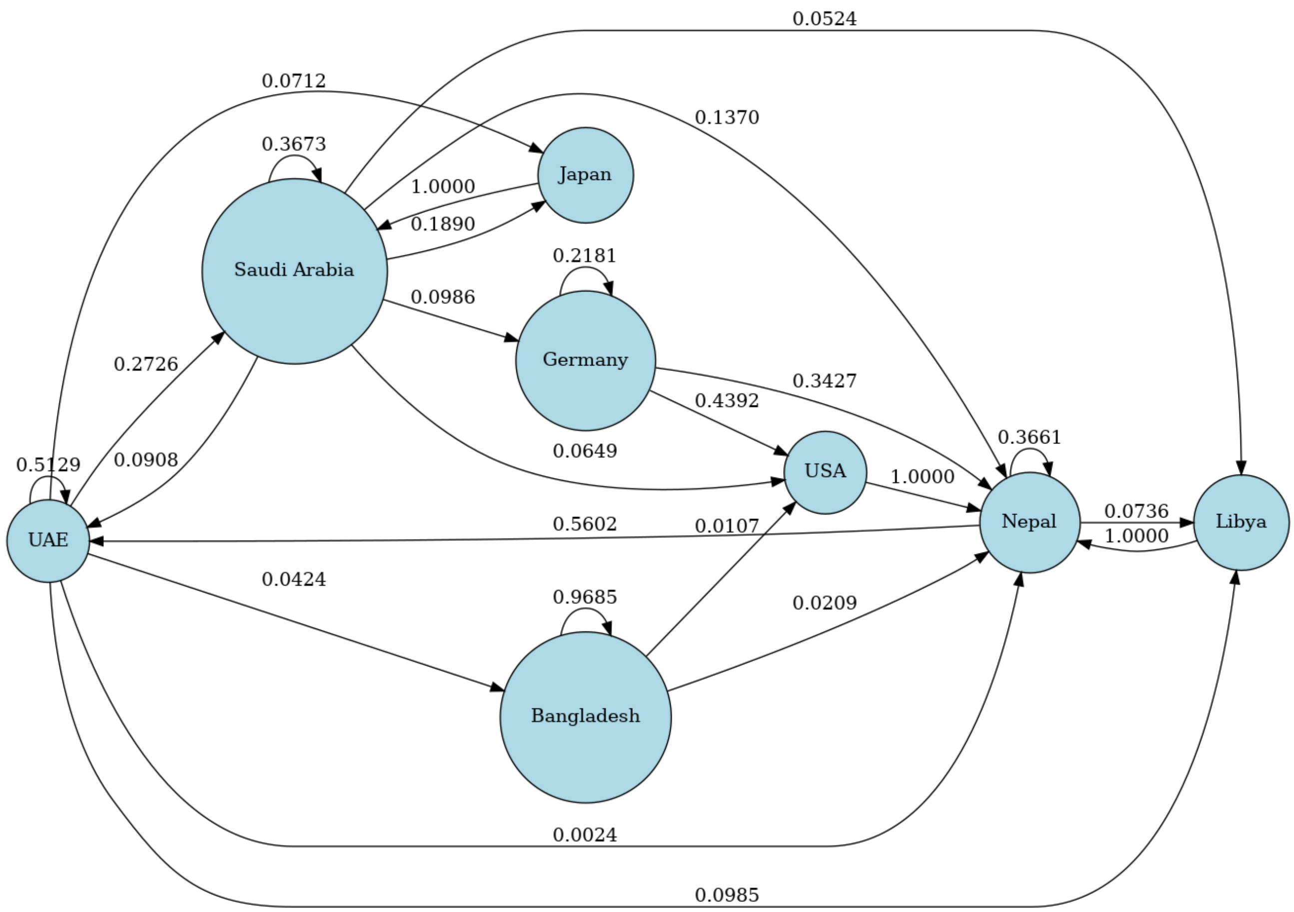

Fig. 2. Graphical representation of the Transitional Probability Matrix for Millet Exports from India (2013–14 to 2022–23)

exports to most countries, underscoring the growing global demand for Indian millets. UAE consistently emerges as a prominent importer, followed closely by Saudi Arabia and Nepal, with Bangladesh exhibiting a steady increase in imports over the years. Germany's imports, though variable, generally demonstrate an upward trajectory, while Japan and the USA display fluctuating patterns, indicative of market dynamics. Notably, Libya emerges as a noteworthy importer in later years, signaling potential diversification in India's millet export destinations. The predicted values suggest a continuation of these trends, with most importing countries projected to sustain or increase their millet imports from India. UAE, Saudi Arabia, and Nepal are anticipated to maintain their positions as significant importers, with steady growth expected in their imports. Bangladesh, in particular, shows promising growth prospects, indicating a strengthening trade relationship with India in the millet market. While Japan and the USA are projected to maintain their import levels with

Table 10. Actual and Predicted quantity of millet export from India to its trading countries **(Metric Tonnes)**

Year	UAE		Saudi Arabia		Nepal		Bangladesh		Japan		U S A		Germany		Libya	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P
2013-14	17087.68	18091.41	14332.34	16130.21	14325.14	12266.89	237.11	954.66	6208.38	3924.65	1750.40	1577.02	1466.40	1732.49	2759.63	3489.74
2014-15	21599.83	19256.04	18451.43	19349.61	11605.09	12336.80	806.50	1697.55	6684.97	5024.20	1382.39	1471.76	604.08	1950.43	3902.00	3949.91
2015-16	14259.16	16079.42	22924.26	18772.20	11930.69	11542.56	1601.42	2155.94	6465.65	5346.74	1244.04	1720.38	489.74	2366.36	2554.00	3485.37
2016-17	17037.00	17393.43	19885.46	17420.36	12225.48	13913.88	2229.32	2881.90	5472.75	4970.32	1820.24	2415.20	2505.68	2506.49	3947.00	3621.34
2017-18	16523.86	17082.75	14545.03	15800.06	13006.41	13398.23	3231.65	3830.85	5953.80	3924.70	2283.03	2140.27	2644.76	2010.44	3347.00	3348.24
2018-19	16875.77	19203.61	19208.90	17902.21	15713.98	16406.95	3632.47	4233.96	6247.04	4831.00	2721.00	2400.08	2537.22	2446.68	4315.00	3826.88
2019-20	16972.99	18888.52	13291.76	13797.02	16021.69	14467.24	4299.17	4883.76	4288.64	3719.87	2416.26	2065.31	2633.46	1884.44	3331.00	3548.81
2020-21	27862.74	28726.65	20349.70	20551.86	22468.43	20182.02	6421.93	7401.63	5482.88	5828.76	2804.64	2573.19	2695.09	2593.56	5238.63	5466.37
2021-22	33264.65	30832.72	20143.03	22572.25	21315.41	18908.67	7810.52	8975.64	6106.73	6174.29	3272.18	2593.69	2738.63	2582.68	3891.50	5902.73
2022-23	34017.21	30890.38	24518.69	24865.93	20020.01	20640.54	12629.45	13674.53	6588.15	7054.66	2105.97	2608.85	2009.52	2854.96	6811.77	6110.93
2023-24	-	29665.71	-	24607.67	-	21021.51	-	14553.98	-	6897.66	-	3013.85	-	3073.57	-	5866.83
2024-25	-	29227.52	-	24021.99	-	21376.90	-	15353.74	-	6761.67	-	3102.46	-	3095.79	-	5760.71
2025-26	-	29148.67	-	23551.45	-	21432.54	-	16109.68	-	6619.81	-	3082.72	-	3042.91	-	5713.01
2026-27	-	29096.67	-	23215.28	-	21318.46	-	16838.44	-	6525.29	-	3037.00	-	2985.00	-	5684.66
2027-28	-	28975.56	-	22983.11	-	21151.81	-	17542.01	-	6458.06	-	2997.50	-	2939.23	-	5653.51

A-Actual export, P-Predicted export by TPM approach.

some fluctuations, Germany's imports are forecasted to gradually increase. Overall, these findings show a positive picture for India's millet export industry, with sustained growth and expanding market opportunities on the horizon.

4. CONCLUSION

Millets have gained prominence as a vital agricultural commodity in India, driven by national and global initiatives. The trend analysis conducted in this study revealed that, while global millet cultivation has declined, Asia remains a major producer, and Africa has shown growth in both area and production. In India, despite a decrease in the cultivation area for some millet varieties, productivity has increased. This highlights the critical need for educating farmers on sustainable practices to prevent further declines in cultivation. Promoting value addition and raising consumer awareness of the nutritional benefits of millets are essential steps to meet growing domestic and global demand. Furthermore, this study provided key insights into India's export dynamics, identifying Bangladesh, UAE, and Nepal as consistent importers, with projections indicating stable or increasing demand. However, the study underscores the necessity of diversifying export markets to reduce dependence on a few key buyers. The Markov chain analysis offers strategic foresight into future trade trends, aiding in strengthening India's competitive position in the global millet market. Overall, the findings contribute to shaping effective policies that support millet cultivation, expand export opportunities and secure long-term sustainability in India's agricultural landscape.

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