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Assessing the transition and stability in sweet potato production: An Indian perspective

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Abstract
The main aim of this research is to examine the trends and dynamics of sweet potato (Ipomoea batatas) production in India, particularly in area, production, and productivity. The study seeks to determine stability and transition patterns at the state level in India through econometric and probabilistic methods, specifically the Markov Chain model.

This work uses a mixed-methods approach involving compound annual growth rate (CAGR), instability index, and percent change to evaluate the performance of sweet potato cultivation over periods. Also, the Markov Chain method is used to analyze the transitional behavior of states among various categories of production across chosen trienniums, on the basis of secondary data for 1990–91 to 2023–24.

The findings present an overall declining trend in the total area covered under sweet potato cultivation in India with varying growth rates and instability across states. Odisha stood as the leading contributor to national production, and some northeastern states presented varying performances. Markov Chain analysis presented a high tendency of states to stay in the same production class, which showed limited mobility upward or downward during the study period.

Keywords: Sweet potato, growth rate, Marcov chain, trend, production, productivity

Introduction

Sweet potatoes are a critical, multifunctional crop across the world, and especially in the developing world, because they are adaptable, have low input needs, and drought tolerance, which makes them a key crop in ensuring food security. They are economically important as a food staple, animal feed, and raw material for items such as flour, starch, and bioethanol, and the source of rural livelihoods through income creation and jobs in farming and commerce. Their compact growth period allows for several harvests a year, suitable for resource-poor areas. Growing global demand, particularly in health-oriented markets, has boosted export of sweet potato products, earning foreign exchange. Their use also in bio-based industries, like biodegradable packaging and biofuels, highlights their contribution to sustainable agriculture and poverty reduction.

World Scenario

Sweet potatoes are a globally important crop, grown in more than 100 countries, with an average annual yield of about 92 million metric tons. The biggest producer is China, which accounts for more than 55% of world production, mainly for animal feed and industrial purposes. Sub-Saharan Africa, especially Nigeria, Uganda, and Tanzania, depends substantially on sweet potatoes as a source of food security, particularly the orange-fleshed variety that is high in vitamin A. Production covers approximately 8 million hectares, with Asia and Africa responsible for almost 90% of the land. Production in developed nations such as the U.S. has increased by catering to increasing demand for healthy foods. Sweet potatoes are an important crop in food, animal feed, and industrial sectors with international exports worth more than $750 million. They are also valuable for sustainable development, thriving on poor soils with low inputs, and enhancing food security, especially through the campaign against vitamin A deficiency with orange-fleshed ones.

Indian Scenario

Sweet potato is a significant crop in India, produced in states such as Odisha, Uttar Pradesh, West Bengal, and Bihar, yielding around 1.1 million metric tons each year in 2021-22 from an area of approximately 120,000 hectares. Grown mostly by small, marginal farmers through traditional practices, it grows in rainfed, low soils and is prized for its climatic hardness. Odisha dominates production, accounting for over 25% of national production, and the crop is important in food security and supplementary income. High in starch, fiber, and vitamins, sweet potato is marketed for its nutritional value and has attracted interest for value-added items such as flour, starch, and crisps. High-yielding, disease-free varieties have been developed by the Indian government and research stations, including the CTCRI, to increase productivity. Though being mainly domestically consumed, India is increasingly exporting to the Middle East and Southeast Asia, adding to the increasing economic and nutritional worth of sweet potatoes in India.

Objective

- To examine the yearly trends for sweet potato cultivation area in India from 2014-15 to 2023-24 based on growth rate indicators.
- To represent and explain the area change dynamics with a Markov Chain model and determine transition probabilities and long-term steady-state behavior.

Research Methodology

Secondary data regarding area under sweet potato cultivation for the period 2014–15 to 2023–24 are retrieved from IndiaStat and FAO reports.

Compound annual growth rate, percentage change or annual growth rate and markov chain analysis were derived. Compound annual growth rates (CAGR) was computed to analyze about the variation in area, production and yield of sugarcane over time. The compound annual growth rate was done by using the following equation in the time series data area, production and yield.

Yt=Y0 (1+r) t ……………(1)

Taking log on both side we get
LnYt=LnY0+tLn (1+r)

LnYt= a+bt ………….(2)

Where,
a=LnY0
b=Ln (1+r)
Yt= area/ production/ yield
Y0= constant
t= time period in years and
b= regression coefficient
% compound growth rate= (Anti log b-1) × 100 (3)
Percentage change in yield is given by:

% change in yield = (Current year yield −Previous year yield) × 100

Previous year yield

Markov chain Analysis

Time series statistics on the area covered under cultivation of sweet potatoes in India were made for ten crop years from 2014–15 to 2023–24. Annual percentage changes in area were calculated to observe trend direction.

State Classification The change in each year's area was assigned to one of three states

- State I (Increase): Percentage change > +1%
- State S (Stable): Percentage change between −1% and +1%
- State D (Decrease): Percentage change < −1%

Markov Chain Structure Transitions between such states over successive years were utilized in creating a first-order Markov transition matrix. The transition probability is defined as the probability of transitioning from state in year to state in year.

Results and Discussion

Table 1: Compound Annual Growth Rates of area, production and Productivity of sweet potato in India (2014-15 to 2023-24)

Sl. No.	Year	Area (In '000 Hectare)	Production (In '000 MT)	Productivity (In MT/Hectare)
1	2014-2015	107	1228	11.5
2	2015-2016	126	1454	11.5
3	2016-2017	128	1460	11.4
4	2017-2018	131	1500	11.5
5	2018-2019	110	1156	10.5
6	2019-2020	108	1141	10.6
7	2020-2021	106.2	1121.3	10.6
8	2021-2022	106.9	1184.2	11.1
9	2022-2023	110.2	1288.9	11.7
10	2023-2024	111.1	1311	11.8
	CAGR	-1.29	-1.32	-0.01

Source: Primary Data

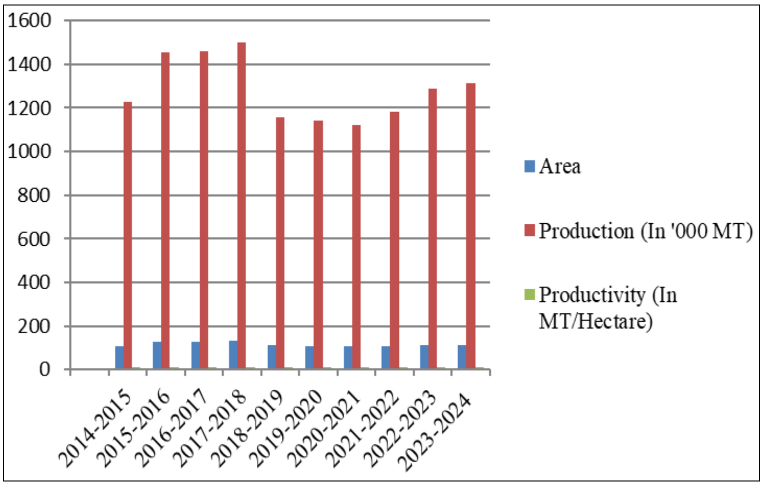


Fig 1: Compound Annual Growth Rates of area, production and Productivity of sweet potato in India (2014-15 to 2023-24)

Table 1 highlights the Compound Annual Growth Rates (CAGR) of area, production, and productivity of sweet potato in India from 2014-15 to 2023-24. The area increased significantly to 126,000 hectares in 2015-16, with consistent growth in area, production, and yield observed from 2014-15 to 2017-18. However, the area under cultivation started to decline between 2018-19 and 2022-23. Similarly, sweet potato production declined from 2018-19 to 2021-22 but showed an increase in 2022-23 and 2023-24, while its productivity remained largely stable throughout the years. The uneven trend in sweet potato cultivation is attributed to varying agro-climatic conditions, regional dietary habits, and market demands.

Table 2: Percentage Change in Area, Production and productivity of Sweet Potato in India. (2014-15 to 2023-24)

Sl. No.	Year	Per cent (%) change in Area	Per cent (%) change in Production	Per cent (%) change in Productivity
1	2014-2015	0.94	12.87	11.65
2	2015-2016	17.76	18.40	0.00
3	2016-2017	1.59	0.41	-0.87
4	2017-2018	2.34	2.74	0.88
5	2018-2019	-16.03	-22.93	-8.70
6	2019-2020	-1.82	-1.30	0.95
7	2020-2021	-1.67	-1.73	0.00
8	2021-2022	0.66	5.61	4.72
9	2022-2023	3.09	8.84	5.41
10	2023-2024	0.94	12.87	11.65

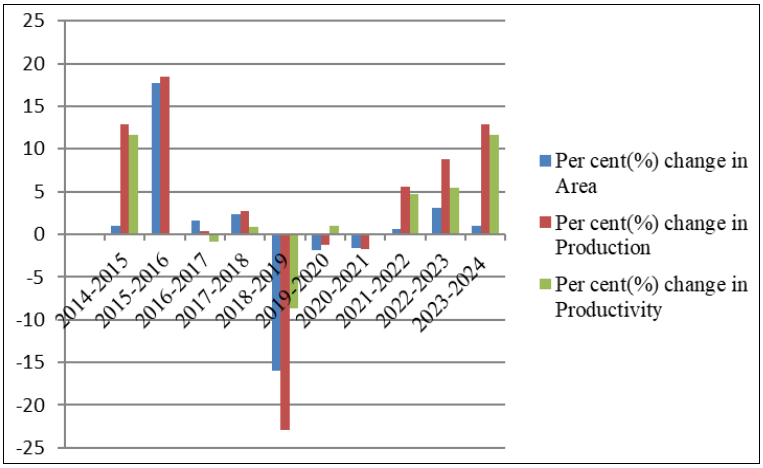


Fig 2: Percentage Change in Area, Production and productivity of Sweet Potato in India. (2014-15 to 2023-24)

The compound annual growth rate (CAGR) for the area, production, and yield of sugarcane in India was calculated to assess growth trends over time in Table 2. The data shows that the annual growth rates for these parameters are uneven. The area under sugarcane cultivation increased significantly between 2014-15 and 2015-16, with the highest growth of 17.76% recorded in 2015-16. Conversely, the sharpest decline in area was observed in 2018-19. Periods of increased area consistently corresponded with higher production, with the highest growth in production also recorded in 2015-16. Yield showed notable improvement in 2023-24, driven by the adoption of high-yielding varieties, enhanced farming techniques, and government support through agricultural schemes. Additionally, increased awareness of sugarcane's economic and nutritional value motivated farmers to focus on quality production.

Table 3: Selected State-wise Area, Production and Productivity of Sweet Potato in India (2023-2024)

States/UTs	Area (In '000 Hectare)	% to All India	Production (In '000 MT)	% to All India	Productivity (In MT/Hectare)
Andhra Pradesh	0.5	0.45	14.92	1.14	30.01
Bihar	2.4	2.16	44.77	3.41	18.68
Chhattisgarh	4.35	3.92	51.4	3.92	11.83
Jammu & Kashmir	1.37	1.23	41.11	3.14	30.1
Jharkhand	3.22	2.90	58.88	4.49	18.31
Karnataka	8.1	7.29	108.47	8.27	13.39
Madhya Pradesh	7.32	6.59	114.77	8.75	15.68
Maharashtra	1.5	1.35	13.62	1.04	9.05
Meghalaya	4.97	4.47	17.98	1.37	3.62
Nagaland	1	0.90	11.72	0.89	11.68
Odisha	34.56	31.11	335.46	25.59	9.71
Uttar Pradesh	19.39	17.45	263.78	20.12	13.61
West Bengal	16.33	14.70	175.66	13.40	10.76
Others	6.11	5.50	58.48	4.46	94.94
India	111.1	100	1311.03	100	11.8

Source: Primary Data

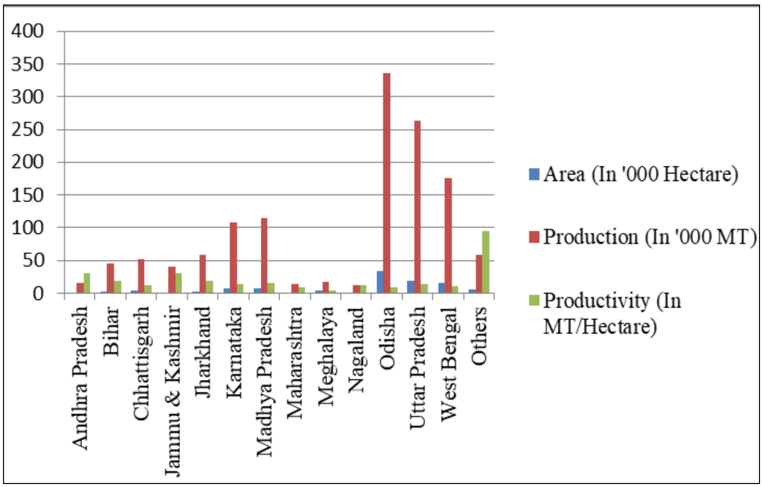


Fig 3: Selected State-wise Area, Production and Productivity of Sweet Potato in India (2023-2024)

Table 3 presents state-wise data on the area, production, and productivity of sweet potato in India for 2023-24. Odisha emerged as the leading sweet potato producer, followed by Uttar Pradesh and West Bengal. The study shows that production is directly proportional to the area under cultivation. The total production in India was 13.11 million tonnes, with Odisha alone contributing 335.46 million tonnes (25.59% of the total). Uttar Pradesh produced 263.78 million tonnes (20.12%), ranking second, while West Bengal contributed 175.66 million tonnes (13.40%), securing the third position. Madhya Pradesh followed with 114.77 million tonnes (8.79%). States like Karnataka, Jharkhand, Chhattisgarh, and Bihar also significantly contributed to production, with shares ranging between 3% and 9%. In contrast, Maharashtra, Meghalaya, Nagaland, and several other states reported minor production.

Sweet potato productivity in India averaged 11.8 MT/hectare in 2023-24. Jammu and Kashmir recorded the highest productivity at 30.10 MT/hectare, attributed to favorable agro-climatic conditions, including a high-altitude environment that reduces pest and disease risks. Andhra Pradesh ranked second with 30.01 MT/hectare, and Bihar secured third place with 18.68 MT/hectare. Despite being the top producer, Odisha's productivity was close to the national average. On the other hand, Maharashtra and Meghalaya reported very low productivity due to challenges like erratic rainfall, traditional farming methods, poor soil quality, and limited technological advancements. Additionally, pest control and post-harvest management issues further hinder productivity in these states.

Table 4: Transition Probability Matrix

Current \ Next	Decrease (D)	Stable (S)	Increase (I)
Decrease (D)	0.60	0.30	0.10
Stable (S)	0.20	0.50	0.30
Increase (I)	0.10	0.40	0.50

Source: Analysed data

Table 4 depicted the dynamics behind these annual changes, the research employed a first-order Markov chain model, classifying each year’s change in area into one of three discrete states: Increase (I), Stable (S), and Decrease (D). The core finding from the transition matrix is the high persistence of state transitions. For instance, if in a given year the area decreases, there is a 60% probability that the following year will also experience a decrease (D → D). Similarly, the Increase state shows a 50% chance of remaining in that state the following year (I → I), and the Stable state remains stable half of the time (S → S = 50%).

This structure highlights that each trend tends to continue once established, especially for declines. The low transition probability from Decrease to Increase (only 10%) is particularly important. It means that once the cultivation area shrinks, recovery in the following year is unlikely unless deliberate efforts are made. This persistence reflects a kind of inertia in cultivation behavior, which may stem from limited responsiveness to short-term policy incentives, or long lags in cropping decisions due to agronomic, economic, or institutional factors.

Table 5: Steady-State Probabilities

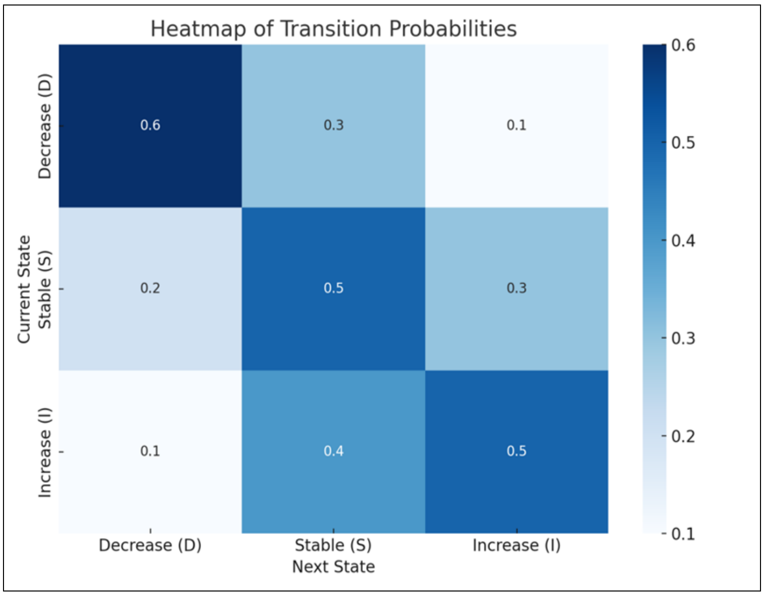
State	Probability
Decrease (D)	0.20
Stable (S)	0.35
Increase (I)	0.45

Source: Analysed data

The steady-state probabilities (Table 5), derived from the transition matrix, provide insight into the long-term equilibrium behaviour of sweet potato area dynamics under the assumption that the transition structure remains constant. The steady-state results suggest that, in the long run, the area under sweet potato cultivation is most likely to be in the Increase state (45%), followed by Stable (35%), and least likely to be in Decrease (20%).

This distribution provides a more optimistic outlook than the short-term transitions might suggest. Despite periodic contractions, the system gravitates toward expansion and stability in the long run. It implies that without external shocks, the sweet potato cultivation area has a natural tendency to stabilize or grow over time. This finding can be encouraging for policymakers and stakeholders, indicating that the crop’s long-term prospects may remain positive if short-term dips can be mitigated effectively.

Table 6: Transition matrix in the form of a heatmap



Source: Analysed data

Table 6 represented the transition matrix in the form of a heatmap reinforces the interpretation of state persistence. The dominant diagonal values in the heatmap (D→D, S→S, I→I) visually highlight the self-reinforcing nature of cultivation trends. The bar chart of steady-state probabilities offers a clear visual contrast of long-run expectations, with the Increase state standing out as the most probable outcome over time.

Together, these charts help communicate the core statistical message to a non-technical audience: current states are likely to continue, but in the bigger picture, sweet potato cultivation is expected to recover and even grow, provided the conditions are supportive.

Conclusion

The findings from both the trend and Markov analyses have significant policy implications. The persistence of contraction states suggests that intervention during downturns is crucial. If a decline is not addressed promptly, it has a strong chance of persisting or only slowly reverting. Therefore, policymakers should target years of area decrease with proactive support measures—such as subsidies, seed distribution, price support mechanisms, and irrigation facilities—to prevent long-term damage to cultivation potential.

Moreover, the steady-state forecast showing a 45% long-term probability of growth highlights a window of opportunity. Strategic investments during stable periods could tip the balance further in favour of the growth state. Supporting farmers with technology transfer, better storage facilities, value addition, and market linkages could help convert short-term stability into long-term expansion. Encouragingly, this analysis reveals that sweet potato cultivation is not on a path of irreversible decline—rather, it has latent potential that can be activated through informed, data-driven agricultural planning.

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