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An Economic Analysis of Changes in Cropping Pattern in Parbhani District of Maharashtra, India: A Markov Chain Approach

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation examines structural changes in the cropping pattern in Parbhani district of Maharashtra, utilizing secondary time-series data on crop areas from 2013-14 to 2022-23. By applying Markov Chain analysis, the study evaluates shifts in cropping pattern by analysing transitions in the area allocated to different crops over time to reveal significant trends through Transitional probability matrix (TPM). Soybean and jowar retained largest area shares. Hence, area under these crops were stable, while sugarcane and soybean emerged as major area gainers, often at the expense of wheat, maize, mung, and safflower. The findings highlight soybean and sugarcane's economic viability and adaptability to local conditions. This analysis underscores the importance of crop selection for economic resilience and sustainable agricultural practices in the region.

Keywords: Cropping pattern; structural changes; Markov chain analysis; Transitional probability matrix (TPM).

1. INTRODUCTION

Cropping pattern refers to adoption of particular type of crops by the farmers in a particular region. A change in cropping pattern implies a change in proportion of area under different crops. The cropping pattern plays a vital role in determining the level of agricultural production and reflects the agricultural economy of a region (Akhter & Acharya, 2015). The existing cropping patterns has witnessed reduced productivity due to shifting climatic patterns such as erratic and inadequate rainfall, along with diminishing water resources (Guiteras, 2007; Ardeshna & Shiynai, 2013). The long-term changes in the cropping pattern in a region could be due to the development of irrigation infrastructure, whereas the vagaries of nature including rainfall and other institutional factors could lead to short term fluctuations in the cropped area as well as productivity. This long term and short-term fluctuations could have implications on the economic returns to the farmers as well as on the environment (Amirthalingam & Devi, 2018). A diversified cropping pattern is often considered prudent strategy to mitigate risks and uncertainties in agriculture caused by climatic fluctuations and biological factors. The extent of irrigation significantly influenced the cropping pattern (Birthal et al., 2006). A dynamic change could have witnessed in agriculture sector in India, particularly during post- green revolution period. The present aims to analyze the dynamics of cropping pattern in Parbhani district over the years and to predict next three years cropping pattern in the district.

2. MATERIALS AND METHODS

Markov Chain Model: The direction of changes in cropping pattern was analyzed by using First order Markov Chain approach. The Lingo software was used for the purpose, transitional probabilities were computed based on a linear programming (LP) technique of cropland from 2013-14 to 2022-23. (Kammar & Basvaraja, 2012), used similar model to study the structural changes in cropping pattern in northern transitional zone of Karnataka. Different crops grown in Parbhani district were taken into account to determine the shift in cropping patterns. Markov Chain Analysis is the estimation of the transitional probability matrix 'P' whose elements, Pij indicate the probability of shifting area from one crop 'i' to another crop 'j' over time. The diagonal element Pij where i=j, measures the probability of a crop retaining its share. The average area shifted to a particular crop was considered to be a random variable which depends only on the area under past crop, which can be denoted algebraically as:

$$E_{jt} = \sum_{i=1}^{n} [\, Ei_{\,t-1} \,] P_{ij} + e_{jt}$$

Where,

E_{jt} = Area of the crop shifted towards the particular j^{th} crop in the year t
Ei_{t-1} = Area lost by i^{th} crop during the year t-1
P_{ij} = the probability the area lost will shift from i^{th} crop to j^{th} crop
e_{jt} = The error term which is statistically independent of Ei_{t-1}
n = the number of crops.

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

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

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

Based on the results of Markov chain analysis, the Projections of area under different crops for the period (2024-2026) was made for Parbhani district by using:

$$B_t = B_0 x T$$

$$B_{(t+1)} = B\,(t+i-1) \times T$$

Where,

B_0 = Area under the crop in base year;
$B_{(t+1)}$ = Area under the crop in next year (prediction);
T= Transitional probability matrix

3. RESULTS AND DISCUSSION

The results of Markov chain analysis is to find out shift in cropping pattern of area under different crops in Parbhani district of Maharashtra were presented in the form of a transitional probability matrix. The Markov chain analysis is a stochastic process that describes transitions from one state to another in a chain-like process. In this case, the "states" are the different crops and transition probability matrix represented the consistency of the crop's acreage share and the direction of change over time. As the diagonal elements approaches zero in the transitional probability matrix the crops become less and less stable as the diagonal components go closer to zero and as they approaches to one, it implies that they become more and more stable over a period of time. The components of the i^{th} row of the Transitional Probablity Matrix indicate the percentages of the i^{th} crop's acerage from the previous period that are expected to be lost to other crops in current period. The i^{th} column's element provides the percentage of the i^{th} crop's area that is projected to increase during the next duration. In the transitional probability matrix (TPM) rows showed the previous period acreage of the corresponding crop lost to other crops in the current period and columns indicate area gained from the other crops (Saritha et al., 2023).

According to the results of the transitional probability matrix (TPM) in Table 1 showed the shift in area of different crops in Parbhani district for the period 2013-14 to 2022-2023. Among all the crops studied, the acreage under other crops retained fairly highest probability to the extent of 0.95. The other crops in the district includes bajra, safflower, sesamum and linseed. The other crops gained (100%) of rice area. Retention refers to the proportion of area that continues to be used for the same crop over time. Among all the crops, total area under soybean has highest retention probability with 82 per cent followed by jowar with 69 per cent. High retention indicates stability in the cultivation of soybean and jowar crops.

Rice and maize lost 100 per cent of its area to other crops. Rice retained 0 per cent of its previous area and lost 100 per cent of its area to other crops (Satishkumar & Umesh, 2017). Rice was the most unstable crop as it lost 100 per cent of its area to other crops. Similar results was identified by Thakare et al. (2024). Maize lost its major share to wheat 61 per cent and 39 per cent to tur. A low retention indicates that the crop area is being reduced and farmers are abandoning the crop either due to economic reasons, changing market demands or climatic conditions. Wheat has retained to an extent of 19 per cent of its area and lost its area share to sugarcane crop with probability of 77 per cent and lost 4 per cent to tur crop. Wheat has gained area shares of 10 per cent a from jowar, 61 per cent from maize,12 per cent from soybean, 61 per cent area from safflower, 3 per cent from cotton and 25 per cent area from sugarcane. The acreage under Jowar had a retention probability of 69 per cent of its previous area the area cultivated with jowar in the previous year's remains to jowar in subsequent years, it lost 2 per cent to maize, 17 per cent tur and 2 per cent to safflower. Jowar gained 69 per cent area from tur and 8 per cent area from sugarcane.

Among pulses, tur retain its 23 per cent of its previous area and lost major share of its area to jowar 69 per cent and lost 7 per cent of its area to sugarcane. Mung retained 15 per cent of its previous area and lost major part of its area to soybean 85 per cent. Soybean retain 81 per cent of its previous area and lost only 12 per cent of its area to wheat. Among oilseeds safflower retain negligible area of 1 per cent of its previous area and lost most of its area to 61 per cent wheat and 38 per cent to other crops. Sunflower retained 47 per cent of its area and lost 13 per cent of its area to rice and lost major part of 40 per cent of its area to other crops (Shabnum et al., 2022).

Table 1. Transitional probability matrix for shift in cropping pattern for 2013-2023

Crops	Rice	Wheat	Jowar	Maize	Tur	Mung	Soybean	Safflower	Sunflower	Cotton	Sugarcane	Other crops
Rice	**0**	0	0	0	0	0	0	0	0	0	0	1
Wheat	0	**0.19**	0	0	0.04	0	0	0	0	0	0.77	0
Jowar	0	0.1	**0.69**	0.02	0.17	0	0	0.02	0	0	0	0
Maize	0	0.61	0	**0**	0.39	0	0	0	0	0	0	0
Tur	0	0	0.69	0.01	**0.23**	0	0	0	0	0	0.07	0
Mung	0	0	0	0	0	**0.15**	0.85	0	0	0	0	0
Soybean	0	0.12	0	0	0	0	**0.82**	0	0	0.06	0	0
Safflower	0	0.61	0	0	0	0	0	**0.01**	0	0	0	0.38
Sunflower	0.13	0	0	0	0	0	0	0	**0.47**	0	0	0.4
Cotton	0	0.03	0	0.01	0.06	0.05	0.07	0.05	0.07	**0.65**	0	0
Sugarcane	0	0.25	0.08	0.01	0.36	0	0	0	0	0	**0.29**	0
Others	0	0	0	0	0	0	0	0.05	0	0	0	**0.95**

Table 2. Projected area under different crops from 2024 to 2026

Year	Rice	Wheat	Jowar	Maize	Tur	Mung	Soybean	Safflower	Sunflower	Cotton	Sugarcane	Other crops
2024	0	669	982	50	566	121	2416	115	125.03	1350.5	426.89	13.43
	(0)	(9.8)	(14.4)	(0.7)	(8.3)	(1.7)	(35.4)	(1.6)	(1.8)	(19.7)	(6.2)	(0.1)
2025	17	763	1103	48	579	90.6	2176	92.83	150.97	1028.2	681.078	106.6
	(0)	(11)	(16.1)	(0.7)	(8.5)	(1.4)	(31.8)	(1.3)	(2.2)	(15.0)	(9.9)	(1.5)
2026	20	803	1217	51	677	68.7	1931	82.79	140.97	802.84	828.183	213.2
	(0)	(12)	(17.8)	(0.7)	(9.9)	(1.1)	(28.3)	(1.2)	(2.0)	(11.7)	(12.1)	(3.1)

Figures in the parenthesis indicates the percentage over total cropped area

Cotton retained its 65 per cent of its previous area and lost minor part of its area to wheat 3 per cent, maize 1 per cent, tur 6 per cent, mung 5 per cent, soybean 7 per cent, safflower 5 per cent and sunflower 7 per cent. Sugarcane retained 29 per cent of its previous area and lost its area to wheat 25 per cent, 36 per cent tur and 8 per cent of its area to jowar.

The changing rainfall affects the cropping pattern with the decrease in rainfall, the crops requiring more rainfall get affected and farmer will prefer to shift towards those crops which require less rainfall, resulting into changing cropping pattern. Crops like soybean and jowar have high retention area indicates farmers tend to grow these crops. These crops face less area loss. Crops like sugarcane and soybean have high area gain from other crops, showing that more farmers are switching to them, contributing to their increase in cultivation area. Crops like rice and maize shows significant area loss indicating farmers are moving away from these crops, possibly due to changes in profitability or climate challenges.

3.1 Area Projections of Different Crops in Parbhani District (2024-2026)

The area projections of different crops grown in Parbhani district was computed based on the transitional probability matrix and projections were made up to 2026 expected shifts in cultivated area for different crops over three – year period is shown in Table 2. Structural changes in the cropping pattern captured were fairly accurate, implying that the model used was reasonably efficient. If the present trend continues in the study area without any intervention of natural calamities, then the prediction of the cropping pattern holds good (Kammar & Basvaraja, 2012). The crops listed include rice, wheat, jowar, maize, tur, mung (green gram), soybean, safflower, cotton, sugarcane, cotton and other crops. The area projected for wheat increases from 669 ha in 2024 to 803 ha in 2026. Jowar also shows steady increase in its area from 982 ha in 2024 to 1217 ha in 2026.The area under maize remains relatively stable with 50 ha in 2024, 48 ha in 2025 and 51 ha in 2026. The area under tur and mung shows increasing and decreasing trend respectively.The projected area shows a decreasing trend in case of soybean 2416 ha in 2024, it decreases slightly to 2176 in 2025 and further to 1931 ha in 2026. Safflower area decreases from 115 ha in 2024 to 82 ha in 2026. The area under sunflower increases to 125 ha in 2024 to 140 ha in 2026. The area under cotton is decreasing from 19 per cent in 2024 to 11 per cent in 2026. The projected area of sugarcane increases steadily from 6 per cent in 2024 to 9 per cent in 2025 and then to 12 per cent in 2026. The area under other crops rises to 0.1 per cent to 3 per cent from 2024 to 2026.The decrease in certain crops like soybean and cotton may indicates shifts in land use, while others like jowar, sugarcane shows significant increase in its area. The projected area shows a decreasing trend in case of soybean and cotton and increasing trend in case of sugarcane, maize, tur while in case of mung, safflower and sunflower the projected area would remain relatively stable. Similar results was observed by Jalikatti & Poddar (2019).

4. CONCLUSIONS

The analysis of structural changes in cropping pattern changes in Parbhani district revealed that shifts of cropping pattern from 2013 to 2023 reveals significant changes in the agricultural landscape, soybean and jowar retained highest area from their previous years' area share with values of 0.82 and 0.69 respectively. They are highest gainer of area share. Stability in the area of soybean and jowar depends on availability of irrigation water and market profitability. Majority of area of tur, sugarcane and green gram were gained by jowar and soybean, farmers have continued to cultivate these crops over the years, indicating their economic viability and adaptability to local climatic conditions. The high retention suggests the stability of these crops in the cropping system. Transitioning to more profitable crops farmers are increasingly adopting crops like soybean and sugarcane, which promise higher financial returns and greater resilience in terms of market demand and environmental sustainability. There is sharp decline in traditional crops such as wheat and maize, despite their historical prominence in the region, signals a transformation in agricultural priorities. This trend points toward the need for policy intervention to address food security concerns. Although transitioning to more profitable crops like sugarcane and soybean may provide short-term benefits, a lack of diversification poses risks in the long run, such as susceptibility to pest outbreaks and reduced biodiversity.

Crops with significant area loss were rice and maize they lost 100 per cent of their previous year area share indicating that farmers have

entirely shifted away from rice cultivation, while maize has also shown complete loss of area to other crops. This shift is potentially due to declining suitability of cultivatable land, reduced profitability or changing in market demands. Sugarcane and soybean emerged as the most significant gainers in crop area. A large portion of wheat and maize cultivation areas shifted towards sugarcane, while mung and safflower area transitioned to soybean. These transitions reflect farmers responsiveness to market incentives or government policies promoting these crops, along with their relatively stable yields and resistance to adverse weather conditions. Crops such as wheat and cotton show moderate retention but significant area losses to sugarcane and other crops, implying that while some farmers grow these crops, a notable fraction are seeking alternatives, possibly driven by market fluctuations or environmental factors.

To analyze the future trends in the area under cultivation for different crops Transition Probability matrix (TPM) for Markov chain analysis was used. The study provides the information about the area under different crops to be evolved over the years, with projections focusing on major crops such as rice, wheat, jowar, maize, tur, mung, soybean, safflower, sunflower, cotton, sugarcane and other crops. The analysis was further projected for the years 2024, 2025 and 2026, showing both increase and decrease in the cultivated area for each crop. The projected area indicates a consistent increase in area under certain crops like wheat, jowar, maize, tur, sugarcane and other crops while soybean and cotton are expected to show a decline in crop area under cultivation. The study demonstrate that Markov chain analysis can be effectively used to forecast the area under different crops, providing policymakers and farmers with valuable data to make informative decision regarding future cropping pattern and land use.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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