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Dynamics of cropping pattern and future crop-area shifts in Latur district of Maharashtra: A Markov chain analysis

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ABSTRACT

The cropping pattern of a region changes over time in response to variations in rainfall, market conditions, resource availability, crop profitability, irrigation facilities and technological developments. The present study examines the dynamics of cropping pattern and future shifts in crop area in Latur district of Maharashtra using Markov Chain analysis. Secondary data on the area under major crops were used for the study period 2015–16 to 2024–25. The Markov Chain approach was employed to estimate the transitional probability matrix and identify the extent to which the area under individual crops was retained or shifted to other crops. The analysis revealed considerable movement of cultivated area among the major crops. Soybean recorded a retention probability of 0.72, followed by Jowar (0.65), while Tur and Gram each recorded 0.53. In contrast, Maize, Green Gram and the Others category showed negligible or zero retention, indicating greater movement of their cultivated area towards other crops. The major transitions included movement of Wheat area towards Gram and Soybean, Tur towards Soybean, and Sugarcane towards Soybean. Based on the estimated transition probabilities, crop-area projections were made for 2026–2028. The projections indicated a decline in the area under Jowar, Wheat, Maize, Green Gram, Gram, Sugarcane and Others, whereas Tur showed a comparatively higher projected area and Soybean showed a small increase followed by a decline. The findings demonstrate that the cropping structure of Latur district is dynamic, with soybean, Tur and Gram playing an important role in the changing crop composition. The study highlights the usefulness of Markov Chain analysis for understanding crop-area movements and supporting future agricultural planning.

Keywords: Cropping pattern, Markov Chain, Transitional probability, Crop-area shift, Soybean, Latur district, Crop projection

Introduction

Cropping pattern represents the manner in which cultivated land is distributed among different crops within a particular region and period. Changes in this distribution reflect the adjustments made by farmers in response to variations in rainfall, irrigation availability, market conditions, input costs, expected returns and other production-related factors. Since these factors change over time, the allocation of agricultural land among competing crops also tends to change. Such changes are important for understanding the direction of agricultural development and the economic conditions of farming households.

In regions such as Marathwada, where agriculture is exposed to variations in rainfall and water availability, farmers may modify their crop choices according to prevailing production conditions. Latur district has an important and diverse cropping system comprising crops such as soybean, jowar, tur, gram, wheat, maize and sugarcane. The relative importance of these crops has changed over time, resulting in movement of cultivated area from one crop to another. Differences in crop profitability, irrigation facilities, climatic conditions and market opportunities can contribute to these changes. Studies conducted in different parts of India have demonstrated that Markov Chain analysis is useful for examining such structural changes in the allocation of cultivated land.

Unlike a simple comparison of crop area between two years, the Markov Chain approach helps identify the direction and magnitude of area movement between competing crops. It also provides information on the probability of an individual crop retaining its cultivated area and the probability of its area shifting to other crops. Previous studies have applied this approach to analyse cropping-pattern changes in *Karnataka*, *Telangana* and *Maharashtra*. The present study aims to analyse the dynamics of cropping pattern in Latur district during 2015–16 to 2024–25 using Markov Chain analysis and to project the likely crop-area distribution for the subsequent three years.

Materials and methods

To examine the changes in the cropping pattern of Latur district during the period 2015 to 2025, the Markov Chain approach was employed. This method helps in understanding how the area allocated to different crops changes over time and the extent to which individual crops retain or lose their cultivated area.

In the Markov Chain framework, a transition probability matrix (P) was estimated, in which each element P_{ij} represents the probability that the area under crop i in one period shifts to crop j in the subsequent period. The diagonal elements, where $i = j$, indicate the proba-

bility of an individual crop retaining its area share over time. Thus, the transition matrix provides a measure of the stability and movement of area among the selected crops.

The average area allocated to a particular crop was treated as a variable influenced by the area under crops in the preceding period. The relationship can be expressed algebraically as follows:

Where,

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

$$E_{jt} =$$

Area of crop shifted towards the particular j th crop in the year t

$$E_{it-1} = \text{Area lost by } i\text{th crop during the year } t^{-1}$$

$$P_{ij} =$$

the probability the area lost will shift from i th crop to j th crop

$$e_{jt} = \text{The error term which is statistically independent of } E_{it-1}$$

n = the number of crops.

($c \times n$) matrix, have the following properties:

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

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

Based on results of Markov chain analysis, the Projections of area under different crops for the period (2015-2025) were made for all the canal Command areas by using:

$$B_t = B_0 \times T$$

$$B(t+1) = B(t+i-1) \times T$$

Where,

B_0 = Area under crop in base year;

$B(t+1)$ = Area under crop for next year (prediction);

T = Transitional probability matrix

Results and discussion

The Markov chain analysis was employed to examine the changes and movement of cultivated area among different crops in Latur district of Maharashtra during the period 2015–16 to 2024–25. The results of the analysis are presented through a transitional probability matrix, which explains the extent to which the area under a particular crop was retained or shifted to other crops during the study period. In the present analysis, the different crops were considered as individual states, while the transition probabilities represented the movement of cultivated area from one crop to another over successive years. Thus, the matrix provides an indication of the stability of individual crops as well as the direction of changes occurring in the cropping pattern of the district.

The diagonal elements of the transitional probability matrix represent the probability that the area under a crop in the previous period continues to remain under the same crop in the subsequent period. A higher diagonal value indicates greater stability or persistence of the crop in the cropping pattern, whereas a lower value indicates that a larger proportion of its cultivated area is likely to move towards other crops. The off-diagonal elements represent the movement of area from one crop to another. The values in each row therefore indicate how the area associated with a particular crop in the previous period was distributed among the same crop and other crops in the following

period. In this way, the transitional probability matrix helps to identify both crop retention and crop-to-crop shifts in the study area.

The results shown in Table 1 showed considerable variation in the retention probabilities of the selected crops. Among the crops included in the analysis, soybean recorded the highest retention probability of 0.72, indicating that about 72 per cent of the area under soybean remained under soybean in the subsequent period. Jowar followed with a retention probability of 0.65, while Tur and Gram each recorded a retention probability of 0.53. These relatively higher diagonal probabilities indicate comparatively greater continuity of these crops in the cropping pattern of Latur district. Wheat recorded a much lower retention probability of 0.10, suggesting greater movement of its cultivated area towards other crops. Maize, Green Gram and the Others category recorded a retention probability of 0, indicating that their area was completely transferred to other crops according to the estimated transition matrix.

In the case of Jowar, the retention probability was 0.65, indicating that a substantial proportion of its cultivated area continued under Jowar in the subsequent period. The remaining area was distributed among other crops, with transition probabilities of 0.02 to Maize, 0.10 to Green Gram, 0.14 to Tur and 0.05 to Others. These movements indicate that although Jowar maintained a relatively stable position in the cropping pattern, some of its cultivated area was shifted towards alternative crops. The movement of Jowar area towards Tur and Green Gram suggests changes in crop choice within the food and pulse crop groups.

For Wheat, only 0.10 of the cultivated area was retained under the same crop. A relatively large proportion of Wheat area shifted towards Gram (0.49), followed by Soybean (0.32) and Sugarcane (0.07). The low retention probability of Wheat indicates that its area was comparatively unstable during the study period. The movement towards Gram and Soybean indicates a change in the allocation of cultivated land among winter and kharif crops, while the transfer towards Sugarcane represents movement towards a commercial crop. These shifts may reflect changes in the relative attractiveness of crops over the study period, although the Markov analysis itself identifies the movement of area rather than the specific reasons for such changes.

The transition pattern of Maize was particularly distinctive. The retention probability of Maize was 0, while its transition probability towards Jowar was 1.00. This indicates that, within the estimated transition matrix, the entire area associated with Maize moved towards Jowar in the subsequent period. Similarly, Green Gram recorded no retention of its previous area. About 0.81 of its area shifted towards Jowar and 0.18 towards Maize. Thus, the estimated matrix indicates

comparatively low persistence of these crops in the cropping pattern and substantial movement of their cultivated area towards other crops. Soybean exhibited the highest degree of stability among all the crops considered. Its retention probability of 0.72 indicates that nearly three-fourths of its previous cultivated area continued under soybean. The remaining area showed relatively small movements towards Wheat (0.02), Tur (0.02), Gram (0.21) and Others (0.01). Among these transitions, the movement from Soybean towards Gram was comparatively larger. The high retention probability of Soybean indicates its established position in the cropping pattern of Latur district during the study period.

For Tur, the retention probability was 0.53, showing that more than half of its previous cultivated area remained under Tur. The remaining area shifted towards Jowar (0.06), Wheat (0.01), Soybean (0.31) and Sugarcane (0.07). The transition towards Soybean was the most prominent among the identified shifts. This indicates that Tur and Soybean had an important interaction in terms of changes in cultivated area during the study period. At the same time, the retention of more than half of the Tur area suggests that the crop maintained a comparatively stable position in the district's cropping pattern.

The Gram crop also recorded a retention probability of 0.53, indicating that 53 per cent of its previous area remained under Gram. The remaining area was mainly transferred towards Soybean (0.30) and Sugarcane (0.15). The relatively high retention of Gram indicates its continued importance, particularly within the rabi cropping system, while the movement towards Soybean shows that a portion of cultivated area was exchanged between these two crops over the study period.

In the case of Sugarcane, the transitional probability matrix indicates a retention probability of 0. Its cultivated area showed movement towards Jowar (0.04), Maize (0.01), Soybean (0.53), Tur (0.16) and Gram (0.24). Among these, the largest transition was towards Soybean, followed by Gram and Tur. Therefore, the estimated transition probabilities suggest that Sugarcane did not retain its previous area within the matrix and that its area was redistributed among several crops, particularly Soybean.

The Others category also showed no retention, with a diagonal probability of 0. Its area was largely transferred towards Tur (0.98), while a

small proportion of 0.01 moved towards Maize. This indicates that the crops grouped under the Others category had limited persistence in the estimated cropping pattern and that most of their area was subsequently associated with Tur. The transition probabilities therefore reveal considerable inter-crop movement even among crops occupying relatively smaller shares of the total cultivated area.

Overall, the transitional probability matrix demonstrates that the cropping pattern of Latur district was not static during 2015–16 to 2024–25. Soybean, Jowar, Tur and Gram recorded comparatively higher retention probabilities, indicating greater persistence of these crops in the cultivated area. In contrast, Maize, Green Gram, Sugarcane and Others recorded very low or zero retention probabilities, indicating greater movement of their cultivated area towards alternative crops. The results also show that the movement of area was not restricted to a particular crop group; rather, area was exchanged among cereals, pulses, oilseeds and commercial crops.

The observed changes may be viewed in the context of variations in rainfall, availability of irrigation, relative returns, input requirements, market conditions and farmers' crop-choice decisions. However, the Markov chain results specifically demonstrate the pattern and direction of area movement, and do not independently establish the causes of these changes. The relatively high retention of soybean and Jowar indicates their continued presence in the cropping system, whereas the lower retention of some other crops reflects comparatively greater changes in their cultivated area. Similar evidence of changes in crop-area allocation and varying degrees of crop stability has also been reported in earlier studies using Markov chain analysis, including *Thakare et al. (2024) [1]*.

Area projections of different crops in Latur district (2024–2026)

The area under major crops in Latur district was projected for the period 2026 to 2028 using the transitional probability matrix. The projected values are presented in *Table 2*. The results indicate that the area under Jowar declined from 415.25 in 2026 to 400.21 in 2027 and further to 379.59 in 2028. Similarly, the area under Wheat decreased from 120.42 to 119.74 and 119.30, respectively. The area under Maize also declined from 26.59 in 2026 to 21.74 in 2027 and 21.07 in 2028.

Table 1. Transitional probability matrix for shift in cropping pattern for 2015-2025

Crops	Jowar	Wheat	Maize	Green Gram	Soybean	Tur	Gram	Sugarcane	Others
Jowar	0.65	0	0.02	0.1	0	0.14	0	0	0.05
Wheat	0	0.1	0	0	0.32	0	0.49	0.07	0
Maize	1	0	0	0	0	0	0	0	0
Green Gram	0.81	0	0.18	0	0	0	0	0	0
Soybean	0	0.02	0	0	0.72	0.02	0.21	0	0.01
Tur	0.06	0.01	0	0	0.31	0.53	0	0.07	0
Gram	0	0	0	0	0.3	0	0.53	0.15	0
Sugarcane	0.04	0	0.01	0	0.53	0.16	0.24	0	0
Others	0	0	0.01	0	0	0.98	0	0	0

The projected area under Green Gram decreased from 41.84 in 2026 to 41.56 in 2027 and 40.02 in 2028. In the case of Soybean, the area increased slightly from 4977.51 in 2026 to 4995.54 in 2027, but declined to 4940.92 in 2028. The area under Tur increased from 541.81 in 2026 to 741.95 in 2027 and subsequently declined to 696.47 in 2028. The area under Gram decreased continuously from 2819.79 in 2026 to 2723.16 in 2027 and 2668.23 in 2028. Similarly, the projected area under Sugarcane declined from 518.31 in 2026 to 488.43 in 2027 and 468.79 in 2028. The area under Others also showed a declining trend from 70.92 in 2026 to 70.55 in 2027 and 69.97 in 2028. Overall, the projections indicate a declining trend in the area under most of the selected crops during 2026–2028, while Tur showed an overall increase, and Soybean exhibited a temporary increase in 2027 followed by a decline in 2028.

Table 2. Projected areas under different crops from 2026 to 2028

Crops	2026	2027	2028
Jowar	415.25	400.21	379.59
Wheat	120.42	119.74	119.3
Maize	26.59	21.74	21.07
Green Gram	41.84	41.56	40.02
Soybean	4977.51	4995.54	4940.92
Tur	814.7	741.95	696.47
Gram	2819.79	2723.16	2668.23
Sugarcane	518.31	488.43	468.79
Others	70.92	70.55	69.97

Conclusions

The Markov chain analysis of the cropping pattern in Latur district during 2015–16 to 2024–25 revealed noticeable changes in the allocation of cultivated area among different crops. The transitional probability matrix showed that Soybean, Jowar, Tur and Gram had comparatively higher retention probabilities of 0.72, 0.65, 0.53 and 0.53, respectively. The relatively high retention of these crops indicates that they continued to occupy an important position in the cropping system of the district. Among them, soybean showed the highest persistence, suggesting that a major proportion of its cultivated area remained under the same crop during the study period.

The analysis also revealed considerable movement of cultivated area from one crop to another. Wheat retained only 0.10 of its previous area, while substantial portions of its area shifted towards Gram (0.49), Soybean (0.32) and Sugarcane (0.07). Similarly, the entire estimated area under Maize shifted towards Jowar, as indicated by a transition probability of 1.00. Green Gram also showed complete non-retention, with its area mainly moving towards Jowar (0.81) and Maize (0.18). These results indicate that some crops experienced greater changes in their cultivated area compared with crops such as soybean and jowar.

Among the major crops, Soybean emerged as the most stable crop, retaining 72 per cent of its previous area. Its area also showed movements towards Gram, Wheat, Tur and the Others category, with the largest transition being towards Gram at 0.21. Jowar retained 65 per cent of its previous area, while some of its area moved towards Tur, Green Gram, Others and Maize. Tur and Gram each retained 53 per cent of their previous area, while a notable share of their area was transferred towards Soybean. These transitions indicate that the cropping system of Latur district has remained dynamic, with farmers re-allocating cultivated land among crops over successive periods.

The analysis further showed that Sugarcane did not retain its previous area in the estimated transition matrix, with its area moving mainly towards Soybean (0.53), Gram (0.24) and Tur (0.16). The Others category also recorded zero retention, with almost its entire area shifting towards Tur. Such movements demonstrate that the composition of cultivated area has undergone continuous adjustment during the study period. However, the Markov chain analysis identifies the direction and magnitude of these area transitions and does not by itself establish whether profitability, rainfall, irrigation, prices or other factors were responsible for the observed changes.

The projected crop areas for 2026 to 2028 further indicate that the future cropping pattern of Latur district is expected to remain concentrated in several major crops. Soybean is projected to occupy 4,977.51 ha in 2026, 4,995.54 ha in 2027 and 4,940.92 ha in 2028, maintaining the largest projected area among the crops considered. Gram is projected at 2,819.79, 2,723.16 and 2,668.23 ha, respectively, while Tur is projected at 814.70, 741.95 and 696.47 ha. Jowar is projected to decline gradually from 415.25 ha in 2026 to 379.59 ha in 2028.

The projections also indicate comparatively smaller cultivated areas for Wheat, Maize, Green Gram and Others during the projected period. Wheat is projected to remain around 120 ha, while Maize is projected at 26.59 ha in 2026 and 21.07 ha in 2028. Green Gram is projected to decline from 41.84 ha to 40.02 ha during the same period. Sugarcane is projected to decrease from 518.31 ha in 2026 to 468.79 ha in 2028. These projected values suggest that the future allocation of cultivated area may continue to differ across crops, with some crops maintaining comparatively larger areas and others showing gradual reductions.

Overall, the study demonstrates that the cropping pattern of Latur district has undergone substantial inter-crop movement during 2015–16

to 2024–25, rather than remaining unchanged over time. Soybean, Jowar, Tur and Gram exhibited comparatively greater stability, whereas Maize, Green Gram, Wheat and the Others category showed greater movement of cultivated area. The Markov chain approach was useful in identifying these retention patterns, crop-to-crop transitions and projected changes in cultivated area. The findings provide a quantitative indication of the direction in which the cropping pattern may evolve and can therefore serve as useful background information for crop planning, agricultural resource allocation and future land-use planning in Latur district.

References

1. Thakare AB, Shende NV, Tingre AS. Dynamics of cropping pattern in Maharashtra: Markov chain approach. *International Journal of Agriculture Extension and Social Development*. 2024;7(5):12–16.
2. Manwar MK, Nagpure SC. Structural changes in cropping pattern. *International Journal of Science, Environment and Technology*. 2017;6(5):2885–2892.
3. Jalikatti V, Poddar RS. An economic analysis of changing cropping pattern in Almatti Command Area of Karnataka, India. *International Journal of Current Microbiology and Applied Sciences*. 2019;8(10):1052–1059.
4. Wali VS, Poddar R, Mundinamani SM, Yenagi BS. An analysis of cropping pattern in Malaprabha Project Command Area. *International Journal of Agriculture Sciences*. 2019;11(2):7739–7742.
5. Devi DAR, Reddy RU, Madavi B, Ravi P, Sadvi P. Dynamics of cropping pattern in Karimnagar district of Telangana – A Markov chain approach. *Asian Journal of Agricultural Extension, Economics & Sociology*. 2019;37(4):1–5.
6. Reddy AR, Bante RP, Dhunde AD, Blaise D. Dynamics of cropping pattern in cotton growing districts of Maharashtra. *Economic Affairs*. 2021;66(4):563–568.
7. Shabnum PS, Venkatesh H, Sumesh KG. Dynamics of cropping pattern in North Karnataka district of Karnataka: A Markov chain approach. *The Pharma Innovation Journal*. 2022;11(12):163–166.
8. Saritha K, Baba A, Devi RDA, Babu KM. A probe into shifts in cropping pattern in Telangana State, India: A Markov chain approach. *International Journal of Environment and Climate Change*. 2023;13(11):1658–1661.
9. More SS, Khairnar KY. Dynamics of changing cropping pattern in Maharashtra—An economic analysis. *Current Advances in Agricultural Sciences*. 2023;15(Special Issue):480–484.
10. Felix KT, Ramappa KB. An economic analysis of crop diversification and dynamics of cropping pattern in Karnataka, India. *Humanities and Social Sciences Communications*. 2023;10(1):1–9.
11. Toppo S, Chavan RV, Bharati SV. Structural changes in cropping pattern of Parbhani district of Maharashtra. *Journal of Experimental Agriculture International*. 2024;46(11):483–489.

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