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A study on cropping pattern changes in Andhra Pradesh: A Markov chain approach

¹Tanuja N, ²K Nirmal Ravi Kumar, ³IVY Rama Rao, ⁴K Suseela and ⁵S Govinda Rao

¹Ph.D. Scholar, Department of Agricultural Economics, Agricultural College, ANGRAU, Bapatla, Andhra Pradesh, India

²Professor and University Head, Department of Agricultural Economics, Agricultural College, ANGRAU, Bapatla, Andhra Pradesh, India

³Principal Scientist, Department of Agricultural Economics, Agricultural College, ANGRAU, Bapatla, Andhra Pradesh, India

⁴Professor and Head, Department of Agricultural Economics, Agricultural College, ANGRAU, Bapatla, Andhra Pradesh, India

⁵Department of Statistics and Computer Applications, Agricultural College, ANGRAU, Naira, Andhra Pradesh, India

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Corresponding Author: Tanuja N

Abstract

Cropping pattern changes have important implications for agricultural sustainability, resource use efficiency and food security, particularly in agrarian states like Andhra Pradesh. The present study analysed structural changes in cropping patterns in Andhra Pradesh during 2013-14 to 2023-24 using secondary data obtained from Seasonal Crop Reports published by the Directorate of Economics and Statistics, Government of Andhra Pradesh. A Markov Chain approach was employed to estimate transition probabilities and examine crop retention and shifts among major crops during Kharif and Rabi seasons. The results revealed that paddy remained the most stable crop in both Kharif (91.8%) and Rabi (79.7%), indicating strong crop persistence. Pulses such as black gram and green gram showed moderate retention, while millets such as ragi, bajra and korra exhibited high instability and continuously lost area to dominant crops. The findings indicate increasing crop concentration towards paddy and pulses, highlighting the need for policy interventions that promote crop diversification, efficient water use and climate-resilient agriculture.

Keywords: Cropping pattern, Markov chain analysis, stochastic process and Transition probability matrix

Introduction

Agriculture is an important sector for economic growth in India, as more than 54.6 per cent of India's population makes their living from agriculture and related industries. Agriculture now accounts for 18.8% of the nation's GDP, down from 20% in 2003-04 to 18.8% in 2021-2022. The agricultural industry in our nation has seen a significant transformation due to the green revolution. In most regions, the shift in cropping patterns from the cultivation of low-value crops to high-value crops results from farmers' behaviour being influenced by technological advancements in crop types and other variables that increase agricultural yield (Reddy *et al.*, 2022) ^[4].

Andhra Pradesh is one of the major agricultural states in India, characterized by diverse agro-climatic conditions and cultivation of cereals, pulses, oilseeds and commercial crops. In recent years, expansion of irrigation facilities, changing market demand, government procurement policies and climate variability have significantly influenced crop choices in the state. The increasing concentration of cultivated area under paddy and declining area under traditional dryland crops have raised concerns regarding sustainability of water resources and crop diversification. Small and marginal farmers dominate the agriculture

industry. Their percentage of all holdings climbed from 65% in the 1970s to 81% in 2000, rendering these holdings unfeasible for both local and international competitiveness. Andhra Pradesh's economy depends mainly on agriculture, which accounts for 34.12 percent of the state's gross state domestic product (GSDP) at current prices and 29.51 percent at constant prices in 2020-21. The agricultural industry provides jobs and money for a sizable portion of the population. Around 66% of Andhra Pradesh's population resides in rural areas and relies on agriculture and the non-farm rural industry.

Globally, cropping patterns have undergone significant changes due to climate change, technological advancement, market integration and changing food consumption patterns. Many developing countries are witnessing a shift from traditional food crops towards high-value commercial crops, which has implications for food security, natural resource management and agricultural sustainability. In India, the Green Revolution significantly altered cropping patterns by encouraging cereal-intensive agriculture through irrigation expansion, input subsidies and price support policies. However, continuous dominance of water-intensive crops in several states has resulted in groundwater depletion, soil degradation and reduced crop diversification.

The cropping pattern of a region shows the percentage of land planted to various crops at a given period, as well as the crop rotation and acreage planted to various crops. A region's agricultural economy is reflected in its cropping pattern, which is a key factor in determining the amount of agricultural produce. Growing a variety of crops in a specific geographic location is known as a cropping pattern (Surendra, 2015) [5]. While the construction of irrigation infrastructure may be the cause of long-term changes in the cropping pattern in the study area, short-term fluctuations in the cropped area and productivity may result from natural events like rainfall and other institutional variables. These fluctuations, whether short-term or long-term, may affect both the environment and the farmer's financial gains. Agro-climatic parameters, or the physical conditions of the area, like soil, temperature, and rainfall distribution, greatly influence cropping patterns (Naidu, V. G *et al.*, 2022).

The concept of cropping pattern is dynamic since no cropping pattern can be considered ideal for a given location at any given time. It is mostly influenced by physical, cultural, and technical elements and shifts in time and place to satisfy needs. The shift in the cropping pattern over a specific period of time amply illustrates the changes in agricultural growth. The socioeconomic environment is the driving force behind these changes. In the majority of cases, the physical environment reduces the choice of certain crops altogether or by reducing their level. Cropping pattern changes are being made as a risk-reduction measure to increase cover crop profitability. The immediate goal is not to make a profit but to stabilize income from the crop sequence adopted in a year. The overall deciding factors regarding the total cropping pattern of the cultivators' holding as a whole also included aspects such as the availability of manure and irrigation facilities and the need of the household for food and fodder (Venkatesh, S. and Sen, C. 2018) [6].

The agricultural sector has undergone a dynamic transformation, especially in the years following the green revolution. The type of crops grown and the areas with less or more concentration of a crop are crucial information for developing an agricultural planning strategy for a region. Additionally, a planner should be aware of the degree of agriculture-related specialization or diversification in a given area. Cropping pattern and land use are both dynamic elements of an agricultural landscape that alter over time. Although several studies have examined cropping pattern dynamics at regional and district levels, limited studies have analysed post-bifurcation cropping transitions in Andhra Pradesh at the state level. Therefore, the present study aims to analyse structural changes in cropping patterns and identify crop retention and transition dynamics in Andhra Pradesh using Markov Chain analysis.

Materials and Methods

The study was based on secondary data collected from Seasonal Crop Reports published by the Directorate of Economics and Statistics, Government of Andhra Pradesh. Time series data on area under major crops for both Kharif and Rabi seasons were collected for the period from 2013-14 to 2023-24. Since Andhra Pradesh was bifurcated in 2014, the year 2013-14 was considered as the benchmark year and subsequent data relate to residual Andhra Pradesh.

A transition probability matrix was constructed using Lpsolve software for Markov chain analysis.

Markov chain analysis

A stochastic process can analyse a set of trials or experiments probabilistically. For a stochastic process, it is assumed that the movements (transitions) of objects from one state (possible outcome) to another are governed by a probabilistic mechanism. A finite Markov process is a stochastic process whereby the outcome of a given trial 't' ($t = 1, 2, \dots, T$) depends only on the outcome a preceding trial ($t-1$) and this dependence is the same at all stages of the sequence of trials (Lee *et al.*, 1965) [2]. Consistent with this definition, let the S_i represent i th state. The whole study is based on secondary data collected from the seasonal crop report of Andhra Pradesh published by the Directorate of Economics and Statistics (DES), Government of Andhra Pradesh. To analyze the cropping pattern, Time series data on the area under major crops grown in the AP state from 2013-14 to 2020-24 were collected for both Kharif and Rabi seasons. The transition probability matrix was constructed using Lpsolve software for Markov chain analysis.

or possible outcomes; $i = 1, 2, r$, W_{it} represent the probability that state S_i occurs on trial t or proportion observed in trial 't', in alternative outcome state i of a multinomial population based on sample size n , i.e. $P_t(S_{it})$. P_{ij} represent the transitional probability which denotes the probability that if for any time t the process is in state S_i , it moves on next trial to state S_j ,

$$\text{i.e. } P_r(S_j, t+1 / S_{it}) = P_{ij}$$

$P_r = (P_{ij})$ represent transitional probability matrix which denotes transitional probability for every pair of states ($i, j = 1, 2, r$) and has the following properties

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

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

The data for study are the proportion of area under crops. The proportion varies year after year due to factors such as weather, technology, pricing and institutional changes etc. It is plausible to infer that the cumulative influence of these individual systemic pressures approximates a stochastic process and that farmers' proclivity to switch crops varies depending on the crop condition. The process of cropping pattern change can be represented by a matrix P of first order transition probabilities. The element P_{ij} represents the likelihood d that a crop state i in one period will migrate to crop state j in the next period. The diagonal element P_{ii} measures the probability that the proportion share of i^{th} category of crop will be retained (Ardeshtna and Shiyani, 2013) [1].

Markov chain analysis is a dynamic programming technique used to solve a stochastic decision process with a finite number of states in order to examine how the cropping pattern varies.

The result of a particular trial " t " ($t = 1, 2, T$) is solely dependent on the result of a trial that came before it ($t-1$), and this dependency remains constant throughout the trial

sequence. The cropping pattern change process can be expressed as a matrix P of first-order transition probabilities. The element P_{ij} represents the likelihood that a crop state i in one period will change to a crop state j in the subsequent period. The diagonal element P_{ij} measures the probability that the proportion share of i th category of crop will be retained matrix form, it can be written as,

$$Y_j = X_j P_j + U_j$$

Where Y_j = proportions in cropping pattern j in time t ,
 X_j = the proportions in cropping pattern in time $t - 1$,
 P_j = unknown transition parameters to be estimated
and U_j = vectors of random disturbances.

The probability of retaining the particular crop and the shift was interpreted by studying the diagonal and off-diagonal elements of the transitional matrix. The transitional probability matrix pertaining to shift in cropping pattern in the study area were estimated and presented in the table.

The Markov chain model was used to investigate the dynamics of cropping patterns in Andhra Pradesh. Cropping pattern data were obtained from 2013-2014 to 2023-2024. LPSolve software is used to derive the transition probability matrix further diagram. The transitional probabilities for the shift in cropping pattern were computed based on the area under major crops between 2013-14 and 2023-24.

Results and Discussion

To understand the dynamics of cropping pattern changes in Andhra Pradesh, Markov chain analysis was employed to estimate the transition probabilities among major crops during the period 2013-14 to 2023-24. The analysis focuses on identifying crop retention, shifts in cultivated area and the stability of major crops across Kharif and Rabi seasons. Higher diagonal values indicate greater crop stability, while

lower values reflect frequent shifts in area allocation among crops. The results provide insights into the persistence of dominant crops and the movement of area from less stable crops to more remunerative alternatives (Rajini Devi *et. al.* (2019) [3].

Cropping pattern-kharif

The Transitional Probability Matrix in the table showed the shift in the area of different crops in Andhra Pradesh during the Kharif season. The high retention probability of paddy (91.8%) indicates strong dominance and stability in Kharif season, mainly due to assured irrigation, procurement support and stable market demand. The shift of area from minor millets and pulses towards paddy suggests increasing crop concentration. Paddy lost its minor share of 8.2 per cent to Green gram. Paddy had gained 77 per cent from kora, 4.2 per cent from Black gram and 3.4 per cent from the green gram. Black gram retained 49.8 per cent of its area and lost 30.8 per cent to paddy and 0.24 percent to ragi, 8.4 per cent to sesamum, 4.9 per cent to red gram, 4.2 per cent to green gram, 4 per cent to Bengal gram, 0.5 per cent to kora and 0.6 to other crops. Black gram grabbed 54 per cent from sesamum, 31.2 per cent from bajra, 34.9 per cent from maize, 3.4 per cent from green gram, and 11.1 per cent from Bengal gram. Red gram retained 66 per cent of its area. It lost 24 per cent to paddy, 5.1 per cent to maize, 3.4 percent to green gram, 3.9 per cent to other crops and 0.2 per cent to ragi. Red gram gained 68.6 per cent from bajra, 53.4 per cent from sunflower, 18.9 per cent from korra, 18 per cent from Jowar and 0.5 per cent Black gram. Ragi, Bajra, sesamum, Korra are unstable crops. Ragi lost 44 per cent to groundnut followed by paddy and red gram. Bajra lost its major share to black gram and red gram. Cropping pattern in kharif season of Andhra Pradesh is shown in Table 1.

Table 1: Cropping pattern in kharif season of Andhra Pradesh

	Rice	Maize	Jowar	Ragi	Bajra	Bengalgram	Blackgram	Greengram	Redgram	Sunflower	Seasumum	Korra	Groundnut	Other crops
Rice	0.918	0	0	0	0	0	0	0.082	0	0	0	0	0	0
Maize	0	0.414	0	0	0	0	0.349	0	0	0	0	0.237	0	0
Jowar	0	0.011	0.51	0.003	0.022	0.001	0	0	0.18	0	0.246	0	0.027	0
Ragi	0.32	0	0	0	0	0	0	0	0.24	0	0	0	0.44	0
Bajra	0	0	0	0	0	0	0.312	0	0.686	0	0	0	0.002	0
Bengalgram	0	0	0	0	0	0.004	0.111	0	0	0	0	0.014	0	0
Blackgram	0.308	0	0	0.0024	0	0.004	0.498	0.0429	0.049	0	0.084	0.0057	0	0.006
Greengram	0.164	0	0.106	0	0.017	0	0.034	0.62	0	0	0.04	0	0	0.019
Redgram	0.24	0.0511	0	0.002	0	0	0	0.034	0.66	0	0	0	0	0.0039
Sunflower	0	0	0	0	0	0	0	0	0.534	0.321	0	0.095	0.05	0
Seasumum	0	0	0	0	0	0.006	0.545	0.449	0	0	0	0	0	0
Korra	0.77	0	0	0.039	0	0	0	0	0.189	0	0	0	0	0
Groundnut	0	0	0	0	0	0	0	0.137	0	0	0.31	0	0.41	0.143
Other crops	0	0	0	0	0	0	0	0.961	0	0	0	0	0	0.039

Cropping Pattern- Rabi

The Transitional Probability Matrix in the table showed the shift in the area of different crops in Andhra Pradesh during the Rabi season. In Rabi season, paddy retained 79.7 per cent of its area, reflecting continued dominance. However, increasing transitions towards black gram and green gram indicate gradual diversification towards less water-intensive

crops during water-scarce periods. Paddy lost its share of 10.3 per cent to black gram and 10 per cent to green gram. Paddy had gained 35 per cent from Bajra, 22.8 per cent to the green gram, 0.43 per cent to jowar, 0.34 per cent to sesamum and 0.14 per cent to groundnut. Green gram retained 68.6 per cent of its area and lost 22.8 per cent to black gram and 11.2 percent to paddy, 2 per cent to sunflower,

and 0.2 per cent to red gram. Green gram grabbed 31 per cent from Maize, 26 per cent from sesamum, 24.6 per cent from black gram, 18.4 per cent from jowar, 12 per cent from bajra and 5.3 per cent from sunflower. Sunflower retained 66 per cent of its area. It lost 16.4 per cent to jowar, 10.5 per cent to black gram, 5.3 per cent to green gram, and 1 per cent to other crops. Sunflower gained its major share from red gram (85 per cent) and from other crops (76 per cent), followed by 10.7 per cent from jowar and 2 per cent from green gram. Maize, Ragi, and Bajra are unstable crops in

Rabi season. Ragi lost its major share to black gram (45 per cent), green gram (31 per cent) followed by sesamum. Bajra lost its major share to paddy (35 per cent), jowar (53 per cent) and green gram (12 per cent). The cropping pattern in Rabi season of Andhra Pradesh is shown in Table 2. Crops such as ragi, bajra, korra and sesamum exhibited low retention probabilities, indicating instability in area allocation. This may be attributed to lower profitability, inadequate policy support, weak market linkages and higher production risks under rainfed conditions.

Table 2: Cropping pattern in Rabi season of Andhra Pradesh

	Rice	Bengal gram	Blackgram	Maize	Greengram	Groundnut	Jowar	Sunflower	Sesamum	Horsegram	Ragi	Bajra	Redgram	Other crops
Rice	0.797	0	0.103	0	0.10	0	0	0	0	0	0	0	0	0
Bengalgram	0	0.41	0	0	0	0	0.35	0	0	0	0.24	0	0	0
Blackgram	0	0.012	0.51	0.179	0.246	0.0006	0	0.022	0.0034	0	0	0.027	0	0
Maize	0	0	0.45	0	0.31	0	0	0	0.24	0	0	0	0	0
Greengram	0.112	0	0.228	0	0.686	0	0	0.2	0	0	0	0	0.002	0
Groundnut	0.014	0	0	0.111	0	0.647	0	0	0	0	0.014	0	0	0
Jowar	0.0429	0	0	0.0025	0.184	0.0038	0.598	0.1075	0.0499	0	0.0054	0	0	0.006
Sunflower	0	0	0.105	0	0.0532	0	0.164	0.6601	0	0	0	0	0	0.0177
Sesamum	0.0345	0.0511	0.1	0.0018	0.261	0	0.0386	0	0.513	0	0	0	0	0
Horsegram	0	0	0	0	0	0	0	0	0.534	0.321	0.095	0.05	0	0
Ragi	0	0.7718	0	0.0392	0	0	0	0	0.189	0	0	0	0	0
Bajra	0.35	0	0	0	0.12	0	0.53	0	0	0	0	0	0	0
Redgram	0	0	0	0	0	0	0	0.8572	0	0	0	0	0.1428	0
Other crops	0	0	0	0	0	0	0	0.7608	0	0	0	0	0.0392	0

Conclusion

The study revealed significant structural changes in cropping patterns in Andhra Pradesh during 2013-14 to 2023-24. Paddy remained the most dominant and stable crop in both Kharif and Rabi seasons, while pulses showed moderate expansion. Traditional millets and oilseeds experienced declining area shares, indicating reduced diversification. Although paddy dominance improves short-term income stability due to assured procurement, excessive concentration may lead to groundwater depletion, soil degradation and climate vulnerability. Therefore, policy efforts should focus on promoting crop diversification, strengthening market support for pulses and millets, improving irrigation efficiency and encouraging climate-resilient farming practices. Since the study is based on secondary data, future research may incorporate farm-level determinants influencing crop choices.

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Data availability

The data supporting the reported results are available on reasonable request to the first author.

Declarations

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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