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Changing land use and crop dynamics in bifurcated Andhra Pradesh

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Abstract

This study investigates shifts in land use patterns and cropping dynamics in Andhra Pradesh over recent decades. Factors like economic liberalization, policy changes, and environmental challenges have affected traditional farming practices and crop diversity. Statistical methods like Composite Entropy Index (CEI), Herfindahl Index (HI), Double Log model, and Markov Chain Analysis were applied to examine crop diversification, the driving factors behind diversification, and the dynamics of cropping patterns in the state. The study also examined trend in crop shifts, irrigation practices, and land use transformation, particularly in the context of state bifurcation in Andhra Pradesh state. Findings reveal that irrigation access, landholding size, and credit availability play significant role in crop diversification, while market demand and environmental factors influence land use changes. Additionally, the Markov Chain Analysis highlights cropping sequence preferences, with an emphasis on shift un cropping pattern.

Keywords: Land use pattern, crop diversification, dynamics of cropping pattern

Introduction

Agriculture is the cornerstone of the Indian economy, playing a vital role in fostering inclusive national growth by contributing significantly to the GDP, providing livelihoods, and ensuring food security for a large portion of the population. Andhra Pradesh was notably one of the few states to adopt Green Revolution techniques in rice cultivation during the 1970s. Currently, agriculture accounts for approximately one-fourth of the state's gross domestic product (GSDP) and supports nearly 60% of the workforce, significantly above the national average. The Gross Value Added (GVA) of agriculture and allied sectors at current prices for 2023-24 is estimated at Rs. 4,53,807 crores, up from Rs. 4,27,961 crores in 2022-23, reflecting a growth rate of 6.04% over the previous year (DES, Govt. of AP). The average monthly income per agricultural household in Andhra Pradesh state was Rs. 10,480 in the agricultural year 2018-19, slightly higher than the national average of Rs. 10,218 (NSS Report, 2019) [12].

Over the past three decades, the agriculture sector in Andhra Pradesh has undergone significant structural and performance-related shifts. Research has primarily focused on the agricultural crisis, which has been intensified by policies associated with economic liberalization - such as subsidy cuts, rising input costs, limited credit access, and insufficient public investment. An emerging issue that has received relatively less attention is the diversion of agricultural land to non-agricultural uses, including industrial development, Special Economic Zones (SEZs), and infrastructure projects (e.g., highways, airports, ports), as well as for power generation and mining. These transitions could pose risks to food security and rural livelihoods.

Farmers face challenges due to unpredictable weather patterns and market-related risks, which add to the uncertainties in agricultural outcomes (Geetha, 2017) [9]. Under these conditions, crop diversification serves as a strategy to mitigate such risks. Since from the state bifurcation, Andhra Pradesh has benefited from multipurpose irrigation projects and a steady water supply from the Tungabhadra, Krishna, and Godavari rivers, facilitating rapid changes in land use and cropping patterns. For effective agricultural planning, it is essential to understand both the types of crops grown and the distribution of crop concentration across areas. This study aims to analyze the patterns of land use and cropping dynamics in Andhra Pradesh, providing insights into the evolving agricultural landscape.

Materials and Methods

The present study is based on secondary sources of information, collected from multiple reliable sources. Time series data pertaining to area, production, productivity of different crops, Fertilizer consumption (Kg/ha), Area sown more than once (ha), Net area irrigated (ha), Area irrigated more than once (ha), Annual rainfall (mm), Average size of landholding (ha), Credit to agricultural sector by SCB (000' Cr), Per-capita availability of power (kw/hr), Per-capita Net State Domestic Product (Rs.), Wholesale Price Index of Primary Articles (WPI) and Consumer Food Price Index (CPI) of bifurcated state of Andhra Pradesh were collected for the period 2014-15 to 2023-24.

Changes in Land Use Pattern and Cropping Pattern
Area under different crops and land use statistics were analyzed by simple tabular method. The proportions were estimated for each of the above years to know the changes in land use and cropping pattern of Andhra Pradesh over the period under study. The crop groups considered in this analysis include Cereals & Millets, Pulses, Oilseeds, Fiber crops, Sugar crops, Condiments & Spices, Fruits & Vegetables, Flowers & Aromatic crops, Fodder & Green manure crops, Pulp & Timber, and Drugs & Narcotics crops.

Crop Diversification
Composite Entropy Index (CEI) was used to examine the degree of crop diversification during two periods (2014 to 2018 and 2019 to 2023), with the index values treated as a dependent variable. The CEI values range from zero to log(i), where lower values indicate low diversity or homogeneity, and higher values indicate greater diversity or heterogeneity.

$$CEI = -\left[\sum_{i=1}^{N} p_i \log_n p_i\right] \times \left\{1 - \left(\frac{1}{N}\right)\right\}$$

Herfindahl Index (HI) was also employed to measure the extent of cropping shifts. The HI ranges from zero to one, where values indicate the degree of shift in cropping patterns: a high extent of shift ($0 \leq H \leq 0.3$), moderate shift ($0.3 \leq H \leq 0.6$), and no shift in cropping pattern ($0.6 \leq H \leq 1$).

$$HI = \sum_{i=1}^{N} P_i^2$$

Where, N is the total number of crops and p_i is the average proportion of the i^{th} crop in the total cropped area and $P_i = \frac{A_i}{\sum_{i=1}^{N} A_i}$; where, A_i is Area under i^{th} crop (ha)

Determinants of crop diversification
Multiple regression analysis was carried out using the time series data for the period from 2014-15 to 2023-24 to identify the important factors affecting crop diversification (Felix and Ramappa, 2023) [8]. Double log model has been attempted in the study. The CEI (Y) was specified as a function of the identified independent variables.

$$\ln Y = a + b_1 \ln X_1 + b_2 \ln X_2 + \cdots . + b_{13} \ln X_{13} + U$$

The explanatory variables considered were; X_1=Area sown more than once (ha), X_2=Net area sown (ha), X_3 =Area irrigated more than once (ha), X_4 =Net area irrigated (ha), X_5 =Annual rainfall (mm),), X_6 =Credit to agricultural sector by SCB (000' Cr), X_7 =Per-capita availability of power (kw/hr), X_8 =Per-capita Net State Domestic Product (Rs.), X_9=Fertilizer consumption (Kg/ha), X_{10} =Average size of landholding (ha X_{11} =Wholesale Price Index of Primary Articles (WPI) and X_{12} =Consumer Food Price Index (CPI), and X_{13} =Period, U=error-term and *ln* =natural logarithm.

Shift in Cropping Pattern
Markov chain model was used to analyze the dynamics of cropping pattern in Andhra Pradesh. Lingo software was used to derive the transition probability matrix.

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

Where, E_{jt} = shift in per capita share of j^{th} crop during the period t; E_{it-1} = per capita share of i^{th} crop during the period t–1; P_{ij} = probability that share will shift from the i^{th} crop to j^{th} crop; e_{jt} = error-term which is statistically independent of e_{jt-1}; and n=number of crops.

Results and Discussion
The land use classification system in Andhra Pradesh state categorizes land into different types such as forest land, non-agricultural land, barren land, grazing land, miscellaneous tree crops, culturable waste, fallow land, and net sown area. Each category provides a distinct view of land use, offering comprehensive data to support agricultural development, policy planning, and resource management in the state.

Changes in Land Use Pattern in Andhra Pradesh
The overall geographical area of 162.97 lakh hectares was allocated to the state of Andhra Pradesh after bifurcation. The analysis highlights significant shifts in land use across the state in the decade following bifurcation. The forest area increased by 0.68% during this period, reaching 22.6% of the total geographical area (Table 1). This increase in forest cover can be attributed to improved conservation efforts, afforestation, and agroforestry. Land used for non-agricultural purposes grew to 20.93 lakh hectares, primarily driven by urbanization and infrastructure demands, potentially posing long-term challenges. Although efforts to reclaim degraded land were evident, they were not entirely effective, as barren land reduced by only 1.18%, due to soil and water conservation measures. Cultivable wasteland rose by 3.06%, while cumulative uncultivable land, including pastures and waste, declined by 0.65%. Fallow land, however, increased to 21.3% by 2023-24.

Table 1: Land use pattern in Andhra Pradesh

S. No.	Particulars	Area in Lakh ha.		Changeover (%)
		2014-15	2023-24	
1	Area under forest	36.63 (22.5)	36.88 (22.6)	0.68
2	**Land not available for cultivation**			
	a. Barren land	13.51 (8.3)	13.35 (8.2)	-1.18
	b. Non-agricultural land	20.02 (12.3)	20.93 (12.8)	4.55
	Total	33.53 (20.6)	34.28 (21.0)	2.24
3	**Other uncultivated land**			
	a. Cultivable waste land	3.92 (2.4)	4.04 (2.5)	3.06
	b. Permanent Pasture	2.14 (1.3)	2.03 (1.2)	-5.14
	c. Trees and Groves	1.6 (1.0)	1.54 (0.9)	-3.75
	Total	7.66 (4.7)	7.61 (4.7)	-0.65
4	**Fallow land**			
	a. Current fallow land	14.01 (8.6)	24.29 (14.9)	73.38
	b. Others	8.58 (5.3)	10.36 (6.4)	20.75
	Total	22.59 (13.9)	26.99 (21.3)	53.39
5	**Area sown**			
	a. Net crop area sown	61.13 (37.5)	47.65 (29.2)	-22.05
	b. Fish ponds	1.22 (0.7)	1.90 (1.2)	55.75
	b. Area sown more than once	15.77 (9.7)	9.79 (6.0)	-37.92
	Total	78.12 (47.9)	69.28 (36.4)	-24.04
6	Cropping intensity (%)	126.1	121.8	-4.41
	Total Geographical Area	162.97 (100)	162.97 (100)	

Note: Figures in the parentheses indicate percentage of respective land use to total area.
Source: Directorate of Economics & Statistics, Government of Andhra Pradesh

The net sown area in Andhra Pradesh was 61.13 lakh hectares in 2014-15. Over the last decade, it has decreased by 22.05%, totaling 47.65 lakh hectares. The area sown more than once decreased by 37.92%, accounting for 9.79 lakh hectares in 2023-24. In contrast, Mouzam *et al*., (2015) [11] reported a contrast trend in the state. The area under fish ponds increased significantly, from 1.22 lakh hectares in 2014-15 to 1.9 lakh hectares in 2023-24, recording 55.74% growth over the decade. The cropping intensity was 126.1% in 2014-15 and it decreased to 120.5% in 2023-24. In summary, the area under land not available for cultivation and fallow land has increased over the study period.

In Andhra Pradesh, numerous government gazette notifications have been issued for land acquisitions to support development projects across sectors such as water resources, industry, mining, non-hydel power, defence, transport, communication, environmental protection, urban development, housing, and more (Seethalakshmi, 2010) [14]. This includes the diversion of forest land for mining and agricultural land for Special Economic Zones (SEZs).

Changes in Area and Source of Irrigation

The main sources of irrigation in Andhra Pradesh are canals, tanks, tube wells, and dug wells. Over the past decade, the area irrigated by canals decreased from 18.82 Lha to 13.24 Lha, and tank irrigation declined from 3.27 Lha to 2.69 Lha (Figure 1). In contrast, well irrigation increased from 15.32 Lha to 15.68 Lha, suggesting a growing reliance on wells. Irrigation from other sources also declined from 1.45 Lha to 1.1 Lha. These trends may reflect changes in extent of water availability or changing irrigation preferences in the state.

Out of gross area irrigated of 32.71 lakh hectares, 57.17% was accounted by paddy alone and followed, 7.64% by chillies, 6.42% by maize, and 2.75% by groundnut respectively. The remaining irrigated area is covered by other crops.

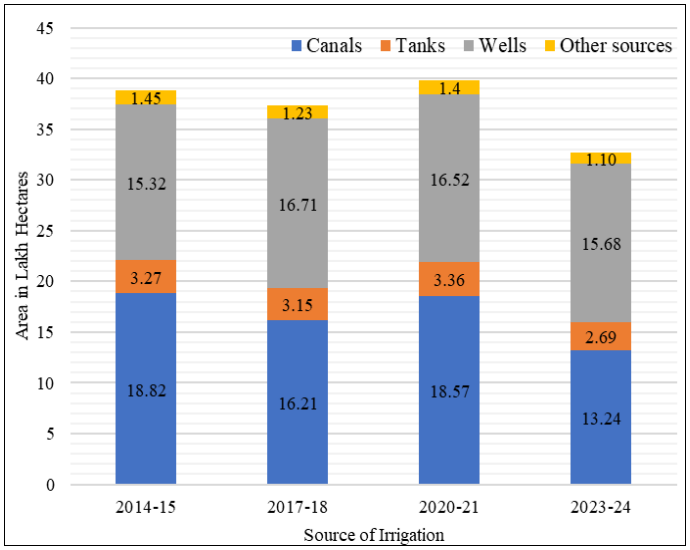

Fig 1: Gross area irrigated by different sources in Andhra Pradesh

As represented in Table 2, the percentage of net irrigated area decreased by 11.1% from the base year to 2023-24. The percentage of net irrigated area to net sown area was 47.88% in 2014-15, which increased to 54.63% in 2023-24, as net sown area decreased by 22.1%. The area irrigated more than once decreased by 37.9%, potentially indicating a shift in cropping patterns. The gross cropped area decreased by 25.3% over the study period.

Table 2: Changes in irrigated area

Particulars	Area in Lakh ha.			Change (%)
	2014-15	2018-19	2023-24	
Gross Area Sown	76.90	72.97	57.44	-25.3
Net Area Sown	61.13	58.91	47.65	-22.1
Area Sown more than once	15.77	14.06	9.79	-37.9
Gross Area Irrigated	38.86	36.35	32.71	-15.8
Net Area Irrigated	29.27	27.96	26.03	-11.1
Area irrigated more than once	9.59	8.39	6.68	-30.3
% of net irrigated area to net sown area	47.88	47.46	54.63	14.1
% of gross irrigated area to gross sown area	50.53	49.82	56.95	12.7

Source: Directorate of Economics & Statistics, Government of Andhra Pradesh

Crop Diversification

The figure 2 shows the results of the Herfindahl Index (HI) and Composite Entropy Index (CEI), which measure the extent of cropping pattern shifts across the state. Further the study period is divided into two phases based on geopolitical changes to analyze government interventions in crop diversification. Both indices reveal a significant shift in cropping patterns during the first period and comparatively lesser shift in the second period. The average Herfindahl Index was 0.22 (H<0.3), and the Composite Entropy Index averaged 0.71 (>0.5), indicating a substantial shift in cropping patterns during study period within the state.

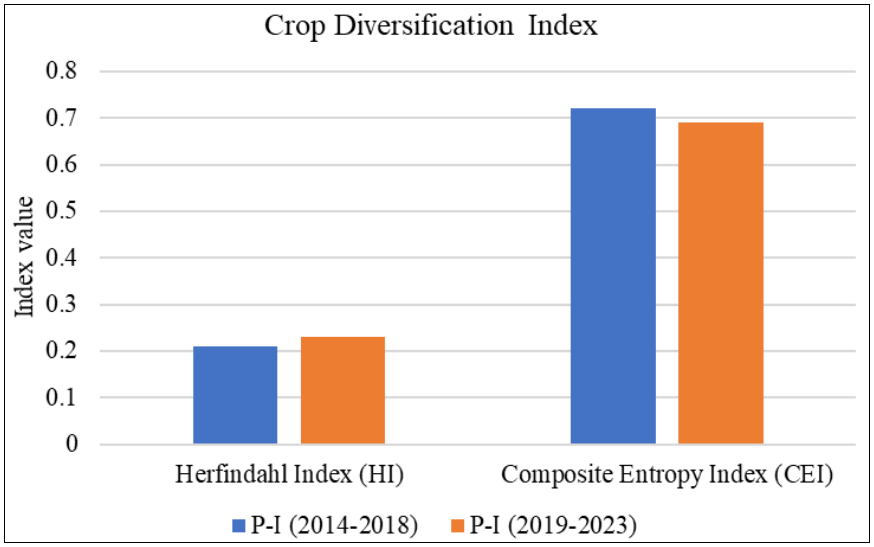

Fig 2: Herfindahl Index and Composite Entropy Index for measuring crop diversification

Table 3 provides an overview of changes in crop area sown in Andhra Pradesh across various crop groups from 2014-15 to 2023-24. The table details both the percentage change in area sown for each crop group and the annualized rate of change (CAGR) over this period.

Several crop groups, including Cereals & Millets, Pulses, Oilseeds, and Sugarcane, have seen a decline in sown area, with Sugarcane experiencing the most significant reduction, depicting a changeover of -82.61% and a CAGR of -17.21. In contrast, Condiments & Spices have shown the highest increase in area sown, with a 45.1% rise and a positive CAGR of 4.0, reflecting increased cultivation, particularly of chilli crop. Fruits & Vegetables show slight changes in area sown, though their CAGRs suggest minimal growth or a slight decline annually.

Table 3: Crop area sown statistics in Andhra Pradesh

Crop group	Area in Lakh ha		Changeover (%)	CAGR (%)
	2014-15	2023-24		
Cereals & Millets	29.21	23.82	-18.45	-0.51
Pulses	10.42	9.42	-9.60	-2.52
Oilseeds	12.37	6.25	-49.47	-4.82
Fiber crops	8.21	4.28	-47.87	-2.79
Sugarcane	2.53	0.44	-82.61	-17.21
Drugs & Narcotics crops	1.62	1.14	-29.63	-4.08
Condiments & Spices	2.04	2.96	45.10	4.00
Fruits & Vegetables	7.83	7.54	-3.70	-0.41
Flowers & Aromatic crops	0.11	0.08	-27.27	-3.24
Pulp & Timber	1.63	1.04	-36.20	-5.53
Fodder & green manure crops	0.73	0.32	-56.16	-8.14
Gross Area Sown	76.9	57.44	-25.31	-2.09

Source: Directorate of Economics & Statistics, Government of Andhra Pradesh

Overall, the Gross Area Sown in Andhra Pradesh has decreased by 25.31%, with a CAGR of -2.09, signalling a reduction in cultivated land over the past decade. This shift may reflect changing agricultural practices, market demands, or environmental factors affecting crop production in the state.

Determinants of Crop Diversification

It is evident from Table 4 that the intercept has a positive and significant coefficient (0.603, $p < 0.05$), suggesting a base level of crop diversification when other variables are held constant. Among the significant variables, area irrigated more than once has a negative coefficient (-0.113, $p < 0.05$), indicating that an increase in the area irrigated multiple times is associated with reduced crop diversification. Similarly, rainfall shows a significant negative effect (-0.050, $p < 0.05$), implying that higher rainfall may correlate with lower diversification, possibly due to reliance on specific water-intensive crops. These findings are consistent with Geetha (2017) [9].

Agricultural credit by scheduled banks has a significant positive effect (0.029, $p < 0.05$), suggesting that increased credit availability may encourage crop diversification (Felix and Ramappa, 2023) [8]. The average size of landholding is another positive and significant predictor (1.553, $p < 0.05$), indicating that larger landholdings tend to support more diverse cropping practices. The time variable also positively impacts diversification (0.022, $p < 0.05$), possibly reflecting a trend toward diversification over time.

Table 4: Determinants of crop diversification in Andhra Pradesh

Particulars	Coefficient	Standard error	t Stat
Intercept	0.603*	0.174	3.454
Area Sown more than once (ha)	0.212	0.253	0.787
Net Area Sown (ha)	-0.084	0.160	-0.291
Area irrigated more than once (ha)	-0.113*	0.027	-4.214
Net Area Irrigated (ha)	-0.158	0.446	-0.291
Rainfall (mm)	-0.050*	0.012	-4.078
Agril. Credit (000' cr) by SBC	0.029*	0.009	3.118
Electricity (kw/hr)	-0.097	0.431	-0.563
Per capita GSDP (Rs.)	-0.246	0.127	-0.793
Fertilizer Consumption (kg/ha)	-0.229	0.221	-0.51
Average Size of Landholding (ha)	1.553*	0.291	5.333
Wholesale Price Index of Primary Articles (WPI)	-0.115	0.632	-0.051
Consumer Food Price Index (CPI)	-0.200	0.507	-0.714
Time	0.022*	0.039	4.116

* Indicates 5% level of significance

The non-significant variables *viz.*, net area sown, net area irrigated, electricity consumption, per capita GSDP, and fertilizer consumption show no strong relationship with crop diversification in the fitted model, as indicated by their high standard errors and low t-statistics. Overall, these results suggest that specific agricultural practices and economic factors, particularly those related to irrigation, landholding size, and credit, play crucial role in influencing crop diversification in Andhra Pradesh.

Dynamics of Cropping Pattern

The Table 5 summarizes the transition probability matrix from a Markov Chain Analysis examining crop dynamics in Andhra Pradesh, illustrating the likelihood of different crop groups being followed by others in subsequent seasons or rotations. Each cell represents the probability of transitioning from one crop group (rows) to another (columns), reflecting the adaptability, compatibility, and prevalence of specific crop sequences in local agricultural practices (Raghunadha Reddy, 2022) [14]. Diagonal values, such as 0.65 for Cereals & Millets, 0.49 for Pulses, and 0.85 for Sugarcane, indicate a strong persistence of the same crop group across consecutive cycles, suggesting frequent re-cultivation on the same land - likely due to high demand, local suitability, or economic factors. It is observed that the sugarcane cultivation area has decreased by 78% in the state. However, area retention is higher in certain regions where repeated cultivation occurs due to abundant water availability.

Notable off-diagonal values, like the 0.43 transition probability from Cereals & Millets to Condiments & Spices (particularly chilli), suggest favourable rotation or replacement dynamics, possibly due to agronomic or market-driven factors that make such sequences advantageous. Similarly, the high transition from Pulses to Fodder & Green Manure (0.68) may indicate soil fertility management practices, as pulses enhance nitrogen content, supporting subsequent fodder growth. Lower transition values between certain groups, such as those involving Drugs & Narcotic crops and Flowers & Aromatic, indicate that these crops are less likely to be rotated in conventional sequences, reflecting specialized cultivation practices. This analysis provides valuable insights into crop rotation patterns and preferences among farmers, offering guidance for future agricultural planning and sustainability efforts in the state.

Table 5: Transitional Probability Matrix for crop shift in Andhra Pradesh

Crop Groups	Cereals & Millets	Pulses	Oilseeds	Fiber crops	Sugarcane	Fruits & Vegetables	Flowers & Aromatic	Condiments & Spices	Drugs & Narcotics	Fodder & green manure
Cereals & Millets	0.65	0.00	0.22	0.03	0.00	0.04	0.00	0.06	0.00	0.00
Pulses	0.24	0.49	0.11	0.00	0.00	0.13	0.01	0.00	0.00	0.02
Oilseeds	0.04	0.29	0.11	0.18	0.00	0.09	0.00	0.28	0.00	0.00
Fiber crops	0.00	0.36	0.24	0.16	0.00	0.23	0.00	0.01	0.00	0.00
Sugarcane	0.00	0.04	0.00	0.00	0.85	0.00	0.01	0.00	0.00	0.11
Drugs & Narcotics	0.00	0.44	0.00	0.27	0.00	0.29	0.00	0.00	0.00	0.00
Fruits & Vegetables	0.00	0.00	0.05	0.44	0.00	0.00	0.35	0.00	0.17	0.00
Flowers & Aromatic	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.57	0.42	0.00
Condiments & Spices	0.43	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.33	0.00
Fodder & green manure	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.21

Conclusion

The study reveals substantial transformations in Andhra Pradesh's cropping patterns, influenced by a range of socioeconomic, environmental, and policy factors. While increased land diversion for non-agricultural purposes and shifts toward cash crops offer short-term economic benefits, these changes pose risks to traditional agriculture and food security. The regression analysis highlights irrigation access, landholding size, and agricultural credit as key drivers of crop diversification. The findings underscore the importance of promoting sustainable land use and diversified cropping systems to address the challenges faced by Andhra Pradesh's agricultural sector. Policy efforts focused on sustainable land management, enhanced irrigation, and financial support for farmers can play a pivotal role in securing long-term agricultural viability and food security in the region.

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