PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 12(2): 1-7
https://doi.org/10.14719/pst.6614

HORIZON
e-Publishing Group
HePG

RESEARCH ARTICLE

Land use and cropping pattern dynamics under the climate change regime

B Vetri Selvi[1], S Varadha Raj[2*], K T Parthiban[3], D Ramesh[4]

[1]Department of Agricultural Economics, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

[2]Department of Basic and Social Sciences, Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam 641 301, Tamil Nadu, India

[3]Department of Agroforestry, Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam 641 301, Tamil Nadu, India

[4]Department of Renewable Energy Engineering, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

*Email: varadharajstnauecon@gmail.com

OPEN ACCESS

ARTICLE HISTORY
Received: 09 December 2024
Accepted: 23 January 2025
Available online
Version 1.0 : 14 March 2025
Version 2.0 : 01 April 2025

Check for updates

Additional information
Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE
Vetri Selvi B, Varadha Raj S, Parthiban KT, Ramesh D. Land use and cropping pattern dynamics under the climate change regime. Plant Science Today. 2025; 12(2): 1-7. https://doi.org/10.14719/pst.6614

Abstract

Climate change poses profound challenges to agricultural landscapes, disrupting farming regions through unpredictable rainfall patterns, extreme temperatures and other adverse environmental conditions. Climatic and institutional factors critically influence land use and cropping patterns, necessitating comprehensive studies to understand agricultural transformations. The study examines changes in land use patterns and cropping systems in Coimbatore district, Tamil Nadu, from 2008-09 to 2022-23, employing a multi-dimensional analytical framework to assess the rationality of land use classifications and agricultural dynamics. Key findings reveal that net sown area declined by -0.67%, while traditional food crops experienced negative growth rates namely: cereals (-1.91%) and pulses (-4.10%). Oilseeds emerged as the most dominant crop group, displaying a positive growth rate of 0.58% with low instability. Permanent fallows increased by 3.37%, coinciding with decreased rainfall. The analysis showed a modest increase in non-agricultural land (0.26%) and a distinguishable trend towards tree-based agriculture (0.63%), indicating changes in land use practices. Land use transitions revealed that forest lands and permanent pastures have complete retention due to the combination of legal protections and natural constraints that limit land-use conversion. An expected 13.17% loss of net sown area to permanent fallow raises concerns about agricultural land degradation, posing a potential threat to food security. Green manure crops exhibited 54.41% retention with 20.86% growth rate reflects farmers' adaptive strategies towards climate change. The findings underscore the intricate relationship between land use, cropping patterns and climate adaptation, calling for integrated policies that support climate-smart agriculture by providing targeted incentives while balancing urban development.

Keywords

CDVI index; climate adaptation; growth rate; land use transitions; location coefficient; Markov-Chain analysis

Introduction

Climate change poses a significant challenge to sustainable development in the 21st century, with agriculture emerging as one of the most economically vulnerable sectors (1, 2). The impact of climate variations on the agricultural landscape is profound, disrupting the existing farming regions through unpredictable rainfall patterns, extreme temperatures, intense cyclonic events and other adverse environmental conditions. Beyond direct agricultural and

biodiversity impacts, climate change and global warming significantly alter land cover and land use. Degradation of agricultural lands leading to increased permanent fallows can threaten food security and disrupt local economies. This transformation indirectly heightens the vulnerability of regions and communities to interconnected economic, climatic and socio-economic challenges associated with shifting of workforce from rural-agricultural to urban areas, thereby increasing land demand for non-agricultural uses (3-6). Land is one of the most basic natural resources and a critical factor in agricultural production, has always been a subject of debate regarding its effective uses and faces huge competing demands from various sectors (7). Climate change coupled with urbanization and rapid economic development has dramatically intensified the pressure on the already constrained natural resource base (8-11). Although technological advances in agriculture have partially addressed the growing need for food production, the population growth and increased demand for non-agricultural land continue to pose significant challenges for researchers, policymakers and stakeholders (6). Comprehensive studies on land use and cropping patterns are critical for addressing interconnected challenges. These include expanding forest cover, reclaiming fallow lands, optimizing agricultural classifications, securing food production for a growing population and developing effective climate change adaptation strategies (7).

Given these challenging scenarios, this paper aims to analyse the dynamic changes in land use and cropping patterns in the Coimbatore district, providing a nuanced understanding of land use and crop-mix dynamics in the context of climate change. The study seeks to develop suitable solutions for managing land use and cropping pattern changes under the climate change regime by comprehensively examining the current landscape and generating forward-looking insights into potential future scenarios. To achieve this, a clear framework will be established to understand the magnitude of variability in land use and cropping patterns, enabling a comprehensive long-term analysis of land use and agricultural transformations.

Materials and Methods

Sampling Design

Coimbatore district, located in the western zone of Tamil Nadu, was selected as the study area. The western zone of Tamil Nadu represents a vital agricultural region with diverse agro-climatic conditions. The purposive selection of the Coimbatore district provides an exemplary context for comprehensively understanding the dynamics of land use and cropping patterns in the region. The research is based on a comprehensive secondary data analysis, comprising time series data on land use patterns, crop categories and rainfall from the Directorate of Economics and Statistics (DES) and Season and Crop Reports of Tamil Nadu. The study period from 2008-09 to 2022-23 was purposively selected, coinciding with the significant administrative restructuring that bifurcated Coimbatore district into Coimbatore and Tiruppur districts. The geographical location of the study area is presented in Fig. 1, highlighting position of Coimbatore within western agro-climatic zone of Tamil Nadu.

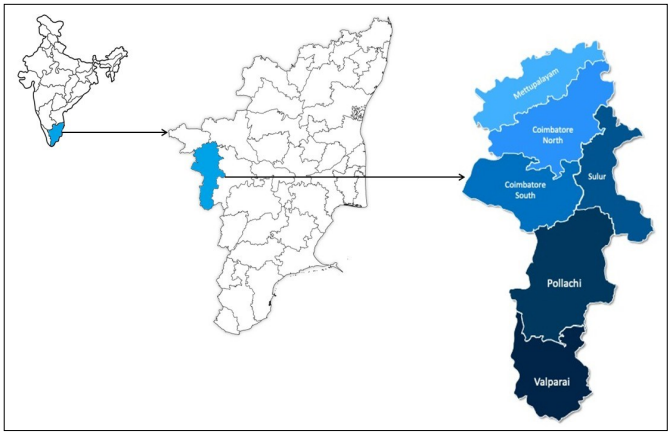

Fig. 1. Map representing the study area.

Analytical Methods

This study employed multiple statistical techniques to comprehensively analyse land use and cropping pattern dynamics. The Location Coefficient was utilized to determine the distribution and concentration of different land use classifications by comparing the district's proportion to the state's (Tamil Nadu). Compound Annual Growth Rate (CAGR) was applied to evaluate overall growth trends in land use classifications and crop transition, providing a normalized perspective on long-term changes. Cuddy-Della Valle Instability Index was used to assess the volatility and fluctuation in land use classifications and areas under major crop groups. Markov chain analysis was employed to trace the direction and probability of land use and crop transitions to provide insights into potential future land use and cropping pattern scenarios.

Location Coefficient of Land Use Pattern

Location coefficient is an analytical tool to quantify land distribution and concentration of various land use classifications across different geographical regions (6). This approach was built upon methodological frameworks employed (12, 13) in their analyses of land use rationality and water use efficiency. In this study, the Location Coefficient is employed to compare land use concentration by assessing the relative distribution of land use classifications in Coimbatore district in comparison to the broader Tamil Nadu landscape and is expressed as in Eqn. 1.

$$L = \frac{L_{ij}/L_i}{L_j/L_s} \qquad \text{Eqn. 1}$$

where, L_{ij} is an area of the j^{th} category of land in Coimbatore district; L_i is area of all classifications of land in the district; L_j is an area of the j^{th} category of land in Tamil Nadu and L_s is area of all classifications of land in Tamil Nadu. When the location coefficient (L) equals one, it indicates that the concentration of a land use type is consistent with the average level in the entire study area. A value greater than one ($L > 1$) suggests a higher concentration of that land use classification in the subregion (Coimbatore) compared to the overall Tamil Nadu. Conversely, a value between zero and one ($0 \leq L < 1$) implies a lower concentration that the average. Greater the L value, higher the

regional concentration level of a particular land use type.

Estimation of Growth Rates – CAGR

Compound Annual Growth Rate (CAGR) of different land use classifications and major crop groups were analyzed using the exponential growth function form, mathematically expressed as in Eqn. 2.

$$Y = ab^t \qquad \text{Eqn. 2}$$

where Y denotes the land under various classifications / major crop groups in year t; t represents the time variable; a and b are parameters. To obtain the CAGR growth rate, the logarithmic form of the equation was used.

Analysis of Instability Index – CDVI

Cuddy-Della Valle Instability (CDVI) Index, developed by Cuddy and Valle in 1978, was used in estimating variability of time series data. Unlike the simple coefficient of variation which over-estimates instability by failing to account for long-term trends, the CDVI index offers a more critical approach to measure fluctuations and this index is particularly advantageous in agricultural research (14, 15). The key strength of CDVI lies in its ability to de-trend time series data using the coefficient of determination, effectively addressing the limitations of traditional CV calculations. The index is applied to analyze the variability of area under different land classifications and major crop groups which enables a more precise assessment of temporal changes and instability in agricultural and land use patterns. The equation is mathematically expressed as in Eqn. 3.

$$IX = CV^* \sqrt{1 - Adj\ R^2} \qquad \text{Eqn. 3}$$

where IX is Instability Index; CV^* is Coefficient of Variation (in %); Adj R^2 is the Coefficient of determination from a time - trend regression adjusted by the number of degrees of freedom (adjusted R square). The instability levels are categorized as: low instability ranges between 0 and 15 ($0 \leq IX \leq 15$), medium instability spans from greater than 15 to lower than 30 a ($15 < IX \leq 30$) and high instability is characterized by values exceeding 30 ($IX > 30$). This provides a clear framework for understanding the magnitude of variability in land use classifications and cropping patterns.

Analysing the Distribution of Land Use Classifications and Area Under Major Crop Groups using Markov Chain Analysis

Markov chain analysis emerges as a useful tool for examining systemic transitions and structural variations over time, particularly when phenomena shift between different states (16). The analysis is employed to comprehensively explore and quantify dynamic characteristics and structural changes in land use and cropping patterns. By creating a matrix of transitional probabilities (denoted as 'P'), the method allows for a detailed examination of how land use and cropping patterns evolve during the study period from 2011 to 2020. The transitional probability matrix developed using linear programming (LP) techniques and LINGO software provides insights into the likelihood of land area and crop group transitioning between different categories (7, 17). This approach enables better analysis of land use and cropping pattern dynamics, revealing patterns of stability, transformation and potential future scenarios in the agricultural landscape of Coimbatore district and mathematically represented as in Eqn. 4.

$$E_{jt} = \sum_{i=1}^{n} (E_{it} - 1) P_{ij} + e_{jt} \qquad \text{Eqn. 4}$$

where,

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

E_{jt} = land under a category/crop group from i^{th} category/crop to the j^{th} category/crop in the year 't'

E_{it} = land under i^{th} category/crop group during the year 't-1'

P_{ij} = probability of shift in land use under category/crop group from i^{th} to j^{th} category/crop group

ejt = error term which is statistically independent of E_{it-1}

n = number of land use classifications/crop groups

T = Study Period

$$\sum_{i=1}^{n} P_{ij} = 1 \ ; 0<P_{ij}<1 \qquad \text{Eqn. 5}$$

The sum of the row elements should be equal to 1 and each of the row elements should be between zero and one as expressed in Eqn. 5. In the transition matrix table, each row represents the initial land use /crop group, while each column represents the resulting categories after transition. The diagonal elements exhibit the retention probabilities, indicating the propensity of land use and crop categories to maintain their current status/area, while off-diagonal elements showcase the potential for inter-category transitions. The matrix values quantitatively represent the probabilities of shifting between different land use and crop categories which provides the understanding of systemic changes.

Results and Discussion

Distribution and Concentration of Nine-Fold Land Use Classifications in Coimbatore

The Location Coefficient analysis of land use classifications in Coimbatore district presented in Table 1, reveals dynamic agricultural patterns between 2008-09 and 2022-23. Net Sown Area's location coefficient decreased from 1 to 0.94 indicating a reduction in the district's concentration and distribution of Net Sown Area compared to the state's overall pattern. Current fallow land's concentration declined from 1.53 to 1.35, while permanent fallows and land under miscellaneous trees and groves saw significant increases from 0.56 to 0.87 and 0.34 to 0.54 respectively. A substantial increase in permanent fallow land concentration likely stems from the reduced concentration on the net sown area and current fallows. This shift suggests that agricultural lands have remained uncultivated for more than 5 years, potentially correlating with significant rainfall variations observed between 2011 and 2016.

Analysis of Growth Rate and Instability Trends in Land Use Patterns

The comprehensive analysis of land use dynamics in Coimbatore district from 2008-09 to 2022-23 presented in Table 2 reveals a complex transformation across nine-fold land

Table 1. Dynamics of distribution of land use classifications in Coimbatore

Land use classifications	Location coefficient	
	2008-09	2022-23
Forests	0.09	0.08
Area under non-agricultural uses	0.94	0.96
Barren and unculturable land	0.27	0.29
Permanent pastures and other grazing lands	0.02	0.02
Land under misc. Tree crops and groves	0.34	0.54
Culturable waste land	0.75	0.65
Permanent fallow lands	0.56	0.87
Current fallows	1.53	1.35
Net area sown	1.00	0.94
Total cropped area	0.90	0.77
Area sown more than once	0.31	0.19

Table 2. Distribution, compound annual growth rate and instability index of land use classifications in Coimbatore district

Land use classifications	Period I (2008-09)	Period II (2022-23)	CAGR %	CDVI index
Geographical area	472321.98 (100.00)	472321.98 (100.00)	-	-
Forest (including reserve forest)	111871.17 (23.69)	111871.17 (23.69)	0.00	0.00
Land under non-agricultural uses	74201.51 (15.71)	76989.49 (16.30)	0.26	0.52
Barren and unculturable land	4786.77 (1.01)	4797.12 (1.02)	0.02	0.05
Permanent pastures and other grazing lands	76.96 (0.02)	76.96 (0.02)	0.00	0.00
Land under misc. Tree grooves	3168.66 (0.67)	3464.96 (0.73)	0.63	1.84
Culturable waste land	9061.71 (1.92)	8239.88 (1.74)	-0.68	1.55
Permanent fallow	30630.44 (6.49)	58074.72 (12.30)	3.37	18.19
Current fallow	56218.72 (11.90)	43690.54 (9.25)	-0.48	26.12
Net sown area	182306.04 (38.60)	165117.14 (34.96)	-0.67	1.77
Gross cropped area	191146.81 (40.47)	175077.07 (37.07)	-0.54	2.64
Area sown more than once	8840.76 (1.87)	9959.93 (2.11)	-0.67	1.77
Cropping intensity	104.85	106.03	2.35	-

classifications. Permanent fallows have the highest positive growth rate of 3.37% and moderate instability (18, 19). Current fallows and Net sown area show negative growth rates of -0.48% and -0.67% respectively. The conversion of net sown area and current fallows into permanent fallows has contributed to the negative trend, as agricultural lands were left uncultivated for extended periods, exceeding 5 years, rendered unsuitable for cultivation. This shift is largely influenced by climatic risks such as recurrent droughts, declining groundwater levels and irregular monsoon patterns. This underscores potential challenges in agricultural productivity and shifting economic priorities. Fig. 2, illustrates a critical correlation where the surge in permanent fallows coincides with a reduction in current fallows and a significant decline in rainfall from 2011-12 to 2015-16. There was a dynamic shift in agricultural and non-agricultural land use patterns, since non-agricultural land area increased by 0.26%, indicating a gradual but persistent trend of urban development, infrastructural growth and workforce migration towards non-agricultural sectors. A significant 0.63% annual growth in miscellaneous tree groves, reflects on emerging climate consciousness and strategic agricultural diversification. The analysis of common property lands reveals a nuanced transformation. Barren and unculturable land marginally increased by 0.02%, while permanent pastures and other grazing lands remained stable and culturable waste lands decreased by -0.68%. The temporal analysis demonstrates a significant correlation between rainfall patterns and land use dynamics. Sharp rainfall reduction in 2011, 2012 and 2016 coincided with substantial changes in fallow lands (Fig. 2 and 3) underscoring the intricate relationship between climatic variations and agricultural land utilization. These multifaceted transitions reflect the district's adaptive resilience and ongoing restructuring of land use strategies in response to climatic challenges.

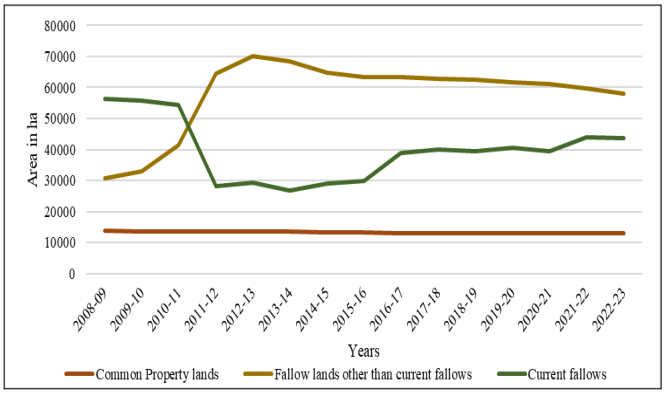

Fig. 2. Share of common property and fallow lands in Coimbatore district (2008-09 to 2022-23).

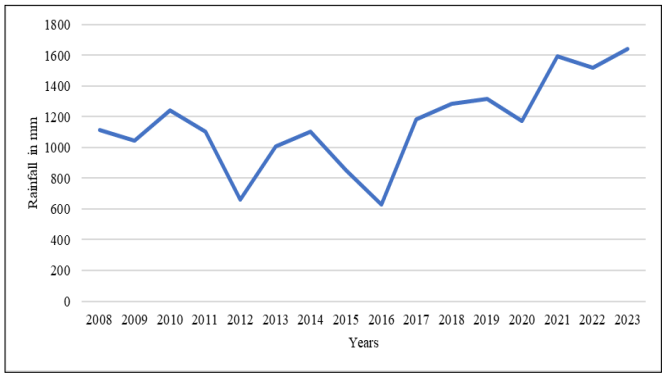

Fig. 3. Rainfall of Coimbatore district from 2008 to 2023.

Trends in Cropping Pattern:

Table 3 presents the significant transformation of Coimbatore district's agricultural landscape from 2008-09 to 2022-23. Traditional food crops experienced a significant contraction, with cereals and pulses showing negative growth rates of -1.19% and -4.10% respectively with low instability. This emphasizes the shifting agricultural priorities of the district. Oilseed emerged as the dominant crop group, displaying a positive growth rate of 0.58% and the lowest instability index of 1.13. The area under oilseeds expanded from 44.93 to 54.47% of the gross cropped area. In contrast, sugar crops suffered the most significant decline, with a negative growth rate of -12.58% and moderate instability, while fibre crops decreased by -6.46% with the highest instability of 39.37. Vegetables and medicinal crops demonstrated resilience with growth rates of 2.14% and 0.35% respectively. This trend highlights the district's strategy of agricultural diversification and adaptive measures towards climate change and food insecurity. Green manure crops showed the highest positive growth rate (20.86%) but had the highest instability index. This volatility might be due to an increase in green manure cultivated areas in recent years. This transformation reflects a shift towards more economically viable crop groups and farmers' growing awareness of environmentally conscious farming practices.

Land Use and Crop Group Transition

Dynamic Changes of Land Use Classifications

The land use transition analysis of Coimbatore district (Table 4) reveals a complex and dynamic transformation. Among various land use classifications, forest land and permanent pasture and grazing land demonstrated exceptional stability with a complete retention probability of one. This reflects strict conversion strategies and effective land preservation mechanisms. Current fallow lands exhibited significant resilience, maintaining a high retention capacity of 90.51%. These lands show a modest propensity for transition, with 3.03% probability of conversion to non-agricultural uses and 4.85% to net sown area. This suggests gradual land reutilization for agriculture and adaptive management practices. Non-agricultural uses maintained a substantial retention capacity of 84.77%, indicating ongoing urban expansion and infrastructural development. Net sown area with 77.48% retention probability, underscores the impact of climatic variations on agricultural land continuity. Net sown area is expected to gain share of culturable waste land, permanent fallows and current fallow lands at probabilities of 73.77, 40.69 and 4.85% respectively, demonstrating strategic optimization of agricultural land use efficiency. Barren and unculturable land and miscellaneous tree crops have zero retention capacity, expected to completely transition to

Table 3. Distribution, compound annual growth rate and instability index of major crop groups in Coimbatore district

Crop Groups	Period I (2008-09)	Period II (2022-23)	CAGR (%)	CDVI index
Cereals	42912.79 (22.45)	28220.48 (16.12)	-1.91	9.74
Pulses	12555.01 (6.57)	6734.14 (3.85)	-4.10	5.39
Spices and Condiments	6870.26 (3.59)	6325.98 (3.61)	-1.33	7.12
Sugar crops	2623.52 (1.37)	420.44 (0.24)	-12.58	17.24
Fruits	13698.63 (7.17)	12499.77 (7.14)	-1.53	9.33
Vegetables	7602.47 (3.98)	7623.98 (4.35)	2.14	15.39
Fibre crops	1183.14 (0.62)	566.23 (0.32)	-6.46	39.27
Oilseeds	85878.57 (44.93)	95358.04 (54.47)	0.58	1.13
Medicinal crops	13658.16 (7.15)	14146.56 (8.08)	0.35	1.86
Fodder	2484.17 (1.30)	1657.73 (0.95)	-5.20	83.05
Green manure crops	10.50 (0.01)	169.02 (0.10)	20.86	134.71
Flowers	795.72 (0.42)	654.77 (0.37)	-1.13	13.64
Misc. non-food tree crops	893.54 (0.47)	699.93 (0.40)	-3.01	23.61
Total non-food crops	104884.14 (54.87)	113252.27 (64.69)	0.33	2.53
Total food crops	86262.67 (45.13)	61824.80 (35.31)	-1.84	6.52
Total food and non-food crops	191146.81 (100.00)	175077.07 (100.00)	-0.63	2.64

Table 4. Transition probability matrix of land use pattern in Coimbatore district

	Forests	Area under non -agricultural uses	Barren and unculturable land	Permanent pastures and other grazing lands	Misc. tree crops and groves	Culturable waste land	Current fallows	Net area Sown	Permanent fallows
Forests	**1.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Area under non-agricultural uses	0.0000	**0.8477**	0.0457	0.0000	0.0425	0.0000	0.0506	0.0135	0.0000
Barren and unculturable land	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Permanent pastures and other grazing lands	0.0000	0.0000	0.0000	**1.0000**	0.0000	0.0000	0.0000	0.0000	0.0000
Land under misc. tree crops and groves	0.0000	0.0000	0.0000	0.0000	**0.0000**	0.0000	0.0000	1.0000	0.0000
Culturable waste land	0.0000	0.0000	0.0000	0.0000	0.0000	**0.2623**	0.0000	0.7377	0.0000
Current fallows	0.0000	0.0303	0.0036	0.0000	0.0043	0.0064	**0.9051**	0.0485	0.0018
Net area sown	0.0000	0.0525	0.0059	0.0000	0.0000	0.0350	0.0000	**0.7748**	0.1317
Permanent fallows	0.0000	0.0292	0.0031	0.0000	0.0000	0.0000	0.0000	0.4069	**0.5608**

permanent fallow lands and net sown area. These findings underscore the urgent need for integrated land use policies that harmoniously balance agricultural expansion and urban development under the regime of climate change.

Dynamic Changes of Area Under Major Crop Groups

Transition probability matrix in Table 5 provides insights into the dynamics of crop cultivation within the agricultural system. under study. None of the crop groups demonstrated absolute retention, with medicinal crops emerging as the most stable category with a probability of retaining 90.87% of their area share followed by oilseeds at 87.41% and cereals at 76.18%. This analysis reveals an intricate transition pattern. Cereals, a staple crop group, are expected to lose 6.63% of their area to pulses showing potential for diversification. Oilseeds exhibit the most dynamic transition characteristics, with remarkable potential to gain land area from multiple crop groups, specifically, 38.65% probability of expansion from vegetables, 37.28% from pulses, 35.53% from fruits. This trend aligns with the observed 0.58% growth in oilseed crops. The 'Others' category, primarily comprising green manure, has demonstrated a moderate retention capacity of 54.41%, which explains the substantial positive growth rate of 20.86%. These transitions suggest a profound shift in agricultural practices, indicating farmers' growing awareness of environmental sustainability and the potential negative impacts of inorganic farming.

Conclusion

The land use and cropping pattern dynamics in Coimbatore district reveal a complex agricultural transformation. The study demonstrates a significant shift in agricultural practices, characterized by a steady decline in net sown area and traditional staple food crops like cereals and pulses, while oilseeds emerged as the dominant crop group. A sudden surge in permanent fallows coincided with declined rainfall patterns, underscores the critical role of climatic variations in shaping land use and crop transitions. The increased concentration of miscellaneous tree crops and groves represents a strategic approach to agricultural resilience adapting to climate risks. The expansion of green manure crops further reflects farmers' growing awareness of environmentally conscious farming practices. Alongside agricultural transformations, the district experienced modest urban expansion evidenced by an incremental increase in non-agricultural land area. The findings call for an integrated land use policy that supports climate-smart agricultural practices and provides targeted incentives while balancing urban development. By developing such a comprehensive framework, the district can develop a more resilient and adaptive agricultural landscape.

Table 5. Transition probability matrix of major crop groups in Coimbatore district

	Cereals	Pulses	Spices & Condiments	Fruits	Vegetables	Oilseeds	Medicinal crops	Fodder	Flowers	Others
Cereals	**0.7618**	0.0663	0.0255	0.0427	0.0298	0.0306	0.0000	0.0143	0.0018	0.0272
Pulses	0.1441	**0.4405**	0.0179	0.0000	0.0000	0.3728	0.0159	0.0000	0.0087	0.0000
Spices and Condiments	0.0000	0.2958	**0.4171**	0.0000	0.0000	0.2380	0.0258	0.0233	0.0000	0.0000
Fruits	0.0000	0.0000	0.0438	**0.5020**	0.0000	0.3553	0.0890	0.0000	0.0099	0.0000
Vegetables	0.0000	0.0000	0.0000	0.0423	**0.5711**	0.3865	0.0000	0.0000	0.0000	0.0000
Oilseeds	0.0516	0.0000	0.0082	0.0433	0.0205	**0.8741**	0.0000	0.0023	0.0000	0.0000
Medicinal crops	0.0000	0.0000	0.0645	0.0000	0.0000	0.0000	**0.9087**	0.0000	0.0267	0.0000
Fodder	0.3038	0.1898	0.0000	0.1395	0.0000	0.0000	0.0045	**0.3520**	0.0000	0.0104
Flowers	0.0000	0.0000	0.9722	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0278**	0.0000
Others	0.2382	0.2177	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.5441**

Acknowledgements

I sincerely thank ICSSR (Indian Council of Social Science Research) for providing financial assistance to the study (ICSSR/RFD/2023-24/35).

Authors' contributions

BVS contributed to the conceptualization of the study, conducted the investigation and was responsible for data collection, analysis, result interpretation and drafting the original manuscript. SVR contributed to result interpretation and participated in the review and editing process. KTP and DR provided critical inputs during the review and editing stages, enhancing the manuscript's clarity and overall quality. BVS and SVR reviewed and edited the final draft All authors contributed to the final version of the work and approved the manuscript for publication.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Chat GPT exclusively to enhance the language and clarity of the text. After using this tool, the authors reviewed and edited the content to ensure accuracy and take full responsibility for the content of the publication.

References

1. Tol R. Estimates of the damage costs of climate change. Environ and Resour Economics. 2002;21(2):135–60. https://doi.org/10.1023/A:1014539414591
2. Mendelsohn R, Williams L. Dynamic forecasts of the sectoral impacts of climate change. Human-induced climate change: an interdisciplinary assessment from Part II - Impacts and adaptation. Published online by Cambridge University Press; 06 December 2010.107–18. https://doi.org/10.1017/CBO9780511619472.012
3. Kasperson JX, Kasperson RE, Turner BL. Regions at risk: comparisons of threatened environments. The United Nations University; 1995. Available at: https://archive.unu.edu/unupress/unupbooks/uu14re/uu14re00.htm
4. Kasperson JX, Kasperson RE. International Workshop on Vulnerability and Global Environmental Change: 2001, Stockholm Environment Institute (SEI), Stockholm, Sweden: a Workshop Summary. Stockholm, Sweden: Stockholm Environment Institute; 2001 Available from: Stockholm Environment Institute, Box 2142, SE-103 14 Stockholm, Sweden or: http://www.sei.se/dload/2002/Vulnerability%20report2.PDF
5. Tyson P, Steffen W, Mitra A, Fu C, Lebel L. The earth system: regional–global linkages. Regional Environl Change. 2001;128–40. https://doi.org/10.1007/s101130100033
6. Ramasamy C, Balasubramanian R, Sivakumar SD. Dynamics of land use pattern with special reference to fallow lands–An empirical investigation in Tamil Nadu. Indian J Agri Economics. 2005;60(4):629-43 Available at: https://ageconsearch.umn.edu/record/204427?v=pdf
7. Priyanga V, Thilagavathi M, Selvaraj KN, Dhevagi P, Duraisamy MR. Land use changes and extent of crop diversification in northwestern zone of Tamil Nadu. J Experi Agri Inter. 2023;45(1):9–20. https://doi.org/10.9734/JEAI/2023/v45i12092
8. Turner II BL, Kasperson RE, Meyer WB, Dow KM, Golding D, Kasperson JX, et al. Two types of global environmental change: Definitional and spatial-scale issues in their human dimensions. Global Environ Change. 1990;1(1):14–22. https://doi.org/10.1016/0959-3780(90)90004-S
9. Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, et al. The causes of land-use and land-cover change: moving beyond the myths. Global Environ Change. 2001;11(4):261–69. https://doi.org/10.1016/S0959-3780(01)00007-3
10. Bardhan D, Tewari SK. An investigation into land use dynamics in India and land under-utilisation. Indian J Agri Economics. 2010;65(4):258-76. Available at: https://ageconsearch.umn.edu/record/204718/?v=pdf
11. Tariq A, Yan J, Mumtaz F. Land change modeler and CA-Markov chain analysis for land use land cover change using satellite data of Peshawar, Pakistan. Physics and Chemistry of the Earth, Parts A/B/C. 2022;128:103286. https://doi.org/10.1016/j.pce.2022.103286
12. Zheng X, Xia T, Yang X, Yuan T, Hu Y. The land Gini coefficient and its application for land use structure analysis in China. PLoS One. 2013;8(10):e76165. https://doi.org/10.1371/journal.pone.0076165
13. Liu H, Jia Y, Niu C, Gan Y. Spatial pattern analysis of regional water use profile based on the Gini coefficient and location quotient. JAWRA J American Water Resour Assoc. 2019;55(5):1349–66. https://doi.org/10.1111/1752-1688.12790
14. Singh AJ, Byerlee D. Relative variability in wheat yields across countries and over time. J Agri Economics. 1990;41(1):21–32. https://doi.org/10.1111/j.1477-9552.1990.tb00616.x
15. Deb U, Pramanik S. Groundnut production performance in Bangladesh: a district level analysis. Economic Affairs. 2015;60(3):391–400. https://doi.org/10.5958/0976-4666.2015.00056.X
16. Dent WT. Application of Markov analysis to international wool flows. The Rev Economics and Stat. 1967;613–16. https://doi.org/10.2307/1928354
17. Kusuma DK, Rudrapur SR. Production and export performance of Indian onion-Markov chain analysis. 2016;11(1):70-74. Available at: http://researchjournal.co.in/upload/assignments/11_70-74.pdf