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An Economic Analysis Of Agricultural Crop Diversification In High Rainfall Zone Of Tamil Nadu

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Abstract: *Kanyakumari district, located in the high rainfall zone of Tamil Nadu, has experienced notable shifts in cropping patterns over the past two decades. The present study was undertaken with the specific objectives of analyzing the trends in area under major crops, examining the direction of change in cropping patterns using the Markov Chain approach and evaluating the extent of crop diversification through Herfindahl and Simpson indices. The study is entirely based on secondary data for a 20-year period from 2004-05 to 2023-24, sourced from the Directorate of Economics and Statistics, Tamil Nadu. Major crops considered include paddy, pulses, banana, mango, tapioca, coconut, rubber, spices and fodder. The compound growth rate analysis revealed that while some crops declined in area, rubber and coconut consistently exhibited significant and positive growth. The Markov Chain analysis showed a gradual decline in the share of food crops and a rise in non-food crops, highlighting a marginal improvement in diversification over time. The diversification indices further confirmed mild shifts in crop concentration, with the Herfindahl index increasing and the Simpson index decreasing slightly across the periods. Based on the findings, the study recommends promoting high-value, perennial crops such as rubber, coconut and spices in high rainfall areas like Kanyakumari to enhance income stability. Additionally, the adoption of agroforestry, intercropping and conservation-based practices is suggested to improve land-use efficiency and ensure sustainable agricultural development.*
Keywords: *Crop diversification, High rainfall zone, Compound growth rate, Markov chain analysis, Herfindahl index and Simpson index.*

INTRODUCTION

Crop diversity and shifts in cropping patterns are essential strategies for promoting agricultural intensification. These transformations play a vital role in enhancing the productivity and sustainability of small-scale farming systems. In India, agricultural diversification began to gain momentum in the early 1980s and has continued to expand, with farmers increasingly opting for high-value crops in response to emerging market opportunities (Palanisami *et al.,* 2009). Diversifying cropping systems is widely regarded as a viable approach to sustaining agricultural productivity and minimizing market-related risks. It also acts as a bridge from subsistence farming to more commercially oriented agriculture (Rehima *et al.,* 2013). Farmers often pursue diversification to reduce their vulnerability to unpredictable weather patterns and market fluctuations, while aiming for improved returns and more efficient use of resources (FAO, 2018; Mango *et al.,* 2018). According to Velavan and Balaji (2012), crop diversity is a key method for boosting income, generating employment and stabilizing revenue streams. Crop diversification involves shifting from less profitable to more profitable crops, modifying crop varieties, adjusting cropping systems and enhancing competitiveness in both domestic and international markets (Nguyen, 2014). According to Clements *et al.,* (2011) and Feliciano (2019), it is characterized by the replacement of low-value commodities with high-value alternatives, such as fruits and vegetables, primarily for export purposes.

Role in Sustainable Agriculture

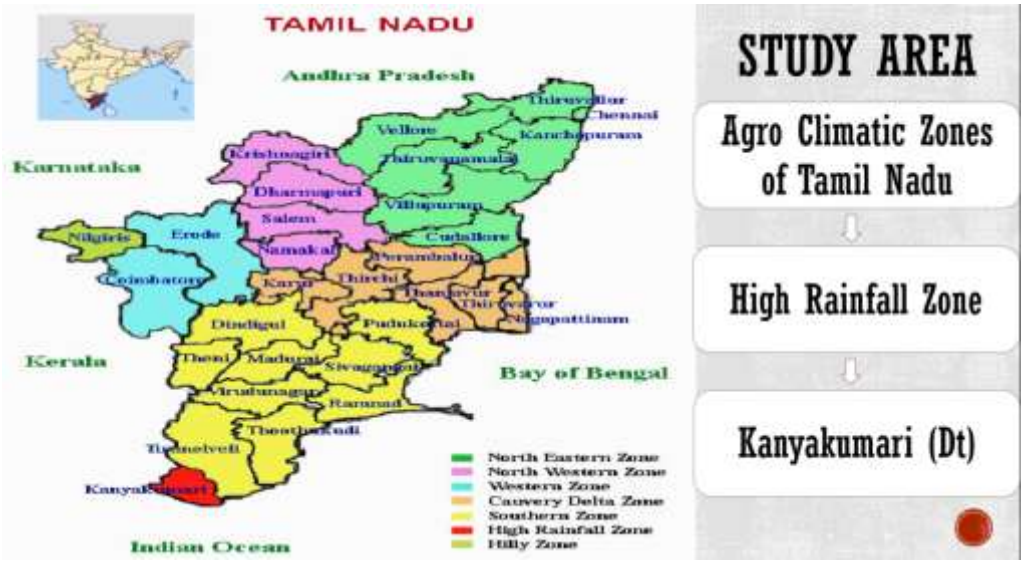
To maintain or enhance the value of natural resources such as land and water, cropping systems have been modified or new systems introduced. This is particularly important for smallholder farmers aiming to improve profitability. Crop diversification accommodates an increasing number of profitable crops, thereby contributing to better income generation (Kalaiselvi, 2012; Krishnan, 2017). In India, crop

diversification is generally viewed as a shift from traditionally grown, less-remunerative crops to more profitable alternatives. It ensures food, nutrition, income and employment security for a broader segment of society and has a significant impact on the country's Gross Domestic Product (Amirthalingam and Devi, 2018). Acharya *et al.,* (2011) highlight that crop diversification enhances cropping intensity, generates employment, reduces male migration and encourages women's participation in income-generating activities.

"Crop diversification as an effective strategy for sustainable agriculture development has the sound capacity for achieving the goal of nutritional security, stabilizing farm income, food security, employment generation, poverty reduction and conservation of natural resources."

Sampling Procedure

The study relies on secondary data collected over a 20-year period (2004-05 to 2023-24) from the Directorate of Economics and Statistics, Tamil Nadu. Kanyakumari district, which falls under the high rainfall zone, was purposively selected due to its climatic and geographical suitability for analyzing crop diversification. The major crops cultivated in the district include paddy, pulses, banana, mango, tapioca, coconut, rubber, spices and fodder. The dataset comprises the annual cropped area for each of these crops.



Since the study adopts a macro-level approach, it is entirely based on secondary time series data without the inclusion of primary sampling units such as farmers or villages. Statistical tools such as the Compound Annual Growth Rate (CAGR), Markov chain analysis and crop diversification indices (Herfindahl and Simpson) were employed to evaluate changes in crop area and diversification trends. The application of these methods ensures the robustness of the study's findings on cropping pattern dynamics over time.

Compound Growth Rate Analysis

The growth in cropping pattern was estimated using the exponential growth function of the form.

$Y_t = a\, b^t\, u_t$ ..... (1)

Where, Y_t = Dependent variable for which growth rate was estimated (Ex. Cropped area), a=Intercept, b=Regression coefficient, t=Year which takes values, 1, 2...., n, u_t = Disturbance term for the year t

The equation was transformed into log linear form for estimation purpose and was estimated using Ordinary Least Square (OLS) technique. The Compound Growth Rate (g) in percentage was then computed from the following relationship.

g = (Antilog of ln b - 1) * 100

The significance of the regression coefficient was tested using the student's 't' test

Markov Chain Model

The direction of change in cropping pattern was analysed by using First Order Markov Chain Approach. The Lingo Software was used for the purpose. Markov Chain Analysis is the estimation of the transitional

probability matrix 'P' whose elements, P_{ij} indicate the probability of shifting area from one crop 'i' to another crop 'j' over time. The diagonal element P_{ij} where i=j, measures the probability of a crop retaining its share. The average area shifted to a particular crop was considered to be a random variable which depends only on the area under past crop, which can be denoted algebraically as:

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

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

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

$\sum_{i=1}^{n} P_{ij} = 1$ And $0 \leq P I j \leq 1$

Based on the results of Markov chain analysis, the Projections of area under different crops for the period (2002-2022) 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 the crop in base year; $B_{(t+1)}$ = Area under the crop in next year (prediction); T= Transitional probability matrix.

Crop Diversification Index

(a) Herfindahl Index (HI):

The Herfindahl index was used to determine the state's level of diversification. The Herfindahl index is calculated as follows:

$HI = \sum^{n}_{i=1} P_i^2$

P_i = Proportion of area under i th crop

$P_i = A_i / \sum A_i$

In which A_i = Area under i^{th} crop and $\sum^{n}_{i=1} A_i$ = Total cropped area

The HI index is a measure that ranges from zero to one. In the event of perfect specialisation, it is one, while in the case of perfect diversity, it is zero.

(b) Simpson Index (SI)

It is defined by;

$SI = 1-\sum^{n}_{i=1} P_i^2$

It ranges between 0 to 1. SI assumes the value 1 at full diversification and 0 at full concentration

RESULTS AND DISCUSSION

Growth Rate of area Under Major Crops in Kanyakumari District

The results of compound growth rate for the major crops in Kanyakumari District were collected from the period 2004-05 to 2023-24, where the study area has been worked out using exponential growth model for two decades viz., Decade 1 (2004-05 to 2013-14) and Decade 2 (2014-15 to 2023-24).

Table 1: Compound Growth Rate for area under major crops in Kanyakumari District, 2004-05 to 2023-24.

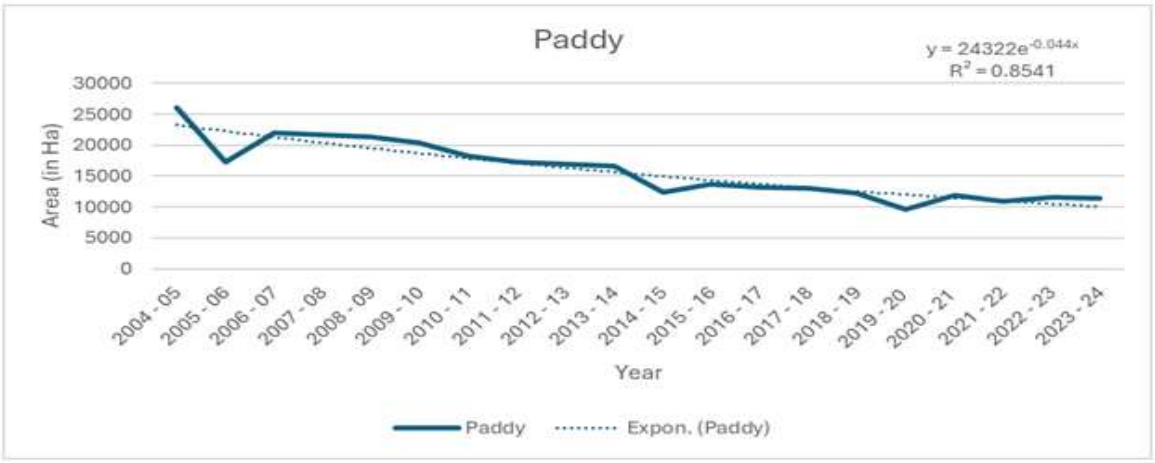
Crops	Decade 1	Decade 2	Overall
Paddy	-3.55**	-1.96	-4.32*
Pulses	-18.10*	-13.55**	-10.35*
Banana	1.70	-4.27*	-0.49
Mango	-1.81*	-0.46	-1.50*
tapioca	-9.53*	11.33	-13.30*
Coconut	0.94*	0.27**	0.15
Rubber	3.48*	0.63*	2.82*
Spices	-3.67*	0.31	-1.63*
Fodder crops	9.34*	-4.76**	2.04

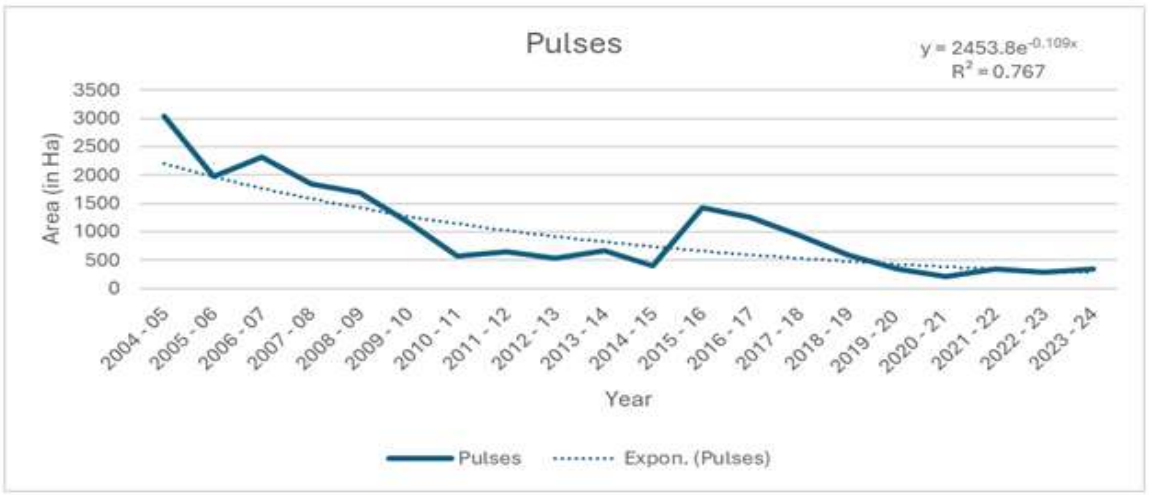
*Note: * and ** indicates 1% and 5% level of Significance*

It is analyzed from the table 1, that the decade 1 (2004-05 to 2013-14) shows positive significant growth

rate in Fodder crops (9.34 Per cent), Rubber (3.48 Per cent) and Coconut (0.94 Per cent). However, Pulses (18.10 Per cent), Tapioca (9.53 Per cent), Spices (3.67 Per cent), Paddy (3.55 Per cent) and Mango (1.81 Per cent) shows negative significant growth rate. Where Banana (1.70 Per cent) shows positive non-significant growth rate. Whereas in the decade 2 (2014-15 to 2023-24) shows positive significant growth rate in Rubber (0.63 Per cent) and Coconut (0.27 Per cent). However, Pulses (13.55 Per cent), Fodder crops (4.67 Per cent) and Banana (4.27 Per cent) shows negative significant growth rate. Whereas Tapioca (11.33 Per cent) and Spices (0.31 Per cent) shows positive non-significant and Paddy (1.96 Per cent) and Mango (0.46 Per cent) shows negative non-significant growth rate.

Overall compound growth rate shows positive significant growth rate in Rubber (2.82 Per cent). However, Tapioca (13.30 Per cent), Pulses (10.35 Per cent), Paddy (4.32 Per cent), Spices (1.63 Per cent) and Mango (1.50) shows negative significant in growth rate. Where, Fodder crops (2.40 Per cent) and coconut (0.15 Per cent) shows positive non-significant and banana (0.49 Per cent) shows negative non-significant growth rate. The Results would clearly, indicates that the area of crops in Kanyakumari district has been somewhat diversified over the two decades in cultivation area while others have shown growth. Coconut and Rubber have been the most successful in terms of consistent and significant expansion in cultivated area. The trend lines of major crops are shown in the Kanyakumari district for the past 20 years is listed below in figures.





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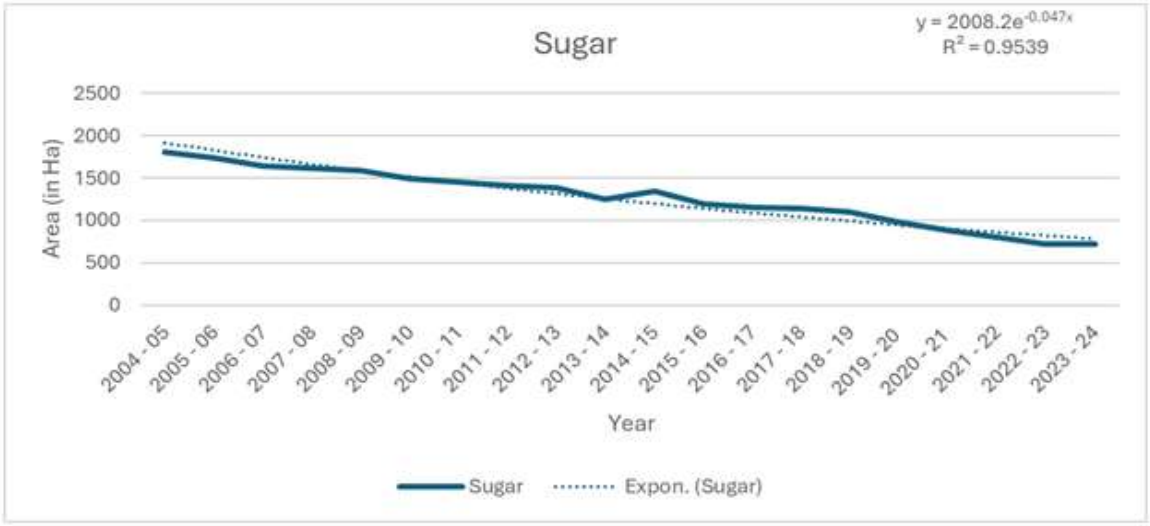

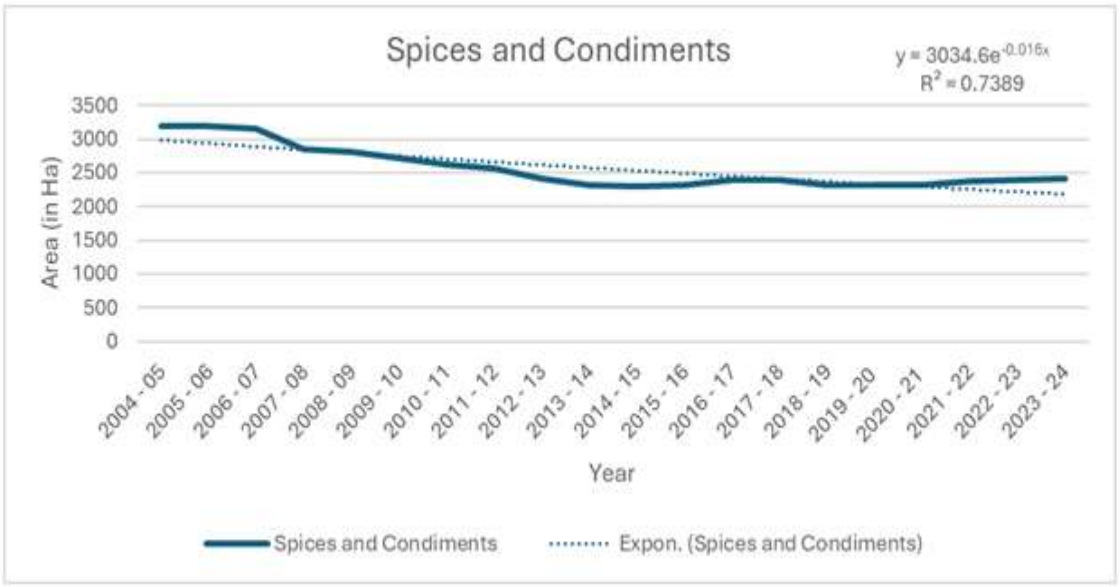

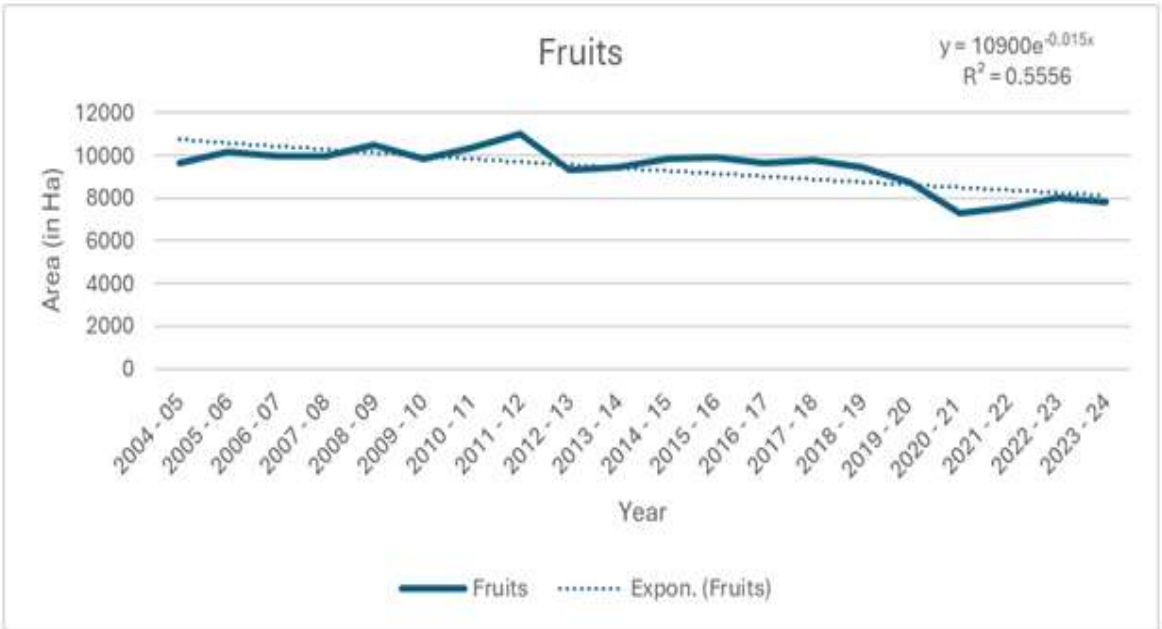

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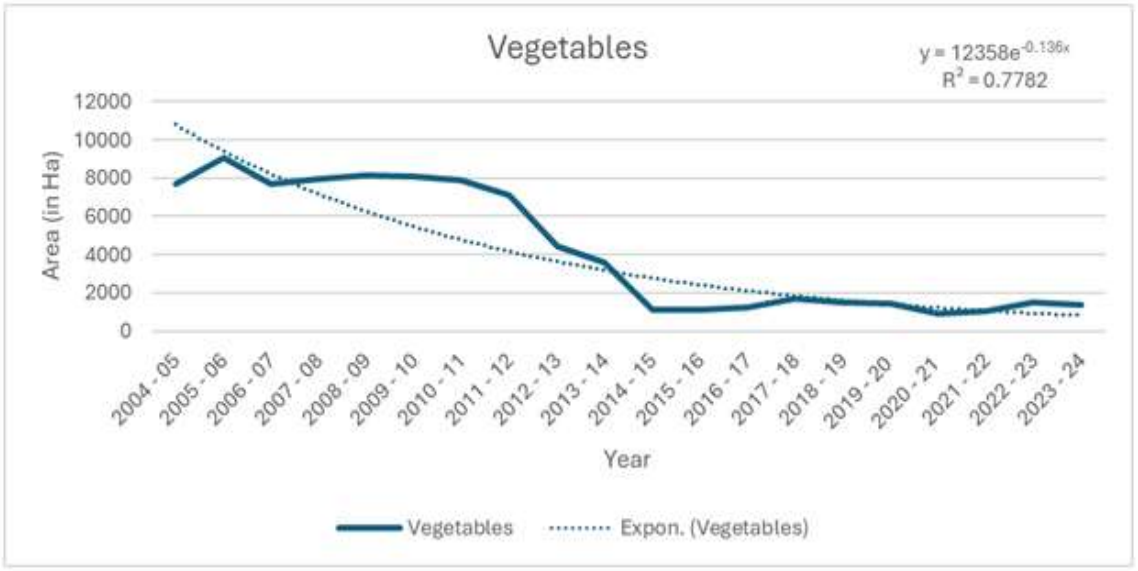

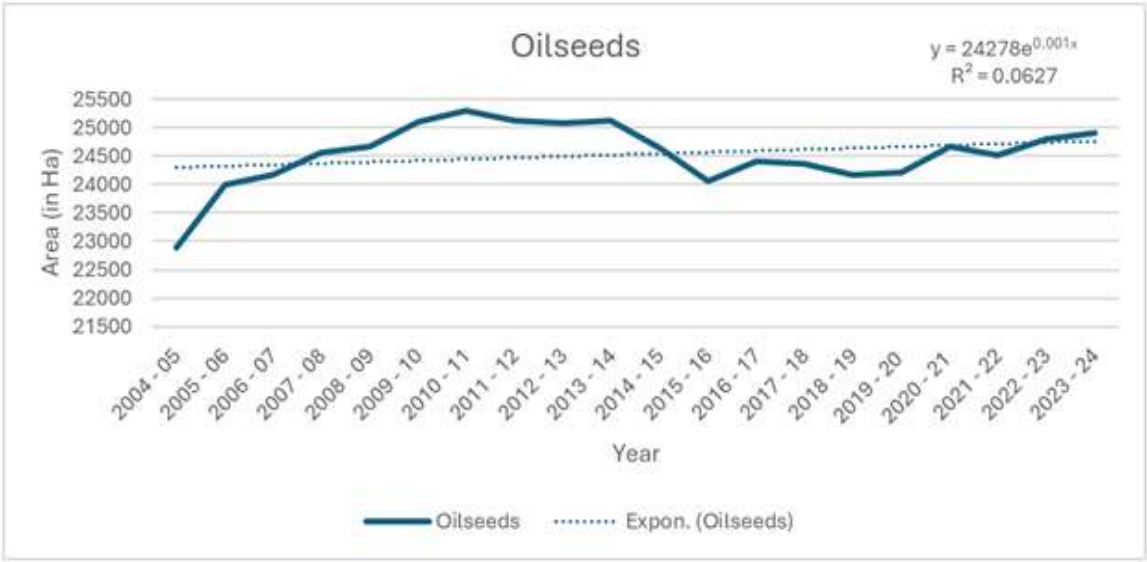

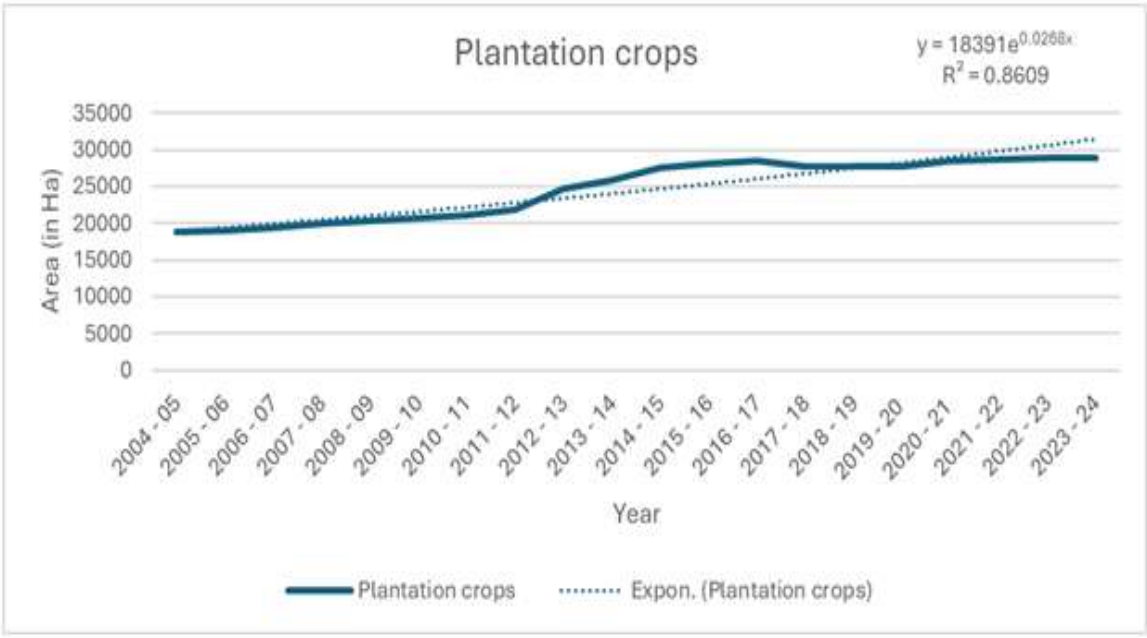

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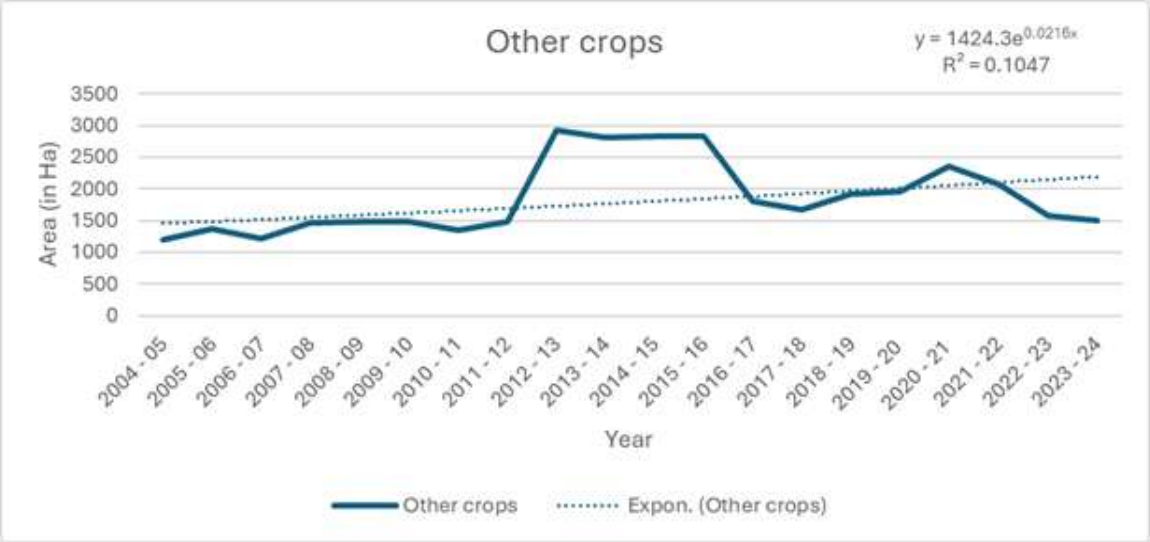

Markov Chain Analysis of Major Crops in Kanyakumari District

Table 2. Transitional Probability Matrix for Major Crops in Kanyakumari District at Decade 1 (2004-05 to 2013-14)

Decade 1	Paddy	Pulses	Banana	Mango	Tapioca	Coconut	Rubber	Spices	Fodders	others
Paddy	**0.356**	0.010	0.057	0.023	0.093	0.285	0.042	0.040	0.017	0.076
Pulses	0.308	**0.334**	0.001	0.003	0.352	0.002	0.000	0.001	0.000	0.000
Banana	0.250	0.000	**0.096**	0.029	0.000	0.393	0.155	0.001	0.033	0.043
Mango	0.800	0.046	0.000	**0.000**	0.000	0.000	0.000	0.005	0.000	0.148
Tapioca	0.299	0.000	0.078	0.053	**0.236**	0.218	0.014	0.063	0.009	0.030
Coconut	0.169	0.000	0.106	0.037	0.052	**0.460**	0.049	0.035	0.029	0.064
Rubber	0.010	0.000	0.005	0.002	0.000	0.065	**0.915**	0.000	0.002	0.001
Spices	0.127	0.069	0.094	0.062	0.250	0.264	0.017	**0.073**	0.010	0.033
Fodders	0.149	0.000	0.081	0.026	0.000	0.591	0.064	0.000	**0.036**	0.053
Others	0.290	0.007	0.081	0.053	0.170	0.225	0.014	0.064	0.009	**0.086**
SSP	**0.176**	**0.007**	**0.054**	**0.023**	**0.058**	**0.244**	**0.358**	**0.024**	**0.014**	**0.042**

The result of the Markov Chain analysis for Major crops in Kanyakumari District has been analyzed for past 20 years from 2004-05 to 2023-24. Where the Table 2 and 3 represents the Transitional and steady state probabilities for the shift in cropping pattern between the two decades viz., Decade 1 from 2004-05 to 2013-14 and Decade 2 from 2014-15 to 2023-24. It is inferred from the Table 2, that the decade 1 (2004-05 to 2013-14) shows the shift in area of different crops. Among all the crops Rubber has the highest retention probability followed by coconut, paddy respectively. Where, Rubber retained 91.5 Per cent of its area and lost 6.5 Per cent of coconut, 1 Per cent to paddy and less than 1 Per cent remaining crops. However, Rubber gained 15.5 Per cent from banana, 6.4 Per cent from Fodder crops, 4 Per cent from both paddy and coconut and remaining crops shares the area of one or less than one Per cent. Coconut retained the second position in decade 1, where it retained 46 Per cent of its area and lost 16.9 Per cent to paddy, 10.6 Per cent to banana and less than 6 Per cent to remaining crops. However, it gained 59.1 from fodder crops, 39.3 Per cent from banana and remaining crops shares the area of less than 30 Per cent. Paddy retained 35.6 Per cent of its area and lost 28.5 Per cent to coconut, 9.3 Per cent to tapioca and less than 8 Per cent to remaining crops. However, it gained 80 Per cent from mango, 30 Per cent from both Tapioca and Pulses and remaining crops shares the area of less than 30 Per cent. Remaining Crops have been retained less than 35 Per cent except Mango, where mango has failed to retain its area and lost 80 Per cent to paddy and less than 15 Per cent to remaining crops. However, it gained 6.2 Per cent spices and remaining crops shares the area less than 5.3 Per cent. The SSP showed that if the trend

continues like this, in future area under cultivation in Rubber is 35.8 Per cent, followed by coconut 24.4 Per cent, paddy 17.6 Per cent and remaining crops have less than 6 Per cent.

Table 3. Transitional Probability Matrix for Major Crops in Kanyakumari District at Decade 1 (2014-15 to 2023-24)

Decade 1	Paddy	Pulses	Banana	Mango	Tapioca	Coconut	Rubber	Spices	Fodders	Others
Paddy	0.321	0.000	0.070	0.000	0.000	0.156	0.453	0.000	0.000	0.000
Pulses	0.000	0.391	0.200	0.000	0.323	0.000	0.000	0.000	0.000	0.086
Banana	0.553	0.000	0.290	0.005	0.000	0.000	0.000	0.000	0.152	0.000
Mango	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tapioca	0.000	0.000	0.000	0.042	0.290	0.221	0.329	0.000	0.117	0.000
Coconut	0.053	0.000	0.000	0.000	0.000	0.535	0.412	0.000	0.000	0.000
Rubber	0.082	0.000	0.000	0.000	0.000	0.122	0.797	0.000	0.000	0.000
Spices	0.000	0.000	0.000	0.000	0.000	0.797	0.000	0.203	0.000	0.000
Fodders	0.473	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.357	0.141
Others	0.152	0.016	0.051	0.000	0.025	0.262	0.296	0.036	0.000	0.162
SSP	0.145	0.005	0.064	0.027	0.013	0.319	0.367	0.031	0.017	0.014

It is inferred from the Table 3, that the decade 2 (2014-15 to 2023-24) shows the higher shift in area of different crops. Among all the crops Rubber has the highest retention probability followed by coconut, pulses respectively. Where, Rubber retained 79.7 Per cent of its area and lost 12.2 Per cent of coconut, 8.2 Per cent to paddy. However, Rubber gained 45.3 Per cent from paddy, 41.2 Per cent from coconut, 32.9 Per cent from tapioca and 29.6 Per cent from other crops. Coconut retained the second position in decade 2 also, where it retained 53.5 Per cent of its area and lost 41.2.7 Per cent to rubber and 5.3 Per cent to coconut. However, it gained 79.7Per cent from spices, 26.2 Per cent from other crops and remaining crops shares the area of less than 25 Per cent. Pulses retained 39.1 Per cent of its area and lost 32.3 Per cent to tapioca, 20 Per cent to banana and 8.6 Per cent to other crops. However, it gained 3 Per cent from fodder crops and 1.6 Per cent from other crops. Remaining Crops have been retained less than 35 Per cent except Mango, where mango has failed to retain its area and lost 100 Per cent to paddy. However, it gained 4.2 Per cent from tapioca and 0.5 Per cent from banana. The SSP showed that if the trend continues like this, in future area under cultivation in Rubber is 36.7 Per cent, followed by coconut 31.9 Per cent, paddy 14.5 Per cent and remaining crops have less than 6.4 Per cent.Overall, the analysis on both decades, it revealed that there is a considerable shift in crop diversification in Kanyakumari district. During Decade-2 (2014-15 to 2023-24), it shows that there are higher shifting probabilities observed between different crops. In contrast, Decade-1 (2004-05 to 2013-14) shows a relatively stable cropping pattern with lower shifting probabilities.

Crop Diversification in Kanyakumari District

To analyze the crop diversification of major crops grown in Kanyakumari District over the period from 2004-05 to 2023-24 was calculated the Herfindahl-Hirschman Index (HHI) and Simpson's Diversity Index (SDI) for four different periods viz., Period 1 (2004-05 to 2008-09), Period 2 (2009-10 to 2013-14), Period 3 (2014-15 to 2018-19) and Period 4 (2019-20 to 2023-24). These Indices will provide insights into the concentration or diversification of crop areas over time.

Table 4: Crop Diversification Index

S. No	Period	HHI	SDI
1.	2004-05 to 2008-09	0.182	0.818
2.	2009-10 to 2013-14	0.196	0.804
3.	2014-15 to 2018-19	0.228	0.772
4.	2019-20 to 2023-24	0.252	0.748
	Average	0.215	0.785

From the Table 4, the result is noted that HHI and SDI value was 0.182, 0.196, 0.228, 0.252 and 0.818,

0.804, 0.772, 0.748 over the periods. While comparing all the four different periods, the HHI value is increases and SDI value decreases, it suggests a slight decrease in crop diversification and mild increase in crop concentration. The average of HHI and SDI values for the period of 2004 -05 to 2023-24 were 0.215 and 0.785, this clearly shows that there is agricultural diversification has occurred in the study area over the periods.

CONCLUSAION

The study of Kanyakumari district over the past two decades reveals a moderate level of crop diversification, with certain crops such as rubber and coconut showing consistent and significant growth, while others have declined. The transitional probability matrices indicate a gradual reduction in the share of food crops and a corresponding increase in non-food crops, reflecting fluctuating yet marginal improvements in overall agricultural diversification. Given the district's high rainfall and favorable agro-climatic conditions, the promotion of perennial and high-value crops like rubber, coconut and spices is recommended to enhance income stability. Additionally, the adoption of agroforestry, intercropping systems and conservation-based practices can help maximize land use efficiency, minimize soil erosion and support the long-term sustainability of agricultural systems in the region.

Conflict Of Interest

The authors declare that there is no conflict of interest regarding the publication of this article. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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