Asian Research Journal of Agriculture

Volume 17, Issue 1, Page 1-9, 2024; Article no.ARJA.111723
ISSN: 2456-561X

Dynamics of Crop Diversification in Midlands of Kerala, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author AGB designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors KPJ and Bhosale S. S. managed the analyses of the study. Authors Banekol S. S. and SMS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARJA/2024/v17i1405

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/111723

Original Research Article

Received: 05/11/2023
Accepted: 11/01/2024
Published: 12/01/2024

ABSTRACT

Aims: This study presents the extent of crop diversification as well as the reasons in the three districts of Kerala state; Thiruvananthapuram, Kottayam and Kannur which falls in the midland region of Kerala.
Methodology: Secondary data on area under cultivation of various crops for the time period of 2005-06 to 2020-21 was subjected to analysis using Simpson Index, Modified Entropy Index and Markov chain analysis.
Results: Kannur was found to be highly diversified with high value of Simpson Index of around 0.79 followed by Thiruvananthapuram with SI of around 0.74. Transitional probability matrix of Thiruvananthapuram revealed that coconut, spices and condiments retained more area in the district followed by non-food crops with an area retention. Non-food crops retained highest area

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followed by coconut, spices and condiments in Kottayam. More area occupying crop in Kannur was found to be non-food crops followed by coconut, spices and condiments. However, overall scenario in midland region showed that more area was occupied by non-food crops followed by coconut, spices and condiments.

Conclusion: The period from 2005-06 to 2020-21 showed changing pattern of acreage distribution in the three selected districts of Kerala with a declining trend in total cropped area and shift from food crops to non-food crops.

Keywords: Crop diversification; midlands; Markov chain; non-food crops; Simpson index.

1. INTRODUCTION

Looking from a narrow perspective, crop diversification means increasing the types of agricultural commodities produced at the farm level which can either be driven by market forces or biotic/abiotic stress conditions whereas from broader aspect, agricultural diversification involves the entire rural economy and leads to expanding the income sources of rural households [1]. Crop diversification aims to provide a wider range of options in the production of crops in a given area, to expand production related activities on various crops, reduce agricultural risks, ensure food and nutrition security, increase income and employment for a wider segment of society and has a substantial impact on the country's GDP.

The formation and strengthening of Farmer Producer Organizations that provide collective marketing, technical assistance, and input procurement support to farmers, encouraging them to diversify crops based on market demands, have played a vital role in promoting crop diversification in Kerala. Agricultural research institutions and extension services in Kerala develop and disseminate improved crop varieties, provide training on sustainable farming practices, and offer technical guidance to farmers thus actively contributing to crop diversification.

One of the significant features of Kerala's agricultural scenario is the gradual shifting of areas from food crops like rice and tapioca to plantation crops like coconut, rubber and coffee [2]. Rice was considered the prominent food crop even though the agro climatic conditions of Kerala is favourable for spices and plantation crops. In recent years, perennial crops have taken over the agricultural lands of the state. In contrast to rest of the country where diversification occurred among annual crops, Kerala faced a shift from seasonal crops like paddy to perennial crops such as coconut and rubber [3]. The trend of crop diversification in Kerala started slowly in favour of non-food crops since the mid-1970's [4]. The reduction in the area under food crops in Kerala from 40.43 percent in 1970-71 to 18.74 percent in 1992-93 and 16.52 percent in 2002-03 is a phenomenon that has happened very rarely in any state [5] Agriculture in Kerala became more vulnerable due to decline in cultivable area, fragmentation of land holdings and reduction in availability of agricultural labour [6]. The state has high population density and limited availability of arable land which results in farmers having small and fragmented landholdings. The area under food crops in Kerala has been dwindling over the years, while the area under commercial crops like rubber, arecanut and banana has been rising [7]. Also, Kerala has witnessed many environmental challenges like soil erosion, recurring floods, biodiversity loss and declining soil fertility in recent years. Hence this study focusses mainly on extend of crop diversification in the midlands of Kerala over the years.

2. METHODOLOGY

Kerala is the most literate state, however, there is ample amount of cultivation of crops in the state. Nearly 30 per cent of the families in Kerala depend upon agriculture for their livelihood. Agricultural land of the state accounts for 55 per cent, while forest land covers 28 per cent and 11 per cent lands are put for non-agricultural use [8]. Kerala has a rich agricultural heritage with a wide range of traditional and indigenous crops including rice, coconut, banana, pepper, cardamom, rubber, ginger, turmeric, yam, tapioca, and various types of vegetables. With the state government and agricultural agencies actively promoting high-value horticultural crops, such as fruits, vegetables, spices, and flowers, crops like pineapple, mango, jackfruit, passion fruit, cashew, nutmeg, clove, vanilla, and various leafy green vegetables are being encouraged which diversify income sources and enhance nutritional security. Moreover the state encompasses different regions with varying

altitudes, rainfall patterns and soil type which allows for the cultivation of different crops that thrive in specific microclimates contributing to overall crop diversification.

Kerala state has 14 districts, among which the midland area is spread over all the districts except Wayanad, which is predominated by the highlands. Among the midlands, three districts, i.e., Thiruvananthapuram from the southern side, Kottayam representing the central region and Kannur from the northern region were selected randomly. Published sources and reports like Agricultural statistics by Department of Economics and Statistics, Kerala and Natural Resource Data Bank by Kerala State Land Use Board were referred for statistical data [8].

2.1 Compound Annual Growth Rate

Compound Annual Growth Rate is calculated by using following formula:

$$\mathrm{CAGR} = [\mathrm{antilog(b)} - 1] \times 100$$

Where, b= Regression Coefficient that shows the rate of change or growth rates in a series.

The positive sign and magnitude in CAGR suggests accelerated growth rate while negative sign suggests deceleration.

2.2 Diversification Index

Given the widespread applicability in research works, we employed Herfindahl index, Simpson index and Modified Entropy index to measure the degree of agricultural diversification. Among all the indices, Simpson's and Entropy Index are widely used in the view of agricultural diversification [9].

2.2.1 Modified Entropy Index (MEI)

Entropy Index (EI) measures crop diversification directly which has a logarithm character. The formula of Entropy index is,

$$\mathrm{EI} = \sum_{i=1}^{N} P_i \times \ln\left(\frac{i}{P_i}\right)$$

Here, $P_i = \frac{A_i}{\sum_{i=1}^{N} A_i}$

Where,

P_i= percentage of area of the i^{th} crop in total cropped area

A_i=actual area under i^{th} crop
$\sum A_i$ = total cropped area
N= number of crops grown

When Entropy Index takes up the value 0, it indicates complete specialization whereas the upper limit of EI value indicates full diversification. The upper limit of Entropy Index is determined by the base of the logarithm and number of crops. The upper limit can exceed one, when the number of total crops are higher than the base of logarithm. In order to bound the Entropy Index within 1 and 0, logarithm to the base of total number of crops are considered. This is Modified Entropy Index (MEI) and is given as,

$$\mathrm{MEI} = \sum_{i=1}^{N} P_i \times \log_N\left(\frac{i}{P_i}\right)$$

2.2.2 Simpson Index (SI)

Simpson index is the most practicable and widely used index for measuring horizontal crop diversification in any specific geographical area.

The formula of Simpson Index is,

$$\mathrm{SI} = 1 - \sum_{i=1}^{N} P_i^2$$

The value of SI ranges between 0 and 1. The value almost zero denotes area is close to specialization whereas value near to one denotes that area is fully diversified.

2.3 Markov Chain Analysis

The First order Markov chain analysis was used to study the diversification towards shares of land use of different crops. The process of crop diversification can be described in the form of a matrix P of first order transition probabilities. The element P_{ij} of the matrix indicates the probability of a farmer to cultivate crop i in one period will move to crop j during the following period. The diagonal elements of the matrix measure the probability that the proportion i^{th} crop will be retained.

$$E_{jt} = \sum_{i=1}^{r} \left(E_{it-1} \times P_{ij} + e_{jt}\right)$$

Where,

E_{jt} = Area under j^{th} crop during period t
E_{it-1} = Area under i^{th} crop during the period t-1
P_{ij}= Probability that the share of area will shift from i^{th} crop to j^{th} crop

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

t = Number of years considered for the analysis

3. RESULTS AND DISCUSSION

Table 1 depicts the changing pattern of acreage distribution among different crops in three chosen districts of Kerala during 2005-06 to 2020-21. Allocation share of acreage under paddy shows a declining trend in Thiruvananthapuram and Kannur, with subsequent rise in non-food crops. Unlike in other parts of country where shifts occurs within the annual crops, in Kerala shift has been from seasonal crops such as paddy to perennial crops like coconut and rubber [3]. Total cropped area shows a declining trend in all the three districts (CAGR of -0.16% for both districts Thiruvananthapuram and Kottayam and -0.14% for Kannur). Significant decline in pulses (-9.04 %), paddy (-5.28 %), spices and condiments (-6.90 %) is chiefly responsible for the downfall in total cropped area in Thiruvananthapuram whereas significant decline in pulses (-28.23 %) is responsible for the subsequent downfall of total cropped area in Kottayam district. Significant decline in acreage of paddy (-3.00 %), tapioca (-1.93 %), spices and condiments (-5.46 %) explains the decrease in total cropped area of Kannur district. Non-food crops shows a significant increase of 1.14% and 1.47% in Thiruvananthapuram and Kannur respectively, whereas Kottayam show a non-significant rise of 0.09 %. It is concluded from the table that the overall crop area of paddy, pulses, tapioca, coconut, spices and condiments have been shifted towards the total fruit crops and non-food crop area over a period of time. Cost of cultivation in Kerala is high compared to other states as the labour charges are very high. This is one of the main reason for the farmers to shift from highly labour intensive food crops to that of non-food crops. The declining total area under cultivation can be explained by the unattractive prices of agricultural products, labour scarcity and import of foodgrains and vegetables from neighbouring states such as Tamil nadu and Andhra Pradesh.

Indices of diversification is carried out and Table 2 depicts the extent of Diversification Indices in study area during 2005-06 to 2020-21 period. A close perusal of Table 2 depicts extend of crop diversification in three districts, i.e., Thiruvananthapuram, Kottayam and Kannur during different points of time i.e., 2005-06, 2009-10, 2013-14, 2017-18 and 2020-21. All the three methods used showed similar pattern of results in crop diversification. The districts having cultivation of a number of crops (n= >25) shows a very good range of crop diversification indices (similar to results of similar to results of Mithiya et al., [10] Basu and Barman, [11]. Though, small extend of changes in diversification has been observed in the districts over the years, SI remains around 0.74 in Thiruvananthapuram, 0.67 in Kottayam and 0.79 in Kannur. Ayyoob [12] pointed out that crop diversification in the state declined as the state focussed more on cash crops like rubber, plantation crops, spices etc. Among the three districts, Kannur was evidenced to be highly diversified with HI around 0.21 and SI around 0.79. Even though the district showed a downfall of SI from 0.82 during 2005-06 to 0.78 in a time span of 8 years, Kannur topped during all the time period in sense of crop diversification. Thiruvananthapuram stagnated at SI of 0.73 and 0.74 which is considered to be fairly diversified situation. Kottayam had SI of 0.70 during 2005-06 which slipped down to 0.64 over 7 years span. However, ranking of the district based on diversification indicated that the crop area was slightly shifting to the specialized farming like non-food crops and fruit crop farming. As the food crops such as paddy and vegetables demand labour throughout the production period resulting in high cost of cultivation due to the high labour charges leads to the shift from these crops to non-food crops, rubber, coconut etc. whose labour requirements are comparatively low.

Table 3 proves that Kannur district ranked first during all the time period. Both the indices (SI and MEI) shows similar results i.e. Kannur ranks first followed by Thiruvananthapuram and then Kottayam. From Table 3 it is clear that diversification indices is going down slightly over 15 years.

Transitional probability of area in Thiruvananthapuram, Kottayam and Kannur district has been presented in the Tables 4, Table 5 and Table 6 respectively which helps in determining the crop retention area and shift in crop area over a period of time in the district.

It is revealed from Table 4 that over a period of 15 years, Thiruvananthapuram district retained 39 per cent of area under paddy, 35 per cent of area under tapioca, 59 per cent of area under

Table 1. Growth of area coverage under major crops in the selected districts

Crops	Thiruvananthapuram					Kottayam					Kannur				
	CAGR (%)	R^2	*P*-Value	SE	t-value	CAGR (%)	R^2	*P*-Value	SE	t-value	CAGR (%)	R^2	*P*-Value	SE	t-value
Paddy	-5.28**	0.68	0.00	0.01	-5.43	3.46**	0.59	0.00	0.01	4.53	-3.00**	0.50	0.00	0.01	-3.72
Pulses	-9.04*	0.25	0.05	0.04	-2.19	-28.23**	0.56	0.00	0.08	-4.20	2.02^{NS}	0.07	0.32	0.02	1.03
Spices & Condiments	-6.90**	0.93	0.00	0.01	-13.45	-4.85**	0.72	0.00	0.01	-6.03	-5.46**	0.80	0.00	0.01	-7.54
Fruits	1.79**	0.57	0.00	0.00	4.29	0.06^{NS}	0.00	0.90	0.00	0.13	-0.51^{NS}	0.07	0.33	0.01	-1.02
Tapioca	-2.41**	0.68	0.00	0.00	-5.44	0.30^{NS}	0.06	0.34	0.00	0.98	-1.93**	0.48	0.00	0.01	-3.63
Vegetables	1.34*	0.35	0.01	0.00	2.77	0.13^{NS}	0.00	0.84	0.01	0.21	0.82^{NS}	0.14	0.16	0.01	1.50
Coconut	-0.64**	0.39	0.01	0.00	-2.98	-2.71**	0.79	0.00	0.00	-7.20	0.13^{NS}	0.01	0.69	0.00	0.41
Non-food crops	1.14**	0.93	0.00	0.00	13.19	0.09^{NS}	0.20	0.08	0.00	1.87	1.47**	0.83	0.00	0.00	8.20
Other crops	-2.89**	0.52	0.00	0.01	-3.89	-5.35**	0.78	0.00	0.01	-7.07	-3.59**	0.66	0.00	0.01	-5.19

**Significant at 5% level; **Significant at 1% level*

Table 2. Dynamics of crop diversification in selected districts

Year	Thiruvananthapuram			Kottayam			Kannur		
	SI	EI	MEI	SI	EI	MEI	SI	EI	MEI
2005-06	0.74	1.83	0.67	0.70	1.75	0.65	0.82	2.10	0.78
2009-10	0.73	1.78	0.66	0.67	1.67	0.62	0.80	2.04	0.75
2013-14	0.74	1.81	0.67	0.64	1.57	0.58	0.78	1.95	0.72
2017-18	0.75	1.81	0.67	0.67	1.49	0.55	0.78	1.95	0.72
2020-21	0.74	1.78	0.66	0.67	1.66	0.61	0.78	1.93	0.71

Table 3. Ranking the districts based on diversification Indices in three districts over the year

Districts	Simpson Index			Modified Entropy Index		
	2005-06	2013-14	2020-21	2005-06	2013-14	2020-21
Thiruvananthapuram	0.74 (II)	0.74 (II)	0.74 (II)	0.67 (II)	0.67 (II)	0.66 (II)
Kottayam	0.70 (III)	0.64 (III)	0.67 (III)	0.65 (III)	0.58 (III)	0.61 (III)
Kannur	0.82 (I)	0.78 (I)	0.78 (I)	0.78 (I)	0.72 (I)	0.71 (I)

**Figures in parentheses indicates the corresponding rank (R_i) among the districts*

Table 4. Transitional probability matrix of area in Thiruvananthapuram district

Crops	Paddy	Tapioca	Vegetables & Pulses	Fruits	Coconut, Spices & Condiments	Non Food Crops & Others
Paddy	0.39	0.42	0.00	0.00	0.19	0.00
Tapioca	0.09	0.35	0.00	0.00	0.39	0.17
Vegetables & Pulses	0.00	0.00	0.59	0.00	0.00	0.41
Fruits	0.00	0.00	0.03	0.52	0.27	0.18
Coconut, Spices & Condiments	0.00	0.11	0.01	0.00	0.83	0.05
Non Food Crops & Others	0.00	0.00	0.00	0.30	0.00	0.70

vegetables and pulses, 52 per cent area under fruits, 83 per cent of area under coconut, spices and condiments and 70 per cent of area under non-food crops and others. It is also indicated that 42 per cent of area was shifted towards tapioca from paddy whereas 41 per cent area shifted towards non-food crops and others from vegetables and pulses. However, no major shift was observed from coconut, spices and condiments and non-food crops and others. Land fragmentation problem in the district hinders the mechanization of cultivation which forces the farmers to depanddepend upon manual labour which is scarce in the current scenario which explains the shift from labour intensive crops such as paddy, vegetables and pulses to non-food crops, coconuts, fruit trees etc.

It is depicted from Table 5 that Kottayam district over a period of time, retain 48 per cent of area under paddy, 15 per cent of area under tapioca, 37 per cent area under vegetables and pulses, 71 per cent area under fruits, 84 per cent of area under coconut, spices and condiments and 90 per cent area under non-food crops and others. However, it is indicated that 35 per cent area was shifted towards non-food crops from paddy and 43 per cent area shifted towards fruits from vegetables and pulses. There was no major shift observed from coconut, spices and condiments, fruit crops and non-food crops and others.

It is clear from Table 6 that over a period of time, Kannur district retained 53 per cent of area under paddy, 49 per cent of area under vegetables and pulses, 45 per cent area under fruits, 61 per cent of area under coconut, spices and condiments and 71 per cent of area under non-food crops and others. It is also revealed that 100 per cent area from tapioca, 47 per cent area from paddy,

51 per cent area from vegetables and pulses and 53 per cent area from fruits were shifted towards coconut, spices and condiments. There was no major shift observed from coconut, spices and condiments and non-food crops and others.

Overall scenario changing cropping pattern of midland area is depicted in Table 7 and it is clear that over a period of time, midlands retained only 17 per cent of area under paddy, 22 per cent of area under tapioca, 47 per cent area under

Table 5. Transitional probability matrix of area in Kottayam district

Crops	Paddy	Tapioca	Vegetables & Pulses	Fruits	Coconut, Spices & Condiments	Non Food Crops & Others
Paddy	0.48	0.02	0.00	0.15	0.00	0.35
Tapioca	0.85	0.15	0.00	0.00	0.00	0.00
Vegetables & Pulses	0.00	0.20	0.37	0.43	0.00	0.00
Fruits	0.00	0.16	0.04	0.71	0.00	0.09
Coconut, Spices & Condiments	0.00	0.00	0.00	0.00	0.84	0.16
Non Food Crops & Others	0.03	0.01	0.01	0.01	0.04	0.90

Table 6. Transitional probability matrix of area in Kannur district

Crops	Paddy	Tapioca	Vegetables & Pulses	Fruits	Coconut, Spices & Condiments	Non Food Crops & Others
Paddy	0.53	0.00	0.00	0.00	0.47	0.00
Tapioca	0.00	0.00	0.00	0.00	1.00	0.00
Vegetables & Pulses	0.00	0.00	0.49	0.00	0.51	0.00
Fruits	0.00	0.00	0.02	0.45	0.53	0.00
Coconut, Spices & Condiments	0.03	0.02	0.00	0.16	0.61	0.19
Non Food Crops & Others	0.00	0.00	0.01	0.14	0.15	0.71

Table 7. Transitional probability matrix of overall midland area

Crops	Paddy	Tapioca	Vegetables & Pulses	Fruits	Coconut, Spices & Condiments	Non Food Crops & Others
Paddy	0.17	0.00	0.00	0.52	0.31	0.00
Tapioca	0.12	0.22	0.00	0.00	0.07	0.59
Vegetables & Pulses	0.00	0.00	0.47	0.00	0.00	0.53
Fruits	0.13	0.00	0.06	0.48	0.10	0.23
Coconut, Spices & Condiments	0.00	0.07	0.00	0.00	0.84	0.09
Non Food Crops & Others	0.03	0.01	0.00	0.14	0.07	0.75

vegetables and pulses, 48 per cent area under fruits, 84 per cent of area under coconut, spices and condiments and 75 per cent area under non-food crops and others. However, it is indicated that 52 per cent area was shifted towards fruits from paddy, 59 per cent area shifted towards non-food crops and others from tapioca and 53 per cent area shifted towards non-food crops and others from vegetables and pulses. There was no major shift observed from coconut, spices and condiments, fruit crops and non-food crops and others in the midland region of Kerala.

4. CONCLUSION

Crop diversification is crucial in creating sustainable and resilient agricultural system, thereby ensuring food security. Midland region of Kerala, known for its fertile plains, is agriculturally significant region of the state. Over the year, farmers are diversified from food crops like paddy, pulses etc. to cash crops like rubber, cashew, nutmeg etc. and also to income earning crops like vegetables, banana, tapioca etc. The period from 2005-06 to 2020-21 showed changing pattern of acreage distribution in the three selected districts of Kerala. Total cropped area showed a declining trend in all the three districts throughout the period. The following conclusions were drawn from the present study,

1. The allocation share of acreage under paddy showed a declining trend in Thiruvananthapuram and Kannur, with a subsequent rise in non-food crops.
2. Total cropped area showed a declining trend in all the three districts which is explained by,

   - Thiruvananthapuram district: Significant decline in pulses (-9.04 %), paddy (-5.28 %), spices and condiments (-6.90 %)
   - Kottayam district: Significant decline in pulses (-28.23 %)
   - Kannur district: Significant decline in acreage of paddy (-3.00 %), tapioca (-1.93 %), spices and condiments (-5.46 %)

3. In Thiruvananthapuram district, significant growth was recorded for fruits (1.79 %), vegetables (1.34 %) and non-food crops (1.14 %). In Kottayam district, a significant growth of 3.46 per cent was observed for paddy. Whereas, a significant growth of 1.47 per cent for non-food crops were observed in Kannur district.
4. Herfindahl values varied from 0.26 to 0.35 in all three districts, which indicated a lesser crop concentration, i.e., diversification, which was also supported by the higher values of the Modified Entropy Index (values near 1) and Simpson index (greater than 0.6).
5. The Simpson Index of diversification for Thiruvananthapuram district was estimated to be 0.74 in the year 2020-21 whereas Kottayam showed a Simpson Index value of 0.67 during the same time period. Kannur with a Simpson Index of 0.78 had higher crop diversification during 2020-21 among the three selected districts.
6. Transitional probability matrix of study area revealed that,

   - Thiruvananthapuram district: Coconut, spices, and condiments (83% retention), as well as non-food crops and other crops (70% retention), occupied more area. The district lost 42 per cent of the area of paddy to tapioca and 19 per cent to coconut, spices and condiments, whereas vegetables and pulses lost 41 per cent of the area to non-food crops and others.
   - Kottayam district: non-food crops and others (90% retention), coconut, spices, and condiments (84% retention), and fruits (71% retention) occupied more area. Paddy lost 35 per cent of its area to non-food crops, and tapioca gained 15% of its area from paddy.
   - Kannur district: Non-food crops and others (71 % retention) and coconut, spices and condiments (61 % retention) occupy more area. Paddy lost 47 per cent area to coconut, spices and condiments in Kannur.

Hence the study implies the immediate need for active efforts to inspire youth to view agriculture as a feasible and profitable commercial endeavour and motivate farmers to resume food crop cultivation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/111723