Cropping pattern and crop diversification in Kerala, India – a spatio-temporal analysis

Shilpa Mathew*, A. Prema and M. Hema

Department of Agricultural Economics, College of Agriculture, Vellanikkara, Thrissur 680 656, India

The assessment of shift in cropping pattern is crucial for a good insight into the agricultural development of a region. The present study focused on the changes in the cropping pattern and the extent of crop diversification in Kerala, India. The results of the study revealed that the share of food crops to the gross cropped area substantially declined from 56.85% in TE 1987–88 to 40.73% in TE 2019–20, whereas the share of non-food crops increased remarkably from 43.14% in TE 1987–88 to 59.29% in TE 2019–20. The extent of crop diversification was higher in Idukki district, while crop specialization was prominent in Kozhikode district. Labour unavailability, high labour wage rates and climate variability were identified as the major constraints faced by the respondents in the study areas.

Keywords: Agro-ecological zones, constraints, crop diversification, cropping pattern, labour.

KERALA has a highly dynamic history of land use and cropping pattern changes. The agricultural sector in the state has changed significantly in terms of land ownership, cropping pattern, cultivation techniques and cropping intensity[1]. Cropping pattern is a dynamic concept concerned with the extent to which arable land categories can be utilized[2–4]. A cropping pattern refers to the proportional area under different crops at a point in time. The farm front of Kerala is distinguished by an incredibly diverse biophysical resource base and agro-climatic endowments that offer a wide range of options for cultivating various crops[1]. Apart from these, farmers are highly influenced by changes in technological, economic, institutional and policy-induced factors[5,6]. Rice, coconut, pulses and vegetables were the major crops cultivated in Kerala during the 19th century, which were intended for subsistence and local trade only. Later, in the early years of the 20th century, with the arrival of European capital into the plantation sector, the commercialization of agriculture started in Kerala[7]. In 1960–61, food crops occupied 66.63% of the gross cropped area, but it substantially declined to 36.92% during 2019–20. On the contrary, the area under non-food crops increased from 33.37% in 1960–61 to 63.07% during 2019–20 (ref. 8).

An analysis of Kerala's cropping pattern changes from its beginning in 1956 demonstrated unequivocally that there has been a consistent shift to garden and plantation crops at the expense of food crops. In particular, land-use experts have observed a shift towards monoculture and traditional cash crop agroforestry at the cost of diversified homegardens[9–11]. A significant amount of Kerala's homegardens were converted to coconut and rubber plantations due to commercialization and landholding fragmentation[12].

After the formation of Kerala in 1956, the first elected Government passed the Agrarian Relations Bill in 1959 to reform the tenancy laws and set land ownership limits. This was replaced by the Kerala Land Reform Act of 1963. This Act, which came into effect in 1970, put a cap on landowners' total land holding size and reapportioned the surplus land among indigent peasants and landless labourers. According to Nair and Dhanuraj[13], the implementation of land reforms also led to landholding fragmentation and the subsequent loss of economies of scale in cultivation. This is evident from the statistics that the average size of operational holding in 1970–71 was 0.57 ha, and it drastically declined to 0.18 ha in 2015–16 (ref. 14). From the 1970s onwards, Kerala witnessed a massive exodus of emigrants to other states and countries. The migration and flow of remittances catalysed the rise in speculative demand and land prices[15]. Exorbitant land prices have also altered the land-use pattern in the state[16,17]. These changes have affected the cropping pattern as well. A sizable decline in area under field crops like paddy and tapioca and an increase in area under rubber and coconut are noticed in the state. Thomas[18] pointed out that the shortage of farm labourers, rapid increase in wages and absentee landowners have also favoured the shift in cropping pattern.

Currently, the cropping pattern followed by the farmers in Kerala is unique and distinct, such as (a) monocropping, viz. paddy, rubber, cardamom, tea and coffee; (b) mixed cropping or multiple cropping, especially with coconut as the major crop and black pepper, cocoa, arecanut, banana, ginger, turmeric, tubers and fodder as multiple crops; and (c) intercropping, particularly banana and vegetables. The principal crops which account for more than 80% of the gross cropped area of the state are paddy, coconut, rubber, tapioca, banana and other plantain varieties, black pepper, cashew, coffee, tea, arecanut and cardamom. According to Guillerme et al.[19] crop choice by the farmers depends on factors like topography, soil type, irrigation facilities, crop profitability and Government policy decisions. The determinants of cropping pattern changes in the state are the

anticipated price of the crop, price of the competing crop, anticipated yield, differences in the climate, soil, vegetation, irrigation facilities and cost of cultivation[20,21]. The climate, soil and land characteristics of a region heavily influence its agricultural productivity and agro-biodiversity. Agricultural diversification is an important mechanism for economic growth. Crop diversification refers to the shift from the production of one crop to several crops in a region. It enhances the cropping intensity and productivity growth of the crops. The levels of crop diversification vary for different regions due to varied agro-climatic conditions and resource endowments of the cultivators. The growth of the agricultural sector acts as a catalyst for the growth of the other sectors. In the context of Kerala's agriculture, several studies were conducted on agricultural trends such as land-use changes and dynamics of cropping pattern[22–31]. Since cropping pattern can affect the entire agrarian economy of the state, studies on the changes in cropping pattern and crop diversification are the need of the hour. The present study analyses the cropping pattern changes and crop diversification in Kerala. The constraints faced by the respondents in the study areas in crop production and marketing are also analysed.

Methodology

For the integrated development of agriculture as a production sector, Kerala has been divided into five agro-ecological zones (AEZs), 23 agro-ecological units and 98 agro-ecological subunits[8]. The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur, undertook the agro-ecological delineations of the state in 2012 to make it possible for the agricultural sector to adjust to the long-term consequences of climate change and flood control. The five AEZs of Kerala are coastal plain, midland laterites, foothills, high hills, and Palakkad plain. The study on cropping pattern changes in the AEZs of Kerala was conducted for the year 2021–22 using primary data, and a multistage sampling technique was followed for primary data collection. The dynamics of cropping pattern and crop diversification in Kerala was studied using the time-series data from 1985–86 to 2019–20.

Study area

The study was carried out in Alappuzha, Malappuram, Ernakulam, Idukki and Palakkad districts of Kerala, which were selected from the five AEZs. These districts were chosen as they occupy the highest area in the respective AEZs, and from each district, one block with the highest cropped area was selected. The selected blocks were Champakulam (18,197 ha), Perumpadappu (11,259 ha), Kothamangalam (9748 ha), Nedumkandam (22,363 ha) and Chittur (25,171 ha) from Alappuzha, Malappuram, Ernakulam, Idukki and Palakkad districts respectively. In

the third stage, four panchayats were selected randomly from each block and at the final stage, 12 farmers having at least 50 cents of cropped area were selected randomly from each panchayat, constituting a total sample size of 240. The data were collected through a personal interview method employing a structured and pretested interview schedule.

Crop diversification

This is perceived as one of the most ecologically feasible, cost-effective and rational ways of reducing uncertainties in agriculture, especially among smallholder farmers[32]. Even crop diversification aims to reduce the vulnerability of small farmers towards climate change, and the diverse production system can enhance the state's food security. The two indices used to assess crop diversification in this study were Herfindahl index (HI) and Simpson's diversity index.

Herfindahl index

HI is a measure of crop concentration. It is computed by taking the sum of squares of acreage proportion of each crop in the gross cropped area.

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

where N is the total number of crops, i the number of crops ($i = 1, 2, ..., N$) and P_i is the proportion of the ith crop in the gross cropped area.

The value of HI decreased with an increase in diversification. It approached zero when diversification was perfect, and at complete specialization, the value was 1. The HI value less than 0.15 indicated that the cropping pattern was highly diversified, while a value between 0.15 and 0.30 denotes a moderately diversified pattern. The cropping pattern was specialized when HI > 0.45. However, the major limitation of this index is that it cannot assume the theoretical minimum, i.e. zero for smaller values of N[33].

Simpson's diversity index

The most widely used method for measuring crop diversity in recent times is the Simpson's diversity index, D and it is also easy to compute and interpret[34–36]. The index takes into account both species richness and evenness, and provides a clear dispersion of crops in a geographical area. The index was computed using the following formula:

$$D = 1 - \sum_{i=1}^{N} (P_i)^2,$$

where N is the total number of crops grown, i the number of crops ($i = 1, 2, ..., N$) and P_i is the proportionate area of the ith crop in the gross cropped area.

The index ranged between 0 and 1; and higher value of the index indicates a high degree of crop diversification.

Constraints faced by farmers in the study areas

Garrett's ranking technique: This was used to determine various constraints faced by the farmers in the study areas. The orders of the merit assigned by the respondents were converted into ranks using the following formula:

$$\text{Per cent position} = 100\,(R_{ij} - 0.5)/N_j,$$

where R_{ij} is the ranking given to the ith attribute by the jth individual, and N_j is the number of attributes ranked by the jth individual. The percentages obtained were converted into scores on a scale of 100 points by referring to the table given by Garrett and Woodworth[37].

Results and discussion

Dynamics of cropping pattern in Kerala

Table 1 provides an overview of the cropping pattern changes in Kerala from 1985 to 2019. The share of food crops and non-food crops to the gross cropped area was analysed for different trienniums. The different triennium years selected for representing the per cent share of crops to gross cropped area (GCA) were obtained by conducting structural break analysis in R software using gross state value added (GSVA) from agriculture data for the overall period. During triennium ending (TE) 1987–88, the area under paddy cultivation was 22.53% of the gross cropped area but decreased to 7.70% in TE 2019–20, whereas the area under tapioca decreased from 6.58% to 2.51%. From 25.31% of the GCA in TE 1987–88, coconut increased its share to 29.50% in 2019–20. Regarding the area share, rubber increased from 12.01% of the GCA to 21.38%. These four crops accounted for the most significant variation in area under cultivation in Kerala over the past 35 years. The area share of pulses declined from 0.95% in TE 1987–88 to 0.09% in TE 2019–20. From 4.60%, the area under pepper increased its share to 7.05%, but later it substantially declined to 3.25% in TE 2019–20. Cardamom also exhibited a decline in area from 1985 to 2019. The share of arecanut in GCA increased from 2.05% during the first phase to 3.71% in the final phase.

The share of area under fruits such as mango, banana and other plantain varieties increased from the first to the sixth phase, indicating that the farmers increased their acreage under fruit crops due to high demand and remunerative market prices. Vegetables showed a marginal increase in area from TE 1985–86 to TE 2009–10 and later

showed a marginal decrease. During the first phase, coffee accounted for 2.28% of GCA, and in the subsequent phases, the area increased, but the share of the area of tea was almost stagnant through all the phases. The food crops accounted for 56.85% in TE 1987–88 and 54.15% in TE 1989–90. In the subsequent phases, the share of area under food crops plummeted from 49.94% in TE 1994–95 to 40.73% in TE 2019–20. On the contrary, the area under non-food crops was 43.14% and 45.83% in TE 1987–88 and TE 1989–90 respectively. However, in the subsequent phases, the area under non-food crops increased remarkably to 56.03% in TE 2009–10, 58.93% in TE 2014–15 and 59.29% in TE 2019–20. Thus, a shift from food crops to more remunerative cash crops was prominent from the late 1990s in Kerala.

Due to the increased trade liberalization in this phase, the price variability among commodities such as rubber, cocoa and spices escalated when the newly introduced multilateral trade agreements lessened the state's ability to safeguard the growers using quantitative restrictions[38,39]. This could be accounted as a significant factor for the rapid decline in area under food crops and the increase in non-food crops from 1995–96 to 2019–20. Also, the shortage of labourers, expeditious increase in wages and non-remunerative farm price of the crops prompted the cultivators to shift from the cultivation of labour-intensive crops such as paddy to commercial crops such as rubber and coconut for which the per hectare labour requirements are comparatively lower. The steep rise in the price of rubber had significantly enhanced the area under this crop from the late 2000s in Kerala. Moreover, the price of land under food crops like paddy and tapioca was comparatively lower than that of cash crops in the state.

The Directorate of Economics and Statistics (DES), Government of Kerala, estimated that the per ha average price of paddy fields in the state during 1989–90 was ₹ 100,190, while for coconut plantations, it was ₹ 381,980. Thus, the conversion from food crops to commercial crops enhanced the property value of the farmers in the state, and the frequency of yields also contributed to the shift to cash crops. Annual food crops such as paddy and vegetables yield income once or twice a year, whereas perennial crops such as coconut, rubber, arecanut and cocoa yield income at more frequent intervals for an extended period[40].

Cropping pattern changes in the agro-ecological zones of Kerala

The cropping pattern followed by the respondents in the five AEZs of Kerala showed that in the coastal plain, the primary crop cultivated was paddy, which occupied 56.44% of the total cropped area (Table 2). Nearly 89.58% of the farmers cultivated paddy in the Puncha season, and only 8% cultivated it in both Virippu and Puncha seasons. The flooding of fields in the Virippu and Mundakan seasons was the main reason for this trend in the study area. Nearly

Table 1. Dynamics of cropping pattern in Kerala, India (ha)

Crop	TE 1987–88	TE 1989–90	TE 1994–95	TE 2003–04	TE 2009–10	TE 2014–15	TE 2019–20
Paddy	648,722	588,342	516,217	306,743	232,405	198,349	198,441
	(22.53)	(19.87)	(16.95)	(10.32)	(8.58)	(7.60)	(7.70)
Pulses	27,363	25,407	21,363	6,108	4,290	3,179	2,247
	(0.95)	(0.86)	(0.70)	(0.21)	(0.16)	(0.12)	(0.09)
Pepper	132,170	156,730	184,869	209,668	166,959	84,734	83,889
	(4.60)	(5.29)	(6.07)	(7.05)	(6.16)	(3.25)	(3.25)
Cardamom	62,556	64,574	43,693	41,360	40,981	40,353	39,220
	(2.17)	(2.18)	(1.43)	(1.40)	(1.51)	(1.55)	(1.52)
Arecanut	58,967	62,067	68,267	97,727	98,822	99,489	95,747
	(2.05)	(2.10)	(2.24)	(3.29)	(3.65)	(3.81)	(3.71)
Ginger	15,569	14,348	12,976	9,407	7,231	4,614	3,488
	(0.54)	(0.48)	(0.43)	(0.32)	(0.27)	(0.18)	(0.14)
Turmeric	3,146	3,020	3,375	3,157	2,792	2,509	2,513
	(0.11)	(0.10)	(0.11)	(0.11)	(0.10)	(0.09)	(0.09)
Mango	62,940	70,219	76,125	86,027	66,662	76,300	78,400
	(2.19)	(2.37)	(2.50)	(2.90)	(2.46)	(2.92)	(3.04)
Cashew	149,168	147,985	106,406	88,214	53,453	48,876	39,466
	(5.19)	(5.00)	(3.49)	(2.97)	(1.97)	(1.87)	(1.53)
Banana	18,054	20,142	24,223	54,148	55,118	61,736	58,561
	(0.63)	(0.68)	(0.80)	(1.82)	(2.04)	(2.36)	(2.27)
Other plantain varieties	36,342	38,849	46,668	54,497	49,765	53,377	55,622
	(1.26)	(1.31)	(1.53)	(1.83)	(1.84)	(2.04)	(2.16)
Other fruits	82,601	90,526	99,184	133,183	119,259	127,073	137,110
	(2.87)	(3.06)	(3.26)	(4.48)	(4.40)	(4.87)	(5.32)
Tapioca	189,568	167,509	126,769	103,222	82,052	70,889	64,712
	(6.58)	(5.65)	(4.16)	(3.47)	(3.03)	(2.72)	(2.51)
Vegetables	63,220	68,233	76,633	78,686	68,932	61,283	59,784
	(2.20)	(2.30)	(2.52)	(2.65)	(2.55)	(2.35)	(2.32)
Other food crops[1]	86,298	85,416	114,481	143,796	142,044	139,651	131,057
	(3.00)	(2.88)	(3.76)	(4.83)	(5.24)	(5.35)	(5.08)
Food crops[2]	1,636,685	1,603,369	1,521,250	1,415,943	1,190,767	1,072,052	1,050,256
	(56.85)	(54.15)	(49.94)	(47.63)	(43.96)	(41.06)	(40.73)
Coconut	728,718	808,139	890,089	901,138	795,066	800,222	760,722
	(25.31)	(27.94)	(29.22)	(30.32)	(29.35)	(30.65)	(29.50)
Rubber	345,695	378,366	441,499	476,496	518,309	545,915	551,143
	(12.01)	(12.77)	(14.50)	(16.03)	(19.14)	(20.91)	(21.38)
Cocoa	15,289	13,444	8,154	9,135	13,926	13,151	14,229
	(0.53)	(0.45)	(0.27)	(0.30)	(0.51)	(0.50)	(0.55)
Tea	34,680	34,622	34,675	37,431	36,511	30,205	34,183
	(1.20)	(1.17)	(1.14)	(1.26)	(1.35)	(1.16)	(1.33)
Coffee	65,630	68,777	82,899	84,197	84,536	85,359	85,277
	(2.28)	(2.32)	(2.72)	(2.83)	(3.12)	(3.27)	(3.31)
Other non-food crops[3]	52,077	53,810	66,928	48,023	69,122	63,742	83,273
	(1.80)	(1.82)	(2.20)	(1.62)	(2.55)	(2.44)	(3.23)
Non-food crops[4]	1,242,089	1,357,158	1,524,243	1,556,421	1,517,471	1,538,594	1,528,827
	(43.14)	(45.83)	(50.04)	(52.36)	(56.03)	(58.93)	(59.29)
Gross cropped area	2,878,922	2,960,800	3,045,833	2,972,363	2,708,238	2,610,646	2,578,152
	(100)	(100)	(100)	(100)	(100)	(100)	(100)

Figures in parentheses indicate per cent to gross cropped area.
[1]Those that are not mentioned in the table.
[2]Other food crops + food crops given in the table.
[3]Those that are not mentioned in the table.
[4]Other non-food crops + non-food crops given in the table.

12.5% of the farmers followed coconut + banana intercropping, which is one of the common intercropping patterns observed in the block and at the state level. In the midland laterites, 90% of the respondents cultivated paddy in the Kole wetlands. The cultivation of paddy constituted 42.31% of the total cropped area. Other than paddy, coconut, arecanut, pepper, nutmeg and mango constituted 47.69% of the cropped area. Paddy cultivation in the Puncha season (52.08%) and coconut + banana + arecanut multiple cropping (29.17%) were widely practised by the farmers.

A dominance of plantation crops over field crops was observed in the cropping pattern followed by the farmers in the foothills. Monocropping of rubber was practised by 64.58% of the respondents. The intercropping of

Table 2. Cropping pattern followed by the respondents in the agro-ecological zones (AEZs) of Kerala

AEZ	Cropping pattern	Season/details	No. of farmers
Coastal plain (Champakulam block)	Paddy	Puncha	43 (89.58)
	Coconut + banana	Intercropping	6 (12.5)
Midland laterites (Perumpadappu block)	Paddy	Puncha	25 (52.08)
	Coconut + banana + arecanut	Multiple cropping	14 (29.17)
Foothills (Kothamangalam block)	Rubber	Monocropping	31 (64.58)
	Coconut + banana	Intercropping	5 (10.42)
	Arecanut/coconut + banana + tapioca	Multiple cropping	4 (8.33)
High hills (Nedumkandam block)	Cardamom	Monocropping	15 (31.25)
	Pepper	Monocropping	7 (14.58)
	Rubber	Monocropping	5 (10.42)
	Cardamom + pepper	Intercropping	11 (22.92)
	Cardamom + pepper + coffee/cocoa	Multiple cropping	7 (14.58)
Palakkad plain (Chittur block)	Paddy	Virippu–Mundakan	19 (39.58)
	Paddy	Mundakan	8 (16.67)
	Coconut	Monocropping	18 (37.50)
	Coconut + banana	Intercropping	8 (16.67)

Note: Figures in parenthesis indicate per cent to total sample size of the block.

Table 3. Computed values of Herfindahl index of different crops for the districts of Kerala

District	TE 1987–88	TE 1989–90	TE 1994–95	TE 2003–04	TE 2009–10	TE 2014–15	TE 2019–20	Average
Thiruvananthapuram	0.20	0.22	0.24	0.26	0.25	0.26	0.25	0.24
Kollam	0.18	0.19	0.19	0.20	0.19	0.21	0.19	0.19
Pathanamthitta	0.17	0.17	0.21	0.23	0.21	0.29	0.27	0.22
Alappuzha	0.26	0.27	0.29	0.27	0.43	0.25	0.24	0.29
Kottayam	0.21	0.24	0.28	0.31	0.22	0.35	0.33	0.28
Idukki	0.14	0.14	0.12	0.12	0.19	0.10	0.10	0.13
Ernakulam	0.20	0.20	0.21	0.19	0.16	0.22	0.21	0.20
Thrissur	0.27	0.26	0.26	0.26	0.33	0.27	0.26	0.27
Palakkad	0.27	0.24	0.21	0.19	0.17	0.15	0.16	0.20
Malappuram	0.17	0.18	0.20	0.21	0.24	0.24	0.25	0.21
Kozhikode	0.32	0.33	0.35	0.36	0.38	0.40	0.37	0.36
Wayanad	0.20	0.20	0.19	0.18	0.17	0.19	0.19	0.19
Kannur	0.16	0.16	0.18	0.19	0.17	0.22	0.22	0.19
Kasargod	0.15	0.16	0.18	0.21	0.25	0.24	0.25	0.21

coconut + banana and multiple cropping of arecanut/coconut + banana + tapioca were followed by 18% of the respondents. Nutmeg, arrowroot, rambutan, pineapple, pepper and vegetables were also cultivated in the study area. In case of the high hills, the cropping pattern differed from other AEZs, as plantation crops and spices were the major crops cultivated in this zone. The monocropping of cardamom (31.25%), intercropping of pepper with cardamom (22.92%) and multitier cropping of cocoa + pepper + coffee/cocoa (14.58%) were the notable cropping patterns in the high hills. Multitier cropping was advantageous for the farmers in terms of better space utilization, crop diversification and reduction in the cost of cultivation. Similar findings were reported by Shaji and Duniya[41].

In the Palakkad plain, 33% and 11% of the total cropped area accounted for paddy and coconut respectively. The monocropping of paddy in the Virippu and Mundakan seasons (39.58%), monocropping of coconut (37.50%) and intercropping of banana with coconut (16.67%) were the major cropping patterns. Majority of the respondents have been cultivating paddy for more than 30 years, and the paddy fields in Chittur block are known as 'poonthalpadams'. The soil in these fields contains 60–80% clay and silt, and therefore, such fields can hold more water. Nutmeg, mango, arecanut, bittergourd, amaranthus, snakegourd and coccinia were also grown in the study area. HI and D for the 14 districts of Kerala were computed for TE 1987–88, TE 1989–90, TE 1994–95, TE 2003–04, TE 2009–10, TE 2014–15 and TE 2019–20. HI decreased with the increase in diversification, whereas D increased with diversification. Tables 3 and 4 show that the value of HI falls in the range 0.10–0.43 and D in the range 0.57–0.90 respectively. Kozhikode registered the highest HI (0.36) and lowest D (0.64) throughout the study period. Coconut is the major dominating crop in Kozhikode district. In 1985–86, coconut accounted for 55% of the GCA, and the share increased to 59% in 2019–20. This positive growth in area of coconut indicates specialization in the district. The lowest HI in all the TEs was noted for Idukki district. The average HI for the whole period was 0.13, and this lowest value indicated that Idukki was the most diversified district. The climatic conditions in Idukki are favourable for the growth of

Table 4. Computed values of Simpson's diversity index of different crops for the districts of Kerala

District	TE 1987–88	TE 1989–90	TE 1994–95	TE 2003–04	TE 2009–10	TE 2014–15	TE 2019–20	Average
Thiruvananthapuram	0.80	0.78	0.76	0.74	0.75	0.74	0.75	0.76
Kollam	0.82	0.81	0.81	0.80	0.81	0.79	0.81	0.81
Pathanamthitta	0.83	0.83	0.79	0.77	0.79	0.71	0.73	0.78
Alappuzha	0.74	0.73	0.71	0.73	0.57	0.75	0.76	0.71
Kottayam	0.79	0.76	0.72	0.69	0.78	0.65	0.67	0.72
Idukki	0.86	0.86	0.88	0.88	0.81	0.90	0.90	0.87
Ernakulam	0.80	0.80	0.79	0.81	0.84	0.78	0.79	0.80
Thrissur	0.73	0.74	0.74	0.74	0.67	0.73	0.74	0.73
Palakkad	0.73	0.76	0.79	0.81	0.83	0.85	0.84	0.80
Malappuram	0.83	0.82	0.80	0.79	0.76	0.76	0.75	0.79
Kozhikode	0.68	0.67	0.65	0.64	0.62	0.60	0.63	0.64
Wayanad	0.80	0.80	0.81	0.82	0.83	0.81	0.81	0.81
Kannur	0.84	0.84	0.82	0.81	0.83	0.78	0.78	0.81
Kasargod	0.85	0.84	0.82	0.79	0.75	0.76	0.75	0.79

Table 5. Constraints faced by farmers in the study areas

Constraint	Garrett's score	Rank	Kendall's 'W' statistic
Unavailability of labour	69.06	1	
Climate variability	67.18	2	
High wage rates of labour	65.08	3	
Increase in the cost of fertilizers and plant protection chemicals (agro-inputs)	63.22	4	0.45***
Attack from animals and birds	54.90	5	
Fluctuation in market prices	54.76	6	
Disease and pest incidence	48.63	7	
Non-availability of water for irrigation	48.08	8	
Unavailability of inputs	47.25	9	
Insufficient marketing facilities	47.14	10	
Poor quality of seeds and seedlings	41.52	11	
Lack of proper technical guidance	40.62	12	
Sinking of harvester machines in paddy fields	38.65	13	
Soil acidity	38.17	14	
Lack of technical know-how	37.50	15	

***Significant at 1% level.

spices such as pepper, cardamom, cloves and plantation crops such as coffee, tea, rubber, cocoa, nutmeg and arecanut. With a low HI value, Idukki obtained the highest values of D (0.87).

Alappuzha and Thrissur districts showed only minor changes in their indices. This could be attributed to the predominance of paddy cultivation in both districts. The Kuttanad region of Alappuzha and the Kole wetlands of Thrissur are the prominent rice-growing tracts that account for a sizable share of the cropped area of the districts. Moreover, the agro-ecological conditions of these districts favour the extensive growth of paddy. Alappuzha, Thrissur and Kottayam districts obtained HI values of 0.29, 0.27 and 0.28 respectively, while the D values were 0.71, 0.73 and 0.72, for the entire study period. These values indicated that Alappuzha, Thrissur and Kottayam were moderately specialized districts. Thiruvananthapuram, Pathanamthitta, Malappuram, Kannur and Kasargod exhibited lower values of diversification indices, indicating higher crop diversity in the earlier phases, which subsequently increased in the later phases, showing crop specialization.

Constraints

The constraints faced by the respondents of the coastal plain, midland laterites, foothills, high hills and Palakkad plain in crop production and marketing were ranked using Garrett's ranking technique (Table 5). The unavailability of labour was identified as the major constraint faced by the respondents in all the five blocks selected from the AEZs for the study. The respondents pointed out that the MGNREGA scheme was the prime cause for the non-availability of labour for agricultural operations. The active participation of rural women in MGNREGA has created an acute labour shortage in the state. In Kerala, the participation of women has been observed to be more than men in this scheme. A wage rate of ₹ 291/day augmented the flow of women's labour from agricultural to non-agricultural activities through this scheme. As a result of the diversion of labour, the paddy farmers were forced to reduce the crop acreage or leave their land fallow. This is in agreement with the findings of Harish *et al.*[42]. The second major constraint was climate variability. The respondents mentioned that the

untimely heavy rainfall reduced the crop yield and thereby affected the livelihood of the farmers. This even elicited them to get entangled in the debt trap. The cardamom and pepper growers of the high hills mentioned that heavy rainfall and high relative humidity reduced the yield and net returns from these crops. The high wage rate of labourers was noted as another vital constraint faced by the respondents. In Kerala, the daily wage rate of agricultural labourers usually varies from ₹ 800 to ₹ 950 for men and ₹ 500 to ₹ 650 for women. The high labour wage rates augmented the cost of cultivation of respondents in the study areas. The respondents were also grievously affected by constraints such as an increase in the cost of fertilizers and plant-protection chemicals, attacks from animals and birds, fluctuation in market prices, disease and pest incidence, and non-availability of water for irrigation. The respondents of Palakkad plain, foothills and high hills faced severe attacks from animals such as wild boars and monkeys in their fields. This resulted in the large-scale destruction of the crops, especially in the banana fields. Attacks from peacocks and cattle egrets were also noticed in the rice fields of Palakkad plain and coastal plain. The poor quality of seeds and seedlings, inadequate transportation facilities, soil acidity and lack of technical knowledge were also found to considerably affect the farmers. The paddy cultivators in the coastal plain, Palakkad plain and midland laterites mentioned that when the harvesting of paddy coincided with heavy rainfall, there were problems, especially with respect to the use of harvester machines. The flooding in the fields resulted in the sinking of harvester machines, and the farmers mentioned that a lot of time and money was spent on lifting these machines from the fields. The acidity of the soil was found to be a common problem in the Kuttanad region, which was controlled to an extent by applying lime.

Conclusion and policy implications

Kerala has witnessed significant changes in its cropping pattern, with a sizable decline in the area under field crops and an increase in the share of non-food crops, particularly plantation crops. This micro-level study on cropping pattern changes in the AEZs of Kerala revealed that farmers practised monocropping, intercropping and multiple cropping, among which cultivation of paddy (monocropping) was prominent in the coastal plain, midland laterites and Palakkad plain. The crop diversification estimated using HI and D showed that Idukki district registered the lowest HI (0.13) and highest D (0.87), whereas Kozhikode registered the highest HI (0.36) and lowest D (0.64). These indicated that cropping pattern was highly diversified in the Idukki district, whereas it was specialized in the Kozhikode district. The decreasing proportion of food crops to non-food crops is an indicator of food insecurity in the state. Various incentives may be provided to the farmers cultivating food crops, and they could focus on the inclusion of climate-resilient food crops in the cropping pattern. Moreover, the supply of inputs at subsidised rates, mainly quality seeds and seedlings through Krishi Bhavans, and assured marketing facilities at the panchayat/block level can be prioritized. The unavailability of labour was one of the major concerns reported by the farmers in the study areas. In order to deal with the issue of labour shortage, successful models of 'Agricultural Labour Banks' initiated by many panchayats may be replicated elsewhere. Also, more research and development funds can be granted to the institutions concerned with developing farm implements and machinery, which could address labour shortage and reduce drudgery.

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