STRUCTURAL TRANSFORMATION AND SPATIO-TEMPORAL VARIATIONS OF AGRICULTURE IN KERALA

By

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(2018-11-115)

DEPARTMENT OF AGRICULTURAL ECONOMICS

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DECLARATION

I declare that this thesis entitled "**STRUCTURAL TRANSFORMATIONS AND SPATIO-TEMPORAL VARIATIONS OF AGRICULTURE IN KERALA**" is an original work prepared by me and has not been copied from any other previous works or presented at this institution or any other for the award of any title or degree by any university or society.

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Date: **(2018-11-115)**

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Certified that this thesis entitled "**STRUCTURAL TRANSFORMATIONS AND SPATIO-TEMPORAL VARIATIONS OF AGRICULTURE IN KERALA**" is a bonafide record of research work done independently by Mr. Otieno Felix Owino (2018-11-115) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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1. INTRODUCTION

The agricultural sector directly influences the levels of farm income, availability of industrial raw materials and food safety in most countries around the world. However, as economies pass through periods of transformations within the sectors, the agricultural sector continues to lag despite being solely tasked with the provision of food and stimulating growth in other sectors. This happens to be more significant for countries that rely heavily on agriculture. India, a country backed by the agricultural sector, had been confronted by rapid development in various sectors. The share of agriculture in India's Gross Domestic Product (GDP) was about 42 per cent in 1970-71. However, during 2018-19, the major concern was that over 50 per cent of the country's workforce who were being supported by agriculture, was contributing only 17 per cent of the total GDP (GoK, 1970; 2019). The gross value added (GVA) from the service sector however, increased from 33.2 per cent in 1970-71 to 54.3 per cent in 2018-19 (GoK, 1970; 2019).

This trend observed at the national level could be observed in several Indian states because the macroeconomic aggregates for India is the aggregate reflection of what is happening in the states. A state in this context that had been facing a similar trend was Kerala, which was buoyed by the agrarian economy, nevertheless distinct in the manner of its transformation. Despite the agriculture gross state value added (GSVA) from agriculture increasing from 1970-71 to 2018-19, its contribution to the state's gross state domestic product (GSDP) had been on the decline. The proportion of agriculture GSVA in the gross income of the state had declined from 23.83 per cent in 1970-71 to 6.76 per cent in 2018-19 (GoK, 1970; 2019). This happened despite improvements in shares of secondary and tertiary sectors in the Kerala GSDP over the same period. The share of the secondary sector had increased from 13.07 per cent in 1970-71 to 22.55 per cent share in the GSDP of Kerala in 2018-19, while the tertiary sector consistently contributed more than 50 per cent to GSDP of Kerala over the period (GoK, 1970; 2019). These transitions over time had shown a tendency of shift from agrarian-backed economy to service-dominated one (Sanitha and Naresh, 2016). This was compounded by a steep fall in farm income, especially after implementation of the trade liberalisation policies by Government of India (GoI) from 1991, which adversely affected the cash crop dominated agricultural sector of the state due to challenges from cheap imports and for its exports (Joseph & Joseph 2005).

The events leading to the transformations witnessed in the agricultural sector of Kerala from 1970-71 to 2018-19 could be drawn from the decade preceding 1970s. Several studies had related it to the government policies that were implemented from 1960s in the agricultural sector of Kerala. First notable policy was the Agrarian Relations Bill 1959, which was later replaced by Kerala Land Reforms Act of 1963 that was implemented in the late 1960s after being included in the constitution (Nair and Dhanuraj, 2016). The reforms were meant to end exploitative tenancy and landlordism (Mahesh, 1999). The new legislation included protection against unlawful ejection of tenants and was expected to be instrumental in improving the rural wages and helping the introduction of social welfare systems for the agricultural workers (Qureshi 2016). When Kerala State was formed in 1956, the rice production was only enough to sustain less than 50 per cent of the state's staple requirement (Prakash, 1987). The idea of land reforms was therefore based on the premise that, distributing the excess land to local farmers would help to produce more food and create employment especially in the rural areas (Qureshi 2016). However, soon after the implementation of the Act, it was found that just distributing land to the local landless farmers was not enough to realise more food production and enhance employment opportunities in the rural areas. It followed that inadequate capital and lack of managerial skills among the two million tenants who were given title possessions, made the reforms bear little fruits due to the lack of capacity to develop the lands as was previously envisaged (Nair and Dhanuraj, 2016).

Over time, the agricultural lands that were distributed among the local farmers were inherited by the successive generations. These new landowners saw the agricultural lands as a commodity of exchange and thus, became absentee landlords, which on the aggregate, led to loss of economies of scale (Nair and Dhanuraj, 2016). Among other factors, this phenomenon led to two dire consequences. One, agricultural land was increasingly left fallow and two, with increasing population pressure on land, these lands were subdivided into smaller holdings (Mahesh, 1999). In 1970-71, there were 28.23 lakhs agricultural holdings, while twenty years later in 1990-91, the number of holdings increased by 91.95 per cent to 54.18 lakhs and over 80 per cent of the holdings were less than 0.5 hectares (GoK, 1971; 1992). The holdings increased further by 40 per cent from 1990-91 to 75.83 lakhs in 2015-16. During the same period (1970-71 to 2015-16), the size of the holdings also declined for the various categories. The marginal holdings decreased from 0.23 ha to 0.12 ha, small holdings decreased from 1.36 ha to 1.34 ha, while the medium holdings declined from 5.56 ha to 5.32 ha (GoK, 1971; 2016). Remarkably, before the land reforms, only 81 per cent of the holdings were below one ha, while it increased to over 92.66 per cent in 1990 (GoK, 1970; 1992), which increased to 96 per cent in 2015-16. The fragmented pieces of land led to loss of economies of scale and thus, land reforms that started in the 1960s and finally culminated in extremely small uneconomical holdings had been assessed as one of the factors that led to the weakening of agricultural growth in Kerala (Nair and Dhanuraj, 2016).

The declining profitability because of uneconomical size of holdings, declining commodity prices and the absentee landlordism fuelled the rise of fallow lands (Viswanathan, 2014). This could be seen after 1974-75, when the income from agriculture started declining and the area under current fallow shot up from 24,545 ha in 1974-75 to 35,668 ha in 1975-76 (GoK, 1978). The extent of land area under current fallow land kept rising and only marginally declined in magnitude of growth from 1978-79 when most farmers were shifting their lands to plantation crops, mainly triggered by market opportunities and demand factors (Sanitha and Naresh, 2016). The area under fallow lands peaked in 2007-08 when rubber was experiencing substantial increase in prices locally and internationally, which was in turn affecting the production incentive in crops like paddy (GoK 2009). Land put to non-agricultural uses also increased by 65 per cent from 2.8 lakh ha in 1970-71 to 4.5 lakh ha in 2018-19 due to high demand for land for non-agricultural uses as the profitability of raising most of the crops in Kerala declined (GoK, 1970; 2019).

Scarcity of family labour, volatility of the agricultural sector and sustained remittances from abroad had seen a reduction in number of wage earners willing to work in agricultural sector over time (Munster 2012; John 2018). The waning profitability of farming and high social prestige provided by the government jobs made the younger generation to relatively avoid the farming sector (Kannan, 2011), which over time led to shortage of agricultural labour in Kerala. The agricultural labour per 1000 rural households was only 189 in Kerala as compared to the all-India average of 223 and 336 in Tamil Nadu in 2015 (Nair and Dhanuraj, 2016). In turn, a significant rise in the wage rates for agricultural operations had been noted under the pressures of bargaining for wages by the trade unions, which had Kerala rank the highest average daily wage rates for male and female agricultural workers (Devi, 2012; Nair and Dhanuraj, 2016). The actual wage paid for men in Kerala in 2015 was 139 per cent higher than the fixed wage, while at the national level it was only 25 per cent higher (Jose and Padmanabhan, 2016). Additionally, the lack of full-time farmers progressively led to steep decline in agricultural employment and an increase in farm wages (Parappurathu, 2015; Nair and Dhanuraj, 2016). Thus, rising wages, lack of adequate labour even at high wages coupled with enhanced institutional guidance and promotion of perennial crops, made farmers to shift to less labour-intensive crops like rubber and coconut (Darvishi and Indira, 2013; Viswanathan, 2014). While farmers shifted to less labour intensive crops, the secondary sector was believed to have received most of these workers who migrated from the farming sector (Mahesh, 1999; Nair and Dhanuraj, 2016).

Consequently, one of the most notable structural change was the relative decline in area under food crops like paddy due to shift to plantation crops. The area under paddy declined from 8,74 lakh ha in 1970-71 to 1.98 lakh ha in 2018-19 (GoK, 1970; 2018). While paddy area declined by 77 per cent, production declined by 55 per cent in the same period from 12.92 lakh tonnes to 5.78 lakh tonnes (GoK, 1970; 2018). The demand-supply gap was about 50 per cent in 1970-71, however by 2009, Kerala's paddy production could only suffice for 15 per cent of the State's staple needs (Leenakumari, 2010).

The government policies and interventions in the cropping system was the second aspect which was discussed as a major cause for the distortion of agricultural growth in the State of Kerala. As in the case of land reforms, after the formation of the State of Kerala, the State Government embarked on a process of developing the agricultural system to ensure that the State was self-reliant in terms of food and hence, paddy received the utmost attention in this process. Out of the plan expenditure from 1950s to 1980, irrigation received 31 per cent of the investment (Prakash, 1987). In addition, major share of the plan investments was used in promoting the production of paddy through agricultural research, irrigation and several special programmes meant to encourage its cultivation (GoK, 1978). Consequently, agricultural sector on an average grew at a rate of 2.3 per cent annually from 1960 to 1974. However, despite the huge investments in the sector, the annual growth rate thereafter started declining (GoK, 1978). The Command Area Development Authority (CADA) established in 1985 to include farmers in the administration of irrigation facilities also led to inflexibilities in the irrigation system. This was because most of the CADA projects were meant for wetland crops like paddy and in the process ignored the specific requirements of other crops (Nair and Dhanuraj, 2016).

Paddy also received increased attention through the implementation of Land Utilisation Order of 1967 and the Kerala Conservation of Paddy and Wetland Act of 2008, which only prioritised on cultivation of paddy despite declining profitability by instituting artificial restrictions against farmers' motivations and disincentivising them (Nair and Dhanuraj, 2016). The cultivation of paddy was also found to be affected by the abolition of food zones and commencement of distribution of rice at subsidised prices (Mahesh, 1999). These distorted the market forces leading to decline in rice prices, which together with rising labour wages, made paddy cultivation less remunerative. The policy aimed at attaining self-reliance in food production by focusing mainly on paddy production was therefore questioned for the decline in growth of agricultural income, since it was grounded on unviable strategies and sacrificing the expansion potential of crops that had the ability to spur growth of the sector (Prakash, 1987; Nair and Dhanuraj 2016).

The shift in resources from the agricultural sector to the secondary and tertiary sectors could be viewed from the angle of structural transformation, which is the large-scale allocation of resources from some sectors to others in a system, dictated by essential variations in its policies or purposes. The agricultural transformation should also be understood in the context of rising agricultural wages, which affected the profitability of major crops in Kerala due to the excessive increase in the cost of production. The shortage of farm labourers coupled with other factors like uneconomic size of land holdings, sustained conversion of agricultural lands to non-agricultural uses and low profitability in agriculture had hampered growth in the sector and led to the transformation. The structural adjustments could also be observed on the state income in which an increase in share of income from the tertiary sector and a decline in share from the primary sector was observed. With this background, the proposed study analysed the growth of agriculture in Kerala and assessed the disparities among the districts of the State in agricultural development. It also examined the dynamics in land use and cropping patterns, studied the dynamics in economics, efficiency and profitability of cultivation of major crops and estimated the total factor productivity for major crops in Kerala.

Objectives of the Research

General Objective

The general objective of the study is to find out the structural transformation and spatio-temporal variations of agriculture in Kerala from 1970-71 to 2018-19.

Specific Objectives

Specific objectives of the study are:

1. To analyse the growth of agriculture in Kerala.
2. To study the inter-district disparities and contributing factors in agricultural growth in Kerala.

3. To examine the dynamics in land use and cropping pattern in Kerala.
4. To study the dynamics in economics, efficiency and profitability of cultivation of major crops in Kerala.
5. To estimate the total factor productivity and its determinants for major crops in Kerala.

Organisation of Thesis

The thesis is set into five chapters. The first chapter has been presented to give the background of the study, its significance and specific objectives. The second chapter outlines the theoretical background of the study by reviewing previous studies related to the research. The third chapter explains the study area and the methodology followed in conducting the research. The fourth chapter outlines the results and discussion. The fifth chapter summarises the study and is succeeded by policy implications, references, appendices and abstract.

2. REVIEW OF LITERATURE

This chapter aims to establish the present study on agricultural transformation and variations in Kerala in the context of dynamics, disparities and development in agriculture over time. The chapter outlines conceptual and methodological frameworks from the review of theories and discussions from similar studies conducted previously as well as results, with a view of pointing out the scope for further study. The chapter is presented in five sections based on the objectives of the study. Section 2.1, Growth performance of agricultural economy of Kerala, investigates the indicators of agricultural development and from previous studies the directed changes in the agricultural economy of Kerala are discussed under this section. Section 2.2, Inter-district disparities in agricultural growth views the Kerala State from its subdivisions with unequal agricultural growth and performance and therefore reviews related studies. Section 2.3 is further subdivided into two subsections. Subsection 2.3.1, Dynamics in land use pattern discusses the changes in land use and issues surrounding the loss of agricultural land resources to other competing sectors. Subsection 2.3.2, Dynamics in cropping pattern explores dynamics in cropping pattern. Section 2.4, Economic dynamics, efficiency and profitability inspects related studies on the economics, efficiency and profitability of crops in Kerala and section 2.5. Total factor productivity studies the changes in total factor productivity (TFP) of crops in Kerala and other related studies.

2.1 Growth performance of agricultural economy of Kerala

Krishnan *et al.* (1991) used time series data for the years from 1970-71 to 1986-87 to examine the growth rates and magnitude of instability in area, production and productivity of major crops in Kerala. They also highlighted the percentage contribution of area and productivity in the total production of major crops in Kerala. An exponential function was used to find the Compound Annual Growth Rates (CAGR) and changes in yield. They pointed out that paddy cultivation had become economically unviable and a shift to plantation crops and other commercial crops was more prevalent, which led to food insecurity in the state. They maintained that the change in cropping pattern from paddy to plantation and commercial crops was necessitated by a sharp increase in wage rates and the socio-economic factors including the migration to the Gulf.

Thomas (1999) studied the agricultural performance in Kerala and found that the growth rate in agriculture had declined from the early 1990s. He also asserted that within the period, the contribution of agriculture in the gross state domestic product (GSDP) had declined and that there was a shift in cropping pattern towards cash crops. The study pointed out that the main factors affecting crop productivity was shortage of labour, high price of agricultural land and uneconomical size of operational holdings. It was found that productivity was positively affected by the adoption of high yielding varieties, use of fertiliser and irrigation.

Several studies have been carried out to estimate the growth of agriculture in the pre-liberalisation and post-liberalisation periods. One such study was conducted by Joseph and Joseph (2005) by using a kinked exponential model to estimate the period-wise growth rates of Kerala with continuity restriction at the breakpoint between sub-periods by using data for the period from 1975-76 to 2002-03. They observed increasing agricultural production costs including rising agricultural wage rates and a decline in the production of food crops. For the net state domestic product (NSDP) from three sub-sectors (primary, secondary and tertiary), four different phases were observed. From their analysis, it was noticed that the first phase (1965-75) recorded a growth rate of over three per cent, followed by a period of stagnation in the second phase (1975-87). The third phase (1987-97) showed almost three times increase in growth rate in relation to the second phase. The fourth phase showed slowing growth rate of the economy. The fluctuations were highest in the primary sector in which the high growth was succeeded by relatively declining growth rate.

Niaz and Imam (2008) tried to find out suitable models to demonstrate the trend in the production of pigeon pea, chickpea and field pea in Bangladesh using the coefficient of variation (CV) and percentage deviation from three years moving average values. The instability and growth rates of pigeon pea, chickpea and field pea production were also examined to find out the efficient time series models to forecast the pigeon pea, chickpea and field pea production in Bangladesh. The results showed that the production of pigeon pea with a CV of 26.7 per cent was relatively stable, while chickpea and field pea exhibited CV of 49.43 per cent and 27.78 per cent respectively.

Paltasingh and Goyari (2013) used the kinked exponential growth model and instability indices to analyse the performance of agriculture in Odisha. The growth rates in area, production and yield of major crops showed that all the crops except for rice, experienced decline in the post-reform period. The crops such as bajra, jowar, wheat, ragi and small millet had a higher rate of decline. However, after the reforms, there was an increase in crop concentration due to intensified efforts for rice production. The results thus confirmed that it was only rice that benefitted from the reforms and maize to a smaller extent. This analysis asserted that the production performance of other crops in the post-liberalisation period was not favouring the agricultural development in Odisha. The other causes of variability were found to be variations in weather and price risk.

Ramachandra *et al.* (2013) used CAGRs to analyse the trends in area, production and productivity of crops in Karnataka for the period from 1982-83 to 2007-08. They observed that pulses, fruits and vegetables manifested an increase in growth. However, the area under oilseeds and commercial crops registered negative growth rates and the production of these crops registered less significant growth rates. On the other hand, the productivity of cereals, fruits and pulses showed increased growth rates. The productivity of commercial crops however reported an insignificant growth, while that of vegetables exhibited a decline. The study also confirmed that the area under jowar, ragi, minor millets and bajra showed significant annual deceleration, while that of rice showed a mild increase. It was concluded that overall, the area under cereals showed a decreasing trend in Karnataka.

Sharma (2013) by using linear-quadratic exponential function, CAGRs, and instability index models studied the trends in the area, production and productivity of food grains in the north-eastern states for the period from 1980-81 to 2011-12. The study revealed that increasing the production of food grains was less risky as depicted by the lower coefficient of variation and positive instability indices for the area, production and productivity.

The yield response model with regressors specified in linear terms was used by Sekar (2014) to estimate the response of area, production, productivity in rice in India during the period from 1965 to 2010. He found that the growth in production of rice in India was highly positive in the eighties mainly due to the technological capabilities evolved within the period. However, during 2010s, the rate of growth in production declined, which showed the need to focus on technologies that will enhance the improvement in yield. By using a decomposition model to disaggregate the effects of yield and area on production growth, the study revealed that yield effect was more in Eastern states like West Bengal, Orissa, and Assam. He suggested promotion of high yielding variety technology in the region.

Parappurathu (2015) studied the performance of agriculture in Kerala emphasising the demand and supply of major crops. He observed that the state had lost a major area under essential food crops like paddy, pulses, tapioca, vegetables, cashew nut and spices to commercial plantation crops due to the business of real estate which offered more returns relative to the food crops. He noted that this opportunity encouraged rapid urbanisation that led to the loss of land under high-value crops like tea, coffee and spices. He also noted that the state relied on the importation of essential commodities and therefore the high levels of income realised from the sale of commercial crops were used to counterbalance the imports.

While studying the role of agriculture in Kerala's economic and structural changes, Sanitha and Naresh (2016) found that the share of the primary sector in the GSDP had declined sharply over the last three decades. The per hectare fertilizer consumption was also found to have declined due to cropping pattern changes to plantation crops which required relatively lower amount of fertilizers. This consequently reduced the total cropped area under food crops, with a simultaneous increase in commercial crops like rubber, coffee, coconut, black pepper and to some extent tea.

2.2 Inter-district disparities in agricultural growth

Narain *et al*. (2005) analysed the level of agricultural development in different districts of Kerala using a composite index developed based on an optimum combination of thirty-nine socio-economic indicators, including area under various crops, productivity of selected crops, fertiliser consumption and irrigated area. They utilised district-wise data on thirty-nine indicators for the year 2001-02. The level of development was estimated separately for the agricultural sector, industrial sector, infrastructural facilities and overall socio-economic development. Based on the analysis, Thrissur district was ranked first and Wayanad district ranked last in the socio-economic development. Wide disparities were also observed in the level of development among different districts. Kollam, Kottayam, Idukki, Palakkad and Kannur districts were found to be better developed in the agricultural sector, whereas Thiruvananthapuram, Kollam and Ernakulam were industrially better developed.

A composite index based on the optimum combination of 48 indicators by the method of principal component analysis (PCA) was used by Ayyoob *et al.* (2013) to study the level of agricultural development of different districts in Kerala State from 2003 to 2008 . The districts were categorised into three groups based on the mean and standard deviation of the composite index. Pathanamthitta, Alappuzha, Kottayam, Idduki, Kozhikode and Kasaragod districts were categorised as low developed districts, while Thiruvananthapuram, Kollam, Wayanad and Kannur districts were categorised as moderately developed districts. The highly developed districts were found to be Ernakulam, Thrissur, Palakkad and Malappuram. They emphasised the need for increased efforts to increase the area under paddy cultivation in Kerala, which in turn would lead to improving agricultural development in most of the districts.

Kumar and Jain (2013) studied the relationship between economic growth and inequality of Indian agriculture at the district level using data from 1990-91 to 2007-08. They employed CV and Gini coefficients to understand the level of disparity among districts and found a mixed state-wise trend in the level of inequalities, with districts depicting declining, increasing and sustained rates of inequalities. The trend in the instability index for crop productivity across different districts during the period from 1990 to 1999 was found to be slightly higher than that during the period from 2000 to 2007, which confirmed that a higher level of instability in crop productivity was manifested in the districts in 1990s.

A study to identify the causative factors for the regional disparity in the agrarian development of Kerala by Ayyoob and Krishnadas (2016), used a composite index based on an optimum combination of forty-nine indicators, by assigning weights to the indicators using the principal component analysis. The districts were classified into three groups based on the development and factors affecting the agricultural development across districts were obtained by multivariate analysis of variance technique. They reported that the area under paddy and high yielding varieties (HYV), net sown area, area under total cereals, rainfall and credit flow from regional rural banks, marine fish landing, fertilizer consumption and percentage of the coastal line were significantly different across three categories of districts. Even though the total geographical area of the state was so small, there was wide inequality in the pace of development across districts. They found that the different factors affecting agricultural development were net sown area, area under paddy and high yielding varieties (HYV), marine fish landing, rainfall, regional rural bank credit etc.

Barik (2017) examined the geographical concentration ratio, which defines the difference between concentration index of agriculture production and the concentration index of population index to measure the inter-district disparity in the agricultural development of districts in West Bengal and the food availability status of the state for the years from 1990-91 to 2010-11. The geographical concentration ratio and Geographical Information System (GIS) tools were used to find out the disparity. He also estimated the impact of the agro-climatic condition, infrastructure facilities and population growth on agricultural development and food availability status. The results pointed out that large disparity existed across the districts and the regional disparity divergence over the periods was a barrier to balanced development. From the results, he asserted that districts like Hooghly, Burdwan, Nadia, Birbhum were more developed in agriculture, while the districts like Purulia, Bankura and Jalpaiguri, depicted relatively low agricultural productivity.

Haque and Joshi (2018) examined aspirational, non-aspirational and frontier districts of Bihar to understand the important solutions for the inter-district disparities. They observed that irrigation was one of the most significant determinant of inter-district disparities in the yield of rice, wheat and maize. They also found that agricultural diversification in favour of livestock was one of the most important factors determining the level of per capita agricultural income in a district. The literacy was found to have a positive and statistical significance on the productivity of rice, but non-significant influence on the productivity of wheat, despite being positive. They noted that other important determinants of the inter-district disparities in agriculture were income, size of operational land holding, cropping intensity, risk management in flood-prone areas and agricultural marketing reforms.

2.3.1 Dynamics in land use pattern

Pandey and Tewari (1987) studied the ecological implications of land-use dynamics from 1967-68 to 1983-84 in Uttar Pradesh by estimating the annual rate of change using CAGRs and, linear and log-linear time trend equations for various land classes. They divided the ecological sector into two: desirable ecological sector (E_1) and non-desirable ecological sector (E_2). The inter-sectoral land budgeting revealed that substantial land shifts had taken place from the undesirable part of the ecological sector, i.e. from Usar and other barren lands to other sectors throughout the state and this highly favoured both the desirable part E_1 of the ecological sector and the agricultural sector. They also showed that almost half of the land released from E_2 sector had gone to the non-agricultural sector and the remaining half was shared by E_1 and the agricultural sector.

Pandey and Tewari (1987) analysed the trends and dynamics of annual shifts among different land-use classes in Indian states, which had adverse implications for agricultural growth and ecological balance. Generally, a decelerating trend was seen in areas under permanent pastures, grazing lands and, barren and uncultivable lands. Growth was observed in areas under non-agricultural uses, cultivable wastes and fallow land. An inter-sectoral land budgeting was also conducted and it showed that that area-shifts were occurring from both desirable and undesirable ecological sectors to agricultural as well as non-agricultural sectors. Further, the study identified the operation of a vicious circle of land use dynamics within the agricultural sector and it was observed that the vicious land cycle depletes the cultivated area by an amount equal or more than the increase in area under fallow lands. Bihar, Madhya Pradesh, Maharashtra and Orissa were the states that witnessed the vicious land-use dynamics.

Kumar (2005) studied the land-use changes in Kerala and pointed out that the cropped area increased from 2.3 million hectare in 1960 to 2.9 million hectares in 1969 mainly because of the increase in acreage under rice. The actual area under rice declined by over 60 per cent in the period from 1975 to 2003. When the area under rice declined, there was a simultaneous rise in area under rubber, coconut, black pepper and coffee. Coconut increased by 106 per cent between 1955 and 2000, rubber increased by 627 per cent and arecanut increased by 41 per cent during the period. He concluded that the land use pattern in Kerala demonstrated a shift from food crops to cash crops.

Ramasamy *et al*. (2005) examined the dynamics of land use pattern in Tamil Nadu, with special reference to fallow lands. They employed the instability index to estimate the extent of variability or the absence of stability in time-series data on land use. The instability index for the period from 1970 to 2000 was the highest for the area under current fallows and the area under other fallows. The decadal instability was also found to be higher for fallow lands as compared to other categories of land use in all the three decades of the period under study. The instability in the net cropped area (NSA) and gross cropped area (GCA) was observed to show no significant change over the period under the study.

Wani *et al*. (2009) examined the dynamics of shift among different land-use classes in Jammu and Kashmir from 1966-67 to 2004-05. They fitted an exponential function to find out the determinants of productive land-use. The study showed that the net irrigated area, literacy level and area not available for cultivation were the positive and significant determinants of variation in cropping intensity. Even though a positive contribution to the improvement of cropping intensity was reported by a regression coefficient of the average holding size (0.15), it was not found to be statistically significant. The significant improvement in cropping intensity was shown by the regression coefficient of the area not available for cultivation (0.79). The cropping intensity was noted to have been lower in Kashmir than Jammu province due to unsuitable climatic conditions. The study did not find any significant association between the irrigated area and cropping intensity, which indicated the lack of location-specific technological advancements and respective channelization.

A study on the dynamics of land utilization in Himachal Pradesh from 1972-73 to 2003-04 was conducted by Gupta and Sharma (2010). They found out that the instability index during the period was more for barren land, which was followed by the area under non-agricultural uses and other fallow lands. The decadal instability was observed to be more for other fallow land in the first period (1972-81), cultivable wastes in the second period (1981-91) and barren land in the third period (1991-2004) in comparison to other categories of land. The decadal instability was also found to be higher for fallow lands as compared to other categories of land-use during the study period. The instability in current fallows was mainly due to fluctuation in year-to-year rainfall pattern. The decadal instability was highest for other fallows in the first period, cultivable wastes in the second period and barren land in the third period in comparison to other land-use categories. The NSA manifested insignificant instability, whereas there was no specific trend for other categories of land.

The shifts in land use pattern in Kerala from 2001 to 2012 were examined by Rejula and Singh (2015) using data on area, production and productivity of major food crops and non-food crops. They computed CAGRs and Cuddy-Della Valle instability indices to examine the growth and instability of crops over the period, while the crop diversification index was also calculated for the state for individual years. They observed that land which was categorized as cultivable waste, fallow other than current fallow and current fallow recorded increased growth. They also found that banana (1.53%) and rubber (1.07%) showed the maximum improvement in terms of area and food crops like rice (4.01%) tapioca (3.83%) and plantain (1.01%) exhibited decline in area. Rice recorded decline in both area and production. They concluded that in Kerala, the GCA was decreasing and food crops were adversely affected by this shift than the non-food crops.

Sharma (2015) by using multiple regression analysis, found that urbanisation, industrialisation and rapid increase in road development in India were the main factors influencing the conversion of prime agricultural land. He also found a consistent pattern across most of the states which pointed to a loss of net sown area and total arable land to other sectors. From TE 1991-92 to TE 2011-12, about 1.8 million hectares of net area sown and over 3 million hectares of total arable land were lost to other sectors. According to the study, the area under non-agricultural uses increased by approximately 23 per cent (21.3 million ha to 26.3 million ha) during the period under the study. The States of Uttar Pradesh, Andhra Pradesh, Odisha, Madhya Pradesh, Bihar and Tamil Nadu were observed to have higher rates of acceleration, while Gujarat and some North-Eastern States presented a lower rate of increase in land under non-agricultural uses. He also observed the under-utilisation of agricultural land, as indicated by the share of net sown area in total arable land, as an issue and which was concentrated in Andhra Pradesh, Odisha, Rajasthan, Tamil Nadu, the hilly states and states comprising of a significantly large number of tribal areas. The absence as well as inadequacy of irrigation facilities were reported to be the main reasons for under-utilisation of the arable lands. Punjab, Haryana, Uttar Pradesh, and West Bengal presented a considerably higher utilisation of agricultural land. He also found out that from an all-India perspective, reclamation and development of wastelands with the ability to be cultivated could help in increasing the NSA. However, non-agricultural uses were competing with the efforts of reclamation and development of the wastelands which were suitable for cultivation. Rajasthan, Gujarat, Madhya Pradesh and other few north-eastern states were found to have been successful in raising more area under cultivation during the period under the study. Odisha, Bihar, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh and West Bengal States were found to have lost significantly large areas of agricultural land to other sectors.

Remote sensing methodology was used by Aneesh *et al*. (2018) by preparing the land conversion matrix through the ArcGIS platform to understand the nature and trend of land conversion in Thiruvananthapuram district of Kerala. They found a major difference in the way land conversion was carried out in the two periods, that is 1967-1991 and 1991-2017. They confirmed that land conversion to a large extent during the period from1967 to1991 was aimed at the accomplishment of the necessities. However, during the period from 1991 to 2017, they observed an urbanisation-dominated scenario. They stressed on three main findings; (i) the area under forest land shrank very fast majorly due to conversion to plantations. (ii) The proportion of built-up land increased sharply in the period under review. The built-up area constituted an increase of 243.71 per cent, while plantations had a rise of 137.22 per cent. (iii) They also observed a significant decline in area under paddy which translated to a reduction of 62.17 per cent. The study concluded that extreme conversion trends had dire effects on the environment as it adversely affected the water quality and land surface temperature.

2.3.2 Dynamics in cropping pattern

Unni (1983) examined the changes in cropping pattern of Kerala for the period from 1960-61 to 1978-79 during which the major emphasis was on the substitution of coconut for rice. Since paddy was a highly labour-intensive crop and coconut a garden crop, a shift from paddy to coconut was given more relevance. The study found out that garden-land crops especially, coconut had gained at the expense of wet-land crops like paddy.

Thomas *et al*. (1990) examined the changes in cropping pattern in Kerala during the period from 1973-74 to 1986-87. The study concentrated on 16 principal crops in Kerala based on physical, economic and sociological considerations. The CAGRs of area were computed for each of the crop and the shift in cropping pattern was tested using Spearman's rank correlation. Increasing trends in the acreage of small cardamom, cashew, coffee and rubber were observed mainly due to farmers' speculation of high prices in the future and favourable climatic conditions.

Mahesh (1999) assessed the causes and consequences of the changes in cropping pattern in Kerala and he theorised that the market forces were the major determinants of the emerging trends. He pointed out a constant growth in agricultural income until mid-seventies when it began to decelerate and depict a wavering trend up to the eighties. The analysis of the cropping pattern showed that the area under paddy had nearly halved during the period under study, while the income was seen to be mostly drawn from cash crops. He pointed out that the paddy land conversion took place in three different phases and the converted area was used in the cultivation of tapioca, vegetables and, banana and plantains in the first phase. The second phase witnessed the cultivation of coconut, black pepper and arecanut, while conversion to non-agricultural uses happened in the third phase.

Singh and Sidhu (2004) used a diversification index to study the factors responsible for declining crop diversification in Punjab. This study was motivated by a sharp deceleration in agricultural production which was reflected in declining diversity in the cropping pattern and emergence of wheat-rice dominance in Punjab. Rice and wheat witnessed the highest improvement in yields and area which led to increased growth in output of the crops. However, this led to ecological problems, increasing income risk due to less diversity and over-use of natural resources.

Joseph and Joseph (2005) used a kinked exponential model to estimate period-wise growth rates of cropping pattern in Kerala for the period from 1975-76 to 2002-03. They found out that there was an increase in the share of commercial crops in the NSA in the state, which registered an increase from 57 per cent in 1970-71 to approximately 84 per cent in 2001-02. Increasing growth in area was observed more in the case of rubber, coconut and black pepper. Rubber, particularly increased from 9 per cent to approximately 21 per cent share in the NSA. The rising cost of production and reduced profitability were implied to be the main causes of shift from labour-intensive food crops to less labour intensive and high-value commercial crops.

Rao and Parwez (2005) used the Markov transition probability model to analyse the shifts in cropping pattern in sorghum growing states of India. The study found that Dharwad district had other competing crops like groundnut and cotton to sorghum whereas, Belgaum district had other competing crops like pearl millet and maize to sorghum. The study maintained that Karnataka's retention probability of area under sorghum was 31 per cent during the period from 1970 to 1998

To study on agricultural development and source of output growth in Maharashtra State for the years from 1961-62 to 1997-98, Kalamkar (2007) employed CAGRs to estimate the growth in area, production and productivity of crops. He also used the Herfindahl and Entropy indices to find out the crop diversification index. He found out that an increase in productivity and shift in cropping pattern were the major factors that accounted for the growth in crop output of the state. The results showed that the growth in area of major crops in the state had a mixed trend. He subdivided the periods into three sub-periods to evaluate the impact of new production technology on agricultural development and assess the changes in the relative contribution of different factors to the output growth over the period. These periods were Period I from 1961-62 to 1970-71, Period II from 1971-72 to 1980-81, and Period III from 1981-82 to 1997-98. All the crops with the exception of jowar, bajra and wheat exhibited an increase in area. The increase in production and productivity of the crops were witnessed in the second period, while commercial crops presented significant growth in the third period of the study. The change in yield was observed to be the main contributor to the growth in production of kharif jowar, paddy, bajra, rabi jowar, wheat and cotton. The area expansion was on the other hand contributing to increased production in gram, tur and sugarcane.

Meenakshi and Indumathy (2009) used data from 1981-82 to 2005-06 to study the cropping pattern in the districts of Tamil Nadu to find out the extent of possible improvement in production through changes in cropping pattern. The study constituted eight major crops, *viz.* tapioca, cotton, paddy, ragi, sugarcane, maize, groundnut and cumbu. The analysis concluded that there was a significant decline in the cultivated area and hence output was greatly affected.

Kannan (2011) while using indices to analyse the determinants and estimate the TFP for major crops grown in Karnataka found that the cropping pattern had undergone visible changes since 1960s, with a shift in area from cereals to pulses, oilseeds and high-value crops like vegetables and plantation crops.

Tingre *et al*. (2011) conducted a study to understand the cropping pattern changes and crop diversification in Akola district of Vidarbha for the period from 1970-71 to 2001-02. The study showed that cereal crops like rice and bajra exhibited negative and low growth rates in area, while other crops did not exhibit any change during the first period of the study. In the second period, the growth rates were stagnant except for soybean. Cotton dominated the cropping pattern followed by soybean, pigeon pea and kharif jowar. These four crops constituted a tremendous share of 86.41 per cent in the cropping pattern. It was also found that the cropping intensity and the trend of crop diversification increased significantly during the period.

Ramachandra *et al*. (2013) used compound growth function to analyse the area, production and productivity of crops for the period from 1982-83 to 2007-08 to highlight the trends of crops in Karnataka. They observed that the cropping pattern and crop diversification showed significant growth in Vidarbha region.

The shifts in land use pattern and changing trend of cropping pattern in Kerala from 2001 to 2012 were examined by Rejula and Singh (2015) using data on area, production and productivity of major food crops and non-food crops. They computed CAGR and Cuddy-Della Valle instability index to examine the growth and instability of the crops over the period, while the crop diversification index was also calculated for each year. The computed crop diversification index pointed towards an increasing trend of mono-cropping in the state, in favour of non-food crops which were perennial cash crops. This specialisation by farmers on perennial cash crops was due to less labour requirement and more remunerative nature of these crops as compared to food crops.

Johnson (2018) studied the shift in cropping pattern in Kerala for the period from 1956-57 to 2016-17 by finding out the likelihood of farmers' shift to cash crops. The area under oilseeds increased from 5 per cent to 17 per cent during the period of the study. The horticultural crops consisting of flowers, spices, aromatic plants, fruits and vegetables gained in the study period. The study identified three different phases in terms of the changes in cropping pattern in Kerala. These were 1956-57 to 1974-75, 1975-76 to 1994-95, and 1995-96 to 2016-17. There was an increase in the area under food crops in the first phase, which declined in the second and third phases. However, for the non-food crops, the area exhibited an increasing trend in the first and second phases, but stagnated in the third phase. Based on the analysis of the study of 15 crops in Kerala, the study showed that the proportion of area under

10 of the selected food crops (ginger, sugarcane, arecanut, rice, tapioca, small cardamom, black pepper, turmeric, banana and plantain, and cashew) decreased and the proportion of area under five selected non-food crops (tea, rubber, sesamum, coffee, and coconut) remained unchanged from 1956-57 to 2016-17. The study used Hirschman-Herfindahl index to examine the crop diversification. The results showed that the cropping pattern was mostly distinct from 1956-57 to 1986-87 and less distinct from 1986-87 to 2016-17.

2.4 Dynamics in economics, efficiency and profitability of crops

Baliyan (1998) did a study on the costs and returns of sugarcane production in Muzaffarnagar district, Western Uttar Pradesh. From the study, he found that per hectare cost of cultivation of planted sugarcane was ₹9,118, ₹19,681 and ₹20,229 in small, medium and large-scale farms respectively. He found that the operational cost, rental value of land and material cost were constituting a large proportion of the total cost of cultivation. Harvesting, transportation and intercultural operations accounted for 40 per cent in the total cost of production in all the three farms sizes which accounted for the major share in the operational cost. The input cost in all the three-size groups of farms mainly comprised of the cost incurred for seed and irrigation, manures and fertilisers, which ranged from 18 to 24 per cent in the total cost of production.

Chowdry and Radha (2005) conducted a study to examine the economics of seed production of cotton in Karnool district of Andhra Pradesh. They found out that the cost of seed production was higher than that of commercial production and were ₹74,412 and ₹26,461 respectively. They also found that the total cost incurred for human labour, manures and fertilizers, plant protection chemical and rent for leased land constituted the largest proportion of the total cost.

Rajalakshmy (2006) assessed the cost of cultivation of crops while reviewing the agricultural sector of Kerala and found that the major factor discouraging investment in paddy was increased cost of cultivation arising out of labour costs. She pointed out that compared to neighbouring states, the cost incurred for labour was higher in Kerala. The decline in the profitability of cultivators arising out of a steep increase in cultivation cost was cited as the major factor that led to the steady decline in paddy cultivation.

Visawadia *et al*. (2006) sampled 125 cotton farmers (64 Bt cotton growers and 64 hybrid cotton growers) in Saurashtra region of Gujarat and made a comparative analysis of production and marketing of Bt Cotton and hybrid Cotton. He used simple tabular analysis to estimate and evaluate the costs and returns structures of Bt cotton and hybrid cotton. From the study, it was found that the mean total cost per hectare of cultivation was ₹44,553 for Bt Cotton and ₹39,816 for hybrid cotton. The cost incurred for plant protection costs was found to be higher in hybrid cotton than in Bt Cotton. The study also found that the average productivity in Bt Cotton farms relative to hybrid cotton farms was higher by 29 per cent.

Kshirsagar (2008) collected data from 72 sugarcane farmers (38 organic sugarcane farmers and 34 inorganic sugarcane farmers) in Jalgaon and Kolhapur districts of Maharashtra. The study found out that that the mean cost of cultivation of organic sugarcane crop was ₹37,017 per ha, while for the inorganic sugarcane it was ₹43,164 per ha. The 14 per cent lower cost incurred in organic sugarcane farms was explained by the non-application of inorganic fertilizers and lower cost incurred on irrigation, seed and plant protection. The gross value of production and net returns were higher on organic sugarcane farms (₹1,16,711 per ha) compared to ₹1,12,088 per ha in the inorganic sugarcane farms.

The conventional analysis, budgeting technique, decomposition analysis and adoption model were used by Thennarasu and Banumathy (2011) to examine the economics of sugarcane production using eco-friendly technology in the adopter and non-adopter farmers of bio inputs in Cuddalore district of Tamil Nadu. They found out that the unit cost of production was higher in the case of non-adopters than adopters. The difference in gross return per hectare of sugarcane between adopters and non-adopters was found to be ₹9,003 per hectare.

Ramanan (2012) examined the cost of production and capital productivity of grape cultivation in Tamil Nadu. He reported ₹2,41,986 as the establishment cost for grape garden and ₹48,284 as the yearly operational and maintenance cost per hectare of bearing grape. He estimated the cost of production at ₹7.59 per kg. Additionally, the capital productivity analysis showed that the Net Present Value (NPV) was ₹1,55,865 and Benefit-Cost Ratio (BCR) was 1.33. The Internal Rate of Return (IRR) was found to be 24.76 per cent, while the opportunity cost was 7 per cent. It was also found that the payback period was 2.25 years which meant that the investment made in a vineyard could be obtained by the end of 2.25 years.

Rao (2012) used the data on costs and returns for the year 2008-09 to analyse the economics and yield gap in irrigated and rain-fed sugarcane cultivation in North Coastal Zone of Andhra Pradesh. To achieve this, the study employed budgeting techniques, cost concepts, BCR, yield gap analysis and response-priority index. The BCR value was found to be higher for the irrigated crop (1.49) when compared to the rain-fed one (1.43). The yield gap between irrigated and rain-fed regions was found to be 67.8 per cent, with a higher input usage of 41.86 per cent. The total cost of cultivation of sugarcane was highest in irrigated conditions at ₹1,47,454 per ha, followed by rain-fed crop at ₹90,939 per ha. The cost of cultivation was observed to be least in ratoon irrigated crop and was estimated as ₹81,106 per ha. Seventy-six per cent (₹72,569) of the total operational cost under irrigated conditions was incurred for labour and 24 per cent (₹22,917) was on inputs. On the other hand, 65 per cent (₹11,733) was incurred on labour charges and 35 per cent (₹6,318) on inputs under rain-fed conditions. This brought out the labour-intensive nature of sugarcane cultivation under both conditions. Labour wages were found to be the main contributor of operational cost on the cultivation of sugarcane in the North Coastal Zone which had increased from ₹39,398 per hectare in 2001-02 to ₹90,939 per hectare in 2008-09, accounting for an increase of 230 per cent. The labour wages increased by three times from ₹40 per day to ₹120 per day during the same period.

Papang and Tripathi (2014) carried out a study on the costs and returns of turmeric and constraints faced by producers in Jaintia hills district of Meghalaya. They found that the proportion of variable cost was about 98 per cent of the total cost. The total costs of cultivation for turmeric was estimated as ₹77,012 per hectare, while the net returns was ₹6475 per hectare and ₹28,109 per hectare for fresh turmeric and dried turmeric respectively. It was found that ₹12,719 per hectare of extra expenditure was used on post-harvest management of turmeric. They noted that a higher net income was realised when the farmers released the product after drying, which also prevented distress sales by the farmers. The cost of production incurred for fresh, semi-processed and processed (powdered) form of turmeric were estimated as ₹15.68 per kg, ₹60.93 per kg and ₹70.17 per kg respectively.

Agarwal *et al*. (2018) estimated the cost and return structure of paddy cultivation under traditional and SRI methods in Burmu block of Ranchi district in Jharkhand. The study found that the cost incurred in traditional method was ₹14,015 per acre, while it was ₹12,155 per acre in SRI method. The yield realised from traditional method and SRI methods were ₹1,560 kg per acre and ₹1,821 kg per acre respectively. The BCR was found to be higher in SRI method of paddy cultivation.

2.5 Total factor productivity (TFP) of crops

Kumar and Mittal (2006) used growth decomposition to study the agricultural productivity trends and sustainability issues in India by estimating the growth in TFP. The temporal and spatial variations in growth of TFP for major crops in India were examined in the study. They observed that agriculture had been experiencing diminishing returns to input use and the significant proportion of the gross cropped area had been facing stagnation or negative growth in TFP. They noted that approximately 60 per cent of the area under coarse cereals was facing stagnation in TFP.

Kannan (2011) used indices to estimate the TFP and analyse the determinants of TFP of ten major crops in Karnataka. The analysis confirmed that most crops had registered low productivity growth during the period from 2000-01 to 2007-08. However, all the crops registered a growth in TFP. By using growth accounting method of Tornqvist-Theil Index, aggregate output and aggregate input of individual crops were constructed. Two outputs and nine inputs had been used to construct output and input index. The growth analysis had revealed that yield of most crops especially food grains had declined during the period from 1980-81 to 1989-90 leading to stagnation in production. However, during the period from1990-91 to 2007-08, there was a reversal of growth in production and yield for some food and non-food crops. The public investment in agriculture was believed to have played a vital role in improving growth. There was a revival in terms of positive TFP growth during the 1990s, despite most of the crops showing decrease in productivity growth. Input and output indices had registered the growth rates of 0.77 per cent and 1.85 per cent respectively during the period from 1980-81 to 2007-08 and the TFP had risen at 1.09 per cent per annum, contributing about 58.67 per cent to the total output growth. The study confirmed that government expenditure in research, education and extension, canal irrigation, rainfall, and the balanced use of fertilisers contributed majorly to the growth in crop productivity in Karnataka. The study further claimed that a low TFP growth suggested that there existed a huge scope for improving agricultural production through technological progress by way of enhancement on investment in research and technology, and rural infrastructure.

Chaudhary (2012) estimated TFP in Indian agriculture at the state-level using an index of agricultural production as the measure of output. The variations in TFP were estimated using non-parametric Sequential Malmquist TFP index and the change in TFP was decomposed into efficiency change and technical change. The study found that there were marked productivity improvements as well as technical change in fewer states. The improvements in efficiency were observed to be low for most of the states and the efficiency decline was observed in several states implying huge gains in production possibility even with existing technology. He concluded that, to attain increased productivity it was paramount to improve efficiency levels as well as an even-spread of new technology.

While studying the performance of agriculture in Kerala with emphasis on demand and supply of major crops, Parappurathu (2015) examined the TFP of major crops to understand the essential growth in productivity of crops which was not attributed to increase in input use, but an improvement of technology, management practices, or other exogenous factors like institutional innovations in crop management by using the Divisia Tornqvist index to estimate the TFP. He found out that the TFP of paddy grew at the rate of 1.84 per cent, pointing to the possible improvement in technology and management in paddy which had resulted in the improved productivity. For coconut, use of inputs grew at the rate of 1.27 per cent per annum, while output per hectare increased at the rate of 2.04 per cent. This led to the growth of 0.77 per cent in TFP. Tapioca showed higher improvement in TFP (4.92 %) due to large growth in the input use at the rate of 1.27 per cent. For tapioca, TFP contributed a higher share (73.5 %) to growth in output. Banana showed a mild growth in TFP (0.81 %) and it contributed 66.9 per cent to total output growth. Spice crops like black pepper and ginger showed negative growth in TFP due to higher rate of input growth compared to output growth. He added that output per hectare in black pepper decreased at the rate of 3.83 per cent, while the use of inputs increased at the rate of 3.16 per cent, resulting in the estimated TFP decline of -6.78 per cent. Turmeric showed an enhancement in TFP at 0.49 per cent per annum that accounted for 24.5 per cent of the total growth in output.

Suresh (2015) used non-parametric data envelopment analysis to study technical efficiency in agricultural production in India and decomposed it into pure technical efficiency and scale efficiency. The study took a total of 409 districts as the decision-making units (DMUs). The study also identified major determinants that influence the technical efficiency by regressing the estimates of efficiency yielded in the first step on probable contributory variables. The output variable was taken as district level per-hectare value of crop, while inputs were taken as fertiliser application, rainfall, extent of degraded land, irrigation and availability of workers per hectare of net cropped area. The study found the average level of technical efficiency as 42 per cent, while pure technical efficiency was about 54 per cent and scale efficiency was about 78 per cent, indicating presence of large level of inefficiencies. The study also found out that there was considerable variation of efficiency over agro-ecological regions. The highest level of technical efficiency was exhibited by the hill and mountainous region, while rainfed region had the lowest. The rainfed and irrigated regions posted comparable levels of pure technical efficiency showing the likelihood for improving the productivity through manipulation of conditions that enable efficiency. Factors that were found to be significant in enhancing technical efficiency were infrastructure, education and capital assets.

Suresh and Reddy (2016) estimated the TFP growth of major pulses (chickpea, pigeon pea, green gram and black gram) in India. The study used Malmquist productivity approach to estimate the TFP for the period from 1994-95 to 2012-13. The study also explored the role of technological change in improving pulse productivity using the case of chickpea in Andhra Pradesh. Among the pulses studied, only chickpea and green gram exhibited improvement in TFP. The case study on chickpea in Andhra Pradesh showed that productivity improvement was directly related to the share of adoption of improved varieties. The study concluded that the development of affordable technologies suitable for marginal environments and emerging cropping patterns would help to improve the productivity of pulses in India, thereby contribute to addressing the under-consumption of protein.

3. METHODOLOGY

This section outlines the information on how the study was conducted and the description of the analytical tools that were employed in the study. It is broadly organized into six subsections.

3.1 The study area

3.2 Data and sources of data

3.3 Crops selected for the study

3.4 Period of study

3.5 Analytical tools and techniques

3.6 Definition of concepts and terminologies

3.7 Limitations

3.1 The study area

3.1.1 Location of the study area

The study was conducted in the state of Kerala, in India. Kerala is one of the 28 states of India and was formed on 1st November 1956, following the passing of the States Reorganisation Act, by combining the Malayalam-speaking regions of the erstwhile provinces of Travancore-Cochin and Madras. It is located on the south-western part of India. Kerala is bordered by two states, Karnataka in the north and Tamil Nadu in the east and, the south and west of the state is the Arabian Sea. The coast runs up to 590 km in length. The total geographical area of Kerala is 38,863 sq. km and the capital is Thiruvananthapuram. Kerala lies between the latitudes 8°.17'.30" N and 12°.47'.40" N and longitudes 74°.27'47" E and 77°.37'.12" E. The State had an estimated per capita income of ₹2,25,484 in 2018-19. The State is divided into 14 districts, namely, Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kottayam, Idukki, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Wayanad, Kannur and Kasaragod.

Figure 1: Map of Kerala

3.1.2 Topography and climate

Kerala's climate is largely tropical, which mostly receive heavy seasonal monsoon rainfall. For the past 10 years from 2009-10 to 2018-19, Kerala received an average annual rainfall of 2756 mm for an average of 120 to 140 rainy days per year against a normal of 2963 mm. The average daily temperature of the state ranges from 19.8°C to 36.7 °C. The summer season in the state is from February to May, while the winter season is experienced from October to January.

3.1.3 Demographic features

Kerala forms the twenty first largest state based on the area and twelfth largest state based on population. Kerala is the state with the lowest positive population growth rate in India (4.9%) and has a population density of 860 people per Square km based on the 2011 census. According to the 2011 census, Kerala has an average literacy rate of 93.91 per cent and best life expectancy and sex ratio.

3.2 Data and sources of data

The study was carried out using the time series data collected from the publications of various departments and institutions: Directorate of Economics and Statistics (DES), Kerala, Ministry of Agriculture and Farmers Welfare of India, National Sample Survey Organisation (NSSO), Reserve Bank of India (RBI), www.agristat.com, www.keralastat.com and State Planning Board (SPB), Kerala. The details of the data collected from these sources are presented in Table 3.1 and Table 3.2.

The data collected from these agencies were statistics on gross state domestic product (constant and current prices), net district domestic product (constant and current prices), gross fixed capital formation, development expenditure in the primary sector, value of output, land use pattern, average annual rainfall, gross and net irrigated area, area and production of crops, quantity of inputs used and prices, agricultural credit, agricultural wages, cost of cultivation/production and farm commodity prices.

3.2.1 Sources and period of data collected

Table 3.1: Details of State level data collected for Kerala

Sl. No.	Details /Period of data	Sources
1	Agricultural wages - 1970-71 to 2018-19	Economic Review, State Planning Board (SPB), Government of Kerala (GoK) (various years)
2	Area and production of crops - 1970-71 to 2018-19	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years) Economic Review, SPB, GoK (various years)
3	Average annual rainfall - 1970-71 to 2018-19	Economic Review, SPB, GoK (various years) Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years)
4	Consumption of inputs (fertiliser, plant protection and planting materials) - 1970-71 to 2018-19	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years) Economic Review, SPB, GoK (various years) keralastat.com
5	Cost of cultivation, hired human labour hours and cost of production for paddy - 2000-01 to 2016-17	Reports on Cost of Cultivation of crops, DES, GoK (various years)
6	Farm commodity prices - 1978-79 to 2018-19	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years) Economic Review, SPB, GoK (various years)
7	Gross fixed capital formation - 1990-01 to 2017-18	Annual survey of industries, DES, GoK (various years) Handbook of Statistics on Indian States, RBI (various issues)
8	Gross State Domestic Product (sector-wise) -Current and Constant - 1970-71 to 2018-19	State Income reports, DES, GoK (various years) Economic Review, SPB, GoK (various years)
9	Irrigated area (Gross and Net) - 1970-71 to 2018-19	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years) Economic Review, SPB, GoK (various years)
10	Land use statistics 1970-71 to 2018-19	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years)
11	Net State Domestic Product (sector-wise)-Current and Constant 1970-71 to 2018-19	State Income reports, DES, GoK (various years) Economic Review, SPB, GoK (various years)
12	Operational holdings 1970-71 to 2018-19	Statistics for planning, DES, GoK (various years) Economic Review, SPB, GoK (various years)
13	Prices (fertiliser, paddy seeds, coconut) 1970-71 to 2018-19	Price Statistics, DES, GoK Economic Review, SPB, GoK (various years) Statistics for planning, DES, GoK (various years)
14	Value of output - 2000-01 to 2016-17	Reports on Cost of Cultivation of crops, DES, GoK (various years)

Table 3.2: Details of district-wise data collected for Kerala

Si. No.	**Details /Period of data**	**Sources**
1	Area, production and productivity of crops - 1985-86 to 2017-18	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years)
2	Average annual rainfall - 1985-86 to 2017-18	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years)
3	Consumption (fertiliser) - 1985-86 to 2017-18	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years)
4	Gross District Product - (sector-wise)	Statistics for planning, DES, GoK (various years) Economic Review, SPB, GoK (various years)
5	Irrigated area - (Gross and Net)	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years)
6	Land use statistics	Statistics for planning, DES, GoK (various years) Agricultural statistics, DES, GoK (various years)
7	Net District Domestic Product (Sector-wise) Current and Constant	Statistics for planning, DES, GoK (various years) Economic Review, SPB, GoK (various years)

Note: 1. Procedure for rebasing the GSDP and NSDP at different constant prices to the 2011-12 prices and computation of other missing data such as arable land and cropping intensity are provided under sections 3.2 and 3.5 respectively.

2. The reason for collecting district level data from the year 1985-86 instead of 1970-71 has been explained in section 3.6.

3. Weighted fertiliser prices were also computed from the prices and consumption of NPK fertilisers.

3.2.2 Procedure for rebasing data at 1980-81, 1983-84, 1993-94, 1999-00 and 2004-05 prices to 2011-12 prices

The computation of data on terms of trade and rebasing the GSDP and NSDP at constant prices (2011-12 prices) are explained under this section. DES, GoK estimated the state income data by implementing the production, expenditure and income approaches. The state income for the years 1970-71 to 2006-07 at constant prices were collated and rebased from previous prices, that is, 1980-81 prices, 1983-84 prices and 1993-94 prices to the 1999-00 prices by DES, GoK. The state income data for the years from 2004-05 to 2011-12 at 2004-05 prices and state income from 2011-12 to 2018-19 at 2011-12 prices were collected. The district level domestic product data were collected from Economic Review for various years at different constant prices (1980-81, 1983-84, 1993-94, 1999-00, 2004-05 and 2011-12 prices). Thus, the real GSDP and NSDP at state level were available with three different bases, while at district level were presented at six different base prices and hence all the above data were rebased to the 2011-12 (latest) series as below.

The overlapping values for the current base year and the previous base year were identified. For example, the value of GSDP constant for the year 1999-00 and base year 2004-05 reported for the year 2004-05. Similarly, this was repeated for the other years, like the 2011-12 based on the 2004-05 prices and 2011-12 prices. Then a constant (*k*) that converts the previous price level to the current price level was worked out as $k = \frac{V2}{V1}$

Where:

V_1 = value of GSDP/NSDP at constant prices for previous base year

V_2 = value of GSDP/NSDP at constant prices for current base year

The constant *(k)* was then used to convert the previous base year values to the succeeding base year values by multiplying the previous base year values with *k*.

3.2.3 Procedure for computation of agriculture terms of trade (ToT)

$$ToT_{agri} = \frac{\text{Agri Deflator}}{\text{Non−agri Deflator}} \times 100$$

3.3 Crops selected for the study

The principal crops selected for the study were coconut, rubber, tea, coffee, black pepper, small cardamom, arecanut, cashew, paddy, tapioca, mango, banana and other plantains, fruits and vegetables. These crops cumulatively accounted for 90 per cent of the GCA in 1970-71 and 85 per cent in 2018-19.

3.4 Period of study

The overall study was carried out using time series data for the period from 1970-71 to 2018-19.

3.5 Analytical tools and techniques

This section outlines the various tools used to conduct the study based on the objectives.

3.5.1 Growth of agriculture in Kerala

3.5.1.1 Compound Annual Growth Rates

The Compound Annual Growth Rates (CAGRs) were computed to understand the historical trend and performance of area, production and productivity of crops in Kerala. These were estimated by using the exponential growth function of the form:

$Y_t = ab^t e^u$

Where,

Y_t= dependent variable for which growth rate was estimated

a = intercept term

b = Regression coefficient=($1+r$) and r is the compound growth rate

t = time trend (Years which take values *1, 2, …, n*)

u = Disturbance term for the year 't'

The significance of b was tested using students t-test

The LOGEST function in MS Excel was used to estimate the CAGR values. This function applies the OLS method so that instead of calculating the CAGR based only on the starting and ending values, it considers all the values in the series to provide a CAGR that best fits the historical trend. Therefore, the LOGEST approach was found better since it utilises the transitional values to produce the result. To ensure consistency, LOGEST approach was used all through the study.

3.5.1.2 Cuddy-Della Valle Instability index

The Cuddy-Della Valle Instability (CDVI) was used to find out the fluctuations or instabilities in area, production and productivity of crops. As the first step, the parameter of a log-linear trend line for the variable (Y_t) for which instability is to be calculated is estimated. If the estimated parameter is statistically significant, then the instability index (*IIN*) is defined as:

$$\text{Instability index}, IIN = \left(\frac{\delta}{\mu} \times 100\right) \times (1 - \bar{R}^2)^{0.5}$$

Where,

$\bar{R}^2$ = Adjusted coefficient of determination

μ= Mean

σ= Standard deviation

If the estimated parameter in the regression equation in not significant, then the CV itself is the instability index. An instability index value from zero to 15 per cent denotes low instability, while a value ranging from 15 to 30 per cent indicates medium instability and any index value greater than 30 per cent is considered as high instability.

3.5.1.3 Structural Break Analysis

The structural change can be obtained based on the Chow test as explained by Gujarati, *et al.* (2018) and Greene (2019). This involves identifying the probable breakpoints and subjecting the periods on computed F statistics based on their unrestricted residual sum of squares (RSS_{UR}) and restricted residual sum of squares (RSS_{R}). The Chow test assumes uniform variance of the disturbance term in all the regressions and suffers from subjectivity of the researcher in determining the break points. Therefore, to overcome these drawbacks, methodology by Bai and Perron (1998) was used.

Consider the following multiple linear regression with m breaks (m+1 rules) with h as the minimum length assigned to a segment:

$$y_t = x_t' \beta + z_t' \delta_j + u_t \qquad t = T_{j-1} + 1, \ldots \ldots \ldots, T_j \ldots\ldots\ldots \text{(i)}$$

For $j = 1, \ldots \ldots, m + 1.$
Where:

y_t = dependent variable at time *t*

$x_t(p \times 1)$ and $z_t(q \times 1)$ = vectors of covariates

$\beta \; and \; \delta_j \; (j = 1, \ldots, m + 1)$ = corresponding vectors of coefficients

u_t = disturbance at time *t*.

The indices $(T_{1,\ldots,}T_m)$, or the break points, are explicitly treated as unknown ($T_0 = 0$ and $T_{m+1} = T$ are assumed). The purpose is to estimate the unknown regression coefficients together with the break points when T observations on $(y_t, x_{t,} z_t)$ are available. This is a partial structural change model since the parameter vector β is not subject to shifts and is estimated using the entire sample. When $p = 0$, a pure structural change model in which all the coefficients are subject to change is obtained. The variance of u_t need not be constant. Therefore, breaks in variance are permitted provided they occur at the same dates as the breaks in the parameters of the regression.

The multiple linear regression (i) may be expressed in matrix form as,

$$Y = X\beta + \bar{Z}\delta + U$$

Where:

$Y = (y_1, \ldots, y_T)'$

$X = \quad (x_{1,\ldots,}x_T)'U = (u_{1,\ldots,}u_r)'$

$\delta = (\delta_1', \delta_2', \ldots, \delta_{m+1}')'$

$\bar{Z}$ = the matrix which diagonally partitions Z at $(T_1, \ldots, T_m)$, i.e. $\bar{Z} = diag(Z_1, \ldots, Z_{m+1})$ with $Z_i = (zr_{i-1} + 1, \ldots zr_i)'$.

True value of a parameter is denoted with a 0 superscript. In particular, $\delta^0 = \left(\delta_1^{0'}, \ldots., \delta_{m+1}^{0'}\right)' and\ (T_1^0, \ldots, T_m^0)$ are used to denote, respectively, the true values of the parameters δ and the true break points. The matrix $\bar{Z}^0$ is the one which diagonally partitions Z at ($T_1^0, \ldots, T_m^0$). Hence, the data-generating process is assumed to be

$Y = X\beta^0 + \bar{Z}^0\delta^0 + U$…………………………………….. (ii)

The method of estimation considered is thus based on the least-squares principle. For each m-partition $(T_1, \ldots, T_m)$, the associated least-squares estimates of $\beta\ and\ \delta_j$ are obtained by minimizing the sum of squared residuals

$$(Y - X\beta - \bar{Z}\,\delta)'(Y - X\beta - \bar{Z}\,\delta) = \sum_{i=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} [y_t - x_t'\beta - z_t'\delta_i]^2$$

Let $\hat{\beta}(\{T_j\}) and\ \hat{\delta}(\{T_j\})$ denote the estimates based on the given m-partition $(T_1, \ldots, T_m)$ denoted $\{T_j\}$. Substituting these in the objective function and denoting the resulting sum of squared residuals as $S_T(T_1, \ldots, T_m)$, the estimated break points $(\hat{T}_{1,} \ldots.., \hat{T}_{m,})$ are such that $(\hat{T}_{1,} \ldots.., \hat{T}_{m,}) = argmin_{T_{1,\ldots\ldots\ldots,T_m}} S_T(T_{1,\ldots\ldots,}T_m)$, where the minimization is taken over all partitions $(T_{1,\ldots\ldots}T_m)$ such that $T_i - T_{i-1} \geq q$.[2] Thus, the break-point estimators are global minimizers of the objective function. The regression parameter estimates are the estimates associated with the m-partition $\{\hat{T}_j\}, i.e. \hat{\beta} = \hat{\beta}(\{\hat{T}_j\}), \hat{\delta} = \hat{\delta}(\{T_j\})$. Since, the break points are discrete parameters and can only take a finite number of values, they can be estimated by a grid search. This method becomes rapidly computationally excessive when m>2. Instead of a dynamic programming algorithm that allows computation of estimates of the break points as global, minimizers of the sum of squared residuals can be devised to efficiently estimate the optimal break points for the series starting from one to the maximum allowed by T and h.

Strucchange package in *R Studio* was used to obtain the breakpoints on log-transformed values of GSDP agriculture constant (2011 prices) and areas under crops. In this case, sample size of 49 observations on crop areas and GSDP from agriculture at constant prices from 1970-71 to 2018-19 was used. Here *h* was not set and the program was set to obtain the maximum possible breakpoints among the various combinations of break points. The optimal breakpoints were selected based on a two-step validity test on the residual sum of squares (RSS) and the Bayesian information criteria (BIC). The lowest value of RSS was considered optimal on the first step. In case the optimal breakpoints found in step one coincided with the lowest BIC, this was taken as the optimal breakpoint. Therefore, the lowest BIC held precedence on validity. Results of the breaks are discussed under preliminary part of section 4.1 and 4.1.2 for the break points of GSDP from agriculture at constant prices and break points of crop areas respectively.

3.5.1.4 Seemingly Unrelated Regression (SUR) Model

To understand the effect of various factors and their interactions on the growth of agriculture GSDP in Kerala, (Zellner, 1963) Seemingly Unrelated Regression [Equations] (SUR/SURE) model was used.

Supposing there are m regression equations,

$$y_{ir} = x_{ir}^{T}\beta_i + \varepsilon_{ir}, i = 1, \ldots, m.$$

Where,

i is the equation number,

t = 1, …, T is the time variable involved in the calculation of transpose of the x_{ir} column vector.

The number of observations T is presumed to be large, so that in the analysis it is taken as T → ∞, whereas the number of equations m remains fixed. The every i^{th} equation has a single criterion variable y_{ir}, and a $k_i$dimensional vector of predictor variables x_{ir}. The matrix representation of the model is as follows. Stacking the observations corresponding to the i^{th} equation into T-dimensional vectors and matrices, the model can be written in the form of a vector as:

$$y_i = X_i\beta_i + \varepsilon_i, i = 1, 2, \ldots, m.$$

Where,

y_i , x_i and ε_i are T×1 vector

X_i is a $T \times k_i$ matrix

β_i is a $k_i \times 1$ vector and the dimension of ε_i is $\varepsilon_i \times T$

Stacking the m vector equations separately, the model can be shown as:

$y_1 = X_1\beta_1 + \varepsilon_1$

$y_2 = X_2\beta_2 + \varepsilon_2$

$\vdots$

$y_m = X_m\beta_m + \varepsilon_m$

$$\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{pmatrix} = \begin{pmatrix} X_1 & 0 & \cdots & 0 \\ 0 & X_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & X_m \end{pmatrix} \begin{pmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_m \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_m \end{pmatrix} = X\beta + \varepsilon$$

Where the order of y is $TM \times 1$, X is $TM \times k^*$, β is $k^* \times 1$, ε is $TM \times 1$ and $k^* = \sum_i k_i$.

Assume that each of the M equations are classical regression model and make conventional assumptions for $i = 1, 2, \dots, M$ as

- X_i is fixed
- $rank\ (X_i) = k_i$
- $\lim_{T\to\infty} \left(\frac{1}{T} X_i' X_i\right) = \sigma_{ii}$ where Q_{ii} is non-singular with fixed and finite elements
- $E\ (u_i) = 0$
- $E\ (u_i u_i') = \sigma_{ii} I_T$ where σ_{ii} is the variance disturbance in i^{th} equation for each observation in the sample.

Considering the interactions between the M equations of the model, assumption is made that:

- $\lim_{T\to\infty} \left(\frac{1}{T} X_i' X_j\right) = Q_{ij}$
- $E\ \left(u_i u_j'\right) = \sigma_{ij} I_T; i, j = 1,2, \dots, M$

Where:

Q_{ij} is non-singular matrix with finite and finite elements

σ_{ij} is the covariance between the disturbances of i^{th} and j^{th} equations for each observation in the sample.

Therefore, it can be written as:

$E\ (\varepsilon) = 0$

$$E(\varepsilon\varepsilon') = \begin{pmatrix} \sigma_{11}I_T & \sigma_{12}I_T & \cdots & \sigma_{1M}I_T \\ \sigma_{21}I_T & \sigma_{22}I_T & \cdots & \sigma_{2M}I_T \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{M1}I_T & \sigma_{M2}I_T & \cdots & \sigma_{MM}I_T \end{pmatrix} = \sum \otimes I_T = \psi$$

Where,

$\otimes$ denotes the Kronecker product operator,

ψ is $MT \times MT$ matrix and

$\sum = \left((\sigma_{ij})\right)$ $is\ \ (M \times M)$ positive definite symmetric matrix.

The definiteness of $\sum$ avoids the possibility of linear dependencies among the contemporaneous disturbances in the M equations of the model.

Xβ+ε, $E\ (\varepsilon) = 0, V\ (\varepsilon) = \sum \otimes I_T = \psi$

The structure $E\ (uu') = \sum \otimes I_T$ implies that:

- Variance of ε_{ti} is constant for all *t*.
- Contemporaneous covariance between ε_{ti} and ε_{tj} is constant fir all *t*.
- Intertemporal covariance between ε_{ti} and $\varepsilon_{t\times j}$ $(t\ \neq t\ ^{*})$ are zero for all *i* and *j*.

Terminologies "contemporaneous" and "intertemporal" covariance are used on assumption that the data is available in time series form however, this is not limiting. It can also be employed for cross sectional data. The constancy of the contemporaneous covariances across sample points is a natural generalization of homoscedastic disturbances in a single equation model.

The *M* equations may appear to be not related in the sense that there is no simultaneousness between the variables in the system and each equation has its own explanatory variables to explain the study variable. The equations are therefore assumed to be related stochastically through the disturbances which are serially correlated across the equations of the model. That is why this system is referred to as SUR model. The SUR model is a particular case of simultaneous equations model involving *M* simultaneous equations with *M* jointly dependent variable and k $(\geq\ k_i$ for all $i)$ distinct exogenous variables and in which neither current nor lagged endogenous variables appear as explanatory variables in any of the structural equations.

The SUR model differs from the multivariate regression model only in the sense that it takes account of the prior information concerning the absence of certain explanatory variables from certain equations of the model. Such exclusions are highly realistic in many economic situations.

The SUR model can be estimated by incorporating the Feasible Generalized Least Squares (FGLS) method. This is a two-step method where in the first step OLS is used for equation one. The residuals from this regression are used to estimate the elements of the matrix ∑:

In summary of the model explanation above, assuming that ψ is known, the SUR model is:

$$X\beta + \varepsilon, E\ (\varepsilon) = 0, V\ (\varepsilon) = \sum \otimes I_T = \psi$$

3.5.1.4.1 Ordinary least squares (OLS) and the generalised least squares (GLS) estimation

OLS estimator of β

$$b_o = (X'\ X)^{-1}X'y$$

$$E\ (b_o) = \beta$$

$$V\ (b_o) = E\ (b_o - \beta)(b_o - \beta)'$$

$$= (X'X)^{-1}X'\psi\ X\ (X'X)^{-1}$$

The generalised least squares (GLS) estimator of β

$$\hat{\beta} = (X'\psi^{-1}X)^{-1}X'\psi\ y$$

$$= [X'\ (\textstyle\sum^{-1} \otimes\ I_T)X]^{-1}\ X^{-1}(\textstyle\sum^{-1} \otimes\ I_T)y$$

$$E\left(\hat{\beta}\right) = \beta$$

$$V\left(\hat{\beta}\right) = E\left(\hat{\beta} - \beta\right)\left(\hat{\beta} - \beta\right)'$$

$$= [X'\ (\textstyle\sum^{-1} \otimes\ I_T)X]^{-1}$$

Define

$$G = (X'X)^{-1}X' - (X'\psi^{-1}X)^{-1} X'\psi^{-1}$$

Then $GX = 0$ and it is found that

$$V(b_o) - V(\hat{\beta}) = G\psi G'$$

Since ψ is positive definite, so $G\psi G'$ is atleast positive semidefinite and so GLS estimator is, in general, more efficient than OLS estimator for estimating β. In fact, using the result that GLS best linear unbiased estimator of β, it can be concluded that $\hat{\beta}$ is the best linear unbiased estimator in this case also.

3.5.1.4.2 Feasible generalized least squares regression

In the second step, the feasible generalized least squares regression (FGLS) is used. When ∑ is unknown, then FGLS of β cannot be obtained. Then ∑ can be estimated and replaced by $(M \times M)$ matrix *S*. With such replacement, we obtain a feasible generalized least squares (FGLS) estimator of β as

$$\hat{\beta}_F = [X'(S^{-1} \otimes I_T)X]^{-1} X'(S^{-1} \otimes I_T)y$$

Assuming that $S = ((s_{ij}))$ is a non-singular matrix and s_{ij} is some estimator of σ_{ij}.

Estimation of ∑

There are two possible ways to estimate $\sigma_{ij}'s$. Use of unrestricted residuals and use of restricted residuals. To compute the determinants of growth drivers in Kerala, unrestricted residuals methodology was used.

Let *K* be the total number of distinct explanatory variables out of $k_1, k_2, \ldots, k_m$ variables in the full model

$$y = X\beta + \varepsilon, E(\varepsilon) = 0, V(\varepsilon) = \sum \otimes I_T$$

and let Z be $T \times K$ observation matrix if these variables.

Regress each of the M variables on the column of Z and obtain $(T \times 1)$ residual vectors

$$\hat{\varepsilon}_i = y_i - (Z'Z)^{-1}Z'y_i \quad i = 1,2,\ldots,M$$

$$= \bar{H}_z y_i$$

Where $\overline{H}_z = I_T - Z\,(Z'Z)^{-1}Z'$

Then obtain

$$s_{ij} = \frac{1}{T}\,\hat{\varepsilon}_i\,\hat{\varepsilon}_j$$

$= \frac{1}{T}\,y_i'\,\overline{H}_z\,y_j$ then construct the matrix $S = \left(\left(s_{ij}\right)\right)$

Since X_i is a submatrix of Z, it can be written as:

$$X_i = ZJ_i$$

Where J_i is a $K \times k_i$ selection matrix. Then,

$$\overline{H}_z X_i = X_i - Z\,(Z'Z)^{-1}Z'X_i$$

$$= X_i - ZJ_i$$

$$= 0$$

Thus,

$$y_i'\overline{H}_z X_j = \left(\beta_i' X_i{}' + \varepsilon_i'\right)\overline{H}_z\left(X_j\beta_j + \varepsilon_j\right)$$

$$= \varepsilon_i'\overline{H}_z\varepsilon_j$$

Hence,

$$E\,\left(s_{ij}\right) = \frac{1}{T}E\left(\varepsilon_i'\overline{H}_z\varepsilon_j\right)$$

$$= \frac{1}{T}\sigma_{ij}tr\,(\overline{H}_z)$$

$$= \left(1 - \frac{1}{T}\right)\,\sigma_{ij}$$

$$E\left(\frac{T}{T-K}\,s_{ij}\right) = \sigma_{ij}$$

Therefore, unbiased estimator σ_{ij} is $\frac{T}{T-K}\,s_{ij}$

This estimator is unbiased in small samples assuming that the error terms ε_{ir} have symmetric distribution; in large samples it is consistent and asymptotically normal with limiting distribution: $\sqrt{R}(\hat{\beta} - \beta) \xrightarrow{d} N\left(0, \left(\frac{1}{R}X^T(\Sigma^{-1} \times I_R)X\right)^{-1}\right)$

Assumptions of explanatory variable are as follows:

Rank of $Xi = k_i < T$.

X_i is of full column rank. X_s are fixed, non-stochastic and without any measurement error.

$r\ (X_i'X_i) = k_i$. $X_i'X_i$ has full rank k_i and is invertible.

$X'X$ has full rank K and hence is also invertible.

Assumptions of the residual term

(i) Within Individuals

- $E(\varepsilon_{it}) \quad = 0\ for\ all\ i, t.$
- $E(\varepsilon_{it}\varepsilon_{is}) = \sigma_{ii}\ if\ t = s$ (contemporaneous correlation)

  $= 0\ if\ t \neq s$
- There is homoscedasticity within individuals (σ not indexed by *t*) but heteroscedasticity across individuals (σ indexed by (*i*).
- No direct autocorrelation.

(ii) Across Individuals

- E ($\varepsilon_{it}\ \varepsilon_{is}$) = σ_{ij} if $t = s, i \neq j$

  = 0 if $t \neq s, i \neq j$
- There exists contemporaneous correlation, however, there is no cross autocorrelation.

The SUR model was hence used to capture the dynamic effects of the response variables and their respective exposure variables on the relationships on the drivers of agricultural growth in Kerala. To perform this, a system of equations was formed with four response variables and in which the other three response variables were also exposure variables in the first main equation. In doing so, the model was used to find out the factors that affect the main variable however, through the other exposure variables. The following system of equations was formed for the model to find out the determinants of agriculture.

$y_1 = X_1\beta_1 + X_2\beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \varepsilon_1$ …….. (i)

$y_2 = X_8\beta_8 + X_9\beta_9 + \varepsilon_2$……………………………………………………(ii)

$y_3 = X_{10}\beta_{10} + X_{11}\beta_{11} + X_{12}\beta_{12} + X_{13}\beta_{13} + \varepsilon_3$………………………… (iii)

$y_4 = X_{14}\beta_{14} + X_{15}\beta_{15} + \varepsilon_4$……………………………………………. (iv)

Where:

Y_1= per capita agriculture GSVA in Kerala at constant prices (₹)

X_1 = gross fixed capital formation per gross cropped area in Kerala (₹/ha)
X_2 = fertiliser consumption per gross cropped area in Kerala (Kg/ha)
X_3 = long-term average of actual rainfall in Kerala (mm)
X_4 = Terms of trade = agriculture GSVA deflator against the non-agriculture GSVA deflator
X_5 = Gross area irrigated per gross cropped area (%)
X_6 = area under high value crops. Summation of area under fruits (inclusive of banana and other plantains, mango, jack and other fruits), area under vegetables, area under rubber, area under spices and condiments (black pepper, ginger, arecanut and small cardamom) (ha)
X_7 = dummy variables less one to represent the growth periods

Y_2 = Gross area irrigated per gross cropped area (%)

X_8 = development expenditure by Kerala Government on agricultural sector (₹)

X_9 = percentage ratio of gross cropped area to net sown area (%)

Y_2 = fertiliser consumption per gross cropped area (kg per hectare)

X_{10} = real price of fertiliser = weighted price of fertiliser nutrients (NPK) (₹)

X_{11} = development expenditure by Kerala Government on agricultural sector (₹)

X_{12} = institutional credit flow to the agricultural sector (₹)

X_{13}= average field wage rates of men and women (₹)

Y_4 = gross fixed capital formation per gross cropped area (₹/ha)

X_{14} = Terms of trade = agriculture GSVA deflator against the non-agriculture GSVA deflator

X_{15} = development expenditure by Kerala Government on agricultural sector (₹)

β_i = estimator of for X_i, $X_i = 1 \ldots 15$

ε_i = disturbance term i=1,2,3,4

Note that response variables for the equation (ii), (iii) and (iv) are also predictor variables for the first main equation, equation (i). By doing so, the determinants of GSDP agriculture that do not affect it directly but through the other response variables could be found.

The basic assumptions of SUR model are homoscedasticity and serial independence (Correlation of errors between time points (autocorrelated)). Thus, computation of the estimators will be laden if the same equation is named more than once or the covariance matrix of the residuals is singular. Natural logarithms of the variables were computed and imported into Stata for further analysis. *Sureg* package in Stata was used to compute the SUR model. The partial elasticities obtained from the model that were used to explain the determinants of agriculture in Kerala are given under section *4.1.2*.

3.5.2 Inter-district disparities in Kerala

3.5.2.1. Compound annual growth rates

The compound annual growth rates (CAGRs) were computed to understand the historical trend and performance of area, production and productivity of crops among the districts. These were estimated by using the exponential growth function of the form:

$Y_t = ab^t e^u$

Where,

Y_t= dependent variable for which growth rate was estimated

a = intercept term

b = Regression coefficient=(*1+r*) and r is the compound growth rate

t = time trend (Years which take values *1, 2, …, n*)

u = Disturbance term for the year '*t*'

The significance of *b* was tested using students t-test

The LOGEST function in MS Excel was used to estimate the CAGR values.

3.5.2.2 Cuddy-Della Valle Instability index

The Cuddy-Della Valle Instability (CDVI) index was used to find out the fluctuation or instability in area, production and productivity of crops among the districts. As the first step the parameter of a log-linear trend line for the variable (Y_t) for which instability is to be calculated is estimated. If the estimated parameter is statistically significant, then the instability index (*IIN*) is defined as:

$$\text{Instability index}, IIN = \left(\frac{\delta}{\mu} \times 100\right) \times (1 - \bar{R}^2)^{0.5}$$

Where,

$\bar{R}^2$ = Adjusted coefficient of determination

μ= Mean

σ= Standard deviation

If the estimated parameter in the regression equation in not significant, then the CV itself is the instability index. An instability index value from zero to 15 per cent denotes low instability, while a value ranging from 15 to 30 per cent indicates medium instability and any index value greater than 30 per cent is considered as high instability.

3.5.2.3 Herfindahl index (HI)

The Herfindahl index was used to study the differences in crop diversification in the districts of Kerala state. The Herfindahl index decreases when there is increase in diversification. At complete specialisation in cropping, the index value is equal to one. It approaches zero as N becomes large, that is, if diversification is perfect

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

Where:

N = total number of crops

i = number of crops ($i = 1, 2, \ldots, N$)

P_i= the proportion of the i^{th}crop in the gross cropped area

Cropping pattern is considered highly diversified when the HI is less than 0.15, moderately diversified if the index is between 0.15 and 0.3, less diversified if the index is above 0.3 and below 0.45. The situation of specialisation is attained when the index is more than 0.45. The results of the HI are discussed under section 4.2.2.

3.5.2.4 Entropy index (EI)

The Entropy index (EI) was used in conjunction with the Herfindahl index to understand the level of crop diversification among the districts. The EI is the weighted sum of shares [Weights being log (P_i)] of the various crops in the gross cropped area. It attains zero with complete specialization and log (*N*) with perfect diversification. It is good for capturing concentration of crop aspect as *N* varies. The value of EI varies from zero (perfect concentration) to Log N (perfect diversification). The upper value of EI can exceed one or be less than one, when *N* is greater or less than the base of logarithm. Thus, it does not correspond to any standard scale of measuring degree of diversification. The results of the index are presented under section 4.2.2.

$$\text{EI} = \sum_{i=1}^{N} P_i \times \log\left(\frac{1}{p_i}\right)$$

Where:

N = total number of crops

i = number of crops ($i = 1, 2, \dots, N$)

P_i= the proportion of the i^{th} crop in the gross cropped area

3.5.2.4 Panel data regression models

Panel data is obtained when the same samples of a cross sectional unit are observed over time. Therefore, just as pooled data, panel data which is also known as longitudinal data, have the cross-sectional component and the time series component. Therefore, time series data would allow a researcher to study cross section effects, that is along *N* (for example, variation across districts) and time series effects, that is along *T*.

Cross section

Time series
$$\begin{bmatrix} y_{11} & y_{21} & \cdots & y_{11} & \cdots & y_{N1} \\ y_{12} & y_{22} & \cdots & y_{i2} & \cdots & y_{N2} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ y_{1t} & y_{2t} & \cdots & y_{It} & \cdots & y_{Nt} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ y_{1T} & y_{2T} & \cdots & y_{iT} & \cdots & y_{NT} \end{bmatrix}$$

Panel data sets notation

$$y_1 = \begin{bmatrix} y_{11} \\ y_{12} \\ \vdots \\ y_{1t} \\ \vdots \\ y_{1T} \end{bmatrix}; \ldots; y_i = \begin{bmatrix} y_{i1} \\ y_{i2} \\ \vdots \\ y_{it} \\ \vdots \\ y_{iT} \end{bmatrix} \quad X_i = \begin{bmatrix} x_{11} & x_{21} & \cdots & x_{k1} \\ x_{12} & x_{22} & \cdots & x_{k2} \\ \vdots & \vdots & \ddots & \vdots \\ x_{1t} & x_{2t} & \ldots & x_{kt} \\ \vdots & \vdots & \ddots & \vdots \\ x_{1T_i} & x_{2T_i} & \cdots & x_{kT_i} \end{bmatrix}; \ldots; X_j = \begin{bmatrix} w_{11} & w_{21} & \cdots & w_{k1} \\ w_{12} & w_{22} & \cdots & w_{k2} \\ \vdots & \vdots & \ddots & \vdots \\ w_{1t} & w_{2t} & \ldots & w_{kt} \\ \vdots & \vdots & \ddots & \vdots \\ w_{1T_j} & w_{1T_j} & \cdots & w_{1T_j} \end{bmatrix}$$

A standard panel data set model stacks the $y_i's$ and the $x_i's$ as:

X is $a \sum_i T_i \times k$ matrix

β is $k \times 1$ matrix

c is $\sum_i T_i \times 1$ matrix associated with unobservable variables

y and ε are $\sum_i T_i \times 1$ matrices

Data on districts of Kerala, say, area under paddy for several years will have the cross-sectional component being the 14 districts and the time series components being the respective number of years. To effect regression on this type of data, specific models that can be able to track the behaviours of individual districts in the cross-sections and through time will be necessary. Since this is panel data, panel data models can be employed to study it. Thus, panel data models were used to study the various determinants of income variability among the districts. The panel data models allow control over variables that change over time but not across groups while accounting for individual heterogeneity. With panel data, it is possible to study cross-sectional variation (unobservable in time series data), time series variation (unobservable in cross-sectional data), heterogeneity (observable and unobservable individual heterogeneity), hierarchical structures (for example, district effects in this case), dynamics in economic behaviour and individual/group effects and time effects.

A simple panel data repression model takes the form as:

$y_{it} = \alpha + \beta x_{it} + \varepsilon_{it}$…………………………………….. (i)

Where:

y= response variable

x= predictor variable

α and β= parameters

i= individual indices (cross section identifier)

t= period (time identifier)

Note that, for each of the subsequent equations, the residual term can be denoted by different symbols, i.e. u, e, ε etc to show that, for each model, the residual term is independent of the residual term in the other model(s) in the computation of the panel data models. However, in this document, ε will be used throughout to denote the disturbance term for all the independent panel data models.

Suppose there is a causal relationship between a dependent random variable and a vector of observable random variables, in a cross-sectional setting, it is assumed that there is no correlation between the error term and the regressors. When the unobserved random variable is correlated with the regressors, it will violate the process of estimating the vector of parameters by using the Ordinary Least Square (OLS) method. However, in a panel data model like the one used in this study; several models can be used for this estimation. These models are fixed effect model, random effect model and panel ordinary least squares (OLS) model. Panel data analysis has several independent approaches that are discussed below.

3.5.2.4.1 Fixed effects model/within estimation (FEM)

This is feasible generalised least squares technique which is asymptotically more efficient than Pooled OLS when time constant attributes are present. Random effects adjust for the serial correlation which is induced by unobserved time constant attributes.

The key assumption under fixed effects model is that there are unique attributes of individuals that do not vary across time. These attributes may or may not be correlated with the individual dependent variables.

The FEM can be computed using two ways, one, least-squares with unit dummy variables and two, with de-meaned data.

3.5.2.4.1.1 Least-squares with unit dummy variables (LSDV)

Introduce dummy variable for each unit (individual) in sample:

$y_{it} = \sum_{j=1}^{N} \beta_{1j} D_{ji} + \beta_{2i} x_{2it} + \beta_{3i} x_{3it} + \varepsilon_{it}$ (expanded equation (i))

We now have $N + K - 1$ regressors with *NT* observations. If *T* is moderately large *(> 2 or 3)*, then we can get reliable estimates, but note computational difficulty: moment matrix is $N + K - 1 \times N + K - 1$, which with *N > 100* is probably computationally difficult. The LSDV can test the block of unit dummies to see if individual fixed effect is statistically significant.

3.5.2.4.1.1 Fixed effects estimator using de-meaned data

$$y_{it} = \beta_{1i} + \beta_{2i} x_{2it} + \beta_{3i} x_{3it} + \varepsilon_{it}$$

Averaging across *T* time periods for each unit *i*:

$$\frac{1}{T}\sum_{T=1}^{T} Y_{it} = \beta_{1i} + \beta_2 \frac{1}{T}\sum_{T=1}^{T} x_{2it} + \beta_3 \frac{1}{T}\sum_{T=1}^{T} x_{3it} + \sum_{T=1}^{T} \varepsilon_{it}$$

$$\bar{y}_i = \beta_{1i} + \beta_{2i}\bar{x}_{2i} + \beta_{3i}\bar{x}_{3i} + \bar{\varepsilon}_i$$

Subtracting the means from the original equation yields

$$y_{it} - \bar{y}_i = \beta_2(x_{2it} - \bar{x}_{2i}) + \beta_3(x_{3it} - \bar{x}_{3i}) + (\varepsilon_{it} - \bar{\varepsilon}_i)$$ or

$$\tilde{y}_{it} = \beta_{1it} + \beta_{2i}\tilde{x}_{2it} + \beta_{3i}\tilde{x}_{3it} + \tilde{\varepsilon}_{it}$$

Where ~ indicates deviation from the unit mean

This is the "within-unit estimator"

- It uses only variation over time within each unit to identify the coefficients
- If one *x* varies mostly across units rather than over time, there is not going to be much information in the sample to allow it to be identified by fixed-effects estimation.
- If a variable varies only across units (e.g., districts, ethnicity etc), then its effects cannot be identified at all in a fixed-effects model
    - All ~ values will be zero because each observation equals the unit mean.

- This also happens in LSDV because the *x* in question will be perfectly collinear with the unit dummies.

The constant term is gone because both it ($\tilde{y}_{it}$ and $\tilde{x}_{kit}$), have zero means.

- We can estimate the mean of the individual unit constant terms from "between unit estimator" $\bar{y}_i = \bar{\beta}_1 + \beta_2\bar{x}_{2i} + \beta_{3i}\bar{x}_{3i} + \left(\bar{\varepsilon}_i + \beta_{1i} - \bar{\beta}_1\right)$
- We can calculate the estimated intercept for any individual unit $\hat{\beta}_{1i} = \bar{y}_i + \hat{\beta}_2\bar{x}_{2i} + \hat{\beta}_3\bar{x}_{3i}$ under the assumption that $\bar{\varepsilon}_i = 0$

Degrees of freedom:

- Although there are NT observations on the ~ variables, only $N(T - 1)$ of them are independent.
- Should use $\hat{\sigma}^2 = \frac{SSE}{(NT - N - K + 1)}$ to reflect this: An FE estimator will correct this but if you de-mean yourself and use OLS it will not.
- Note that using LSDV will do this automatically because there will be $N - 1$ additional coefficients being estimated.

3.5.2.4.2 Random effects models

It is also called Error-Components/Random-Intercepts model. The key assumption in the random effects model is that there are unique, time constant attributes of individuals that are not correlated with the individual regressors.

The fixed-effects model thinks of β_{1i} as a fixed set of constants that differ across i. The random-effects model thinks of β_{1i} as a random variable (with mean $\bar{\beta}_1$) that has one value for each i drawn from a given probability distribution.

$$\beta_{1i} = \bar{\beta}_1 + \varepsilon_i$$

$$E\ (\varepsilon_i) = 0$$

$$\text{Cov}\ \left(\varepsilon_i, \varepsilon_j\right) = 0, i = 1$$

$$\text{var}\ (\varepsilon_i) = \sigma_\varepsilon^2$$

$$y_{it} = \left(\bar{\beta}_1 + \varepsilon_i\right) + \beta_2 x_{2it} + \beta_3 x_{3it} + \varepsilon_{it}$$

$$= \bar{\beta}_1 + \beta_2 x_{2it} + \beta_3 x_{3it} + (\varepsilon_i + \varepsilon_{it})$$

$$= \bar{\beta}_1 + \beta_2 x_{2it} + \beta_3 x_{3it} + v_{it}$$

This leads to a particular pattern of correlation among the error terms v_{it}

- Error terms of observations corresponding to the same i will be correlated because they have ε_i in common
  - $corr\ (v_{it} v_{is}) = \frac{cov\ (v_{it} v_{is})}{\sqrt{var\ (v_{it}\ ) var(v_{is})}} = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \sigma_e^2} = \rho$
- Error terms of observations with different i will be uncorrelated (by assumption)

We can estimate ρ by looking at the correlation of error terms within units and use the estimated $\hat{\rho}$ to do feasible GLS: this is the random-effects estimator.

Assumptions of the random-effects estimator

$$E\ (v_{it}) = 0$$

$$var\ (v_{it}) = \sigma_\varepsilon^2 + \sigma_e^2$$

$$cov\ (v_{it} v_{is}) = \sigma_\varepsilon^2, t \neq s$$

$$cov\ (v_{it} v_{is}) = 0, i \neq j$$

$$cov\ \left(e_{ij} v_{kij}\right) = 0, k = 2,3, \dots, K$$

$$cov\ (\varepsilon_i \varepsilon_{kit}) = 0, k = 2,3, \dots, K$$

Testing for presence of random effects vs. OLS assumption of independent errors:

- Is $\sigma_\varepsilon^2 = 0$?
  - If so, then there are no correlations because the ε error term is degenerate
- One tailed LM test for H_o: $\sigma_\varepsilon^2 = 0$ against H_1: $\sigma_\varepsilon^2 > 0$ in large samples is

$$LM = \sqrt{\frac{NT}{2(T-1)}} \left[\frac{\sum_{I=1}^{N} (\sum_{t=1}^{T} \hat{\varepsilon}_{it})^2}{\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\varepsilon}_{it}{}^2} \right] \sim N(0,1)$$

If we reject $\sigma_\varepsilon^2 = 0$, then OLS is inefficient and we should use random effects (if assumptions are satisfied).

3.5.2.4.3 The pooled OLS model

The pooled ordinary least square (OLS) can be used to derive unbiased and consistent estimates of parameters even when time constant attributes are present, but random effects will be more efficient. It assumes that the individual specific effects are effects that are independent of the regressors. The individual specific effect is included as the residual.

The panel OLS will be estimated with a sample of NT observations, without recognising panel structure of data. Standard OLS would assume homoskedasticity and no correlation between unit’s observations in different periods (or between different units in the same period).

3.5.2.4.4 Hausman test

To test whether fixed effects rather than random effects, is appropriate, the (Durbin-Wu-) Hausman test can be used. Then the Wu–Hausman statistic is:

$$H = (b_1 - b_0)'\left(Var\ (b_0) - Var(b_1)\right)^{\dagger}$$

where † denotes the Moore–Penrose pseudoinverse. Under the null hypothesis, this statistic has asymptotically the chi-squared distribution with the number of degrees of freedom equal to the rank of matrix Var(b0) − Var(b1).

If we reject the null hypothesis, it means that b_1 is inconsistent. This test can be used to check for the endogeneity of a variable (by comparing instrumental variable estimates to ordinary least squares (OLS) estimates). It can also be used to check the validity of extra instruments by comparing the estimates using a full set of instruments that use a proper subset of Z. For the test to work in the latter case, the validity of the subset of Z must be certain and the subset must have enough instruments to identify the parameters of the equation. Hausman also showed that the covariance between an efficient estimator and the difference of an efficient and inefficient estimator is zero. The Hausman test can also be used to differentiate between fixed effects model and random effects model in panel data.

Table 3.3: Hausman Test

	H_0 *True*	H_1 *True*
b_1 *(RE estimator)*	Consistent Efficient	Inconsistent
b_0 *(FE estimator)*	Consistent Inefficient	Consistent

3.5.2.4.5 Lagrange multiplier (LM) test

The Lagrange Multiplier (LM) test is used to check whether random effects model or the OLS is the best for the given specification. The LM test tests the null hypothesis that there is no significant difference across the cross-sectional units, that is, there is no panel effect. This implies that the RE model is inappropriate.

To employ the panel data analysis, the following equation was formed to represent the panel data model for the study of determinants in the districts.

$$y_t = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + \beta_6 X_{6it} + \beta_7 X_{7it} + \beta_8 X_{8it} + \beta_9 X_{9it} + \beta_{10} X_{10it} + \varepsilon_{it}$$

Where:

y= response variable

x= predictor variable

α and β = parameters

i= cross-sectional identifier

t= period

y = net district domestic product of various districts (₹)

X_1= gross irrigated area per gross cropped area in each district (ha)

X_2 = average annual rainfall received in each district (mm)

X_3= fertiliser consumption per gross cropped area per district (kg/ha)

X_4 = production of paddy in each district (tonnes)

X_5 = production of rubber in each district (tonnes)

X_6 = production of coconut in each district (million nuts)

X_7= production of banana and other plantain in each district (tonnes)

X_8 = production of cashew in each district (tonnes)

X_9 = production of tapioca in each district (tonnes)

X_{10} = production of black pepper in each district (tonnes)

t = 1985-86 to 2017-18

The values were subjected to log transformation and loaded onto Stata for further analysis. Since the cross-sectional identifier (variable name: districts) was in string form, it was encoded to enable the computation of the models. The results of the models are explained in section 4.2.3 with additional models given in the appendix section.

3.5.3 Dynamics in land use and cropping pattern changes

3.5.3.1 Tabular Presentation of Proportions

The tabular presentation method was used to study the proportion of various crops in the gross cropped area over the years. The percentages were worked out to for the presentation of the data in tables. Where *n* is the area under a particular crop and *N* the GCA, the per cent share was worked out as

$$\frac{n}{N} \times 100$$

3.5.3.2 Compound annual growth rates

The compound annual growth rates (CAGRs) were computed to understand the growth in various land use classes in Kerala. These were estimated by using the exponential growth function of the form:

$$Y_t = ab^t e^u$$

Where,

Y_t= dependent variable for which growth rate was estimated

a = intercept term

b = Regression coefficient=($1+r$) and r is the compound growth rate

t = time trend (Years which take values *1, 2, …, n*)

u = Disturbance term for the year ‘t’

The significance of b was tested using students t-test

The LOGEST function in MS Excel was used to estimate the CAGR values. The results are presented under section 4.3.1.

3.5.3.3 Cuddy-Della Valle Instability index

The Cuddy-Della Valle Instability (CDVI) index was used to find out the fluctuation or instability in various land use classes. As the first step the parameter of a log-linear trend line for the variable (Y_t) for which instability is to be calculated is estimated. If the estimated parameter is statistically significant, then the instability index (*IIN*) is defined as:

$$\text{Instability index}, IIN = \left(\frac{\delta}{\mu} \times 100\right) \times (1 - \bar{R}^2)^{0.5}$$

Where,

$\bar{R}^2$ = Adjusted coefficient of determination

μ= Mean

σ= Standard deviation

If the estimated parameter in the regression equation in not significant, then the CV itself is the instability index. An instability index value from zero to 15 per cent denotes low instability, while a value ranging from 15 to 30 per cent indicates medium instability and any index value greater than 30 per cent is considered as high instability.

3.5.3.4 Markov chain analysis

The Markov chain analysis is an application of dynamic programming to the solution of a stochastic decision process that can be described by a finite number of conditions. The Markov process was used to study the shifts in the shares of land use categories and crops thereby to understand the dynamics in the land use categories and cropping pattern.

Markov probability model

Any sequence of trials (experiments) that can be subjected to probabilistic analysis is called a stochastic process. For a stochastic process, it is assumed that the movements (transitions) of objects from one state (possible outcome) to another are governed by a probabilistic mechanism or system. A finite Markov process is a stochastic process whereby the outcome of a given trial t $(t = 1, 2, \dots, T)$ depends only on the outcome of the preceding trial (t_{-1}) and this dependence is the same at all stage in the sequence of trials. Consistent with this definition, Let,

S_i $be\ the\ i^{th}\ state\ of\ r\ possible\ outcomes;\ i = 1, 2, \dots, r$

W_{it} be the probability that state S_i occurs on trial *t* or the proportion observed in trial *t* in multinomial population based on a sample of size *n*, *i.e.* $P_r(S_i)$.

P_{ij} represents the transitional probability which denotes the probability that if for any time *t* the process is in state S_i, it moves onto next trial to state S_j, *i.e.*, $P_r\left(\frac{S_{j.t+1}}{S_{jt}}\right) = P_{ij}$

$P = P_{ij}$ represents the transitional probability matrix which denotes the transitional probability for every pair of states $(i, j = 1,2, \dots, r)$, and has the following properties.

$0 < P_{ij} < 1$ …………………………………………… (i)

and

$SP_{ij} = 1$ for $\mathrm{i} = 1, 2, \dots, \mathrm{r}$ ……………………………….. (ii)

Given this set of notations and definitions for a first-order Markov chain, the probability of a particular sequence S_i on trial *t* and S_j on trial t_{+1} may be represented by

$P_r(S_{it}, S_{jt} + 1) = P_r(S_{it})P_r\left(\frac{S_{j.t+1}}{S_{it}}\right) = W_{it}P_{ij}$…..………. (iii)

and the probability of being in state j at trial t+1 may be represented by,

$P_r(S_{j.t+1}) = SW_{it}P_j\ or\ W_{j.t+1} = SW_{it}P_{ij}$ …..…...…..… (iv)

Data on the share of the geographical area of the state under different land use classes and the share of area under different crops in the gross cropped area was used for the study. It was reasonable to assume that the combined influence of these individually-systematic forces approximates a stochastic process and the tendency of farmers to move from one land use class or crop to another differs according to the land use class or crop involved. If these assumptions were acceptable, then the process of dynamics in land-use and cropping pattern may be described in the form of a matrix *P* of first-order transition probabilities. The element P_{ij} of the matrix indicates the probability that a land use class or crop i in one period/ phase will move to land use class/ crop *j* during the successive period. The diagonal element P_{ij} measures the retention probability or the probability that the share of i^{th} class of land use or crop (whichever is applicable) will be retained.

The transition probability matrix was estimated using the minimum absolute deviation (MAD) estimator. The elements P_{ij} of the matrix are the conditional probabilities of the area under a specific land use class or crop (whichever is applicable) in time *t* given its share in time t_{-1}. The diagonal elements P_{ij}, (i = j) indicate the extent of stability of land use classes or crops. Hence, as the diagonal elements approach zero, area under a specific land use class or crop becomes less and less stable, and as they approach one, the land use class or crop tend to exhibit increased stability over time. The off-diagonal elements P_{ij}, (i = j) are the probabilities of switching over between different land use classes or crops. If P_{ij} is the diagonal element corresponding to the i^{th} land use class or crop, the other elements in the i^{th} row give the proportions of previous period's area of i^{th} land use class or crop it is likely to lose to in the current period. The elements of the i^{th} column give the proportions of areas of other land use classes and crops in the previous period, the i^{th} land use class or crop is likely to gain in the current period. Thus, the off-diagonal element P_{ij}, (i ≠ j), indicates the probability of the i^{th} state moving to the j^{th} state, while, the diagonal element P_{ij}, (i = j), indicates the probability of retaining in the current state of land use class or area under a particular crop, whichever applies.

The Estimation of the transition probability matrix is as follows:

Equation *(iv)* can be used as a base for specifying the statistical model for estimating the transition probabilities. If errors are incorporated in equation *(iv)* to account for the difference between the actual and estimated occurrence of $W_{j(t_{-1})}$, the sample observations may be assumed to be generated by the following linear statistical model

$W_{jt} = SW_{it-1}P_{ij} + U_{jt}$ …………………………………………..... (v)

or in matrix form, it can be written as

$Y_j = X_jP_j + U_j$……………………...…………………………...… (vi)

Where,

Y_j $is\ a$ $(T \times 1)$ vector of observations reflecting the proportion of land use pattern in time *t*

X_j is a $(T \times r)$ matrix of realized values of the proportion in land use class or crop *i* in time t_{-1}.

P_j is a $(r \times 1)$ vector of unknown transition parameters to be estimated.

U_j is a vector of random disturbances.

3.5.4 Economics, efficiency and profitability of major crops

3.5.4.1 Tabular presentation of proportions

The tabular presentation method was followed to study the proportional contribution of various cost components in the total cost. The percentages were worked out for the presentation of the data in the tables. When *n* is the cost component and *N* the total cost, the per cent share of cost components in the total cost was worked out as

$$\frac{n}{N} \times 100.$$

3.5.4.2 Returns and profitability

It was imperative to compute the returns and profitability of the principal crops over the years to understand the trends and possibly elucidate on the contributing factors. The net returns were computed by getting the difference of value of output and total cost of cultivation in value terms. This result could not infer any meaningful information since the prices were current. To make the result convey more information, a ratio of the output to input in value terms was worked out. This gives an index with no unit and can be compared across periods without worry of rebasing. Thus, profitability which is the excess of returns on value of input, was concluded from the output-input ratio.

3.5.5 Total factor productivity

Total factor productivity is the increase in output that cannot be explained by the related input use. Thus, it is the excess output of the input used. For example, total factor productivity can be identified where a farmer changes from local seeds to high yielding variety seeds. Production is expected to increase due to improvement in productivity. The increase in output in this case would not be attributed to increase in input use (since the firm did not increase the level of input) but to technology that is innate to the input used. Several models can be used to compute total factor productivity: frontier and non-frontier models. Under each, there are parametric and non-parametric ones. For this study, non-parametric frontier model using Malmquist Indices was used. The section below gives more details on Malmquist Indices.

3.5.5.1 Estimation of Malmquist indices by Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) is a mathematical technique, based on linear programming (LP), which is used to measure the relative efficiency of decision-making units (DMUs) with multiple inputs and multiple outputs. This analysis is based on data envelopment analysis program (DEAP) Version 2.1 by Prof. Timothy Coelli, Department of Economics, University of Queensland and explained in Coelli *et al* (2005). Coelli (1995) indicated that the DEA approach has two main advantages in estimating efficiency scores. First, it does not require the assumption of a functional form to specify the relationship between inputs and outputs and secondly, it does not require the distributional assumption of the inefficiency term.

DEAP decomposes productivity into five components which are the Malmquist Indices:

(i) technical efficiency change (effch)

(ii) technological change (tech)

(iii) pure technical efficiency change (pech)

(iv) scale efficiency change (sech) and

(v) total factor productivity change (tfpch).

The scale efficiency is defined as the level of average productivity a firm can attain on operating at optimum scale size. This is the point of time when the average productivity will be at its maximum level. Technical efficiency is the skill and capability to use a minimal amount of input to make a given level of output. Pure Technical Efficiency is the capacity of the management to save the input for producing a certain amount of output or to produce more output with a given level of input (Coelli, *et al* 2005). According to Coelli, *et al* (2005), Scale efficiency is the parameter that which level of average productivity a firm can achieve on operating at optimum scale size. This is where the average productivity will be at its maximum level. To the degree a firm falls short of attaining an output combination on its production possibility frontier (PPF), and falls below this frontier, it can be concluded, the firm is technically inefficient. Over time, nevertheless, the level of output a firm could yield will increase due to technological changes that impact the skill to optimally combine inputs and outputs. These technological changes cause the PPF to shift upward, as more outputs can be obtained from the same level of inputs. Therefore, for any firm in an industry, productivity improvements over time (more outputs while keeping inputs constant or lower) may be either technical efficiency progresses (catching up with their own PPF) or technological improvements (because the PPF is shifting up over time) or both.

To compute the total factor productivity changes, a total of six inputs were used and one output. These were human labour, machine labour and interest on working capital (used as a dummy for capital). Intermediate inputs were seeds, fertilisers (and farmyard manures) and plant protection. Since these were changes from the preceding years, results for a particular year are changes from its preceding year. It then followed that the results were shown from 2001-02. To compute the TFP using DEAP, one of the important syntaxes is to decide whether the model being estimated is input-oriented or output-oriented and whether it is on assumption of constant returns to scale (CRS) or variable returns to scale (VRS). CRS assumes overall technical efficiency which measures inefficiencies due to the input/output configuration as well as the size of operations while VRS assumes pure technical efficiency which measures inefficiencies due to only managerial underperformance.

The input-oriented measure of technical efficiency which was introduced by Farrell (1957) explains by how much inputs could be reduced while maintaining the existing level of output while output-oriented measure explains by how much could output can be increased while using the given level of inputs. From the definition, in agricultural firms, the assumption is to maximise output from scarce resources. Thus, the input-oriented case is seeking the maximum possible proportional reduction in input usage with output level held constant, for each crop while in the output-oriented case explains the maximum proportional increase in output with input levels held constant. The two measures provide the same technical efficiency values when a constant CRS applies but unequal values when VRS is assumed. Thus, in this case, output-oriented CRS was chosen.

If one has data for *N* crops in a particular time period, the LP problem that is solved for the i^{th} crop in an output-orientated DEA model is as follows:

$max\ \varphi, \lambda\ \varphi,$

Subject to $-\varphi y_1 + y\lambda \geq 0,$

$x_1 - X\lambda \geq 0,$

$\lambda \geq 0,$ ………………………. (i)

Where,

y_i is a $M \times 1$ is vector of output quantities for the i^{th} crop;

x_i is a $K \times 1$ vector of input quantities for the i^{th} crop;

Y is a $N \times M$ matrix of output quantities for all N countries;

X is a $N \times K$ matrix of input quantities for all N countries;

λ is a $N \times 1$ vector of weights; and

φ is a scalar.

Observe that φ will take a value greater than or equal to one, and that φ-1 is the proportional increase in outputs that could be achieved by the i^{th} crop, with input quantities held constant. Note also that 1/φ defines a technical efficiency (TE) score which varies between zero and one (and that this is the output-orientated TE score reported in the results). The above LP is solved N times – once for each crop in the sample. Each LP produces a φ and a λ vector. The φ-parameter provides information on the technical efficiency score for the i^{th}crop and the λ-vector provides information on the peers of the (inefficient) i^{th}crop. The peers of the i^{th} crop are those efficient crops that define the facet of the frontier against which the (inefficient) i^{th}crop is projected.

The Malmquist index is defined using distance functions. Distance functions allow for the ability to describe a multi-input, multi-output production technology without the need to specify a behavioural objective (such as cost minimisation or profit maximisation). One may define input distance functions and output distance functions. An input distance function characterises the production technology by looking at a minimal proportional contraction of the input vector, given an output vector. An output distance function considers a maximal proportional expansion of the output vector, given an input vector. For this study, only output vector is considered in detail. However, input distance functions can be defined and used in a similar manner. A production technology may be defined using the output set, P(x), which represents the set of all output vectors, y, which can be produced using the input vector, x. That is,

$$P(x) = \{y : x \text{ can produce } y\}. \dots\dots\dots\dots\dots\dots\dots\dots \text{(ii)}$$

It can be assumed that the technology satisfies the axioms listed in Coelli *et al* (2005). The output distance function is defined on the output set, P(x), as:

$$d_o(x, y) = \min\{\delta : (y/\delta) \in P(x)\}. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

The distance function, $d_o(x, y)$, will take a value which is less than or equal to one if the output vector, y, is an element of the feasible production set, P(x). Furthermore, the distance function will take a value of unity if y is located on the outer boundary of the feasible production set, and will take a value greater than one if y is located outside the feasible production set. The Malmquist TFP index measures the TFP change between two data points (e.g., those of a particular crop in two adjacent time periods) by calculating the ratio of the distances of each data point relative to a common technology. The Malmquist(output-orientated) TFP change index between period *s* (the base period) and period *t* is given by

$$m_o(y_s, x_s, y_t, x_t) = \left[\frac{d_o^s(y_t, x_t)}{d_o^s(y_s, x_s)} \times \frac{d_o^t(y_t, x_t)}{d_o^t(y_s, x_s)}\right]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

where the notation $d_o^s(x_{t,} y_t)$ represents the distance from the period *t* observation to the period *s* technology. A value of m_o greater than one will indicate positive TFP growth from period *s* to period *t* while a value less than one indicates a TFP decline. Note that the above equation, is in fact, the geometric mean of two TFP indices. The first is evaluated with respect to period *s* technology and the second with respect to period *t* technology.

An equivalent way of writing this productivity index is:

$$m_o(y_s, x_s, y_t, x_t) = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)} \left[\frac{d_o^s(y_t, x_t)}{d_o^t(y_t, x_t)} \times \frac{d_o^s(y_s, x_s)}{d_o^t(y_s, x_s)}\right]^{\frac{1}{2}} \ldots\ldots\ldots \text{(v)}$$

where the ratio outside the square brackets measures the change in the output-oriented measure of technical efficiency between periods *s* and *t*. That is, the efficiency change is equivalent to the ratio of the technical efficiency in period *t* to the technical efficiency in period *s*. The required distance measures for the Malmquist TFP index can be calculated using DEA-like linear programs. For the i^{th} crop, four distance functions must be calculated to measure the TFP change between two periods, *s* and *t*. This requires the solving of four LP problems. In this study, constant returns to scale (CRS) technology is assumed as explained before. The required LPs are:

$$[d_o^t(y_t, x_t)]^{-1} = max\ \varphi, \lambda\ \varphi, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(vi)}$$

Subject to $-\varphi y_{it} + y_t \lambda \geq 0,$

$$x_{it} - X_t \lambda \geq 0,$$

$$\lambda \geq 0,$$

$$[d_o^s(y_s, x_s)]^{-1} = max\ \varphi, \lambda\ \varphi, \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(vii)}$$

Subject to $-\varphi y_{is} + y_s\lambda \geq 0,$

$$x_{is} - X_s\lambda \geq 0,$$

$$\lambda \geq 0,$$

$$[d_o^t(y_s, x_s)]^{-1} = max\ \varphi, \lambda\ \varphi, \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(viii)}$$

Subject to $-\varphi y_{is} + y_t\lambda \geq 0,$

$$x_{is} - X_t\lambda \geq 0,$$

$$\lambda \geq 0,$$

$$[d_o^s(y_t, x_t)]^{-1} = max\ \varphi, \lambda\ \varphi, \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ix)}$$

Subject to $-\varphi y_{is} + y_t\lambda \geq 0,$

$$x_{it} - X_s\lambda \geq 0,$$

$$\lambda \geq 0,$$

Note that in LP's in (viii) and (ix), where production points are compared to technologies from different time periods, the φ parameter need not be greater than or equal to one, as it must be when calculating standard output-orientated technical efficiencies. The data point could lie above the production frontier. This will most likely occur in LP (ix) where a production point from period *t* is compared to technology in an earlier period, *s*. If technical progress has occurred, then a value of $\varphi<1$ is possible. Note that it could also possibly occur in LP (viii) if technical regress has occurred, but this is less likely.

The results of Malmquist Indices obtained from the output-oriented CRS DEA are given in section 4.5.2.

3.6. Concepts and terminologies definitions

3.6.1 Irrigated area

The irrigated area is cropped area supplied frequently with water. It is divided into two categories net irrigated area and gross irrigated area.

3.6.1.1 Net irrigated area: It is the area supplied with water by canals, tanks, wells, lift irrigation and other sources for a specific crop.

3.6.1.2 Net un-irrigated area: =NSA-Net irrigated area

3.6.1.3 Gross irrigated area: It is the total area under a specific crop, irrigated at any time in a year. It is counted as many times as the number of times the areas are cropped and irrigated in a year.

3.6.1.4 Gross un-irrigated area: It is the difference of gross irrigated area from the gross cropped area.

3.6.2 Land use related terminologies

3.6.2.1 Geographical area

This is the total physical territorial land coverage of the whole state.

3.6.2.2 Forest area

Is all land identified either as forest under any legal presentation, or managed as forest, whether state or privately owned, and whether it is wooded or preserved as future forestland.

3.6.2.3 Area under non-agricultural uses

This is all land occupied by any other land uses other than agriculture. This includes the area covered by transport infrastructure, buildings, water etc (GoK, 2018).

3.6.2.4 Barren and uncultivable land

This is land which need high amount of funds to be brought under cultivation. This includes all land covered by hills, degraded lands, mountains, deserts, etc. (GoK, 2018).

3.6.2.5 Permanent pasture and other grazing land

This includes all grazing land. Permanent pastures, temporary pasture lands and village communal grazing land is included under this category (GoK, 2018).

3.6.2.6 Land under miscellaneous tree crops

This includes all cultivable land which is not included in the Net Sown Area (NSA) but is put to some agricultural use like thatching grasses, bamboo bushes and other groves for fuel (GoK, 2018).

3.6.2.7 Cultivable waste land

This is land accessible for cultivation, whether used cultivation before or not, but not cultivated within the last five years or more in sequence including the present year for any reason (GoK, 2018).

3.6.2.8 Fallow lands other than current fallows

This is land which was under cultivation before but is currently temporarily not cultivated for a period exceeding one year and less than five years (GoK, 2018).

3.6.2.9 Current fallows

This is land that has been reserved fallow out of the NSA during the previous year is classified as current fallow for the reporting year (GoK, 2018).

3.6.2.10 Net area sown (NSA)

This is area cultivated during any part of the agricultural year. Area sown more than once in the reporting year is counted only once (GoK, 2018).

3.6.2.11 Area sown more than once

This represents the areas on which crops are cultivated more than once during the agricultural year. Area Sown more than once = GCA-NSA (GoK, 2018).

3.6.2.12 Gross cropped area (GCA)

This is the total area sown under food and non-food crops in a particular year. It is also called total cropped area or total area sown.

3.6.2.13 Arable land/agricultural land/total cultivable land

This consists of NSA, current fallows, fallow lands other than current fallows, culturable wasteland and land under miscellaneous tree crops.

3.6.2.14 Total un-cultivable area/land

Is the difference between total geographical area and arable land.

3.6.2.15 Cropping intensity

Is the cultivation of several crops in the same field during one agricultural year.

$$\text{Cropping intensity} = \frac{\text{GCA}}{\text{NSA}} \times 100$$

3.7. Limitations

The main concerns regarding data for Kerala State were:

3.7.1 Non-comparability of data due to changes in administrative boundaries

This problem comes from the fact that the number of districts in Kerala had increased from 10 districts in 1970 to 14 districts in 2020. Between January 1972 and May 1984, four more districts were formed by hiving off parts of 10 districts that were present during 1971. This means that before Idukki district was formed on 26th January 1972, the statistics pertaining to the district were previously being reported in the neighbouring districts to which it was hived. DES, GoK reported the statistics pertaining to the districts at the existing status. This is the same case with Wayanad district (formed on 1st November 1980), Pathanamthitta (formed on 1st November 1982) and Kasaragod (formed on 24th May 1984). Due to this, the data on districts had been collected from 1985-86. This was to ensure comparability and consistency in reported statistics for individual districts.

3.7.2 Problems with reported statistics on forest area in land-use classification

The geographical area relating to area under forests was surveyed and reported by DES, GoK. However, there had been criticism from previous studies based on satellite imagery which had shown a discrepancy between the reported area and actual area of forest land on the ground. About 19 per cent of the land reported under state forest land was found to have been converted to cropland (Kumar 2005). The changes had not been accounted for in the reported area under forest land which according to official DES, GoK estimates, had not changed for the last 45 years, that is, since 1975-76.

3.7.3 Problem of consistency due to changes in geographical area and inclusion of more land-use classes

The land-use categories reported by DES, GoK increased in the year 2005-06 from the initial 11 categories to the currently reported 15 categories. These were:

- **Marshy land**: Land which gets permanently or periodically flooded by water and characterised by vegetation which includes grasses and weeds.
- **Still water**: Land occupied by water bodies like rivers, lakes, ponds, reservoirs, backwater, canals and tanks.

- **Waterlogged area**: Land where water is almost at the surface and stands for most of the year.
- **Social Forestry**: Land which has trees planted by the side of railway lines, roadside, river and canal banks to meet the fuel and the fodder needs of the rural population and to serve the broader goals of soil conservation and provision of shed and shelter for crops.

Consequently, due to the addition of four more land-use classes, the geographical area for Kerala had to be revised upwards to accommodate the new land classes. Previously from 1970-71 to 2004-05, the geographical area reported for Kerala was 38,85,497 ha. This area rose to 38,86,287 ha after the addition of the four land use classes. The difference was accounted for annually under the newly formed land use classes. The main concern here was, since the four classes were introduced in 2005-06, any study that goes back beyond 2005-06, the geographical area for Kerala could not be taken at the current 38,86,287 ha but at the previously reported 38,85,497 ha. For example, in this study, to conduct Markov chain analysis, the total proportions should be equal to one. In other words, the individual class percentages should be equal to 100 per cent which represent the state total area. Hence, this study excluded the newly formed land classes for consistency. For the Markov chain analysis, all land use class components were used.

3.7.4 Issues with reported area under vegetables

The area under vegetables reported by DES, GoK in earlier publications like the Statistics for Planning for the year 1976-77 included tapioca, sweet potato, tubers, tamarind among other crops. Lately, based on Report on Agricultural Statistics in the last thirteen years leading up to 2017-18, area under vegetables included crops such as bitter gourd, amaranthus, ladies finger, drumstick, snake gourd, tomato, brinjal, ash gourd, cabbage, green chillies, bottle gourd, payar, potato, carrot, beetroot, pumpkin, little gourd, cauliflower, beans, onions and cucumber. Some of the crops listed earlier under vegetables like tapioca, tubers and sweet potatoes are reported individually (based on the latest DES, GoK agricultural statistics publication, 2017-18.

Though it appeared that the area under vegetables started excluding area under tapioca and tubers in 2003-04, it was still not clear if the recently listed crops under vegetables were included before in the total area under vegetables for the earlier publications in 1970s, 1980s, 1990s and early 2000s. To work out the vegetable area for this study, the area under tapioca was subtracted from the vegetable area for the year 1970-71 to 2002-03. This value obtained included other tubers and sweet potatoes. Since these areas under other tubers and sweet potatoes were not available for the previous years, area under other tubers and sweet potato were added to the area under vegetables reported from 2003-04 to 2018-19 for continuity and consistency of the data. The obtained values were tested for any outliers and peculiarities and were found to be statistically consistent over the study period (1970-71 to 2018-19).

4. RESULTS AND DISCUSSION

This chapter in five sections discusses the transformation that agricultural sector has undergone in Kerala. The chapter presents results based on the objectives of the study as presented below:

4.1 Growth of agriculture in Kerala

4.2 Inter-district disparities in Kerala

4.3 Dynamics in land use and cropping pattern

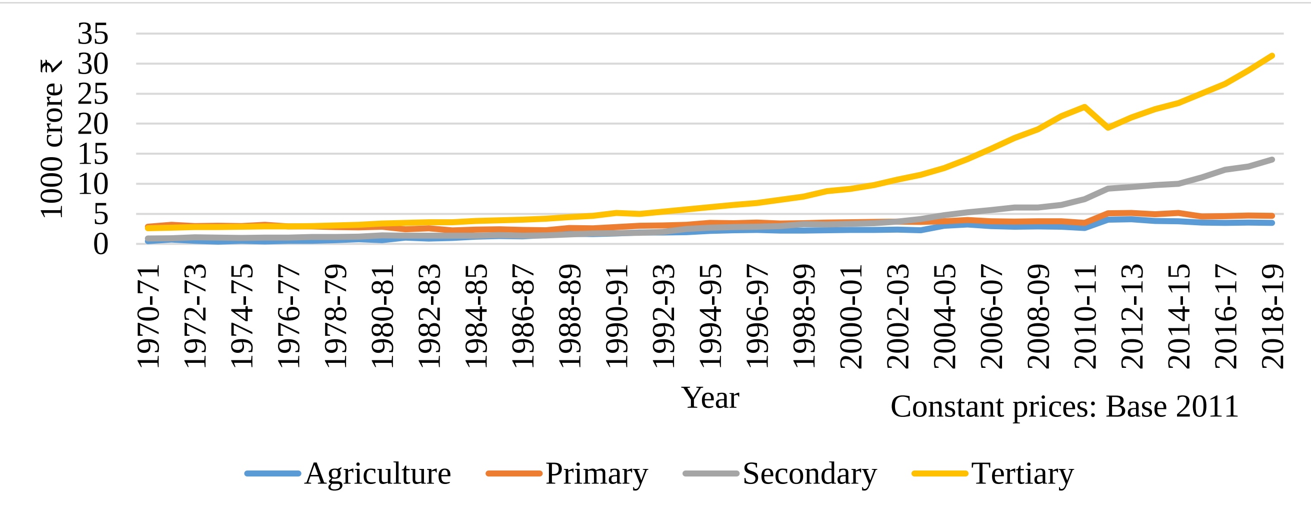
4.4 Economics, efficiency and profitability of major crops in Kerala

4.5 Total factor productivity of major crops in Kerala

4.1 Growth of agriculture in Kerala

The agricultural sector in Kerala had been facing transformations over the period of the study, that is, from 1970-71 to 2018-19. The income from various sectors in Kerala economy had been rising albeit at different rates. The state income from the agricultural Gross State Value Added (GSVA) in Kerala increased from ₹ 4,59,529 lakh in 1970-71 to ₹ 34,72,280 Lakh in 2018-19, registering a CAGR of 4.8 per cent.

Figure 2: Trend in Gross State Value Added of Various sectors in Kerala



The agricultural GSVA is the summation of the total value of output from crops and livestock. The primary sector which includes the agricultural GSVA had a CAGR of 1.3 per cent from ₹ 28,65,899 Lakh in 1970-71 to an estimated ₹ 46,49,543 Lakh in 2018-19. The GSVA from primary sector is the total of GSVA from crops, livestock, forestry and logging, fishery and, mining and quarrying. Therefore, the growth in primary sector was lower than the growth in agricultural GSVA because of the reduced growth performance of the other sub sectors included in it. During the period under study, the annual growth rate of GSVA from forestry and logging declined by a CAGR of -1.48 per cent.

The secondary and tertiary sectors in Kerala had the biggest improvements in the state's sectoral GSVAs. The secondary sector had a 5.95 per cent growth per annum from ₹9,01,523 lakh in 1970-71 to ₹ 1,40,33,264 Lakh in 2018-19. This was buoyed by the impressive performance of the construction and, electricity, gas and water supply sub sectors which had 6.31 per cent and 6.1 per cent growth per annum respectively. The tertiary sector had a 5.69

Table 4.1: Dynamics in sectoral contribution to Kerala GSDP

Sector	1970-71	1980-81	1990-91	2000-01	2010-11	2018-19	Growth Rate (% per annum)
Agriculture	23.83	14.54	16.9	11.88	12.89	6.76	4.83
Agriculture and Allied	28.11	22.61	20.83	15.72	15.71	9.56	2.5
Primary	32.59	30.86	25.23	20.02	16.37	9.95	1.3
Secondary	13.07	17.26	19.42	21.67	22.43	22.55	5.95
Tertiary	54.33	51.88	55.35	58.31	61.21	57.1	5.69

per cent annual growth from ₹ 26,11,582 Lakh in 1970-71 to an ₹ 3,13,25,312 Lakh in 2018-19. The impressive growth in tertiary sector received a boost from the annual growth in the transport (7.9 %), communication (10.7 %), banking and insurance (10.3 %), public administration (7.2 %) and, real estate and legal services (6.12 %).

The share of Kerala state's GSDP (Gross State Domestic Product) derived from the secondary sector had increased from 13.07 per cent in 1970-71 to 22.55 per cent in 2018-19. The tertiary sector remained largely consistent over the period by contributing more than 50 per cent to the Kerala GSDP. Its contribution improved from 54.33 per cent in 1970-71 to 57.1 per cent in 2018-19. Despite the growth in GSVA from agriculture in Kerala, its contribution had been declining over the period.

The contribution of GSVA from agriculture to the state's GSDP declined from 23.83 per cent in 1970-71 to 6.76 per cent in 2018-19. Consequently, the share of the contribution from the primary sector declined from 32.59 per cent to 9.95 per cent. The study on the agricultural transition of Kerala State was thus based on the understanding that the performance of the GSVA from agriculture was a reflection of the performance of the different components under it. It so followed that, a change in area, production and productivity of any crop was reflected in the behaviour and trend of the agriculture GSVA and contribution to the Kerala State's GSDP. To better understand what transpired in the different phases of the Kerala agricultural transformation, the series was studied to find breaks in the data by analysing the trend breaks. The breaks occur due to changes in the mean or volatility of the series within the period. This objective hence sought to understand the changes in mean and volatility of the components that contribute to the GSVA agriculture, i.e., the individual crops. To obtain the structural break points, methodology by (Bai and Perron, 1998) was used as explained in section *3.5.1.3*. For computation of the break points, *strucchange* package was used in *R Studio* software and the following *m* breakpoints were obtained.

The package was set to obtain the optimal breakpoints with either uniform or non-uniform periods in between the breaks. This was also true in the context of the differences in factors leading to the volatility and changes in means of the series over time. The optimal breakpoints were decided based on a two-step validity test on the Residual Sum of Squares (RSS) and the Bayesian Information Criteria (BIC). The lowest value of RSS was considered

Table 4.2: Estimated number of breakpoints in GSDP agriculture in Kenya (constant prices)

Particulars	m=1	m=2	m=3	m=4	m=5
Breakpoints	1986-87	1980-81	1980-81	1980-81	1980-81
		1993-94	1987-88	1987-88	1987-88
			2003-04	2003-04	1994-95
				2010-11	2003-04
					2010-11
RSS	5.1493	2.5331	1.2168	1.0009	0.8248
BIC	44.2286	17.2509	-10.8925	-12.6818	-14.3811

optimal in the first step. In case the optimal breakpoints found in step one coincided with the lowest BIC, this was taken as the optimal breakpoint and therefore, the lowest BIC held the precedence on validity. Optimal breakpoints coincided with *m*=5 having the minimum BIC of -14.3811. The five breakpoints computed in the GSDP agriculture were 1980-81, 1987-88, 1994-95, 2003-04 and 2010-11.

Based on the breakpoints obtained, six phases of growth were identified in Kerala agriculture for the period from 1970-71 to 2018-19. The phases thus obtained were:

- Period I - 1970-71 to 1980-81
- Period II - 1981-82 to 1987-88
- Period III - 1988-89 to 1994-95
- Period IV - 1995-96 to 2003-04
- Period V - 2004-05 to 2010-11
- Period VI - 2011-12 to 2018-19

The percentage analysis, CAGRs, instability indices, decomposition analysis and seemingly unrelated regression (SUR) models were used to analyse the first objective, i.e., growth of agriculture in Kerala.

4.1.1 Growth performance of crops in Kerala

4.1.1.1 Growth and instability in area, production and productivity of crops

The annual growth rates in area, production and productivity and, instability of crops in Kerala were studied for the different phases of growth in the economy which were obtained by the trend break analysis. To understand the growth and instability of crops in Kerala during the overall period of the study, analysis was also conducted for the entire period of the study. The Cuddy-Della Valle Index (CDVI) was used to measure the instability in area, production and productivity of crops while, CAGRs were used to analyse the annual growth in the area, production and productivity of crops grown in the state.

Period I (1970-71 to 1980-81)

The first phase (1970-71 to 1980-81) which coincided with the period of Green Revolution, was a phase when most of the crops in Kerala were facing stagnation in yield. It could be observed that all crops, except for small cardamom, ginger, banana and coffee, registered decline in area. During this period, the area under food grains, especially paddy and pulses registered negative growth rates of -1.20 per cent and -1.12 per cent respectively. Tapioca (-1.9 %), also exhibited the same trend in area. However, the production of pulses had a positive and significant growth (5.18 %) which was due to the impressive growth in its productivity (6.39 %), which offset the decline in area. The growth in production of paddy was negative because the decline in area was more than increase in productivity. In tapioca however, the decline in productivity (-2.19 %) as well as area (-1.90 %) contributed significantly to the decline in production (-4.08 %).

Table 4.3: Growth and instability in area, production and productivity of crops in Kerala during Period I (1970-71 to 1980-81)

Crop	Compound Annual Growth Rate (%)			Cuddy Della Valley Index (%)		
	Area	Production	Productivity	Area	Production	Productivity
Paddy	-1.20***	-0.57**	0.64	1.88	0.59	2.77
Tapioca	-1.90*	-4.08***	-2.19***	6.21	5.90	4.14
Pulses	-1.12**	5.18***	6.39***	1.41	4.29	5.10
Arecanut	-5.38**	-3.05**	2.47***	6.10	4.06	2.82
Black pepper	-1.63***	-0.01	1.63**	2.19	5.73	4.52
Small cardamom	2.03***	8.68***	6.33**	1.48	14.91	15.1
Ginger	1.09	5.17***	4.03***	5.22	3.07	3.19
Turmeric	-5.93***	2.68**	9.02***	16.03	1.48	21.45
Banana and plantains	1.32**	-0.9**	-2.17***	2.36	5.15	4.34
Cashew	4.40**	-4.88***	-8.84**	4.07	6.40	8.77
Coconut	-1.65**	-2.97***	-1.36	1.69	4.52	5.89
Rubber	1.89***	4.77***	2.84***	0.87	7.93	7.97
Coffee	7.47***	10.16**	2.44***	4.84	11.11	5.87
Tea	-0.29	1.67***	1.94***	2.23	3.08	2.70

Note: 1. * denotes significance at ten per cent level
2. ** denotes significance at five per cent level
3. *** denotes significance at one per cent level

Most of the spices, except for black pepper exhibited a growth in production mainly because of the significant increase in productivity. Black pepper and turmeric exhibited a decline in area of -1.63 per cent and -5.93 per cent respectively. Among the spices, small cardamom registered the highest growth rates in area and production while turmeric registered the lowest growth rate in production in this phase.

Despite having the significant and highest decline in area, turmeric compensated this decline with positive and significant increase in productivity of 9.02 per cent, which resulted in the growth in production of 2.68 per cent. Black pepper had the lowest growth rate in productivity of 1.63 per cent among all the listed spices in the first phase. Plantation crops like rubber coffee and tea realised growth in production. The growth in production in rubber was mainly contributed by growth in productivity while it was the increase in area which mainly contributed to the rising production in the case of coffee. In spite of the slight decline in area, the production of tea increased because of the increase in productivity of tea by 1.94 per cent.

The largest growth rate in area and production was shown by coffee at 7.47 per cent and 10.16 per cent respectively. Rubber among the plantation crops, had the largest growth rate in yield.

The production of arecanut declined because the decline in area was strong enough to offset the increase in productivity during the phase. Banana and other plantains, and cashew showed an increase in area of 1.32 and 4.4 per cent respectively. They both nevertheless registered negative growth rates in production due to decline in productivity which was greater than the growth in area. Coconut, an oilseed plantation crop registered negative growth rate in its area, production and productivity in this phase. The decline in area as well as productivity, resulted in decline in the production of coconut.

Area under rubber was the most stable having CDVI of less than one per cent (0.87 %). The area under turmeric was the most unstable (16.03 %), while it also registered the least rate of growth among all the crops in the first phase. Production of small cardamom a registered CDVI of 14.91 per cent which was mainly due to the instability in productivity, while coffee had an instability index value of 11.11 per cent, which was equally contributed by the instabilities in area and productivity. The crop with the most stable production in this phase was paddy (0.59%). Paddy (2.77%), arecanut (2.82%) and tea (2.70%) had the most stable productivity, while turmeric registered the most unstable (21.45 %) productivity.

Period II (1981-82 to 1987-88)

The second phase from 1981-82 to 1987-88 witnessed a further decline in area under food grains and tapioca, while the area under spices and condiments exhibited a pattern of recovery from the decline in the previous phase. The area under plantation crops continued to register positive rates of growth that were registered in the previous phase, which in turn was an indication that area from the food crops was being converted to cultivation of cash crops, mainly, plantation crops. Food grains like paddy and pulses registered further decline in growth rate in this phase. Paddy, tapioca and pulses exhibited negative growth in area and production, in spite of growth in productivity of these crops. The lowest growth rates in area and production were exhibited by tapioca. The growth in productivity among all the three food crops were not able to compensate for the higher decline in area, resulting in the decline in production of these crops.

Arecanut recorded decline area, production and productivity. The decline in area and production of arecanut were much lower than the previous phase, which was the indication that the area under arecanut had started rising, even though the productivity showed slight decline.

Table 4.4: Growth and instability in area, production and productivity of crops in Kerala during Period II (1981-82 to 1987-88)

Crop	CAGR (%)			CDVI (%)		
	Area	Production	Productivity	Area	Production	Productivity
Paddy	-3.48***	-2.54**	0.97**	1.76	1.82	0.48
Tapioca	-4.14**	-3.15***	1.05***	1.99	2.22	1.27
Pulses	-3.39***	-0.80	2.73***	1.37	2.85	2.08
Arecanut	-0.92**	-1.07	-0.16	1.24	6.74	5.61
Black pepper	3.08***	2.18*	-1.03	5.31	14.45	8.95
Small cardamom	2.62***	-0.07	-2.52	2.10	11.44	11.92
Ginger	3.34**	6.20**	2.79	2.76	4.87	2.78
Turmeric	-1.14	-0.37	0.82***	5.33	5.44	1.45
Banana and plantains	1.44***	3.15**	1.66***	1.60	4.64	2.97
Cashew	-1.04***	0.42*	1.50	1.61	3.69	6.14
Coconut	1.53**	1.79***	0.27	1.06	2.79	2.72
Rubber	7.40**	7.19***	-0.20	2.08	1.34	1.17
Coffee	2.46**	-0.07***	-2.49	1.25	14.40	13.08
Tea	-0.61**	1.75	2.38***	0.33	5.58	4.32

Note: 1. * denotes significance at ten per cent level
2. ** denotes significance at five per cent level
3. *** denotes significance at one per cent level

Other than turmeric (-1.14%) which recorded a decline of -1.14 per cent in area, all others spices reported positive rates of growth in area during this phase. Among those spices, ginger exhibited the largest growth in area and production compared to black pepper (3.08 %).

Banana recorded positive annual growth rates of 1.44 per cent, 3.15 per cent and 1.66 per cent in area, production and productivity respectively. Cashew however, recorded negative growth rate in area at (-1.04%) and showing the commencement of decline in area under cashew, which was reflected as slight growth in production in spite of the growth in productivity. Coconut recorded positive rates of growth in area, production and productivity in this phase. The annual growth rate production of 1.79 per cent in this phase was mainly contributed by the increase of 1.53 per cent in area under coconut, which showed that the increase in productivity did not play a major role in raising production of coconut in this phase. Among all the crops in this phase, rubber had the highest growth rate in production (7.19%), which was mainly due to the significant growth rate of 7.4 per cent in area which was strong enough to compensate for the slight decline in productivity. Interestingly, even though tea recorded a decline in area of -0.61 per cent, the production showed 1.75 per cent growth due to the significant growth in productivity.

The area under tea, with a CDVI value of 0.33 was the most stable crop, while turmeric and black pepper with CDVI values of 5.33 per cent and 5.31 per cent respectively, were the most unstable ones in area. The CDVI of 14.45 per cent and 1.34 per cent respectively showed that the production of black pepper was the most unstable, while that of rubber was the most stable in this phase. The productivity of paddy showed the lowest variability during this phase (0.48%), while coffee which had a drastic decline in growth rate from the previous phase, had the highest instability in productivity (13.08%).

Period III (1988-89 to 1994-95)

The third phase from1988-89 to 1994-95 was the phase of increasing production for crops which had impressive growth in acreage in the previous phases. This phase saw the largest increase in annual rates of growth in production for most of the plantation crops, spices including small cardamom and black pepper and, banana and other plantains. All these crops exhibited increased annual rates of growth in area during the previous phase. The food grains and tapioca suffered severely in production due to decline in area of these crops in the previous phase. Nevertheless, the cultivation of paddy was enhanced by the introduction of the group farming approach, which immediately after its introduction ensured stabilised production. The growth rates in area and production of food crops such as paddy, pulses and tapioca were negative in this phase, which was the continuance of the same trend from the previous phase. However, the negative growth rate in area and production of paddy declined relatively, an indication that the decline in area and production of paddy was receding in this phase. One year after the introduction of the programme (1989-90), the production of paddy which was continuously declining previously, increased by 12 per cent. The programme in addition to helping the recovery in the use of HYVs of paddy for cultivation, also ensured enhanced paddy production and consequently, this phase out of all the five different phases registered the lowest decline in production of paddy in Kerala. Even though the area under paddy declined by -2.77 per cent per annum, the production showed only a very slight decline of -0.49 per cent because of significant increase in productivity of 2.34 per cent per annum. Therefore, among paddy, tapioca and pulses, paddy recorded the lowest decline in area and production, while the growth in productivity was the highest. The highest decline in area was exhibited by tapioca (-5.42%).

Table 4.5: Growth and instability in area, production and productivity of crops in Kerala during Period III (1988-89 to 1994-95)

Crop	CAGR (%)			CDVI (%)		
	Area	Production	Productivity	Area	Production	Productivity
Paddy	-2.77***	-0.49*	2.34***	0.72	2.27	2.27
Tapioca	-5.42**	-4.22**	1.26**	1.10	1.19	1.12
Pulses	-3.35***	-3.18***	0.17	0.36	1.04	*0.96
Arecanut	1.77***	5.76***	3.89***	1.25	2.31	1.24
Black Pepper	4.09***	4.25**	0.10	1.90	5.50	4.09
Small cardamom	-7.47***	7.58***	16.2	6.71	4.52	7.40
Ginger	-1.98***	-0.57	1.42***	3.04	2.76	1.23
Turmeric	0.60	1.56*	0.82**	7.00	10.03	2.89
Banana and plantains	3.90***	5.16***	1.22**	0.53	0.57	0.67
Cashew	-2.96***	-0.84***	2.17	0.67	6.16	6.95
Coconut	2.32***	6.84***	4.45**	1.68	1.10	0.65
Rubber	3.46***	11.02**	7.34**	1.23	1.03	1.24
Coffee	4.40***	3.70	-0.88	2.51	22.45	21.76
Tea	0.02*	-0.34	-0.36	0.09	4.54	4.58

Note: 1. * denotes significance at ten per cent level
2. ** denotes significance at five per cent level
3. *** denotes significance at one per cent level

The highest decline ever recorded for area and production of tapioca was recorded in this phase. All the three crops recorded positive rates of growth in yield in the phase nonetheless. Despite the positive annual growth rates in productivity of three crops, the production declined because the growth in productivity in these crops were not able to offset the decline in area.

The CAGRs of area, production and productivity of spices like black pepper and turmeric showed increased rates of growth in this phase in comparison to the previous phase. Among all the phases, black pepper and turmeric recorded the best growth rates in area of 4.09 and 0.6 per cent in this phase respectively. In contrast, small cardamom recorded its worst decline in in area of -7.47 per cent and ginger also recorded a negative growth rate of -1.98 per cent. All the spices except for ginger recorded positive rates of growth in production. This was due to the significant growth in area under spices in the previous phase despite the decline in area of these crops in the present phase. Black pepper exhibited the highest growth in production of 4.25 per cent. Interestingly, small cardamom despite recording its worst growth rate in area, recorded an impressive growth rate in production of 7.58 per cent due to the highest growth rate of 16.2 per cent in yield among all the phases. Ginger also recorded a decline in area of -1.98 per cent per annum.

Banana continued to exhibit increasing growth in area, production and productivity from the previous phase. The annual growth rate in area rose to 3.90 per cent compared to 1.44 per cent in the previous phase. This was an indication that more area was being brought into banana cultivation, which led to higher production. Banana recorded 5.16 per cent growth in production during this phase, its highest growth in production among all the phases of growth. Even though the growth rate in productivity declined in magnitude, it was still positive (1.22%). Cashew exhibited a decline in production because negative growth rate in area of -2.96 per cent more than offset the productivity growth of 2.17 per cent.

The third phase was characterised by impressive growth rates for coconut and rubber. These plantation crops recorded their highest growth rates in area, production and productivity in this phase. Coconut recorded 2.32 per cent, 6.84 per cent and 4.45 per cent growth in area, production and productivity. The impressive growth in production of coconut was mainly contributed by the growth in productivity rather than area. During this phase, rubber recorded the highest growth rate in production and productivity among all the crops. The impressive growth of 11.02 per cent in production of rubber was mainly contributed by the discernible annual growth rate in productivity of 7.43 per cent per annum. A sustained annual increase in area under coffee resulted in significant growth in production.

The area under tea had the highest stability (0.09%), while turmeric had the highest instability in area (7%). Tapioca, pulses, banana and other plantains, coconut and rubber showed the least variability in production during this phase, while coffee had the most unstable production. Consequently, coffee had the most unstable yield during this phase, while tapioca, pulses, arecanut, ginger, coconut, banana and other plantains, and rubber were the most stable crops.

Period IV (1995-96 To 2003-04)

Fourth phase from 1995-96 to 2003-04 marked the largest decline in area under food grains and marginal decline for tapioca. This phase was marked by deceleration in annual growth of black pepper, coffee, rubber and coconut; recovery for tea and further increase in area under arecanut and, banana and other plantains. Paddy recorded -5.57 per cent annual growth rate in area, while pulses recorded -18.47 per cent which was the highest decline in area for the crop in any of the phases and lowest for any crop in this phase. Similarly, paddy recorded its highest decline in production of -4.49 per cent in all the phases, while pulses exhibited a decline in production of -13.09 per cent per annum. The growth in productivity of

Table 4.6: Growth and instability in area, production and productivity of crops in Kerala during Period IV (1995-96 To 2003-04)

Crop	CAGR (%)			CDVI (%)		
	Area	Production	Productivity	Area	Production	Productivity
Paddy	-5.57 ***	-4.49***	1.09***	6.04	3.98	2.33
Tapioca	-1.49***	-0.31**	1.23***	2.13	3.27	2.39
Pulses	-18.47***	-13.09***	9.22***	8.04	6.23	14.36
Arecanut	4.18*	18.57***	13.98***	3.95	16.57	23.58
Black pepper	1.61***	0.64*	-0.91	2.74	5.84	4.91
Small cardamom	-0.69***	8.54***	9.31**	1.61	8.53	7.63
Ginger	-3.70***	-2.99***	0.75***	3.67	3.73	0.96
Turmeric	-1.49	-2.65***	-1.13	*6.65	6.56	4.47
Banana and plantains	5.63***	3.68***	-1.79	3.10	6.13	9.92
Cashew	-2.04***	-2.97	-0.93***	1.98	14.48	4.50
Coconut	0.10	1.19***	1.08***	0.97	1.25	0.92
Rubber	0.92***	3.76**	2.82***	0.83	2.70	2.16
Coffee	0.34***	5.71***	5.35***	0.37	5.20	4.95
Tea	1.02***	-0.47	-1.47***	1.44	3.29	3.76

Note: 1. * denotes significance at ten per cent level
2. ** denotes significance at five per cent level
3. *** denotes significance at one per cent level

paddy and pulses were not able to offset the significant decline in area, resulting in significant decline in production of these crops. This growth of productivity of 9.22 per cent experienced for pulses was its best in any of phase.

Arecanut recorded the highest growth rates in its area, production and productivity compared to other phases. Only banana and plantains had higher growth rate (5.63%) than arecanut. This was the highest annual growth for area under banana in all the phases and the highest of any crop during this phase. Arecanut's annual growth in production of 18.57 per cent which was the highest for any crop in this phase was mainly contributed by the growth in productivity of 13.98 per cent, which also happened to be the highest growth rate of productivity for any crop in this phase. The growth in area under small cardamom even though was, negative (-0.67%), was comparatively better than that of the previous phase. Small cardamom recorded a very high growth in production (8.54%) which in return resulted from the higher growth rates in productivity of 9.31 per cent. The growth rate in area ginger was negative and it more than offset the growth in productivity, resulting in a decline production

Cashew once again in this phase recorded a negative annual growth rate in its area (-2.04%). The declining area along with the decline in productivity, which was a departure from what it recorded in the two previous phases, resulted in a fall in production of -2.97 per cent. impacted its annual growth rate in yield and hence it recorded -0.93 per cent.

Plantation crops recorded positive rates of growth in the area, production and productivity in this phase. It was only tea that recorded a negative growth rate in its productivity (-1.47%). Its area however, recorded an improvement from the previous phase at 1.02 per cent. Among all the plantation crops, only tea exhibited an increase in its annual growth rates in area under the plantation crops. Coffee presented the most stable area (0.37%) in the phase while pulses which had the largest decline in area, had the highest instability of 8.04 per cent. Coconut was the most stable with CDVI of 1.25 per cent, while arecanut which had the largest increase in production was the most unstable, showing a CDVI of 16.57 per cent. Similarly, arecanut had the highest instability in yield, while coconut had the lowest (0.92).

Period V (2004-05 to 2010-11)

The fifth phase from 2004-05 to 2010-11 was the phase in which almost all the crops recorded their negative annual rates of growths in area. It was only rubber, coffee and tea which had positive annual growth rates among the crops under study. Crops that suffered higher loss in area were cashew, black pepper, pulses, banana and other plantains, tapioca, paddy and coconut. In this phase, food crops continued to record negative growth rates in area, an indication that the area under food crops such as paddy (-4.64%), tapioca (-2.98%) and pulses (-10.29%) were declining. The decline in area was however, lower compared to the previous phases for paddy and pulses, while for tapioca, this phase witnessed an intensification of decline in growth rates of its area. Paddy recorded a decline in production of -2.19 per cent in production, which was higher than the previous phase and the decline in area offset the growth in productivity. Tapioca exhibited the highest growth in yield in this phase in spite of the decline in area under the crop which resulted in a rise in production of 0.83 per cent. Pulses recorded their highest decline in production in this phase, which was also the lowest for any other crop.

Small cardamom also had its highest decline in production of -2.26 per cent in this phase, which was mainly contributed by the massive decline in productivity of -2.18 per cent rather than area. Banana exhibited decline in area for the first time in this phase. The area, production and productivity of banana exhibited a fall in this phase, and the decline in production was

Table 4.7: Growth and instability in area, production and productivity of crops in Kerala during Period V (2004-05 to 2010-11)

Crop	CAGR (%)			CDVI (%)		
	Area	Production	Productivity	Area	Production	Productivity
Paddy	-4.64**	-2.19***	2.56***	1.58	2.32	1.31
Tapioca	-2.98***	0.83**	3.92***	1.35	1.31	0.89
Pulses	-10.29**	-14.41***	-4.41*	13.26	16.62	4.34
Arecanut	-1.12***	1.19***	2.35***	2.17	2.11	2.74
Black pepper	-6.04***	-11.68*	-6.08*	6.45	13.01	6.77
Small cardamom	-0.08	-2.26***	-2.18***	0.65	3.49	3.15
Ginger	-6.95	-5.66	-1.92	19.62	18.21	8.61
Turmeric	-2.19	-0.31	2.04	11.21	13.48	3.19
Banana and plantains	-1.41***	-1.45	-0.05	2.44	4.36	0.99
Cashew	-9.48***	-8.84**	0.62	2.50	7.72	5.71
Coconut	-2.64***	-1.13	1.55***	1.62	3.35	0.96
Rubber	1.64***	2.67***	1.03	0.21	3.36	3.82
Coffee	0.07	-0.69	-0.78	0.25	4.24	4.27
Tea	0.15	0.14	-0.01	1.75	1.88	1.76

Note: 1. * denotes significance at ten per cent level
2. ** denotes significance at five per cent level
3. *** denotes significance at one per cent level

mainly contributed by decline area rather than productivity. The growth rates of area and production of cashew continued to plummet into this phase and the decline in area was the reason for the fall in production. Cashew recorded its lowest growth rates in area and production in this phase as -9.48 per cent and -8.84 per cent respectively. Coconut also recorded its highest decline in area of -2.64 per cent in this phase. Area, production and productivity of rubber continued to register positive annual rates of growth, however, were lower than the previous phases.

The area under rubber was the most stable in this phase, while ginger exhibited the highest instability, which could be attributed to the large decline in area during the phase.

Tapioca was the most stable in production, while production of ginger was of the most unstable, which showed the largest decline in production during the phase. The highest instability (8.61%) in the yield of ginger could have been contributed by the large decline in yield during the phase.

Period VI (2011-12 to 2018-19)

The sixth phase from 2011-12 to 2018-19 confirmed that the area under food crops like paddy, pulses and tapioca were on continuous decline throughout the phases of the study. However, it was also to a small extent a recovery period for the area under paddy and tapioca

Table 4.8: Growth and instability in area, production and productivity of crops in Kerala during Period VI (2011-12 to 2018-19)

Crop	CAGR (%)			CDVI (%)		
	Area	Production	Productivity	Area	Production	Productivity
Paddy	-2.04***	-1.32***	0.67*	1.86	2.92	2.96
Tapioca	-1.02**	0.78*	1.80***	1.49	3.76	2.36
Pulses	-9.39***	-4.90*	5.61***	12.5	14.33	9.16
Arecanut	-0.89*	0.10	1.00	0.84	3.91	4.60
Black Pepper	-5.9***	-1.86**	2.98	16.27	3.96	10.82
Small cardamom	-0.98**	11.24***	12.32***	0.51	12.38	12.56
Ginger	-4.25***	-7.80***	-3.52**	6.44	7.17	1.85
Turmeric	-0.03	1.00	1.03***	2.71	4.31	1.27
Banana and plantains	1.25***	1.57***	0.31	2.78	4.70	2.02
Cashew	-3.43***	-6.56***	-3.35***	4.20	4.87	2.22
Coconut	-0.48***	-0.78**	-0.29	1.30	3.76	2.32
Rubber	0.48***	-7.07***	-7.52***	0.46	9.18	9.43
Coffee	-0.03	-0.06	-0.03	0.19	1.98	1.85
Tea	-2.19***	0.64	2.83*	5.96	2.96	9.62

Note: 1. * denotes significance at ten per cent level
2. ** denotes significance at five per cent level
3. *** denotes significance at one per cent level

which increased marginally in relation to the previous phase. Plantation crops like rubber, coconut, and coffee were on the decline in this phase, especially with respect to production and productivity. Even though the area under paddy was declined by -2.04 per cent, the decline was lower than the previous phase. This was an indication that more land was being brought to paddy cultivation after the enactment of the Kerala Conservation of Paddy Land and Wetland Act, 2008 and the intensification of promotion of cultivation on fallow lands. The production of paddy, though negative (-1.32%), also improved in this phase when compared to the previous phase because of the increased acreage under the crop. However, the growth in productivity declined to 0.67 per cent when compared to the previous phase. This could have been because even when the owners of the most of the lands returned to paddy cultivation, they were institutionally and artificially constrained from using their land for any other purpose and therefore, had no incentive invest further on the crop. The decline in area under paddy was higher than the growth in productivity, which reflected as a decline in production of paddy. Tapioca even after experiencing a growth in productivity of 1.8 per cent, witnessed only 0.78 per cent increase in production, due to the decline in area -1.02 per cent. Despite the growth in productivity of 5.61 per cent for pulses when compared to the previous phase, the production declined by -4.9 per cent because the growth in productivity was more than offset by the decline in productivity of -9.29

In this phase, spices like black pepper and small cardamom recorded their best annual growths in productivity and production. Black pepper, despite its negative annual growth in area and production, recorded the best productivity growth of 2.98 per cent, while small cardamom had a productivity growth of 12.32 per cent which led to an impressive 11.24 per cent annual growth in production. Ginger carried over the negative growth rate in its area and production to this phase. The highest decline in productivity of -3.52 per cent was recorded for ginger in this phase. The growth in area, production and productivity of cashew was negative in this phase. The decline production of -6.56 per cent was almost equally contributed by the decline in area and productivity. This yield of cashew exhibited the second lowest decline in this phase after the decline in the first phase.

Most of the plantation crops realised some decline in at least area or productivity during this phase. The decline in area (-0.48%) and production (-0.78%) of coconut were lower than the decline in the previous phases. However, the productivity of coconut declined by -0.29 per cent. The magnitude of the growth in area under rubber declined during this phase to 0.48 per cent, which was the lowest growth rate in area of rubber in any of the phases. The production realised the lowest production growth rate of -7.07 per cent per annum due to highest decline in productivity of -7.52 per cent. The area under tea which had been largely stagnant over time, had its largest decline in area of -2.19 per cent during this phase. The production increased by 0.64 per cent because the growth in productivity more than offset decline in area.

The area under coffee was the most stable crop in this phase, while that of black pepper with a CDVI of 16.27 per cent, happened to be the most unstable one. The production of coffee was the most stable in this phase also, while pulses had showed the most unstable production. While turmeric had the most stable productivity (1.27%), small cardamom was the most unstable (12.56%) crop due to the magnitude of increase in its annual yield from the previous phase.

Overall Period (1970-71 to 2018-19)

In the entire period of the study, it was confirmed that the area and production under food grains and tapioca were exhibiting negative annual growth rates as shown in Table 4.9. The area under paddy declined by -3.89 per cent, while its production declined by -2.48 per cent because the growth in productivity was not able to compensate for the decline in area under paddy in Kerala. Tapioca recorded -3.71 per cent decline in area and it more than offset the 2.10 per cent growth in productivity resulting in a decline of -1.68 per cent in production. The pulses showed the lowest growth rate in area and production of -6.58 per cent and -4.52 per cent respectively in the entire period. Paddy, tapioca and pulses recorded 1.46 per cent 2.10 per cent and 2.27 per cent growth in productivity respectively. This could be explained by two possibilities. One, regardless of the negative growth rates in area, the rates of growths in production were relatively higher than those of the respective crop areas and hence, the productivity showed positive rates of growth. Two, while the area under these crops were declining, to improve production, more farmers employed the use of HYVs and this led to improved rates of growth in yield. However, Kannan and Pushpangadan (1990) asserted that for the period between 1960s and mid-eighties, the rise in productivity in paddy could have been mainly due to loss of marginal fields and not because of any improvement in technical efficiency. Despite the negative annual growth rates in area and production, the crops like paddy recorded positive rates of growth in their productivity. This was the same case with the six phases in which paddy also recorded positive rates of growth in productivity. Since paddy recorded positive annual rates of production in all phases despite decline in acreage since 1970-71, it could be inferred that HYVs of paddy, which were introduced in the after 1966, helped ensure to some extent, productivity growth in the crop.

Arecanut recorded positive rate of growth in its area during the period under study (1.07%) reinforcing the fact that its area was rising. Arecanut also recorded the highest growth in production (7.43%) and similarly in productivity (6.29%) of all the crops within the period. The growth in production in arecanut was majorly contributed by growth in productivity rather

Table 4.9: Growth and Instability in area, production and productivity of Crops grown in Kerala from 1970-71 to 2018-19

Crop	CAGR (%)			CDVI (%)		
	Area	Production	Productivity	Area	Production	Productivity
Paddy	-3.89***	-2.48***	1.46***	8.47	6.76	3.74
Tapioca	-3.71***	-1.68***	2.10***	15.92	16.34	12.08
Pulses	-6.58***	-4.52***	2.27***	14.01	31.82	19.26
Arecanut	1.07***	7.43***	6.29***	15.41	35.66	31.69
Black pepper	0.32	1.64***	1.35***	30.57	30.72	14.47
Small cardamom	-0.84***	5.40***	6.29***	12.38	32.8	38.06
Ginger	-2.12***	-0.26	1.90***	19.49	24.98	7.96
Turmeric	-0.85***	0.56***	1.32***	17.18	14.74	9.72
Banana and plantain	2.5***	2.86***	0.36***	10.08	12.66	8.67
Cashew	-2.44***	-2.78***	-0.36***	17.33	16.49	19.94
Coconut	0.45***	1.55***	1.09***	9.16	11.62	7.97
Rubber	2.56***	4.98***	2.36***	7.87	24.87	21.4
Coffee	1.80***	3.52***	1.70***	10.75	14.63	14.75
Tea	-0.23***	0.62***	0.86***	4.63	9.47	11.5

Note: 1. * denotes significance at ten per cent level
2. ** denotes significance at five per cent level
3. *** denotes significance at one per cent level

than area. This could be due to favourable weather conditions in the growing districts and use of HYVs that ensured improvement in production. Black pepper recorded only a meagre annual growth rate in its productivity (1.32%) and only the first and the sixth witnessed phases witnessed significant growth in productivity of black pepper. This was an indication that the production of black pepper had been declining especially because of the old and senile plantations and due to repeated disease outbreaks like quick wilt. Hence, new ways of operations need to be employed to improve the productivity of black pepper. The other spices like small cardamom, ginger and turmeric recorded negative growth rates of -0.84 per cent, -2.12 per cent and -0 85 per cent in area respectively. Small cardamom however, had a significantly higher annual growth in production (5.40%) even when there was slight decline in area, which was mainly due to the highest growth in productivity among all the crops (6.29%) during the period. Ginger and turmeric experienced decline in area and whatever growth in production occurred was the result of growth in productivity of these crops.

Banana recorded a positive annual rate of growth in its area (2.5%), production (2.86%) and productivity (0.36%). But the growth in production of banana was mainly due to growth in area rather than productivity. Cashew however showed declining annual growth rates in area, production and productivity during the period and the decline in production was mainly contributed by the decline in area. Cashew was the only crop which exhibited negative growth rate in productivity in the entire period. Thus, it follows that, it was only cashew which had a greater decrease in production than its area.

All the plantation crops except for cashew recorded positive CAGRs area, production and productivity. Tea recorded a insignificant decline in area (-0.23%). Rubber had the highest growth rate in area among all the crops (2.56%). Among the plantation crops, rubber also had the greatest increase in production (4.98%) and productivity (2.36%) and the growth in production was equally contributed by growth in area and productivity. Tea showed the lowest growth in production (0.6%) and productivity (0.86%). During the entire period under the study, black pepper was the crop having the highest instability in area (30.57 %), while tea was the most stable (4.63 %) Arecanut, small cardamom, pulses and black pepper were the crops which registered high instability in production of 35.66 per cent, 32.8 per cent, 31.82 per cent and 30.72 per cent respectively. Paddy showed the most stable production and productivity of 6.76 per cent and 3.74 per cent respectively. Small cardamom (38.06%) and arecanut (31.69%) showed the very high instability in yield. The graphical presentation of the trend in area, production and productivity of each crop during each of the phase and the entire period is provided from Appendix I to Appendix XII.

4.1.1.2 Trend break analysis

The breaks identified in the GSVA from agriculture in Kerala helped in determining the phases of growth, which were used to study the performance of crops in the state. Area under the crops is a major factor contributing to production of any crop and therefore, there is a need to understand the volatility and breaks in area of individual crops and the contributing factors as it will affect the production and consequently the GSVA from agriculture in Kerala. The breaks in the series of the crops were obtained by using the methodology followed by (Bai and Perron, 1998) by using the *strucchange* package in *R Studio* software. The analytical model has been explained under section *3.5.1.3.*

A number of studies had shown that the changes in trends in area under crops and consequently cropping pattern changes, are influenced mainly by relative prices and profitability. Kannan and Pushpangadan (1988; 1990) and Viswanathan (2012) also affirmed that the growth dynamisms in Kerala had been appropriate for the development of cash crops, which were more than anything else determined by market forces and prices. The crop-wise trend break analyses is discussed below.

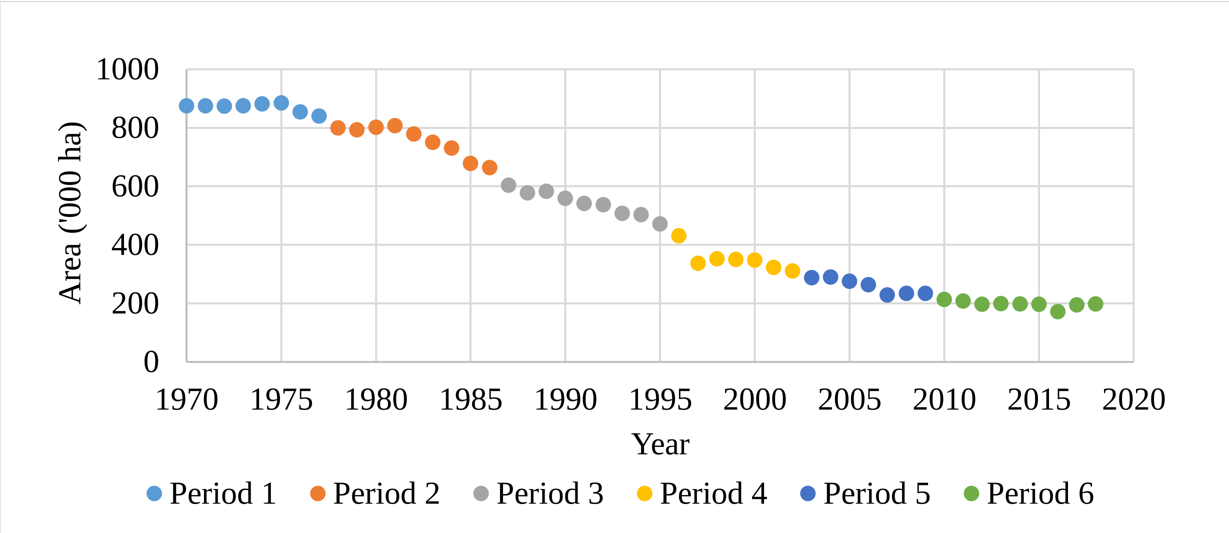
4.1.2.1 Paddy

The area under paddy in Kerala exhibited six breakpoints. The optimal breakpoints were found to be five, which were validated by the lowest BIC of -71.7985 and RSS value of 0.2555. The first phase in the time series data on paddy area was from 1970-71 to 1977-78. This period had a third-degree polynomial trend, with an annual growth rate of -0.24 per cent. The paddy area was generally stagnant for better part of this phase possibly because of the Intensive Agricultural District Programme (IADP) of 1960-61 and the Intensive Paddy Development Programme of 1971-72. However, in 1975-76, the gross irrigated area and area under paddy started declining, which could be attributed to the low rainfall received during the year, which more than halved from 3528 mm to 1781.5 mm. The decline in gross irrigated area from 3,72,842 ha in 1976-77 to 3,53,906 ha in 1977-78 thus adversely affecting the area under which paddy could cultivated. Consequently, the land put under current fallows also started increasing during this phase. The price of paddy output also declined from ₹ 139 to ₹ 128 per quintal, while that of rubber increased by ₹ 10 from ₹ 620 to ₹ 630 per 100 kg just before 1977-78. The interactions of these factors could have led to the break in area in 1977-78.

The second phase for paddy area in Kerala was observed from 1978-79 to 1986-87. This phase had a linear trend with an annual decline of 18,102 ha per year in the area under paddy, exhibiting a decline of -2.06 per cent per annum. From 1982-83, the price of paddy was largely declining, after reaching its peak during the seventies. The turning point in price happened in 1986-87 when the price increased from ₹ 225per quintal to ₹ 242 per quintal in 1986-87. During the two preceding years of 1986-87, the cost of inputs increased significantly. The cost of fertiliser nutrients (NPK) increased from ₹ 5400 per metric tonne (MT) to ₹ 6550 per MT. The cost of paddy seeds also doubled from ₹ 1.5 to ₹ 3 per kg. All these had reduced the profitability of cultivating paddy, which could have forced the farmers to abandon paddy cultivation, resulting in the break in area, which led to a further decline in area under paddy from 6,78,281 ha in 1985-86 to 6,63,803 in 1986-87.

The third phase (1987-88 to 1995-96) was the period when the group farming programme was launched in 1989-90 and paddy area exhibited a decline of -3.15 per cent per annum in this phase. This period had a linear trend with an annual loss in area of 15,462 ha per year, which was an improvement from the previous phase in terms of the reduction in area. A sharp decline in area under paddy started in 1995-96, which culminated in the loss of 1,66,088 ha from 1994-95 (5,03,210 ha) to 1997-98 (3,37,122 ha). The gross irrigated area also declined in the same manner and the rate of decline started to reduce in 1997-98. The irrigated area under the crop declined from 2,72,772 ha in 1994-95 to 2,02,142 ha in 1997-98, depicting the

Figure 3: Breakpoints in area under paddy in Kerala



same trend as the decline in area under paddy. This decline was despite a sharp rise in the price of paddy, while the price of rubber reached its highest pre-2000 price when it peaked at ₹ 5,059 per 100 kg in 1995-96. The land left fallow (current fallow) increased to 51,314 ha in 1995-96 from 47,801 ha in 1994-95. The average wage for paddy field labour also increased to ₹ 64.17 in 1995-96 from ₹ 52.73 in 1994-95. The high price of rubber and increasing cost of labour could have made the paddy farmers disenfranchised to continue with paddy production and therefore, the irrigation facilities were not being used as the farmers were leaving their land fallow. This consequently, led to the break in 1995-96. The fourth phase was 1996-97 to 2002-03 in the growth of paddy area in Kerala and it exhibited a third-degree polynomial trend. Scheme on promotion of paddy cultivation in fallow lands was initiated in 2004-05 for increasing paddy production in the state. This helped reduce the area under fallow lands and the current fallows declined from 70,798 ha in 2002-03 to 68,679 ha in 2003-04. The area sown more than once increased from 7,64,514 ha in 2003-04 to an all-time high in 2004-05. This sharp rise from 2002-03 could have caused the break in area under paddy. Even then, this phase also had the largest decline in area, with an annual decline of -5.86 per cent per annum.

The fifth phase of trend in paddy area was from 2003-04 to 2009-10. This phase had a linear trend, with an annual loss of 18,102 ha of paddy land. From 2006-07, the area under paddy experienced the largest decline, which could have been caused by the highest rise in price of rubber, which peaked at ₹ 9204 per 100 kg in the domestic market and ₹ 9779 in Bangkok. The increase in price of rubber in 2006-07 over 2005-06 was by ₹ 2,505 and 2,347 per 100 kg in the domestic and Bangkok markets respectively. This confirmed that the scheme introduced in 2004-05 (Scheme on promotion of cultivation on fallow lands) was mostly instrumental in increasing the area only for two years, after which there was further decline in paddy area. This phase also saw the enactment of the Kerala Conservation of Paddy Land and Wetland, 2008 act in addition to the interest-free loans for projects based on fallow land cultivation targeting paddy. Farmers therefore, took advantage of these loans and revived paddy cultivation in their lands. This development could have reversed the uncontrolled loss of area under paddy in the state. The effect of this law was felt from the year 2009-10 and therefore, led to a change in the trend in paddy cultivation causing the breakpoint. The area under irrigated paddy went up during these two years while the land put to non-agricultural uses and current fallow decelerated. The land put to other fallow become stagnant and because of all these, the sustained decline in area sown more than once eased.

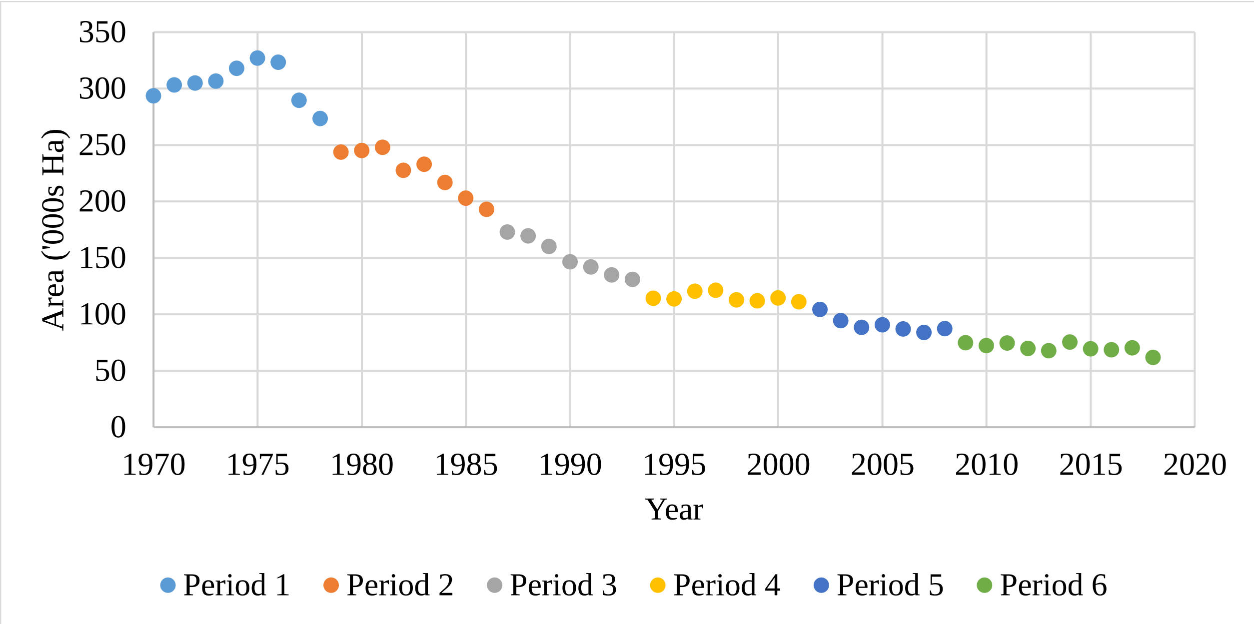
The last period was from 2010-11 to 2018-19 and showed a linear trend with an annual loss of 2,615.3 ha per year. The decline in area under paddy in this phase was -2.47 per cent per annum. This phase saw the intensification of the Rashtriya Krishi Vikas Yojana (RKVY), which since its launch in 2007, had its largest allocation of ₹ 287.32 Crore in 2014-15. This investment was an important initiative in the National Food Security Programme, which was instrumental in turn in ensuring that the area under paddy was not declining and at least stagnant at around 1,98,000 ha in the state in 2014-15. The gross irrigated area also reached its second highest point of 4,14,282 ha in 2014-15, second only to the year 2010-11.

4.1.2.2 Tapioca

Tapioca had five breakpoints in its area in Kerala and the optimal breakpoints were found be five, which were validated by a BIC of -77.3276, giving rise to six phases. According to Kannan and Pushpangadan (1990), tapioca was a main crop in Kerala till the sixties when its area started declining. It witnessed its first break in 1978-79 probably due to the increase in area in other states, mostly Tamil Nadu, and its influx into Kerala at cheaper prices. This phase (1970-71 to 1978-79) had a second-degree polynomial trend, with an annual growth rate of 0.16 per cent.

The second phase, 1979-80 to 1986-87, represented the first annual decline in growth rate under the area of tapioca represented by -3.91 per cent, with an annual loss of 7,799 hectares. The decline in area under tapioca was influenced by factors other than its own price, since the decline from 1978-79 to 1979-80 was despite the rise in the price of tapioca which increased from ₹ 29.16 per quintal to ₹ 39.96 per quintal. In the same period, the price of rubber increased from ₹ 885 per 100kg in 1978-79 to ₹ 1024 per 100kg in 1979-80. It thus follows that the

Figure 4: Breakpoints in area under tapioca in Kerala



impressive increase in the price of rubber could have made the farmers to reduce the area under other crops and increase the area under rubber. During the transition from the first phase to the second phase, the area under rubber increased by 23,354 ha, while the area under tapioca declined by 28,493 ha. This was an indication that the area lost by tapioca in Kerala was taken up by rubber and a host of other crops.

The third phase was from 1987-88 to 1993-94 and had the largest annual decline in area of -5.67 per cent for the area under tapioca. The break from the second phase was triggered by an increase in the price of tapioca output in the year 1987-88 from the previous year, an increase of ₹ 34.83 per quintal from ₹ 70.71 per quintal in 1986-87. This helped to reduce the decline in area under tapioca which stagnated till the year 1988-89. After the stagnation of price in 1988-89, it started to rise while the area continued to be stagnated. The price of rubber also continued to register impressive growth during the transition period and it rose from ₹ 1670 per 100 kg in 1986-87 to ₹ 1811 per 100kg in Kerala during 1988-89. However, the area under tapioca continued the downward spiral despite the rise in its price, which was an indication that other factors were influencing it other than its rising price.

The fourth phase was witnessed from 1994-95 to 2001-02 and this phase had exhibited a decline in area of -1.83 per cent, with a fifth-degree polynomial trend. This phase could have been triggered by a stagnation in the loss of area under tapioca in 1994-95 and 1995-96. The area increased after 1995-96 till 1997-98, when it again began to decline at a slower rate relative to decline experienced in the previous phases. The trigger on the slowdown in the decline and formation of this phase could have come from the increasing price of tapioca, which increased from ₹ 197.6 per quintal in 1993-94 to ₹ 217.13 in 1994-95.

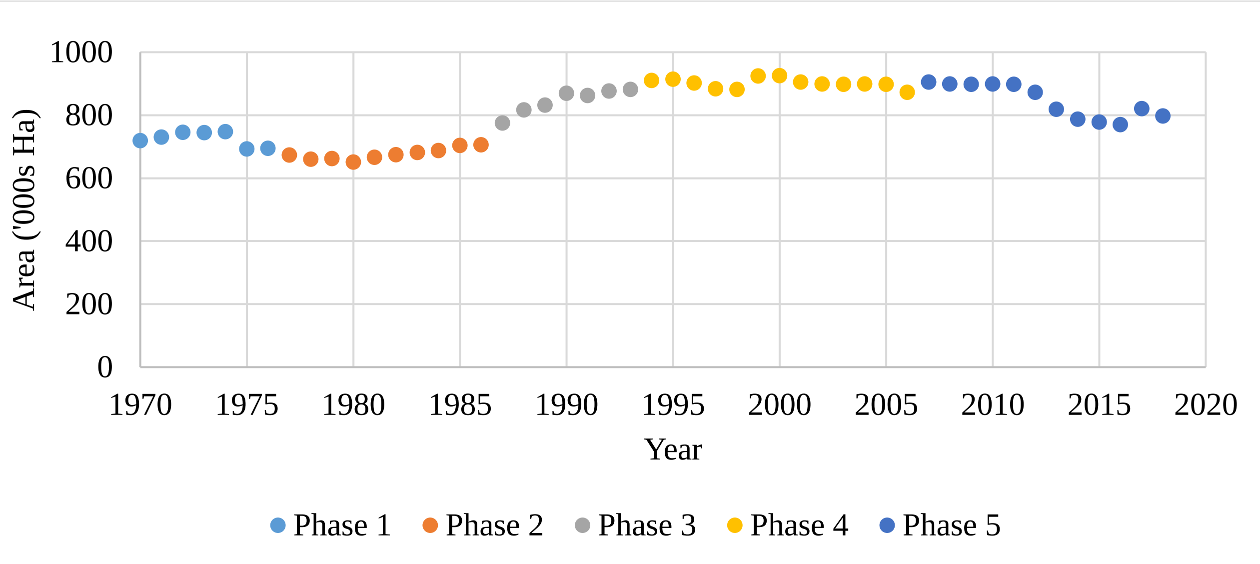
The fifth phase was from 2002-03 to 2008-09 and the start of the fifth phase came in 2002-03, one year after the sharp decline in price of tapioca. In 2000-01, the price of tapioca was ₹ 397.24 per quintal and it declined to ₹ 321.01 per quintal in 2001-02. This sharp decline in price in 2001-01 triggered another phase of decline in the area under tapioca. To separate the phases, the software correctly identified the year which ended the period of stagnation (2001-02) and the start of another decline in the area under tapioca (2002-03). Despite the rise in price in 2002-03 to ₹ 394.01, the area under tapioca continued to fall. This could be because when a volatility in price of a crop grown makes the farmer to shift to another crop, it may take some years of stable prices for the crop from which substitution was made, for the farmers to make a decision to return to the cultivation of the crop. This phase therefore, registered a decline in area of -3.81 per cent and the annual loss in area under tapioca was 2,599 ha.

The sixth phase was from 2009-10 to 2018-19 and was characterised by a sharp decline in area from 2008-09. This coincided with the period in which rubber exhibited the best rally in price, registering ₹ 10,112 per quintal in 2008-09, with a sustained increase in price which peaked out at an all-time high price of ₹ 20,805 per quintal in 2011-12. This impressive performance in the price of rubber caused the trend break in area under tapioca and led to a sustained decline in area, which only recovered in 2014-15 when the price of rubber started to decline continuously. This phase manifested a third-degree polynomial trend with a growth rate of -1.74 per cent.

4.1.2.3 Coconut

The area under coconut in Kerala had five breakpoints, with optimal four breakpoints that were validated by a BIC of -174.21. The first phase was from 1970-71 to 1976-77 And this phase had a polynomial trend with a declining growth rate of -0.7 per cent per annum. Most of the crops grown in the state witnessed decline in the area under those crops in 1976-77. This could be due to increase in input prices, decline in the output prices and increasing price of rubber, which were also the reasons for declining area under paddy. Coconut area started declining in 1976-77 possibly due to decline in coconut prices in the year as opposed to the increasing price of rubber. The second phase was from 1977-78 to 1986-87 and during this phase the area under coconut was mostly stagnant and a sharp increase in area was witnessed from 1987-88. The phase exhibited a second-degree polynomial trend with a growth rate of -0.01 per cent per annum. The price of coconut increased from ₹ 193.85 per 100 pieces in 1986-87 to ₹ 261.25 per 100 pieces in 1987-88 which came after the exorbitant rise in 1978-79

Figure 5: Breakpoints in area under coconut in Kerala



followed by a prolonged stagnation in prices till 1987-88. The rise in price in 1987-88 marked the beginning of increasing area under coconut and possibly could have caused the break in 1986-87. The third phase was from 1987-88 to 1993-94. The phase presented a 3.41 per cent growth in area under coconut and it showed a linear trend with an annual increase in area of 16,829 ha. This was the largest increase in area under coconut among all the phases. During this period, the price of rubber was marginally increasing and it could be inferred that the area under coconut was much influenced by its own price, which was increasing from the beginning of the phase in 1987-88. The area under irrigation for coconut increased sharply till the year1994-95. This good growth rate in area under coconut and gross irrigation of the crop slowed however by the year 1994-95 which witnessed another break.

The fourth phase was from 1994-95 to 2006-07 and in 1993-94, the price of coconut dropped to ₹ 325.55 per 100 pieces from ₹ 420.14 per 100 pieces in 1992-93, which further decreased in 1994-95 to ₹ 307.83 per 100 pieces and this could have made the farmers to forebode a bleak future for the crop and could have reduced planting of coconut seedlings and hence the break in 1993-94. This was intensified by the rising price of rubber which reached the highest pre-2000 price of ₹ 5059 per quintal in 1995-96. Thus, farmers reduced the establishment of new palms in their farms and hence, the low annual growth in area of coconut in Kerala in this phase. The phase had a sixth-degree polynomial trend with a 0.09 per cent annual growth rate.

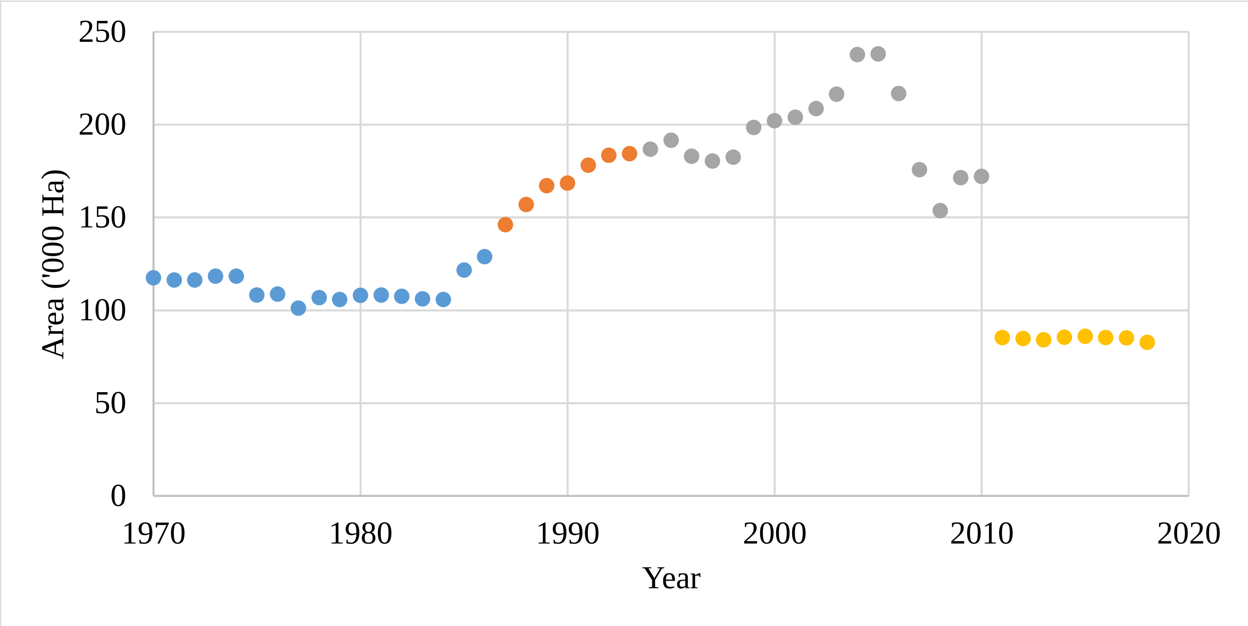
The fifth phase, 2007-08 to 2018-19, had a linear trend with an annual loss in area of 13,188 ha. This was the third time that the area under coconut was showing a decline in area after the first and second phases. The price of coconut was ₹ 635 per 100 pieces in 2004-05 and it declined to ₹ 494.89 per 100, followed by a further decline in 2006-07 to ₹ 473.36. In 2006-07, the price of rubber on the other hand increased to ₹ 9,204 per 100kg from ₹ 6699 in the domestic market. And it was one of the highest prices of rubber ever attained in that period. These developments in the coconut market and rubber could have made the coconut farmers to think of a bleak future for crop and hence reduce the area under coconut. Following the increase in price of rubber in 2006-07, the area under coconut started declining. Therefore, during this phase, the area under the crop was generally declining save for small increase in 2011-12 due to price rise during the year. The area under the crop continued to decline till the end of the phase at a negative annual growth rate of -0.83 per cent.

4.1.2.4 Black pepper

The optimal breakpoints for the area under black pepper for the period under study were found to be three and were confirmed by a BIC of -73.99. The first phase from 1970-71 to 1986-87 exhibited a third-degree polynomial trend with a declining growth rate of -0.37 per cent. The first break was triggered by a deceleration in price of black pepper which occurred in 1986-87. This was the first of the largest deceleration in the price, which till then had been on the rise within the phase. Though the actual decline did not happen within the phase, it seems that the farmers had already started feeling the price shocks due to declining growth rate in 1986-87 and hence started reducing the replanting and establishing new black pepper plants in their farms. The actual decline, happened two years later (1988-89) in the second phase when the price of black pepper reduced to ₹ 3547 per quintal from ₹ 5262 per quintal in 1987-88.

In the second phase from1987-88 to 1993-94, the area under black pepper had a growth rate of 6.14. This period presented a linear trend with an annual increase in area of 6,391 ha

Figure 6: Breakpoints in area under black pepper in Kerala

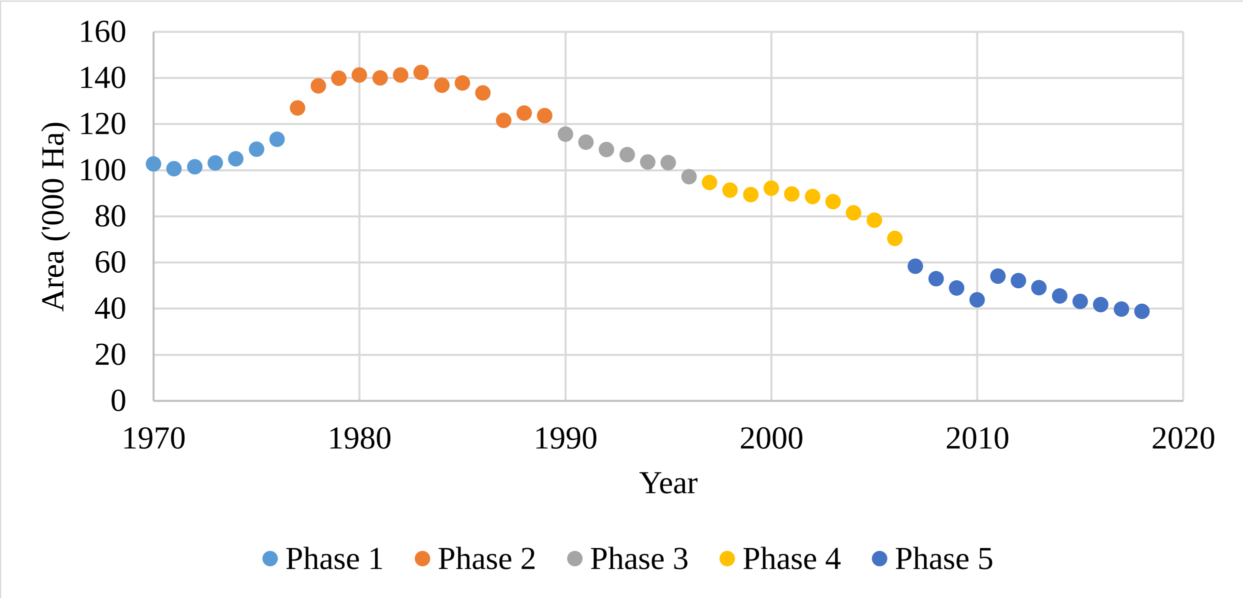


and was the highest annual growth rate in area. This phase started with a decline in price of black pepper, which recovered and continued its impressive increase and consequently, the area too increased as the farmers were able to realise more profitability with the increasing price of the crop. The prices however slowed down in 1993-94 as happened in 1986-87, before the actual decline happening three years later. The slowing down of the price prevented the farmers from establishing more area under the crop and hence, the break that gave rise to the third phase occurred. The third phase was from 1994-95 to 2010-11 and showed a growth rate of 0.26 per cent. This phase continued fluctuating till a sharp decline in 2010-11. The fourth phase from 2011-12 to 2017-18 registered an annual decrease of -7.72 per cent, which was the largest decline in area under black pepper.

4.1.2.5 Cashew

The trend break analysis on the cashew area identified four optimal breaks which were validated by a BIC of -66.86. The phases observed for area under cashew in Kerala were 1970-71 to 1976-77, 1977-78 to 1989-90, 1990-91 to 1996-97, 1997-98 to 2006-07 and 2007-08 to 2017-18. The first phase (1970-71 to 1976-77) showed a growth in area under cashew, with an annual increase in area of 1,859 ha at a growth rate of 1.82 per cent. However, in the second phase (1977-78 to 1989-90), the annual growth in area decreased in magnitude and it was the last positive annual rate of growth in area, which grew at the rate of 0.65 per cent. The end of this phase marked the end of growth in area and from 1990-91, the area started declining

Figure 7: Breakpoints in area under cashew in Kerala



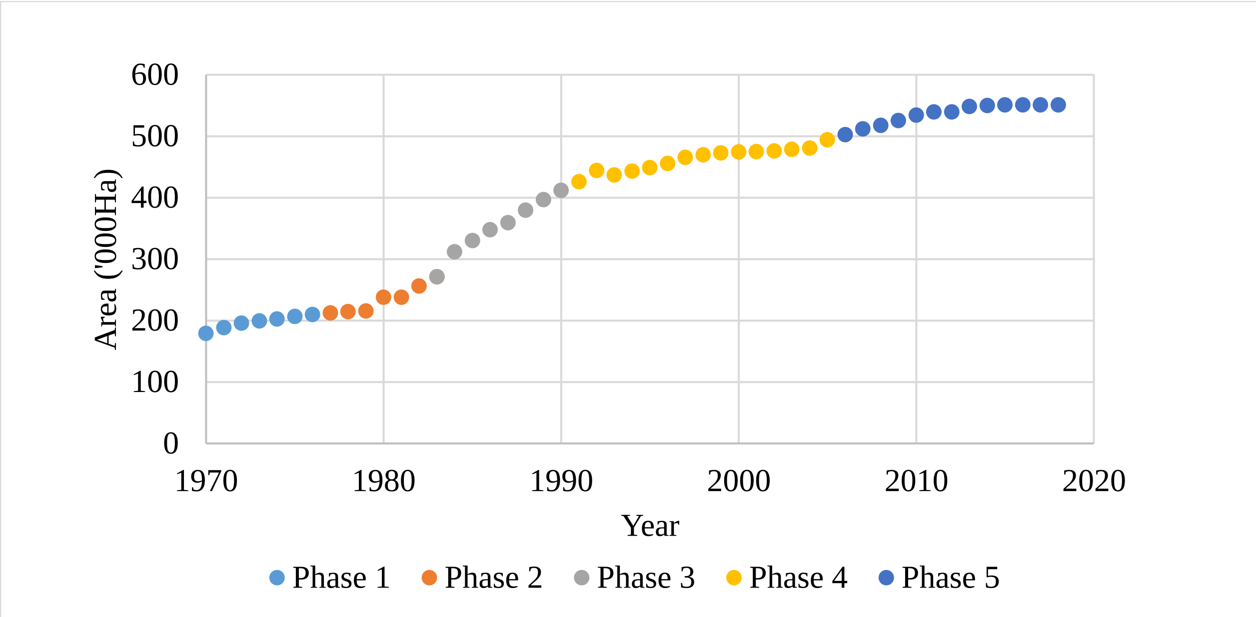
unabated, despite the rise in prices. The third phase (1990-91 to 1996-97) showed a decline in area for the first time at rate of -2.86 per cent and registering an annual decline of 2,807 ha per annum.

The fourth phase (1997-98 to 2006-07) could have been triggered by the high price of cashew in 1997-98. The price of cashew reached its first peak and despite this, the crop continued to decline, however at a reduced pace relative to the third phase. This phase witnessed a growth rate of -2.74 per cent, with annual loss in area of 2223 ha. The fifth phase (2007-08 to 2017-18) was the beginning of another sharp decline in the area under cashew. This was despite increase in the price of the crop and this phase had the largest decline in area under paddy in the whole period under study at -4.39 per cent, with a fourth-degree polynomial trend.

4.1.2.6 Rubber

The analysis of trend breaks in area under rubber in Kerala during the period from 1970-71 to 2018-19 validated four breakpoints with a BIC of -99.98. The phases realised from these breakpoints were 1970-71 to 1976-77, 1977-78 to 1983-84, 1984-85 to 1990-91, 1991-92 to 2006-07 and 2007-08 to 2018-19. Rubber generally had impressive growth in its area all through its growth phases in the entire study period. The first phase (1970-71 to 1976-77) realised a growth of 2.31 percent with 4,794 ha annual increase in area. The first break could have been triggered by a decline in price of rubber which had been increasing from 1970-71. In 1976-77, the price declined to ₹ 620 per 100 kg from ₹ 792 per 100 kg in 1975-76. This decline in price could have affected the pace of establishment of new plantations by the farmers and this phase also represented the less rapid rise in area under the crop. The growth in area under rubber improved further to 3.06 per cent in the second phase (1977-78 to 1983-84), which

Figure 8: Breakpoints in area under rubber in Kerala



marked the beginning of an impressive rise in price of rubber. Due to this, area under rubber was on a sustained rise at the expense of the area under other crops and this phase presented an annual increase of 10,101 ha.

The growth in area under rubber continued to improve into the third phase (1984-85 to 1990-91), with an annual increase of 18,628 ha per year at growth rate of 6.33 per cent per annum, which was an increase from the second phase. The growth in area in this phase could have been triggered by a further increase in price of rubber from ₹ 1,473 per quintal in 1982-83 to ₹ 1,672 per quintal in 1983-84. This development of rising prices could have made more farmers to increase area under the crop. Thus, this was the fast-paced phase of increase in area under rubber supported by the substantial increase in price of the crop. The fourth phase (1991-92 to 2006-07) could have been triggered by the increased import of synthetic and natural rubber which increased considerably since 1990-91. The import of synthetic rubber to India in 1990-91 was 51,715 MT which increased further in the subsequent years and so did the imported natural rubber. This led to stagnation in the price of domestic market price (RRS-4), adversely affecting the establishment of new plantations and the phase's annual growth in area reduced drastically in magnitude in comparison to the third phase. The growth was 0.72 per cent with a linear annual increase of 4,144 ha. Thus, this phase was hampered by the opening of the economy in connection with the trade liberalisation policies of 1991.

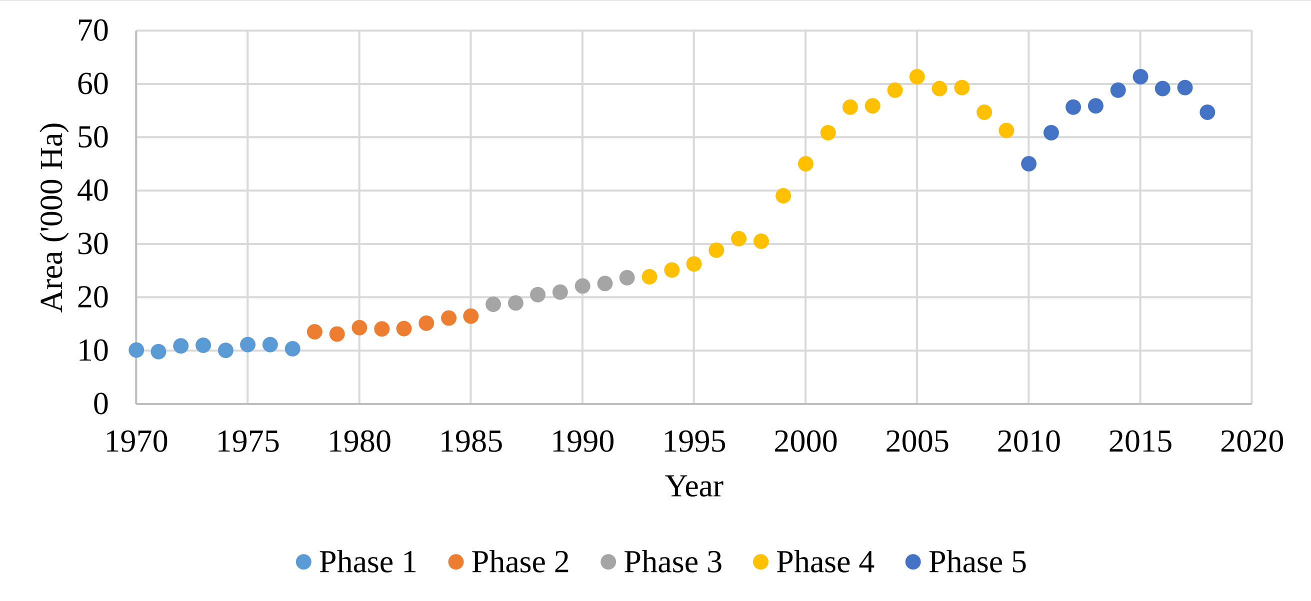
The fifth phase (2007-08 to 2018-19) showed an improved growth from the fourth phase and it also registered the largest growth in price of the crop which triggered the break point as the price of rubber kept rising from 2007-08. However, the rise was not long lived and the price started declining. The declining price of rubber was compounded by shortage of rubber tappers and consequently, the productivity also declined. Because of all these factors, the annual growth in area under the crop was only 1.02 per cent. Despite the recent constraints in the cultivation of rubber, studies have shown that the crop had a spectacular growth in area mainly driven by effective research and development, extension support, marketing support and promotion of the high yielding local clone (RRII 105) with the support of the Rubber Board.

4.1.2.7 Banana

The area under banana showed four optimal breakpoints out of possible five breakpoints. The five phases realised from these breakpoints were 1970-71 to 1977-78, 1978-79 to 1985-86, 1987-88 to 1992-93, 1993-94 to 2009-10 and 2010-11 to 2018-19. The first phase (1970-71 to 1977-78) exhibited a growth rate of -1.06 per cent. During this phase the area under banana was mostly declining or stagnant. However, in the second phase (1978-79 to 1985-86) there was an improvement in the growth of area under banana. This phase area showed a growth rate of 0.1 per cent with its linear trend showing an annual increase of 458 ha.

There was further improvement in area under banana during the third phase (1987-88 to 1992-93), with an annual growth rate of 2.8 per cent. This represented the biggest annual growth rate in area under banana in the period under the study and the growth in this phase was uniform throughout the phase. The end of this phase was marked by an increase of ₹ 13.12 per quintal in the price of banana during the year 1992-93 to ₹ 93.89 per quintal. This resulted in another break since more farmers put their land into banana cultivation as the price of the crop got even better in 1993-94 (₹ 108.56). The fourth phase (1993-94 to 2009-10) saw a decline in area under banana with a negative growth rate of -3.16 per cent despite an increase in price

Figure 9: Breakpoints in area under banana in Kerala

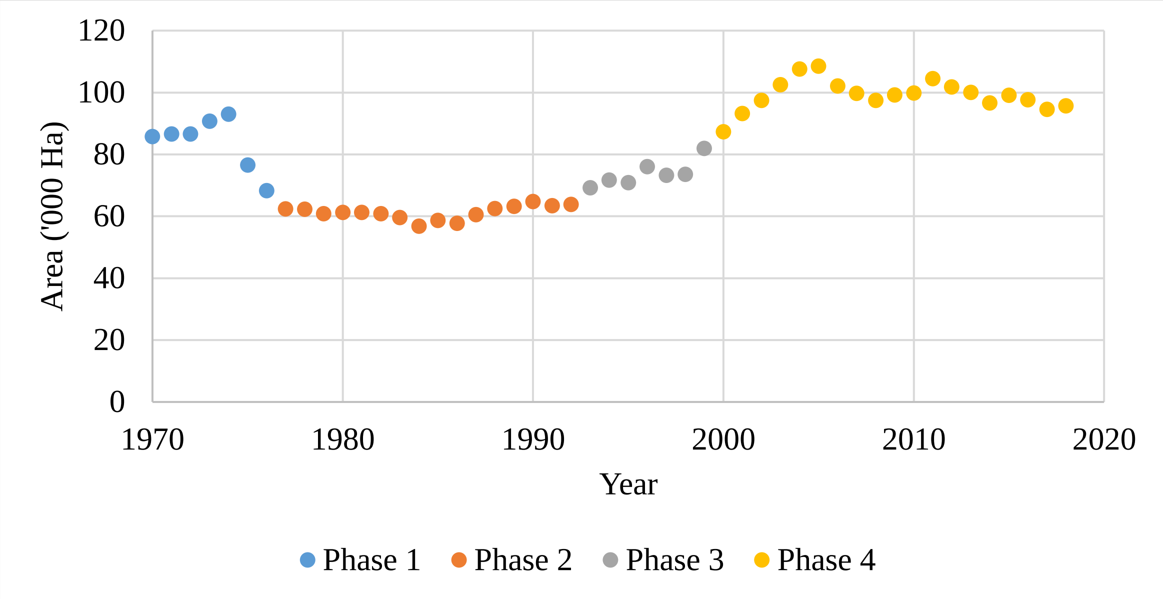


The fifth phase (2010-11 to 2018-19) once again had an improvement from the fourth phase with a growth rate of 0.9 per cent when the price of banana reached more than ₹ 2000 per quintal in 2010-11. This price increase could have encouraged more farmers to put their farms into the cultivation of the crop as the price improved over the years and by the year 2018-19, the average price of the crop was ₹ 4,017. From the start of the phase in 2010-11 to 2018-19, the price of the crop almost doubled and thereby encouraged more farmers to increase the area allocated for the crop.

4.1.2.8 Arecanut

The area under arecanut displayed five breakpoints from the analysis and the optimal breakpoints were found to be three with a BIC of -112.36. The phases realised from these breakpoints were 1970-71 to 1976-77, 1977-78 to 1992-93, 1993-94 to 1999-00 and 2000-01 to 2018-19. The first phase (1970-71 to 1976-77) recorded a declining growth in area under arecanut (-1.83%). This break was in line with other crops which experienced the first break in area under those crops because of the increasing rubber prices. This could have led to the break, which was followed by a period of stagnation in the second phase (1977-78 to 1992-93) during which the area under arecanut saw a slight deceleration in decline in area and this phase marked the first increase in area under arecanut, despite recording a slight negative growth rate (-0.65%). In 1991-92, the price of arecanut increased to ₹ 31.48 per 100 pieces from ₹ 11.89 per 100 pieces in 1989-90, which led to the break in area of the crop in 1992-93 when the price further increased to ₹ 33.01 per 100 pieces. This indicated that due to the increase in price of

Figure 10: Breakpoints in area under arecanut in Kerala



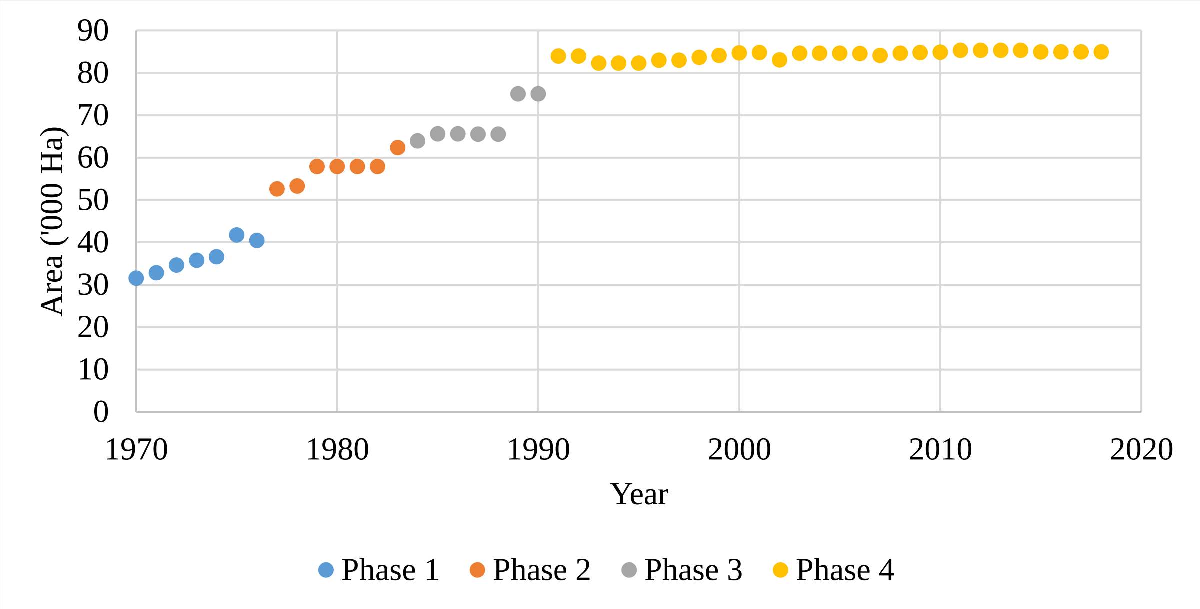
arecanut, more farmers were attracted to the cultivation of it and started increasing area under the crop.

Because of the price increase from 1991-92, the increase in area under arecanut became more evident in the third phase (1993-94 to 1999-00), which recorded the largest increase in growth among all the phases during the period of study. The growth in this phase was 2.54 per cent and the price of the crop continued to rise during this phase and peaked in 1999-00 at ₹ 75.25 per 100 pieces. This was the highest price ever witnessed for the crop and because of this impressive increase in price, there was a spike in area being brought under the cultivation of arecanut from 1999-00, which gave rise to the subsequent phase. The area under irrigated arecanut also increased from 26,798 ha in 1998-99 to 32,115 ha in 1999-00. The fourth phase (2000-01 to 2018-19) for area under arecanut continued with the positive rate of growth in area, recording 0.71 per cent growth per annum, which was represented by a fourth-degree polynomial trend. During this phase, the area under the crop peaked at 1,08,590 ha in 2006-07 which coincided with the increase in price to ₹. 52.17 per 100 pieces in 2006-07. This rise in prices was preceded by a drop and slight rise after the peak price of 1999-00. Therefore, the rise in price in 2006-07 again gave farmers the hope of getting remunerative prices and hence resulted in increased allocation of area under the crop. Despite later improvements in the price of the crop, the annual increase in area was largely stagnant in the phase.

4.1.2.9 Coffee

Five breakpoints were identified from the trend break analysis of area under coffee in Kerala

Figure 11: Breakpoints in area under coffee in Kerala

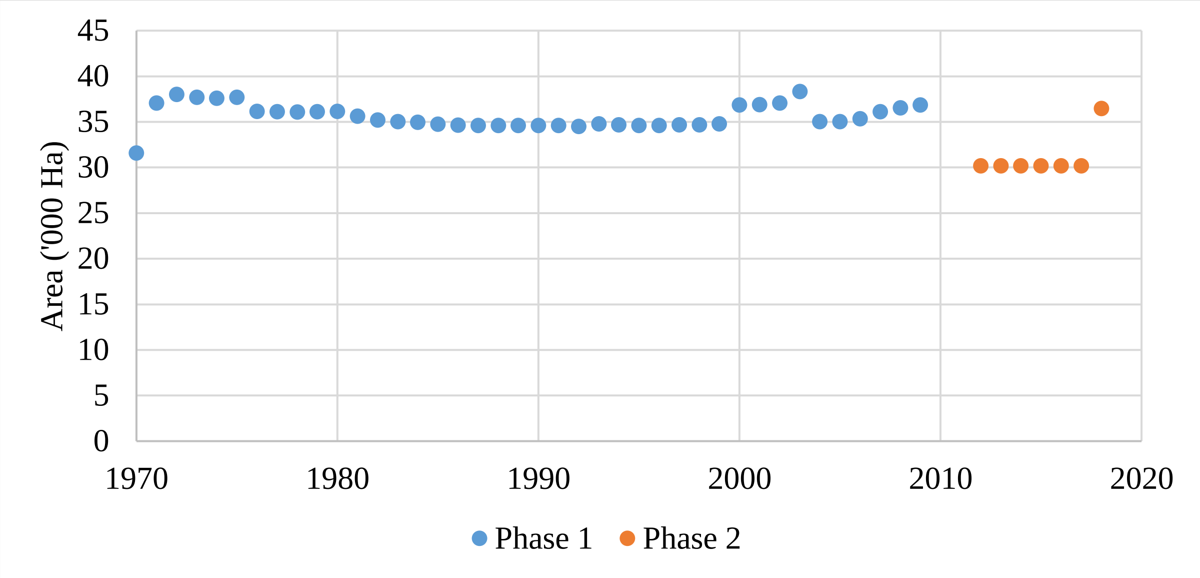


and out of these, three significant breakpoints were confirmed with a BIC of -126.34. The four phases in the area under coffee were therefore found to be 1970-71 to 1976-77, 1977-78 to 1983-84, 1984-85 to 1990-91 and 1991-92 to 2018-19. The first phase (1970-71 to 1976-77) recorded a growth rate of 4.76 per cent with a linear increment of 1,665 ha per year. The second phase (1977-78 to 1983-84) registered a further improvement in area under coffee with a 5.69 per cent growth. The growth of 2.39 per cent registered in the third phase (1984-85 to 1990-91) was a sign of slowdown in the growth of area under coffee. The fourth phase (1991-92 to 2018-19) remained largely constant, still recording a meagre growth of 0.27 per cent. Therefore, the growth in area under coffee was positive in the period under study.

4.1.2.10 Tea

The trend break analysis of the area under tea showed five breakpoints And BIC of -155.16 validated one optimal breakpoint. The area under tea had remained largely consistent throughout the period and the breakpoint in tea area emerged in 2011-12. The phases therefore were 1970-71 to 2011-12 and 2012-13 to 2018-19. The first phase had -0.02 per cent decline in area, while it declined further down to -1.29 per cent in the second phase.

Figure 12: Breakpoints in area under tea in Kerala

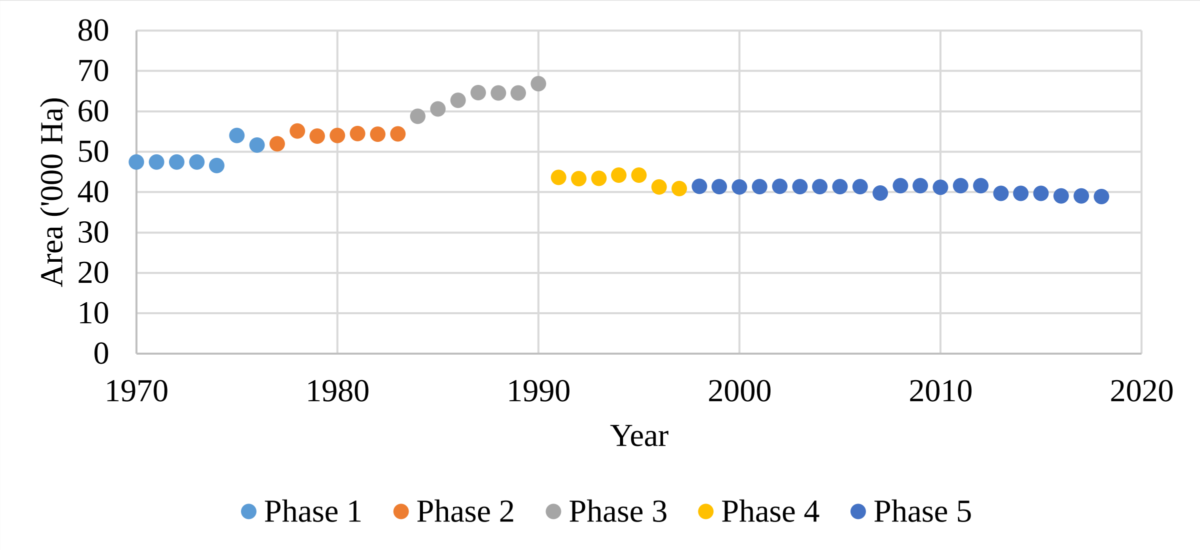


This decline in area under tea in the second phase could be attributed to the decline in price of the crop which in turn affected the profitability and the area declined.

4.1.2.11 Small cardamom

Five breakpoints were obtained for the area under small cardamom in Kerala, with four being the optimal at a BIC of -158.73. The first phase (1970-71 to 1976-77) showed a 1.53 per cent growth, while the second phase (1977-78 to 1983-84) showed a relatively lower growth rate of 0.87 per cent. The third phase (1984-85 to 1990-91) had a growth rate of 2.81 per cent, which was the largest growth in the area under small cardamom. However, in the subsequent phases, there was a setback in the growth rate of area under small cardamom. The fourth (1991-92 to 1997-98) and fifth phases (1998-99 to 2018-19) registered negative growth rates in area. The fourth phase represented the largest negative growth rate of -5.81 per cent of area under small cardamom in the period under study. The decline in growth rate in the fifth phase was not to the magnitude of the fourth phase.

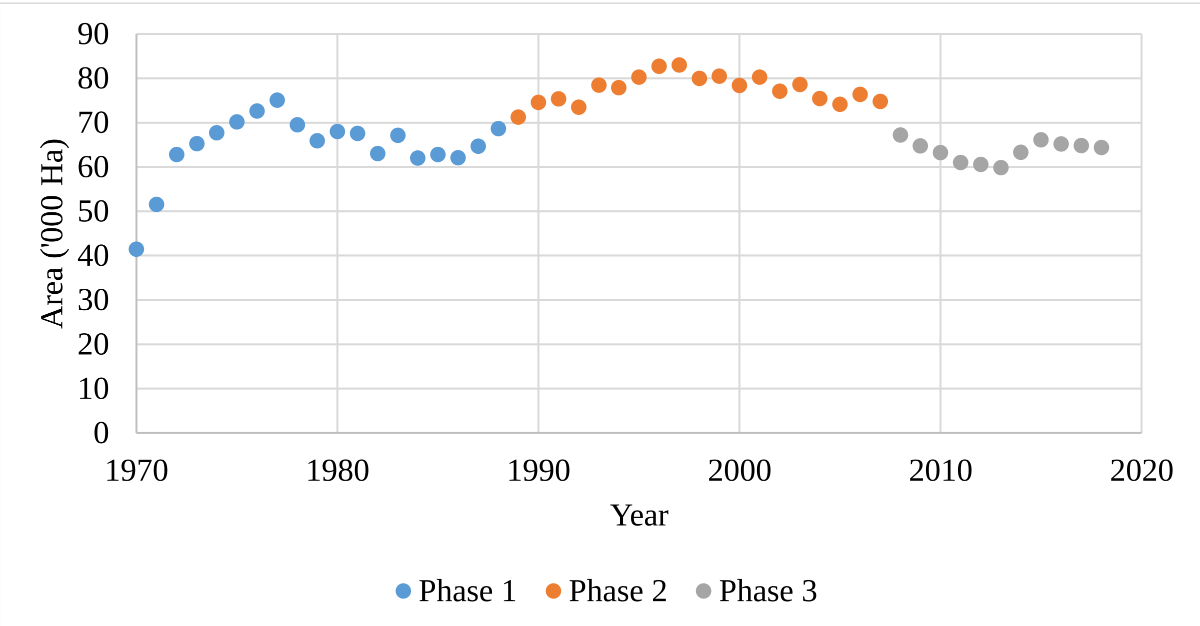
Figure 13: Breakpoints in area under small cardamom in Kerala



4.1.2.12 Vegetables

The area under vegetables was the summation of area under bitter gourd, Amaranthus, ladies-finger, drumstick, snake gourd, tomato, brinjal, ash gourd, cabbage, green chillies, bottle gourd, cowpea, potato, carrot, beetroot, pumpkin, little gourd, cauliflower, beans, onions and

Figure 14: Breakpoints in area under vegetables in Kerala

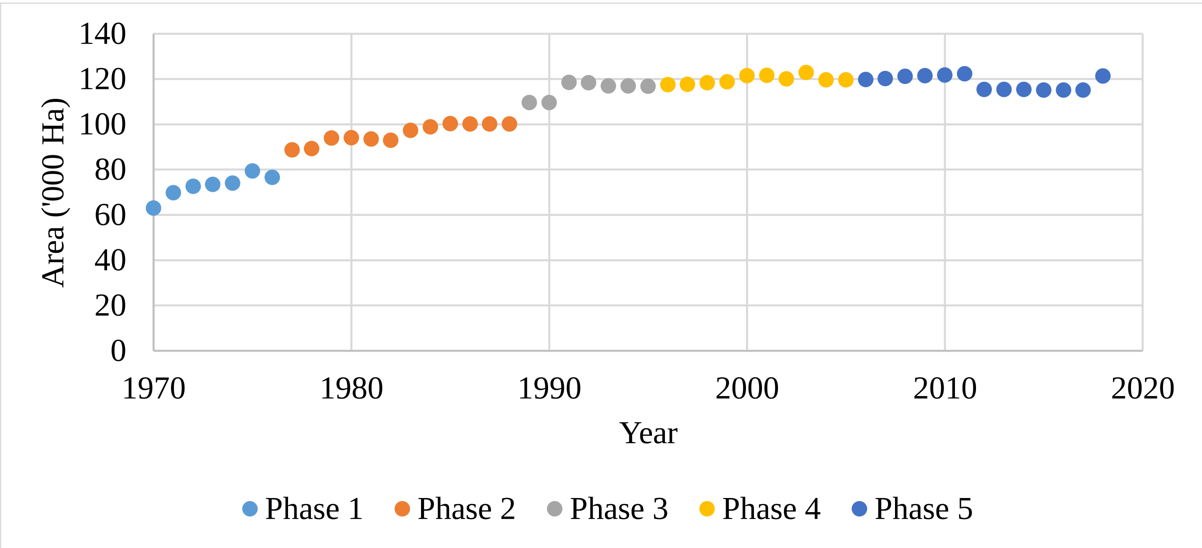


cucumber. The area under vegetables resulted in two optimal breakpoints. The phases realised from these break points were 1970-71 to 1988-89, 1989-90 to 2007-08 and 2008-09 to 2018-19. The area under vegetables in Kerala was generally increasing during the study period with positive annual growth rates in the first two phases and negative annual growth rate in the last phase. The first phase (1970-71 to 1988-89) of area under vegetables had a significant increase in area, recording 0.19 per cent growth rate. There was further increase in area under vegetables in the second phase (1989-90 to 2007-08) which was 0.4 per cent per annum. The third phase (2008-09 to 2018-19) saw a decline of -0.7 per cent in the annual growth rate. Despite the decline in annual growth rate in the last phase, irrigated area under vegetables continued to increase from 19,238 ha in 2008-09 to 30,111.69 ha in 2018-19.

4.1.2.13 Fruits

The area under fruits resulted in four optimum breakpoints, leading to five phases. The area under fruits is the total of all the fruits, excluding the area under mango and, banana and other plantains. The first two phases (1970-71 to 1976-77 and 1977-80 to 1988-89) of area under fruits in Kerala registered negative growth, while the remaining three showed increasing area under fruits. The first and second phases registered -0.46 per cent and -0.1 per cent rates

Figure 15: Breakpoints in area under fruits in Kerala

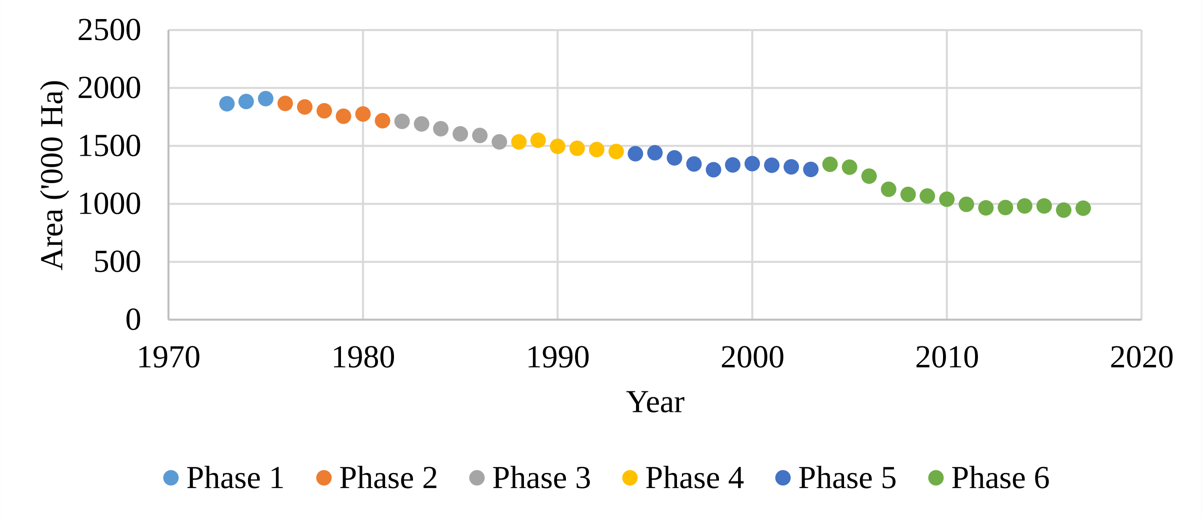


of growth respectively. The third phase (1989-90 to 1995-96) showed an improvement from the second phase, with a growth rate of 1.98 per cent. The fourth phase (1996-97 to 2005-06) had a lower growth rate than the third (1.15%), while there was relative improvement in the fifth phase. The fifth phase (2006-07 to 2018-19) showed a growth rate of 1.15 per cent.

4.1.2.14 Food crops

The area under food crops is the summation of all the food crops grown in Kerala. This consist of cereals, spices, fruits, tubers and vegetables. The volatility in area under food crops was therefore a reflection of the trends in the various groups of crops that individually the crops belonged to. The area had six phases from five optimal breakpoints. The data on food crops was available from 1973-74 hence the first phase was from 1973-74 to 1975-76. The other

Figure 16: Breakpoints in area under food crops in Kerala



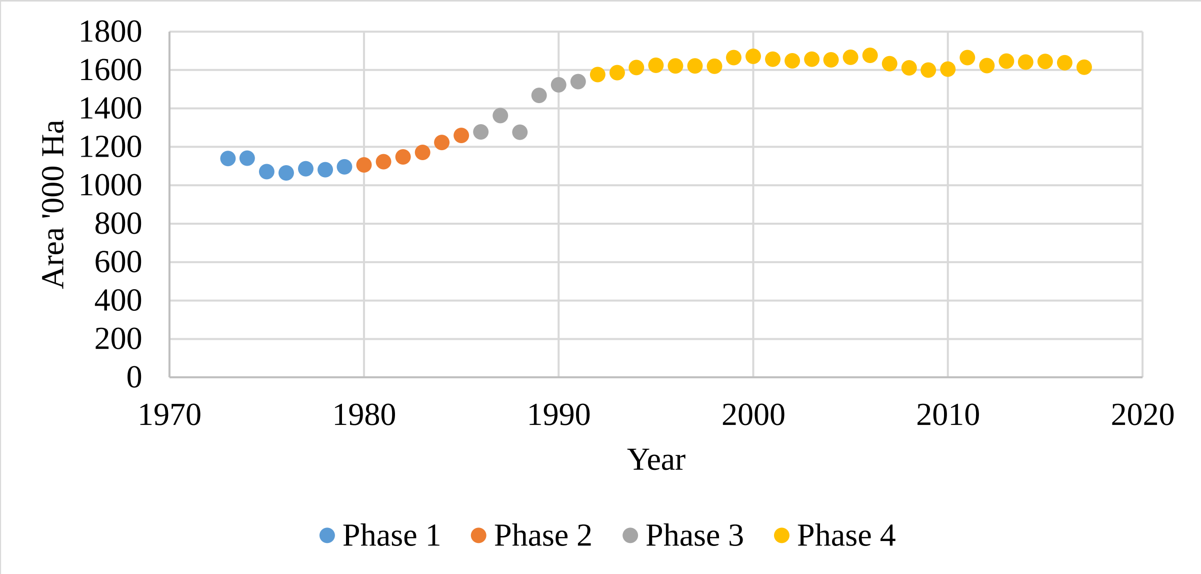
phases were 1976-77 to 1981-82, 1982-83 to 1987-88, 1988-89 to 1993-94, 1994-95 to 2003-04 and 2004-05 to 2017-18. Initially the area under food crops exhibited a growing trend, but afterwards showed a sustained downward spiral. It should be noted that some of the crops listed under the food crops increased in area. However, since some of the crops like paddy and tapioca which contributed larger share in area under food crops, the trend in area of crops other than paddy and tapioca had little significance on the trend in area under food crops. Thus, the first phase (1973-74 to 1975-76) registered a growth rate of 1.19 per cent.

The second phase (1976-77 to 1981-82) marked the beginning of the negative growth with a growth rate of -1.54 per cent. The third phase (1982-83 to 1987-88) witnessed a further decline in growth rate (-2.14%). The decline eased relatively in the fourth (1988-89 to 1993-94) and fifth phases (1994-95 to 2003-04) to -1.27 and -1.03 per cent respectively. The intensification of the decline in area under food crops in the sixth phase (2004-05 to 2017-18) was shown by a growth rate of -2.59 per cent and it was the lowest growth rate that was experienced in the area under food crops.

4.1.2.15 Non-food crops

Plantation crops mostly accounted for the area under non-food crops in Kerala. The trend break analysis of the area showed four phases: 1973-74 to 1979-80, 1980-81 to 1985-86, 1986-87 to 1991-92 and 1992-93 to 2017-18. The area under non-food crops in contrast to the

Figure 17: Breakpoints in area under non-food crops in Kerala



area under food crops declined in the initial phase and then interestingly had the opposite trend as the food crops, while food annual growth was negative, it was positive in this. The first phase (1973-74 to 1979-80) registered a decline of -0.75 per cent, while an improvement was observed in the second phase (1980-81 to 1985-86), which recorded a growth rate of 2.68 per cent. The third phase (1986-87 to 1991-92) showed a significantly growing trend in area of 4.09 per cent per annum, which represented the largest growth in the series. In the fourth phase (1992-93 to 2017-18), the area under non-food crops remained mostly constant. The fourth phase registered a higher growth albeit a lower one (0.05 per cent) in comparison to the third phase.

4.1.2 Drivers of agricultural growth

The analyses of growth rates of area, production and productivity of crops revealed a mixed pattern of trend in different growth phases of agriculture in Kerala from 1970-71 to 2018-19. These trends, some unique to specific crops, as discussed under the trend break analysis were caused by a varied number of factors occurring over the study period. Some of the factors were because of spill over effects affecting more than one crop and, in most instances, the factor like rainfall was a major determinant in the production and productivity of all the crops.

The results of the SUR model for estimating the factors affecting the agricultural GSVA in Kerala are presented in Table 4.10.

Table 4.10: Estimates of SUR Model for estimating drivers of agricultural growth

	Variable	Coefficient	Std. Err.	z-Stat
Equation 1: GDPA = C (1) + C (2) × GFCFGCA + C (3) × FERT + C (4) × RAINFALL + C (5) × TOT + C (6) × GCAIR + C (7) × HVC + C (8) × PERIOD				
C (1)	Intercept of GDPA	1.598***	6.204	0.26
C (2)	GFCFGCA	0.046***	0.033	1.38
C (3)	Fertiliser	0.240***	0.085	2.81
C (4)	Rainfall	0.105	0.211	0.5
C (5)	Terms of Trade	-0.443***	0.147	-3.02
C (6)	GCAIR	0.753***	0.246	3.06
C (7)	High value crops	0.396**	0.398	0.99
C (8)	Period	0.030	0.048	0.61
Adjusted R Square:	0.867		RMSE:	0.062
Equation 2: GCAIR = C (9) + C (10) × DEVTGCA + C (11) ×CROPINT				
C (9)	Intercept of GCAIR	-2.763***	2.519	-1.1
C (10)	DEVTGCA	0.128***	0.016	8.24
C (11)	Cropping intensity	0.918***	0.496	1.85
Adjusted R Square:	0.797		RMSE: 0.054	
Equation 3: FERT = C (12) + C (13) × FERTPRICE + C (14) × DEVTGCA + C (15) × CREDGCA + C (16) × WAGE				
C (12)	Intercept of fertiliser	3.406***	0.852	4.00
C (13)	Fertiliser price	-0.199***	0.139	-1.44
C (14)	DEVTGCA	0.325***	0.102	3.19
C (15)	CREDGCA	0.162***	0.062	2.62
C (16)	Wage	-0.300	0.209	-1.43
Adjusted R Square:		0.631	RMSE:	0.121
Equation 4: GFCFGCA = C (17) + C (18) × TOT + C (19) × CREDGCA				
C (17)	Intercept of GFCFGCA	-3.009	3.246	-0.93
C (18)	Terms of Trade (-1)	1.332***	0.743	1.79
C (19)	CREDGCA	0.605***	0.094	6.45
Adjusted R Square:		0.697	RMSE:	0.523

Note: 1. ** denotes significance at five per cent level
2. *** denotes significance at one per cent level

The model confirmed that over the years, the agriculture GSVA had been increasing and was positive. It also revealed that the largest contributor to agricultural GSVA was gross cropped area irrigated. This meant that for every additional hectare of land brought to irrigation every year, it contributed 75.3 per cent of value of the crop added to the per capita income in agriculture. The area under high value crops was also found to be significant and positively influencing GSVA from agriculture at 39.6 per cent of value realised from crops to the agricultural per capita income and this was a confirmation that increased cultivation of high value crops was key to growth in per capita earnings from agriculture in Kerala State. The fertiliser consumption was also found to be important in improving the earning realised from agriculture. Use of fertiliser improved the value of crops to the agriculture per capita income by 24 per cent while rainfall improved the earnings by 10.5 per cent. While gross fixed capital formation was positive, its contribution to the rise in per capita earnings in agriculture was low at 4.6 per cent, which could have been because of the reason that the data on gross fixed capital formation used in the computation of this model was for all the industries in the state. The terms of trade was inversely proportional to the per capita earnings from agriculture. This meant that the terms of trade was not in favour of agriculture GSVA but was favouring GSVA from non-agriculture. The estimates of the gross fixed capital formation and terms of trade in this model therefore, follows the trend followed by GSDP from agriculture, the share of which in total GSDP of the state was declining.

The gross area irrigated was found to be significantly influenced by the development expenditure and cropping intensity. The increased significance of cropping intensity in the model was straightforward in the sense that with more land brought into repeated cultivation annually, more irrigation potential and irrigation frequency were necessary. In most instances, the Kerala Government (GoK) bears the cost of energy used in operation of the irrigation systems. Thus, the development expenditure by the GoK was significantly one of the determinants of area irrigated in total area cropped. Increase in cropping intensity and development expenditure will therefore lead to more earnings in the agricultural sector by increasing the total area irrigated, which in turn will favour agricultural income growth as demonstrated in the first equation of the model.

The fertiliser consumption was found to be majorly affected by the development expenditure. From the model, it was found out that more development expenditure in the agricultural as well as primary sector leads to more fertiliser consumption per hectare. This could be taken in the context of utilising the development expenditure on subsidising the fertiliser prices, which in turn makes them cheaper and hence the farmers could purchase and apply balanced dose of fertilisers. The reduction in price by increasing the ability of the farmers not only to buy more fertilisers but also ensured optimal usage of fertiliser by the farmers. Fertiliser consumption was found to be inversely proportional to its price. Therefore, for every increase in price per kg of fertiliser in Rupees, the consumption of fertilisers decreased. The institutional credit was also found to be a major driver for encouraging fertiliser consumption among the farmers. The access to credit is one of the important requirements in farming as it helps farmers to acquire the needed inputs for timely planting and management activities. Therefore, it followed that with increased access to credit facilities, the farmers were able to purchase enough fertilisers for application in the farms. Thus, every Rupee lent to the farmers led to an improvement in the fertiliser consumption by 16 per cent. The fertiliser prices were found to affect the negatively earnings realised from the agricultural sector, while development expenditure and institutional credit were instrumental in improving the agriculture GSVA. The wages despite being negative was found to be non-significant.

The gross fixed capital formation was found to be significantly explained by the terms of trade. As discussed earlier, terms of trade was found to be in favour of GSVA from non-agriculture and the gross fixed capital formation was majorly in sectors other than the primary sector. This model therefore, in the last equation, confirms that the terms of trade was in favour of GSVA from non-agriculture and hence promotes capital formation in sectors other than the primary sector. Institutional credit to agriculture was also found to be contributing significantly to the gross capital formation in agriculture. By getting access to liquid assets through the institutional credit facilities, the farmers and other stakeholders in agriculture were able to invest on more capital goods and assets. These assets could help in improving the productivity when used in the production process and thereby ensure more output and ultimately, more income. Thus, each per rupee credit lent to agriculture led to 60.5 per cent increase in gross fixed capital formation, which in turn leads to 4.6 per cent increase in per capita agricultural income.

4.2 Inter-district disparities of agriculture in Kerala

This objective was undertaken to understand the variations among the districts of Kerala in area, production and productivity of select crops and their contributing factors. For working out this objective, the CAGRs, Cuddy-Della Valle instability indices (CDVI), Herfindahl Index, Entropy Index and panel data models were used. The study under this objective was conducted for the period from 1985-86 to 2017-18.

4.2.1 Inter-district variations in area, production and productivity of principal crops

To analyse the trends in area and productivity of principal crops, natural logarithms of the values were taken to smoothen the variations in the data and extreme differences among the districts in area under the crops. The data was then transformed into panel data in Stata. This section discusses the trends in area, production and productivity in the districts of Kerala state, together with pictorial representation in the trend of respective area and productivity of crops in the districts from Appendix XII to Appendix XXXII.

4.2.1.1 District-wise trend in area, production and productivity of paddy

The area under paddy exhibited declining annual growth rates in all the districts of Kerala. The decline was observed to be of greater extent in Kollam (-10.92%), Ernakulam (-9.71%) and Thiruvananthapuram (-9.36%). The increased decline in area under paddy in some districts meant that the districts were having more chances for shifting to other crops or land uses, while those districts like Alappuzha had less options for transformation to other crops, since paddy was the most suitable crop for areas like Kutanad and Kole wetlands in Thrissur. Consequently, Alappuzha, Palakkad, Kottayam, Wayanad and Thrissur experienced the lowest decline in area under paddy compared to other districts. The largest instability of 24.41 per cent for area under paddy was also observed for Thiruvananthapuram, while Palakkad had the lowest instability in area (10%).

All districts registered negative annual growth rates in production. However, due to high decline in area under paddy in Kollam, Ernakulam and Thiruvananthapuram, production was affected and the districts had the highest annual decline of -10.18 per cent, -8.69 per cent and -7.93 per cent respectively in the production of the crop. The districts that had comparatively lower decline in area under paddy like Alappuzha (-1.21%), Kottayam (-1.21%), Palakkad (-1.47%), Wayanad (-2.41%) and Thrissur (-2.71%) consequently had the lowest decline in production of paddy. The highest instability in production of 25.84 per cent and 24.25 per cent were observed in Kottayam and Pathanamthitta respectively. The lowest instability was found in Kannur, which had a CDVI of 10.61 per cent.

The largest annual growth rate in the yield of paddy was observed for Thrissur, while Kollam which had the largest decline in area under paddy had the lowest growth rate in yield.

Table 4.11: Growth and instability in district-wise area, production and productivity of Paddy in Kerala

Districts	Area		Production		Productivity	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Thiruvananthapuram	-9.36	24.41	-7.93	20.09	1.57	7.42
Kollam	-10.92	16.87	-10.18	16.80	0.84	7.24
Pathanamthitta	-6.70	20.83	-5.70	24.25	1.07	9.61
Alappuzha	-2.17	16.66	-0.86	17.02	1.33	12.29
Kottayam	-2.34	23.54	-1.21	24.84	1.15	6.69
Idukki	-6.56	17.37	-5.77	17.83	0.84	5.48
Ernakulam	-9.71	11.67	-8.69	11.68	1.13	4.30
Thrissur	-4.93	16.11	-2.71	12.61	2.33	5.52
Palakkad	-2.31	10.00	-1.47	11.02	0.86	13.61
Malappuram	-7.59	20.41	-5.61	16.54	2.14	5.59
Kozhikode	-6.37	22.11	-5.58	18.39	0.84	6.08
Wayanad	-3.54	14.34	-2.41	13.65	1.17	4.95
Kannur	-5.44	13.08	-4.15	10.61	1.36	4.66
Kasaragod	-6.29	19.09	-5.12	12.63	1.25	5.03

Note: All values are significant at 1 per cent

Interestingly, Thiruvananthapuram, which had one of the largest declines in area and production, registered the third best annual growth rate in productivity of paddy of 1.57 per cent, behind Thrissur (2.33%) and Malappuram (2.14%), was better than Alappuzha which registered lowest decline in production. This could be explained by the fact that the rise in yield of paddy could be due to the loss of marginal lands, as already reported by some studies. This could be true in the case of Thiruvananthapuram which showed very large decline in area under the crop. The highest mean yield in paddy were found to be in Pathanamthitta and Kottayam at 2.54 tonnes per hectare and 2.5 tonnes per hectare respectively. Kozhikode had the lowest mean productivity of 1.31 tonnes per hectare among all the districts in the state. While the State's average yield of paddy was 2.14 tonnes per hectare for the 33 years of the study, it was found that Thiruvananthapuram, Kollam, Kasaragod, Malappuram, Ernakulam, Kannur and Kozhikode had mean productivity lower than the State average. Ernakulam had the highest stability in productivity (4.3%), while Palakkad had the highest instability of 13.61 per cent. It was found that for the entire study period, all the districts had growth in productivity of paddy.

4.2.1.2 District-wise trend in area, production and productivity of coconut

The area under coconut in Kerala showed a different from that of paddy. While the area of coconut declined in some of the districts, it registered positive annual growth rates in most of them. The highest annual growth rate of 3.54 per cent in area was observed in Wayanad, while Pathanamthitta had showed the largest decline of -2.16 per cent. All the districts other than Thiruvananthapuram, Kollam, Ernakulam, Alappuzha and Pathanamthitta exhibited positive annual growth rates in area under coconut. The comparatively lower growth rate of

Table 4.12: Growth and instability in district-wise area, production and productivity of Coconut in Kerala

Districts	Area		Production		Productivity	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Thiruvananthapuram	-0.65	7.75	1.19	11.44	1.85	7.58
Kollam	-1.46	8.43	0.41	12.89	1.90	10.71
Pathanamthitta	-2.16	6.20	-1.27	7.75	0.91	11.56
Alappuzha	-2.00	14.11	-1.03	15.37	0.99	12.20
Kottayam	-2.13	6.41	-1.31	12.52	0.84	8.13
Idukki	0.05	17.52	0.65	16.53	0.60	14.44
Ernakulam	-1.58	8.46	-2.27	14.43	-0.71	9.67
Thrissur	0.42	7.94	0.60	15.50	0.18	10.70
Palakkad	2.43	8.35	5.95	15.34	3.44	12.24
Malappuram	0.93	9.54	3.81	12.51	2.85	10.50
Kozhikode	0.14	4.68	1.07	12.91	0.93	10.72
Wayanad	3.54	17.77	10.00	19.23	6.23**	15.90
Kannur	0.28	11.34	1.42	17.78	1.14	10.18
Kasaragod	1.53	8.02	4.50	13.56	2.92	10.20

Note: 1. ** denotes significance at five per cent level
2. Production CAGR for Wayanad not significant
3. All other values significant at 1 per cent

coconut in some of the districts could had been due to conditions not favouring the cultivation of the crop in those districts. The conditions in districts like Alappuzha were more inclined and favourable towards paddy cultivation than coconut. Due to large annual rise in area under coconut in Wayanad, instability in area under coconut was highest in Wayanad and lowest in Kozhikode.

Palakkad had the largest annual growth in production (5.95%), while the instability was highest in Kannur (17.78%). Ernakulam had the lowest annual growth rate (-2.27%) in production. Therefore, out of the districts that showed negative annual growth rates in area, only Kollam and Thiruvananthapuram showed a positive annual growth rate in production of 0.41 per cent and 1.19 per cent respectively. All districts except for Ernakulam (-0.71%) had positive annual rates of growth in productivity of coconut. The highest growth in productivity and instability of 6.23 per cent and 15.9 per cent respectively were experienced in Wayanad. Wayanad showed the extreme values of growth in area and productivity in coconut among all

the districts. The highest mean productivity of 6939.52 nuts per hectare during 33 years of study was found in Kasaragod, at while the lowest was in Wayanad which reported 3299.18 coconuts per hectare. While the State's average productivity was 5748 nuts per hectare, Ernakulam, Palakkad, Alappuzha, Kottayam, Idukki and Wayanad had mean productivity below 5748 nuts per hectare for the entire period of study (1985-86 to 2017-18).

4.2.1.3 District-wise trend in area, production and productivity of rubber

All the districts experienced positive annual growth rates in area under rubber. However, the growth rates in some of the districts like Kollam (0.41%), Kottayam (0.5%), Ernakulam (0.54%) and Idukki (0.72%) were dismal. The highest annual growth in area under rubber was in Wayanad (3.26%), while the highest instability in area was found in Thrissur, which recorded an instability of 10.07 per cent. Kannur showed the most stable area under rubber. The growth in production of rubber was highest in Wayanad, which was an indication that the high annual growth in area contributed to high growth in production for the district.

All the districts reported medium instability in production and productivity. The annual growth in productivity was highest in Ernakulam at 2.88 per cent, while Kozhikode had the lowest productivity growth of 0.6 per cent. The State's average productivity of rubber for the period under study was worked out as 1.09 tonnes per hectare. Only Thrissur (1.32 T/ha), Kozhikode (1.24 T/ha), Kollam (1.17 T/ha), Alappuzha (1.16 T/ha), Pathanamthitta (1.14 T/ha), Kottayam (1.12 T/ha) and Ernakulam (1.11 T/ha) had higher mean productivity than the state average, while the rest of the districts reported lower productivity than the state average during the period under study.

Table 4.13: Growth and instability in district-wise area, production and productivity of rubber in Kerala

Districts	Area		Production		Productivity	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Thiruvananthapuram	1.88	7.77	4.15	25.42	2.23	23.28
Kollam	0.41	4.44	2.16	22.14	1.74	21.68
Pathanamthitta	1.22	8.66	3.75	24.87	2.50	22.58
Alappuzha	1.19	7.17	2.43	24.43	1.23	23.36
Kottayam	0.50	4.13	2.63	24.55	2.11	23.59
Idukki	0.72	4.00	3.13	23.26	2.39	22.53
Ernakulam	0.54	7.64	3.43	25.66	2.88	26.00
Thrissur	2.26	10.07	2.98	25.94	0.70	23.35
Palakkad	2.52	4.97	5.43	26.49	2.84	25.42
Malappuram	3.09	5.34	4.44	22.35	1.30	21.08
Kozhikode	1.59	8.05	2.19	17.26	0.60	19.25
Wayanad	3.26	9.28	5.85**	21.22	2.50	19.96
Kannur	3.26	3.98	5.72	23.23	2.38	22.33
Kasaragod	3.09	5.26	5.27	20.26	2.11	19.76

Note: 1. ** denotes significance at five per cent level
2. All other values significant at 1 per cent

4.2.1.4 District-wise trend in area, production and productivity of tapioca

The area under tapioca at the state level was found to be declining. Since this was an average of the performance of the districts, a mixed trend was observed for individual districts. Generally, most districts were reporting negative annual growth rates in areas under tapioca. Kasaragod had the largest annual decline in area of -8.07 per cent. Wayanad was the only district which had increasing area under the crop with a CAGR of 0.35 per cent. As a result of the higher decline in area under tapioca in Kasaragod, a comparatively greater instability was also witnessed in the district (42.62%). Apart from Idukki (11.71%) and Palakkad (11.54%), all other districts showed medium instability in area under tapioca. Wayanad (1.99%), Idukki (1.83%), Ernakulam (1.76%) and Pathanamthitta (0.22) were the only districts which exhibited growth in production of tapioca.

Kasaragod showed the highest decline in production of tapioca and as a result the district had the highest instability in production of the crop. Kozhikode also had high instability in production of tapioca, while Idukki and Kollam showed high instability in production. The rest of the districts presented medium instability (15%<CDVI<30%) in the production of tapioca.

Table 4.14: Growth and instability in district-wise area, production and productivity of tapioca in Kerala

Districts	Area		Production		Productivity	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Thiruvananthapuram	-3.85	21.37	-0.95	17.79	3.01	12.80
Kollam	-3.23	21.32	-0.14	11.73	3.20	9.41
Pathanamthitta	-2.61	15.09	0.22	18.42	2.91	12.51
Alappuzha	-4.63	20.57	-2.40	24.81	2.34	14.47
Kottayam	-3.59	23.31	-1.61	18.66	2.06	7.45
Idukki	-0.34	11.71	1.83	12.56	2.18	9.48
Ernakulam	-1.21	26.01	1.76	16.83	3.00	7.29
Thrissur	-4.74	27.92	-1.38	22.10	3.53	17.79
Palakkad	-6.26	11.54	-4.25	17.72	2.14	9.06
Malappuram	-3.33	15.49	-0.25	16.51	3.18	10.97
Kozhikode	-3.10	21.73	-0.44	32.42	2.75	12.83
Wayanad	0.35	19.78	1.99	24.57	1.63	14.55
Kannur	-5.55	16.48	-2.84	19.49	2.88	10.14
Kasaragod	-8.06	42.62	-5.52	38.42	2.76	14.76

Note: All values significant at 1 per cent

Despite some districts having negative annual growth rates in area and production of tapioca, all the districts showed a growth in productivity. Thrissur showed the highest annual growth in productivity, while Wayanad had the lowest growth rate. All the districts except for Thrissur showed low instability in productivity of tapioca. The mean productivity in tapioca was found to be highest in Wayanad at 36.19 tonnes per hectare, while the lowest was in Kozhikode (20.9 T/ha). Thrissur, Kollam, Palakkad, Alappuzha, Thiruvananthapuram, Kasaragod and Kozhikode were the districts with productivity lower than the State average for the period from1985-86 to 2017-18.

4.2.1.5 District-wise trend in area, production and productivity of cashew

The annual growth rate in area under cashew was found to be negative at the state level. At the district level, only Idukki had positive annual growth rate of 1.4 per cent for area under cashew, (while the rest of the districts had negative annual growth rates in area. Malappuram and Ernakulam had the largest annual decline in area of -6.79 per cent and -6.67 per cent respectively. Wayanad and Kasaragod showed high instability in area, while it was comparatively lower in Palakkad, Kozhikode, Malappuram, Thrissur, Kollam and Kannur.

Table 4.15: Growth and instability in district-wise area, production and productivity of cashew in Kerala

Districts	Area		Production		Productivity	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Thiruvananthap uram	-5.61	24.75	-8.70	34.30	-3.27	39.53
Kollam	-3.83	7.48	-7.70	19.14	-4.02	16.52
Pathanamthitta	-5.30	16.20	-8.92	48.97	-3.82	24.55
Alappuzha	-3.82	23.28	-5.77	35.31	-2.02	24.99
Kottayam	-3.96	17.97	-4.04	36.36	-0.09	21.35
Idukki	1.40	17.87	1.09	31.41	-0.31	32.46
Ernakulam	-6.67	22.92	-8.09	27.76	-1.53	18.42
Thrissur	-4.90	8.69	-6.44	21.04	-1.62	21.21
Palakkad	-5.72	12.74	-7.61	16.70	-2.01	17.63
Malappuram	-6.79	10.54	-8.67	27.37	-2.01	31.34
Kozhikode	-2.80	12.44	-4.26	29.60	-1.51	23.07
Wayanad	-1.24	53.04	-0.60	53.84	0.64	36.19
Kannur	-2.13	7.41	-2.63	20.81	-0.51	20.63
Kasaragod	-3.60	34.20	-4.86	31.65	-1.31	56.55

Note: All values significant at 1 per cent

Idukki was the only district with a positive annual growth in production of cashew, while Pathanamthitta recorded the highest decline. Most of the districts showed high instability in production (above 30%), while Palakkad, Kozhikode, Malappuram, Thrissur, Kollam and Kannur recorded medium instability.

Despite recording positive annual growth rates in area and production of cashew, Idukki together with other district recorded decline in productivity. Only Wayanad had a positive annual growth rate in productivity. Most of the districts showed medium to high instability in productivity. Average productivity for cashew at the state level was found to be 0.53 tonnes per hectare. Only Kannur (1.13 T/ha), Kasaragod (0.9 T/ha), Kollam (0.62 T/ha) and Thiruvananthapuram (0.54 T/ha) had higher mean productivity than the State average. Alappuzha had the lowest mean productivity (0.29 T/ha).

4.2.1.6 District-wise trend in area, production and productivity of black pepper

The only districts exhibiting growth in area of black pepper were Idukki and Palakkad, while the other districts registered negative growth rates. Kannur had the lowest annual decline of -6.07 per cent per annum for area under black pepper. The instability in area was relatively high in all the districts and none of the districts showed lower instability. In line with the positive annual growth rates in area, only Palakkad and Idukki had positive annual growth rates in production. The largest annual decline in production was also witnessed in Kannur, due to large decline in area under the crop during the period of study.

Table 4.16: Growth and instability in district-wise area, production and productivity of black pepper in Kerala

Districts	**Area**		**Production**		**Productivity**	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Thiruvananthapuram	-1.93	29.57	-0.94	28.59	1.01	20.00
Kollam	-2.49	32.68	-2.93	34.86	-0.46	20.12
Pathanamthitta	-3.36	23.36	-3.17	18.35	0.20	22.09
Alappuzha	-4.71	19.16	-4.89	53.76	-0.18	41.53
Kottayam	-3.60	15.29	-0.74	23.50	2.97	32.39
Idukki	1.83	17.70	3.14	38.19	1.28	25.57
Ernakulam	-3.90	23.20	-2.67	20.40	1.28	23.04
Thrissur	-2.69	26.01	-1.30	26.73	1.44	26.32
Palakkad	1.38	43.63	4.49	23.17	3.07	36.41
Malappuram	-2.44	37.30	-3.12	25.22	-0.70	37.17
Kozhikode	-4.54	21.21	-4.19	31.94	0.37	34.69
Wayanad	-3.27	44.44	-3.60	51.58	-0.81	27.94
Kannur	-6.07	32.24	-5.02	28.73	1.11	33.70
Kasaragod	-3.24	17.09	-0.12	25.61	3.22	36.94

Note: All values significant at 1 per cent

The district-wise instability was also relatively high for production of black pepper. Despite most of the districts showing annual reduction in area and production, most of them registered a growth in productivity. This could be inferred as due to the lower decline in production of black pepper as compared to area under the crop. This pattern could be observed in Kannur district, which despite the largest annual decline in both area and production, registered positive annual growth rate in productivity during the study period. Only Alappuzha, Kollam, Malappuram and Wayanad registered negative annual growth rates in productivity. Highest productivities for black pepper were observed in Kasaragod (3.22%) and Palakkad

(3.07%). The area, production and productivity of black pepper were highly volatile in all the districts, which could be attributed to the extreme price fluctuations during the study period the area, production and productivity of black pepper showed medium to high instability. The mean productivity of black pepper was highest in Idukki (0.43 T/ha), while Alappuzha reported the lowest (0.16 T/ha) productivity. The average for Kerala State was found to be 0.25 tonnes per hectare and it was found that Kottayam, Thrissur, Palakkad, Ernakulam, Kozhikode, Malappuram and Alappuzha were having lower mean productivity as compared to the State average.

4.2.1.7 District-wise trend in area, production and productivity of banana and other plantain

The area under banana and other plantains registered an impressive annual growth in most of the districts. Decline in area under banana was observed only in Alappuzha, Kannur,

Table 4.17: Growth and instability in district-wise area, production and productivity of banana and other plantains in Kerala

Districts	Area		Production		Productivity	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Thiruvananthapuram	1.00	8.39	3.35	16.43	2.33	14.77
Kollam	1.39	11.38	3.70	17.52	2.28	14.29
Pathanamthitta	-0.57	12.79	1.48	23.41	2.06	15.90
Alappuzha	-0.12	21.17	1.72	36.29	1.84	18.21
Kottayam	-0.77	13.99	0.35	29.18	1.13	15.71
Idukki	2.43	12.06	3.58	21.90	1.12	16.07
Ernakulam	1.15	10.50	3.42	20.58	2.25	13.88
Thrissur	0.88	15.55	3.79	26.95	2.88	20.14
Palakkad	4.56	20.51	8.15	43.79	3.43	29.68
Malappuram	0.64	17.49	2.41	29.77	1.76	21.80
Kozhikode	0.92	10.57	2.10	28.73	1.17	22.49
Wayanad	-0.30	21.34	0.34	38.50	0.64	23.10
Kannur	-0.15	20.48	0.49	34.13	0.64	19.58
Kasaragod	0.65	18.31	1.70	39.42	1.04	25.17

Note: All values significant at 1 per cent

Wayanad, Pathanamthitta and Kottayam. Palakkad had the highest annual growth rate in area of 4.56 per cent. Kottayam, Pathanamthitta, Idukki, Kollam, Kozhikode, Ernakulam and Thiruvananthapuram showed low instability for area under banana and other plantains, while the rest of the districts showed medium instability. Growth in production was observed in all the districts which was an indication that because of the increase in area banana was showing increased production in all the districts. Due to the impressive annual growth rate of area in Palakkad, the district registered the highest growth in production (8.15%). Thrissur came at distant second with 3.79 per cent CAGR, while Wayanad and Kottayam had the least annual growth rates of 0.34 per cent and 0.35 per cent respectively.

The instability in production of banana and other plantains was quite high when compared to its area, which an indication of the high variability in production caused by factors such as weather and variations in varieties grown over the years. Due to impressive annual growth in production in Palakkad, the district also had the best annual growth in productivity (3.43%), while Kannur and Wayanad each lagged at 0.64 per cent. The instability in productivity of banana and other plantains was lower than that of production but higher than the instability in area. It could be inferred that the instability witnessed in productivity was mainly due to variability in production.

Idukki showed the highest average productivity of 8.84 tonnes per hectare for banana and other plantains during the entire period under study, while Kannur had the lowest (4.33 T/ha). The average for the State was worked out as 6.46 tonnes per hectare and Alappuzha, Malappuram, Kasaragod, Thrissur, Kozhikode and Kannur were found to be yielding lower than the State average.

District-wise trend in area, production and productivity of tea

Among the tea growing districts in Kerala, Idukki had a negative annual growth rates in area, production and productivity. This decline in production in the district was equally contributed by the decline in area and productivity. Palakkad registered 0.71 per cent annual growth in area, but a lower annual growth rate in production (0.53%) because of the decline in productivity of -0.18 per cent. The annual growth in area and production of tea was found to be highest in Palakkad, while Wayanad had the lowest growth in production (-0.63%) and highest growth in yield (0.91%) among the three districts. The instability in area was low for all the districts, while Palakkad and Wayanad showed medium instability in production and productivity.

Table 4.18: Growth and instability in district-wise area, production and productivity of Tea in Kerala

Districts	Area		Production		Productivity	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Idukki	-0.12	3.96	-0.30	11.65	-0.18	12.85
Palakkad	0.71	5.64	0.53	18.19	-0.18	16.14
Wayanad	0.22	7.02	-0.63	24.61	0.91	22.97

Note: All values significant at 1 per cent

4.2.1.8 Trend in area, production and productivity of coffee

Coffee registered growth in area, production and productivity in all the districts, except for productivity in Palakkad (-1.21%). This could be due to high annual increase in area under

Table 4.19: Growth and instability in district-wise area, production and productivity of coffee in Kerala

Districts	Area		Production		Productivity	
	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)	CAGR (%)	CDVI (%)
Idukki	1.80	15.42	2.86	26.85	1.04	28.72
Palakkad	3.06	15.87	1.81	71.59	-1.21	108.48
Wayanad	0.45	4.90	3.63	22.59	3.17	22.53

Note: All values significant at 1 per cent

coffee in Palakkad (3.06%) which could not be offset by the decline in productivity of -1.21 per cent (1.81%), which resulted in a growth of 1.81 per cent per annum. Wayanad reported the highest annual growth in production of 3.36 per cent, which was mainly contributed by the growth in productivity rather than area. Instability was quite high in production and productivity of coffee in Palakkad, while the rest of the districts experienced medium instability. Wayanad had the lowest instability in area (4.90%), while Idukki and Palakkad registered instability of about 15 per cent.

4.2.2 Crop diversification in Kerala

The crop diversification is the tendency to have wider choice in the variety and number of crops in a particular area at a particular point of time. To clearly understand the variations in diversification of crops among the districts, it was important to analyse the diversity in crops in the gross cropped area (GCA) of various districts of Kerala using Herfindahl and Entropy indices. The results of the analysis on crop diversification are presented in Table 4.20 and Table

4.21. The Herfindahl Index depicts more diversification of crops as the values approach zero, while the Entropy Index shows more cropping diversity in the GCA as the values approach the maximum.

During each of the year from 1985-86 to 2017-18, most of the districts presented different values for the indices, which was an indication that the number of crops grown every year for 33 years of the study were large and varying across districts. However, some districts like Alappuzha, Thrissur and Kozhikode had little change in their indices. This could be due to the prominence of a particular crops and limited chance to transition to other crops. Alappuzha and Thrissur districts which accounted for the two largest suitable areas for paddy cultivation did not show much changes in both the indices. This was an indication that as much as farmers would want to shift to other crops as witnessed in other districts, they had minimal options due to the ecological conditions in the areas favouring the cultivation of paddy than whatever crop they would have liked to shift to. The Kole wetland and Kutanad regions come under Thrissur and Alappuzha and both are mainly suitable for paddy cultivation. These regions account for large shares of the districts and could have been the reason for low changes in their diversification indices in that, despite existence of moderate diversity in crops, farmers had limited amount of land for mixed cropping and with time, the cropping pattern tend to remain constant.

Kozhikode also depicted largely constant values for both Herfindahl and Entropy indices, which was an indication of a stagnant mixed cropping system. Kozhikode for the entire period of the study, had its GCA covered majorly by coconut. In 1985-86, coconut accounted for 55 per cent of the GCA of Kozhikode. By 2017-18, the percentage increased to 59 per cent of the GCA. These percentages of coconut in the GCA in the district revealed two aspects. One, just as Thrissur and Alappuzha that had paddy dominating their GCA, the remaining land was limited to practice adequate diversity which could have made an impact when computing the Herfindahl and Entropy indices. Two, a movement from 54 per cent to 59 per cent coverage by a single crop in the GCA pointed towards specialisation and consequently, Kozhikode registered the highest Herfindahl index (low crop diversity) and lowest Entropy Index (low crop diversity) all through the study period.

The comparison between the first five years of the study (1985-86 to 1990-91) to the last five years of the study (2013-14 to 2017-18), revealed the pattern of diversification for most of the other districts. Some districts improved on diversity of crops in their GCA, while others declined. Districts like Thiruvananthapuram, Pathanamthitta, Kottayam, Malappuram, Kannur and Kasaragod had higher diversity of crops in their GCA in the earlier years of the study. However, as the years progressed, the indices revealed that the districts moved towards monocropping as shown by increasing Herfindahl Index and declining Entropy Index. This could be explained by the shares of various crops in the GCA of these districts. Thiruvananthapuram had only 6.8 per cent share of rubber in its GCA. By 2017-18, the share increased to 20.6 per cent, while for the same period, the share of rubber moved from 25 per cent to 48 per cent in Pathanamthitta, 35 per cent to 55 per cent in Kottayam, 8 per cent to 17 per cent in Malappuram, 7 per cent to 21 per cent in Kannur and 9 per cent to 21 per cent in Kasaragod. The increase in area under rubber was therefore the main reason for the declining diversity in the GCA of Thiruvananthapuram, Pathanamthitta, Kottayam, Malappuram, Kannur and Kasaragod districts.

Other districts like Palakkad and Wayanad improved on their cropping diversity. On an average, Idukki had the best cropping diversity in its GCA, while Kozhikode had the lowest. The districts that had the highest diversity of crops in their GCA were Kollam, Idukki, Palakkad, Wayanad, and Kannur. The districts that had lowest diversity were Thiruvananthapuram, Pathanamthitta, Kottayam, Malappuram and Kozhikode.

Table 4.20: Estimated Herfindahl Indices for measuring district-wise crop diversification in Kerala (1985-86 to 2017-18)

Year	TVM	KLM	PTM	ALP	KTM	IDK	ERN	TSR	PLK	MLP	KZD	WYD	KNR	KSD
1985-86	0.193	0.176	0.165	0.241	0.196	0.136	0.207	0.274	0.286	0.176	0.322	0.207	0.155	0.152
1986-87	0.197	0.181	0.165	0.266	0.203	0.138	0.202	0.265	0.273	0.170	0.309	0.201	0.157	0.154
1987-88	0.215	0.187	0.170	0.263	0.238	0.137	0.205	0.266	0.252	0.180	0.322	0.200	0.162	0.161
1988-89	0.220	0.193	0.172	0.271	0.237	0.138	0.201	0.263	0.240	0.177	0.337	0.193	0.163	0.159
1989-90	0.226	0.182	0.175	0.276	0.243	0.138	0.202	0.260	0.239	0.184	0.323	0.205	0.166	0.169
1990-91	0.225	0.185	0.191	0.277	0.256	0.121	0.204	0.269	0.227	0.195	0.340	0.195	0.176	0.172
1991-92	0.223	0.184	0.208	0.276	0.269	0.122	0.208	0.274	0.227	0.193	0.347	0.206	0.169	0.180
1992-93	0.233	0.187	0.218	0.287	0.276	0.120	0.210	0.272	0.219	0.194	0.357	0.201	0.172	0.179
1993-94	0.238	0.184	0.212	0.287	0.275	0.119	0.205	0.253	0.208	0.190	0.340	0.188	0.176	0.181
1994-95	0.248	0.198	0.213	0.288	0.290	0.117	0.208	0.256	0.214	0.203	0.344	0.185	0.178	0.195
1995-96	0.246	0.193	0.224	0.273	0.296	0.113	0.201	0.249	0.200	0.204	0.328	0.185	0.178	0.204
1996-97	0.249	0.187	0.223	0.270	0.290	0.116	0.204	0.246	0.196	0.199	0.340	0.184	0.173	0.200
1997-98	0.247	0.187	0.234	0.276	0.312	0.115	0.194	0.237	0.185	0.201	0.332	0.181	0.175	0.206
1998-99	0.260	0.189	0.245	0.264	0.308	0.113	0.197	0.248	0.177	0.203	0.344	0.180	0.172	0.191
1999-00	0.264	0.206	0.243	0.274	0.304	0.120	0.198	0.266	0.193	0.216	0.351	0.178	0.185	0.209
2000-01	0.259	0.205	0.234	0.274	0.292	0.121	0.196	0.267	0.204	0.220	0.348	0.177	0.185	0.212
2001-02	0.260	0.201	0.229	0.272	0.300	0.120	0.187	0.261	0.195	0.209	0.350	0.178	0.188	0.208
2002-03	0.262	0.204	0.227	0.275	0.306	0.124	0.186	0.255	0.194	0.211	0.359	0.178	0.189	0.206
2003-04	0.267	0.200	0.231	0.275	0.317	0.126	0.186	0.258	0.178	0.216	0.357	0.179	0.199	0.213
2004-05	0.264	0.193	0.226	0.276	0.308	0.139	0.185	0.245	0.186	0.223	0.356	0.176	0.198	0.215
2005-06	0.268	0.195	0.233	0.284	0.307	0.143	0.187	0.251	0.184	0.224	0.355	0.170	0.197	0.214
2006-07	0.269	0.199	0.254	0.272	0.294	0.138	0.187	0.265	0.175	0.238	0.374	0.166	0.206	0.227
2007-08	0.266	0.197	0.268	0.268	0.310	0.119	0.197	0.269	0.168	0.241	0.371	0.167	0.210	0.227
2008-09	0.257	0.182	0.200	0.620	0.343	0.251	0.153	0.392	0.168	0.232	0.394	0.174	0.160	0.263
2009-10	0.278	0.184	0.196	0.624	0.365	0.259	0.154	0.409	0.174	0.244	0.401	0.191	0.158	0.282

2010-11	0.260	0.196	0.275	0.258	0.334	0.136	0.199	0.258	0.155	0.241	0.385	0.183	0.200	0.228
2011-12	0.268	0.200	0.283	0.254	0.330	0.103	0.207	0.280	0.152	0.253	0.401	0.186	0.223	0.235
2012-13	0.262	0.202	0.295	0.257	0.350	0.102	0.218	0.277	0.154	0.248	0.398	0.189	0.217	0.237
2013-14	0.256	0.221	0.289	0.254	0.359	0.101	0.219	0.278	0.152	0.249	0.400	0.184	0.219	0.244
2014-15	0.257	0.202	0.281	0.241	0.350	0.100	0.215	0.268	0.152	0.237	0.393	0.187	0.219	0.252
2015-16	0.252	0.203	0.281	0.222	0.346	0.100	0.213	0.262	0.154	0.235	0.384	0.176	0.223	0.247
2016-17	0.253	0.202	0.279	0.224	0.344	0.100	0.215	0.261	0.142	0.239	0.383	0.195	0.226	0.251
2017-18	0.250	0.197	0.273	0.237	0.336	0.099	0.212	0.261	0.155	0.240	0.369	0.192	0.221	0.255
Average	0.248	0.194	0.231	0.287	0.299	0.129	0.199	0.270	0.193	0.215	0.358	0.186	0.188	0.210

Note: TVM denotes Thiruvananthapuram, KLM denotes Kollam, PTM denotes Pathanamthitta, ALP denotes Alappuzha, KTM denotes Kottayam, IDK denotes Idukki, ERN denotes Ernakulam, TSR denotes Thrissur, PLK denotes Palakkad, MLP denotes Malappuram, KZD denotes Kozhikode, WYD denotes Wayanad, KNR denotes Kannur and KSD denotes Kasaragod.

Table 4.21: Estimated Entropy Indices for measuring district-wise crop diversification in Kerala (1985-86 to 2017-18)

Year	TVM	KLM	PTM	ALP	KTM	IDK	ERN	TSR	PLK	MLP	KZD	WYD	KNR	KSD
1985-86	0.893	0.909	0.931	0.805	0.890	1.018	0.865	0.775	0.818	0.921	0.775	0.910	0.951	0.931
1986-87	0.889	0.907	0.943	0.782	0.888	1.019	0.877	0.792	0.831	0.939	0.792	0.924	0.956	0.925
1987-88	0.867	0.908	0.940	0.784	0.840	1.017	0.861	0.783	0.855	0.932	0.782	0.933	0.954	0.922
1988-89	0.863	0.900	0.938	0.771	0.842	1.011	0.865	0.787	0.870	0.939	0.765	0.940	0.952	0.925
1989-90	0.859	0.913	0.931	0.762	0.834	1.005	0.862	0.794	0.869	0.927	0.780	0.919	0.947	0.909
1990-91	0.857	0.915	0.906	0.759	0.819	1.043	0.854	0.777	0.883	0.913	0.769	0.932	0.932	0.904
1991-92	0.853	0.912	0.883	0.760	0.797	1.035	0.841	0.769	0.882	0.918	0.756	0.914	0.940	0.896
1992-93	0.836	0.903	0.871	0.742	0.785	1.038	0.838	0.774	0.890	0.914	0.743	0.919	0.935	0.898
1993-94	0.839	0.912	0.883	0.742	0.792	1.046	0.855	0.800	0.904	0.926	0.750	0.937	0.936	0.895
1994-95	0.836	0.896	0.885	0.741	0.769	1.053	0.844	0.797	0.896	0.906	0.756	0.939	0.932	0.874
1995-96	0.837	0.901	0.871	0.777	0.772	1.062	0.862	0.811	0.906	0.909	0.776	0.938	0.931	0.863
1996-97	0.835	0.906	0.871	0.781	0.787	1.069	0.852	0.821	0.922	0.922	0.756	0.947	0.941	0.865
1997-98	0.832	0.907	0.858	0.769	0.768	1.067	0.878	0.841	0.934	0.918	0.768	0.955	0.934	0.855
1998-99	0.817	0.907	0.840	0.797	0.763	1.075	0.866	0.828	0.954	0.918	0.754	0.954	0.940	0.871
1999-00	0.770	0.839	0.808	0.742	0.732	1.023	0.838	0.754	0.884	0.845	0.689	0.919	0.870	0.822
2000-01	0.776	0.846	0.820	0.739	0.759	1.019	0.848	0.755	0.873	0.840	0.691	0.923	0.868	0.819
2001-02	0.775	0.852	0.830	0.741	0.743	1.021	0.866	0.763	0.881	0.852	0.688	0.923	0.862	0.824
2002-03	0.775	0.840	0.841	0.740	0.736	1.013	0.868	0.771	0.882	0.849	0.675	0.920	0.859	0.823
2003-04	0.771	0.853	0.828	0.739	0.728	1.005	0.868	0.771	0.908	0.846	0.679	0.918	0.842	0.810
2004-05	0.774	0.863	0.833	0.738	0.731	0.978	0.865	0.784	0.888	0.831	0.675	0.921	0.843	0.806
2005-06	0.770	0.858	0.825	0.728	0.745	0.977	0.870	0.783	0.901	0.835	0.674	0.932	0.842	0.803
2006-07	0.760	0.854	0.802	0.740	0.762	0.982	0.874	0.768	0.912	0.815	0.654	0.944	0.832	0.789
2007-08	0.763	0.851	0.784	0.734	0.739	1.026	0.860	0.763	0.918	0.803	0.658	0.953	0.822	0.785
2008-09	0.794	0.931	0.879	0.985	0.731	1.139	0.960	0.998	0.958	0.869	0.745	1.036	0.806	0.842
2009-10	0.767	0.929	0.885	0.986	0.706	1.091	0.958	0.985	0.944	0.846	0.743	1.013	0.810	0.816

2010-11	0.816	0.906	0.813	0.785	0.741	1.031	0.898	0.823	0.975	0.844	0.694	0.971	0.883	0.800
2011-12	0.800	0.895	0.801	0.786	0.736	1.092	0.884	0.800	0.982	0.824	0.671	0.974	0.846	0.789
2012-13	0.813	0.888	0.785	0.782	0.709	1.095	0.862	0.795	0.976	0.826	0.675	0.964	0.855	0.789
2013-14	0.820	0.858	0.791	0.785	0.698	1.099	0.859	0.793	0.982	0.826	0.671	0.971	0.845	0.776
2014-15	0.816	0.883	0.799	0.805	0.709	1.099	0.866	0.801	0.980	0.845	0.679	0.970	0.848	0.768
2015-16	0.825	0.885	0.800	0.833	0.716	1.099	0.871	0.808	0.977	0.847	0.690	0.986	0.844	0.776
2016-17	0.818	0.887	0.802	0.832	0.719	1.100	0.868	0.814	0.998	0.838	0.689	0.960	0.839	0.771
2017-18	0.820	0.894	0.812	0.812	0.731	1.101	0.875	0.814	0.968	0.837	0.706	0.963	0.847	0.766
Average	0.816	0.888	0.851	0.782	0.764	1.047	0.869	0.803	0.915	0.873	0.720	0.946	0.886	0.840

Note: TVM denotes Thiruvananthapuram, KLM denotes Kollam, PTM denotes Pathanamthitta, ALP denotes Alappuzha, KTM denotes Kottayam, IDK denotes Idukki, ERN denotes Ernakulam, TSR denotes Thrissur, PLK denotes Palakkad, MLP denotes Malappuram, KZD denotes Kozhikode, WYD denotes Wayanad, KNR denotes Kannur and KSD denotes Kasaragod.

4.2.3 Determinants of agricultural income variability among districts of Kerala

The analyses of inter-district variation using CAGRs, Cuddy-Della Valle instability index and crop diversification indices have shown considerable differences among the districts. It would therefore be important to understand the variables causing differences in income across the districts. This was based on the understanding that the individual interactions of each crop such as annual growth in area and production, and diversity in crops in a district would eventually affect the aggregate agricultural income from the specific district.

In panel data model methodology, only one model can be used to explain the relationships, however, all the models need to be computed and subjected to tests to ascertain the right model. Therefore, for computation of time invariant variables among the districts, panel OLS was used. This was after computation of panel OLS, random effects and fixed effects models. These models were subjected to tests and while, random effects model was rejected based on the results of the Hausman test, panel OLS was chosen based on the results of Breusch and Pagan Lagrangian multiplier test. The other panel data results, that is, random effects model, fixed effects model and the tests are included in Appendix XXXIII to Appendix XXXVI.

Since the model was based on log variables, the results are presented as partial elasticities. Fertiliser consumption was found to be a major contributor to the net district domestic product (NDDP) from agriculture of various districts. It could be observed from the results that increasing fertiliser consumption by one per cent will lead an increase in NDDP from agriculture by 0.457 per cent. The rainfall and gross irrigated area also significantly contributed to the variabilities of the districts in NDDP from agriculture. The production of banana and other plantains had been on the increase in the districts. With an average annual growth in production of 2.61 per cent in all the districts, the earnings from banana and other plantains had been increasing over the years as its price rose. This growth in production of banana was only second to rubber and the panel OLS model confirmed that banana and other plantains was the crop contributing the highest percentage to the NDDP agriculture in the districts. Hence, an increase in one per cent production of banana and other plantains, led to a 0.9 per cent increase in NDDP from agriculture in the districts of Kerala. Production of rubber was also found to contribute significantly to NDDP from agriculture. The contribution from production of rubber was not to the magnitude of banana and other plantains due to recent declining trend in prices and the resulting declining production which was also due to shortage

Table 4.22: Estimates of Panel OLS to estimate determinants of income variability among districts of Kerala

Variables	Coefficient	Standard Error	t-stat
Intercept of nddpa	3.669***	1.414	2.59
Gross area irrigated	0.264***	0.059	4.45
Rainfall	0.335**	0.144	2.33
Fertiliser consumption	0.457***	0.081	5.64
Paddy production	-0.669***	0.044	-15.24
Rubber production	0.085*	0.047	1.80
Coconut production	-0.086	0.061	-1.41
Banana and other plantain production	0.903***	0.083	10.94
Cashew production	-0.065	0.042	-1.55
Tapioca production	-0.198***	0.050	-3.93
Black Pepper production	-0.248***	0.049	-5.05
Adjusted R-squared = 0.6608			
Root MSE = 0.69678			
F (10,451) = 90.82***			

Note: 1. * denotes significance at ten per cent level
2. ** denotes significance at five per cent level
3. *** denotes significance at one per cent level

of labour availability in the context of declining number of rubber tappers in the State of Kerala.

Production of paddy had and highly significant inverse relationship to NDDP agriculture among the districts. The same relationship was found in the case of production of black pepper, tapioca and to smaller extent coconut and cashew. Over the years, the production of these crops which were showing inverse relationship to the NDDP from agriculture were on the decline. The highest decline was found in cashew and the crop seemed to have lost favour with the farmers; reason for its small elasticity response to NDDP from agriculture. Coconut also has a negative elasticity for a different reason. While coconut was still widely grown across the districts, its production had started declining, albeit by small margin. This therefore led to the very small negative elasticity in comparison to contributions of other crops like paddy, black pepper and tapioca. Thus, the variables that positively impacted NDDP from agriculture across the districts for the period under study were fertiliser consumption, rainfall, gross irrigated area, production of banana and other plantains, and production of rubber.

4.3 Dynamics in land use and cropping pattern in Kerala

4.3.1 Status and trends in land use and cropping pattern

4.3.1.1 Land use changes

Kerala had an estimated 3.5 crore population in 2019, while based on the 2011 census, the population was 3.3 crore. The population had grown by over 30 per cent in 49 years of the study period from1970-71 to 2018-19. Since the geographical area is fixed, with growth in population, the pressure on the land has been increasing. The per capita land availability in 1971-72 was 0.18 ha, while in 2018-19 it declined to an estimated 0.11 ha. This trend was found to be even precarious for the agricultural land which was 24.3 lakh ha in 1970-71 dropped to 22.4 lakh ha in 2018-19. This loss equates to a decline of 3,700 ha of arable land per year. The problem of declining availability of agricultural land was found to be worsened by the population growth and its pressure on land, urbanisation and socioeconomic reasons including profitability of crops that led to the diversion productive arable land to non-agricultural uses (Rejula and Singh 2015).

The share of arable land in the total geographical area in Kerala had been declining over the study period. It could be observed from Table 4.23 that in TE 1972-73, it constituted 62.60 per cent of the total geographical area of the state, but declined to 57.81 per cent in TE 2018-19. Land put to non-agricultural uses had one of the showed considerable over the same period and it increased from a share of 7.09 per cent to 11.49 per cent of state’s total geographical area. While land put to non-agricultural uses showed an annual decline in the first period of the study (-1.07%), it had positive annual growth rates in the other periods except for the period from 2004-05 to 2010-11, when it declined again. For the overall period (1970-71 to 2018-19), land put to non-agricultural uses had a CAGR of 1.2 per cent per annum as shown in Table 4.24. It was also found that only fallow other than current fallow (other fallows) and current fallow had higher (2.1% each) growth rates than the land put to non-agricultural uses.

Exhaustive connotations of the various land use classes are given under section 3.5.2. The land use category of current fallow is the agricultural land left uncultivated for less than a year, while other fallow is the land left untilled for more than a year, but is within a five-year period. The cultivable waste is the agricultural land left untended to for more than five years in a succession. It is believed that as agricultural land shifts between these classes (current fallow, other fallow and cultivable waste), it gets converted to non-agricultural uses. This could also

Table 4.23: Dynamics of land use classes in Kerala (in hectares)

Land use classes /Triennium	TE 1972-73	TE 1980-81	TE 1987-88	TE 1994-95	TE 2003-04	TE 2010-11	TE 2018-19
Forests	1055000 (27.15)	1081509 (27.83)	1081509 (27.83)	1081509 (27.83)	1081509 (27.83)	1081509 (27.83)	1081509 (27.83)
Land put to non-agricultural use	275500 (7.09)	264588 (6.81)	275467 (7.09)	309957 (7.98)	394189 (10.15)	377412 (9.71)	446341 (11.49)
Barren land	70000 (1.80)	79523 (2.05)	79313 (2.04)	52462 (1.35)	29370 (0.76)	22183 (0.57)	10985 (0.28)
Permanent pastures	28000 (0.72)	5769 (0.15)	3667 (0.09)	1618 (0.04)	271 (0.01)	203 (0.01)	0 (0.00)
Miscellaneous tree crops	123500 (3.18)	65250 (1.68)	45800 (1.18)	33498 (0.86)	12489 (0.32)	4705 (0.12)	2271 (0.06)
Cultivable waste	77000 (1.98)	125796 (3.24)	123500 (3.18)	88148 (2.27)	66774 (1.72)	95291 (2.45)	98122 (2.52)
Other fallow	22000 (0.57)	27056 (0.70)	28167 (0.72)	27688 (0.71)	38258 (0.98)	47757 (1.23)	50177 (1.29)
Current fallow	24226 (0.62)	43070 (1.11)	45067 (1.16)	44331 (1.14)	72916 (1.88)	73577 (1.89)	62331 (1.60)
Net area sown	2185667 (56.25)	2192936 (56.44)	2203008 (56.70)	2246286 (57.81)	2189722 (56.36)	2079726 (53.51)	2033566 (51.33)
Area sown more than once	773613 (19.91)	681933 (17.55)	675915 (17.40)	803433 (20.68)	782641 (20.14)	590635 (15.20)	543771 (13.99)
Gross cropped area	2959127 (76.16)	2874868 (73.99)	2878922 (74.09)	3045833 (78.09)	2972363 (76.50)	2670361 (68.71)	2577337 (66.32)
Arable land	2432393 (62.60)	2454108 (63.16)	2445541 (62.94)	2439951 (62.80)	2380158 (61.26)	2301056 (59.21)	2246468 (57.81)
Total uncultivable land	1453104 (37.40)	1431389 (36.84)	1439956 (37.06)	1445546 (37.20)	1505339 (38.74)	1585231 (40.79)	1639819 (42.19)
Other land use	0	0	0	0	0	103924 (2.67)	69641 (1.79)
Total geographical area	3885497 (100)	3885497 (100)	3885497 (100)	3885497 (100)	3885497 (100)	3886287 (100)	3886287 (100)

Note: Figures in parentheses indicate per cent to total geographical area

help to explain the decline in annual growth rates in area under non-agricultural uses in the first period (TE 1972-73 to TE 1980-81) and in the fifth period (TE 2004-05 to TE 2010-11). From mid 1970s, there was substantial shift from food crops to plantation crops in the state and hence, the area under plantation crops exhibited increasing growth. During the same phase, the land under current fallow and fallow other than current fallow increased tremendously, while it was only a marginal increase for the net sown area (NSA). The area sown more than once, which is mostly accounted by seasonal crops like paddy and vegetables, also increased by a relatively large percentage. The decline in area under non-agricultural use in this phase could be because

Table 4.24: Compound annual growth rates of land use classes in Kerala (in per cent)

Land use classes	1972-73 to 1980-81	1981-82 to 1987-88	1988-89 to 1994-95	1995-95 to 2003-04	2004-05 to 20010-11	2011-12 to 2018-19	Overall (1970-71 to 2018-19)
Forests	0.42	0	0	0	0	0	0.0
Land put to non-agricultural use	-1.07	0.50	1.79	3.32	-1.44	2.16	1.20
Barren land	2.13	-0.73	-5.97	-6.62	-4.10	-7.86	-4.30
Permanent Pastures	-18.97	-6.71	-12.63	-22.83	-6.09	-	-
Miscellaneous tree crops	-8.28	-4.41	-4.08	-10.56	-13.71	-6.3	-8.30
Cultivable waste	8.13	-0.51	-5.15	-2.72	6.91	0.71	-0.40
Other fallow	3.30	0.60	-0.52	3.78	2.44	-0.55	2.10
Current fallow	8.99	0.01	-1.20	6.39	1.49	-2.85	2.10
Net area sown	0.03	0.11	0.30	-0.43	-0.80	-0.24	-0.20
Area sown more than once	-2.00	-0.58	1.99	0.16	-5.64	-0.77	-0.50
Gross cropped area	-0.49	-0.05	0.70	-0.27	-2.03	-0.35	-0.20
Arable land	0.17	-0.02	-0.04	-0.36	-0.45	-0.30	-0.20
Total uncultivable land	-0.29	0.03	0.07	0.60	0.69	0.42	0.30

some farmers shifted their land from various non-agricultural uses to the cultivation of plantation crops such as rubber, which in turn could have led to an increase in NSA as discussed earlier. The increase in current fallow and other fallow could be explained by the decline in area sown more than once. During this period, the paddy lands were left fallow due to rising cost of cultivation, decline in rice prices and the consequent decline in profitability of

Table 4.25: Instability of land use classes in Kerala (in per cent)

Land use classes/Periods	1972-73 to 1980-81	1981-82 to 1987-88	1988-89 to 1994-95	1995-95 to 2003-04	2004-05 to 20010-11	2011-12 to 2018-19	Overall (1970-71 to 2018-19)
Forests	0.64	0	0	0	0	0	0.60
Land put to non-agricultural use	1.54	1.52	0.4	2.63	2.71	0.42	6.13
Barren land	3.4	2.92	13.71	8.39	1.58	4.88	19.86
Permanent Pastures	12.94	3.79	29.87	19.63	4.23	49.74	110.17
Miscellaneous tree crops	5.18	1.5	9.59	4.31	2.87	7.47	29.54
Cultivable waste	6.89	1.73	11.81	8.05	4.45	1.39	22.01
Other fallow	4.54	0.54	2.16	3.68	2.21	4.43	12.87
Current fallow	6.42	1.91	1.86	5.75	4.91	1.75	12.95
Net area sown	0.24	0.35	0.29	0.73	0.46	0.27	2.55
Area sown more than once	3.51	0.6	1.86	5.14	6.39	2.76	10.19
Gross cropped area	1.03	0.12	0.66	0.87	1.42	0.37	4.03
Arable land	0.25	0.2	0.07	0.46	0.24	0.12	1.53
Total uncultivable land	0.46	0.35	0.12	0.77	0.36	0.17	2.46

cultivation. In the beginning of the fifth phase (2004-05 to 2010-11), the Government of Kerala (GoK) initiated several projects directed at the promotion of paddy cultivation. One of such projects was the promotion of cultivation in fallow land initiated in 2004-05, which was intensified from 2007 when Government of India (GoI) initiated the project on Rashtriya Krishi Vikas Yojana (RKVY). These two projects helped to arrest the annual increase in area under fallows. Towards the end of the phase in 2008-09, GoK enacted the Kerala Conservation of Paddy Land and Wetland Act, 2008, which was intended to stop the conversion of paddy lands to other uses. During the subsequent two years after the enactment of the Act, the sustained increase in area under non-agricultural uses as well as fallow lands observed earlier declined, consequently the NSA increased. This was as indication that the legislation was successful in achieving its objective just even few months after the enactment. The decline in annual growth in area under non-agricultural uses in the fifth phase could be explained in the light of these developments.

During the different the phases of agriculture in Kerala, the arable land exhibited a growth only in the first phase, when the cropping pattern saw a large shift towards plantation crops. Since arable and uncultivable land classes are two competing entities, the only negative annual growth rate in uncultivable category was in the first phase, when the annual growth of arable land was positive. During the overall, period, the arable land declined by 0.2 per cent, while the uncultivable land increased by 0.3 per cent per annum.

The estimated Cuddy-Della Valle indices for showing the instability of the land use classes in Kerala are presented in Table 4.25. It could be observed from the table that the land under pastures was the most unstable category during the entire period and by 2015-16 was completely depleted, possibly getting converted for agricultural purposes or construction of dwellings. The area under forests, was the most stable since it had not shown any change since 1976-77. However, studies by (Kumar 2005; Fox *et al.* 2017; Aneesh *et al.* 2018) have found that there had been a decline in area under forests in Kerala. Out of all the phases, the gross cropped area had its largest instability in the first phase when there was massive shift in the cropping pattern of the state from food crops to plantation crops and in the fifth phase when another growth in gross cropped area was observed due to the initiatives of GoK s. The arable land showed an instability of 1.53 per cent during the overall period, while it was 2.46 per cent for the total uncultivable land.

4.3.1.2 Cropping pattern changes

The dynamics in the share of various crops in the gross cropped area of Kerala during different trienniums are presented in Table 4.26. The table includes all the major crops grown in Kerala, while few of the crops for various reasons are included in the categories like pulses,

Table 4.26: Dynamics of cropping pattern in Kerala (in hectares)

Crop	TE 1972-73	TE 1980-81	TE 1987-88	TE 1994-95	TE 2003-04	TE 2010-11	TE 2018-19
Paddy	874597 (29.56)	798070 (27.76)	648722 (22.53)	516217 (16.95)	306743 (10.32)	227155 (8.51)	187886 (7.29)
Tapioca	300547 (10.16)	254079 (8.84)	189566 (6.58)	126767 (4.16)	103222 (3.47)	78127 (2.93)	66910 (2.60)
Pulses	38393 (1.30)	34307 (1.19)	27363 (0.95)	21363 (0.70)	4888 (0.16)	4072 (0.15)	1562 (0.06)
Coconut	731610 (24.72)	658218 (22.90)	728796 (25.31)	890100 (29.22)	901138 (30.32)	778953 (29.17)	767629 (29.78)
Rubber	187823 (6.35)	222553 (7.74)	345710 (12.01)	441500 (14.50)	476496 (16.03)	525704 (19.69)	551093 (21.38)
Coffee	33023 (1.12)	56414 (1.96)	65627 (2.28)	82867 (2.72)	84197 (2.83)	84808 (3.18)	84976 (3.30)
Tea	35567 (1.20)	36127 (1.26)	34666 (1.20)	34667 (1.14)	37431 (1.26)	36789 (1.38)	32295 (1.25)
Arecanut	86373 (2.92)	61472 (2.14)	58975 (2.05)	68267 (2.24)	97727 (3.29)	98838 (3.70)	96005 (3.72)
Cashew	101620 (3.43)	139249 (4.84)	130970 (4.55)	106400 (3.49)	88214 (2.97)	48609 (1.82)	40054 (1.55)
Black pepper	116700 (3.94)	106878 (3.72)	132170 (4.59)	184869 (6.07)	209668 (7.05)	165794 (6.21)	84370 (3.27)
Small cardamom	47490 (1.60)	54368 (1.89)	62665 (2.18)	43693 (1.43)	41360 (1.39)	41474 (1.55)	39014 (1.51)
Ginger	11931 (0.40)	13168 (0.46)	15569 (0.54)	12967 (0.43)	9407 (0.32)	6306 (0.24)	4265 (0.17)
Turmeric	4927 (0.17)	3695 (0.13)	3146 (0.11)	3375 (0.11)	3157 (0.11)	2537 (0.10)	2631 (0.10)
Vegetables	51950 (1.76)	67829 (3.14)	63220 (2.20)	76633 (2.52)	78686 (2.65)	65088 (2.44)	64814 (2.51)
Mango	62146 (2.10)	61093 (2.13)	62930 (2.19)	76125 (2.50)	86015 (2.89)	64235 (2.41)	78557 (3.05)
Banana	10306 (0.35)	13656 (0.48)	18054 (0.63)	24223 (0.80)	54148 (1.82)	54895 (2.06)	57378 (2.23)
Other plantain	37680 (1.29)	37064 (1.29)	54303 (1.26)	51315 (1.53)	41345 (1.83)	41480 (1.84)	39297 (2.17)
Other fruits	98418 (3.33)	90227 (3.14)	82601 (2.87)	99184 (3.26)	133183 (4.48)	115339 (4.32)	136348 (5.29)
Other crops	128025 (4.33)	166403 (5.79)	171830 (5.97)	189949 (6.24)	202186 (6.80)	222618 (8.34)	225613 (8.75)
Food crops	1886528 (62.82)	1779632 (61.90)	1577718 (54.80)	1452984 (47.70)	1318216 (44.35)	1063627 (39.83)	954502 (37.03)
Non-food crops	1118150 (37.18)	1095237 (38.10)	1301056 (45.19)	1592510 (52.30)	1654148 (55.65)	1606734 (60.17)	1627351 (63.07)
GCA	2959127 (100)	2874868 (100)	2878922 (100)	3045833 (100)	2972363 (100)	2670361 (100)	2577337 (100)

Note: Figures in parentheses indicate per cent to gross cropped area vegetables, other fruits and other crops. The share of food grains like paddy and pulses in gross cropped area of Kerala declined in all the phases as well as the overall period of the study. Paddy which accounted for about 30 per cent of the gross cropped area (GCA) in TE 1972-73, only had 7.29 per cent share in the GCA by TE 2018-19. Similarly, the share of tapioca also declined from 10.16 per cent to 2.6 per cent in the same trienniums. While the share of area under food grains and tapioca in the GCA declined, area under plantation crops like coconut and rubber increased. The area and the share in GCA of coffee and arecanut increased but that of tea was mostly stagnant. The increasing share of plantation crops in the GCA of Kerala had been due to increasing profitability of these crops resulting from impressive rise in the prices of these crops and relatively lower labour requirements as compared crops such as paddy and tapioca. Paddy is particularly labour intensive and the prices do not commensurate to the amount of work done. Thus, cultivation of paddy was hampered by the rising labour wages and relatively low prices which led to low net returns per hectare compared to the returns in the plantation segment. This led to the decline of area under the crop as farmers shifted to relatively more rewarding crops like rubber and banana.

The share of spices like black pepper, small cardamom and ginger in the GCA increased in the initial phases and then started declining in the fourth phase, while the share of area under turmeric marginally declined in the phases and was stagnant at 0.11 per cent of the GCA. All the crops under the category of fruits showed growth in share in the GCA all through the phases, which was an indication that the farmers were increasing the allocation of their land into fruit cultivation. This was due to rising prices and increased demand of fruits such as banana which ensured better returns. It could be observed that the share of food crops in the GCA declined all through the phases, while area under non-food crops increased in Kerala. While food crops occupied 62.82 per cent of the gross cropped area in TE 1970-71, the share declined all through the period under study to 37.03 per cent in TE 2018-19. Consequently, the non-food crops occupied 63.07 per cent of the GCA in TE 2018-19. The growth in share of food crops and non-food crop was observed to be the opposite of each other, but was mostly in favour of the non-food crops, implying that land lost from food crops in the gross cropped area was being taken up by the non-food crops. This was true from the mid to late 1970s when the area under food crops like paddy and tapioca started declining as a result of declining profitability due to low prices and increase in cost of inputs. At the same time, the price of plantation crops like rubber was rising and the relatively low labour requirement for cultivation of rubber also enticed most of the farmers into rubber cultivation. While some of the lands were left fallow and later transferred to other uses, significant share of the land was shifted to crops such as rubber and coconut. The shift from the food crops to non-food crops was highest in the late 1980s and 1990s, when the prices of rubber continued to rise impressively. Consequently, those periods exhibited the largest increase in total area under non-food crops.

4.3.2 Transition probabilities of land use classes and crops–Results of Markov Chain analysis

To understand the shift in various land use classes and also the shift in area from one crop to another in Kerala, Markov chain analysis was carried and the results of the analysis obtained as the transition probability matrices gave the retention and transition probabilities of various land use classes and crops to find out the likelihood of these crops and land-use classes retaining or losing the area to other crops or land-use categories. . The results of the Markov chain analyses are discussed below.

4.3.2.1 Transition probabilities of land use classes

The transition probability matrices for land use classes in Kerala are shown in Table 4.27 through Table 4.32 for different phases of agricultural growth in Kerala. The diagonal elements in the transition probability matrix show the retention probabilities of various land use classes. The area under forests, area put to non-agricultural uses and, permanent pastures and grazing lands were the most stable land use classes in the first phase (1970-71 to 1980-81). The largest gainer in this phase was net sown area and it showed 96.1 per cent probability of retaining its area. This phase was the beginning of shift from various crops to plantation crops and large tracts of lands in which other crops were grown were converted to the cultivation of plantation crops like rubber due to increasing prices and profitability. This shift in land use helped to increase the net sown area. Thus, one of the largest losers, barren and uncultivable use land had a 75.2 chance of shift or conversion to net sown area. The barren and uncultivable use lands according to the Department of Economics and Statistics (DES), Government of Kerala (GoK) are lands like degraded lands and hills which can only be brought to cultivation at huge costs. The probability that area under barren lands had a high chance of being brought under cultivation showed the extent to which farmers could take effort for bringing land under cultivation of plantation crops. The net sown area also had 4.4 per cent probability of receiving land from permanent pastures and grazing lands, and a probability 21.4 per cent from area under miscellaneous tree crops. Another loser in this phase was the fallow other than current fallow which showed no likelihood of retaining its area and it showed 51.7 per cent probability of losing its area to land put to non-agricultural uses, a probability of 19.6 per cent of losing its area to barren and uncultivable land and 28.7 per cent of losing its area to miscellaneous tree crops.

The transition probability matrix for the second phase (1981-82 to 1987-88) is presented as Table 4.28. During this phase, the intensification in cultivation of plantation crop happened, especially towards the end of 1980s. Rubber had its highest growth in area in this phase and the other crops that had increased growth in area during this phase were coconut, black pepper and, banana and other plantains. Thus, the increase in area under these crops resulted in the increase of net sown area. The area under forests did not show any change since 1976-77 based on the DES data. It was therefore not considered for the discussion, since with no change in area, it automatically had 100 per cent probability of holding on its area in the future. Thus, excluding forests, in this phase only net sown area was stable by having a probability of 93.4 per cent of retaining its area in the current use. However, this probability was lower than the previous phase, which was an indication that despite net sown area showing a chance of gaining from other fallow (100%) and area under non-agricultural uses (43.3%), it had a probability to lose some of its area to land put to non-agricultural uses (4.1%), other fallows (1.3%) and current fallows (1.2%). The largest losers in this phase were the permanent pastures and grazing land, cultivable waste, and fallow other fallow current fallow, for which each had 100 per cent probability of transitioning to cultivable waste, land put to non-agricultural uses and net sown area respectively.

In the third phase (1988-89 to 1994-95) the category of net sown area gained mostly due to the increasing area under plantation crops like rubber and coconut and, banana and other plantains. The decline in area under paddy was also slowed due to the introduction of the group farming programme during the beginning of this phase. Thus, this could be the reason for the improvement in the retention probability of net sown area in comparison with the second phase. It thus follows that net sown area was the most stable land use in this phase, only showing a 2.8 per cent probability of losing its area to area under non-agricultural uses. The land put to non-agricultural uses also exhibited stability in this phase. The losers in this category were barren and uncultivable use land, permanent pastures and grazing fields, miscellaneous tree crops and fallows other than current fallow. The area under barren and uncultivable use land despite having 94.4 per cent of gaining from miscellaneous tree crops and 27.8 per cent probability of gaining from current fallow, also showed a probability of 58.5 per cent of losing its land to cultivable waste, 25.8 per cent probability of losing to miscellaneous tree crops and

2.8 per cent probability of losing to permanent pastures. Thus, despite being a major gainer, barren land and uncultivable land was also a major loser and that is why it showed only 1.3 per cent of retaining its area. The net sown area gained mostly from cultivable waste. According to DES, cultivable waste is the land accessible for cultivation but has not been brought to cultivation for at least five years in a sequence. This means that, some of the lands that could have been left fallow towards the end of 1970s when many farmers abandoned cultivation of crops such as paddy and tapioca were being brought back to cultivation, possibly for cultivation of plantation crops or was cultivation of paddy was being restored in these lands when the group farming programme was implemented.

During the fourth phase (1995-96 to 2003-04) shown in Table 4.30, net sown area was a major loser in its retention probability. It showed only 82.7 per cent probability of holding on its area in the future, a drop from the previous phase's probability. It had 2.1 per cent, 10.9 per cent 1.4 per cent and 1.9 per cent chance of losing its area to land under non-agricultural uses, forests, cultivable waste and current fallow respectively. During this phase, the prices of rubber soared, while labour wage rates also increased. Since rubber was comparatively less labour intensive, the increase in wages at a rate lesser than the growth in prices of rubber made rubber cultivation more remunerative but had a negative impact on returns from paddy. During this period also the State of Kerala registered the largest increase in emigrants to the Gulf which in turn helped to boost remittances. Prakash (1998) and Govindaprasad (2018) noted that the huge inflow of remittances caused massive distortions in the Kerala economy including the land use and cropping sector. The interaction of these factors could have adversely affected the interest of farmers in paddy cultivation and hence favoured the practice of leaving their paddy lands fallow. This period showed an increase in current fallows and this could have been the reason for paddy having its worst decline in area among all the phases. This caused the net sown to decrease since paddy represented 17 per cent of the gross cropped area during the phase. The largest gainers in this phase were area under non-agricultural uses and miscellaneous tree crops. Thus, the land lost from agricultural uses could have been used to develop the lands for non-agricultural uses, which was also encouraged by the increasing influx of foreign remittances. A 0.1 per cent transition probability from net sown area to miscellaneous tree crops also ensured that the miscellaneous tree crops (which showed zero per cent retention probability in the previous phase) also registered a higher retention probability in this phase.

The transition probability matrix for the fifth phase (2004-05 to 2010-11) is shown in Table 4.31. It could be observed from the table that the most stable land uses were barren land and uncultivable land, miscellaneous tree crops and net sown area. The period from 2004-05 to 2010-11 was an important period for paddy since several projects were initiated for promoting paddy cultivation in the state. In 2004, GoK launched a project to promote the cultivation in the fallow lands and towards the latter half of the phase, GoK enacted Kerala Conservation of Paddy Land and Wetland Act, 2008. While the promotion of cultivation in the fallow lands could have led to the increasing probability in the shift of cultivable waste and current fallow to net sown area, the 2008 act could had been important in ensuring that there would be no further loss and possible conversion as well as reversion of paddy land. This could explain the reason for the net sown area gaining from land put to non-agricultural use, cultivable waste and current fallow, which showed transition probabilities of 14.3 per cent, 58.2 per cent and 34 per cent in favour of net sown area. Consequently, the largest losers in this phase were cultivable waste, fallow other than current fallow and current fallow possibly due to GoK intervention. Permanent pastures and other grazing land was also a loser in this phase.

The area under non-agricultural uses which got an impetus in the fifth phase, showed a 100 per cent probability of holding to its share in the sixth phase (2011-12 to 2018-19). The cultivable waste drew gains from net sown area. Interestingly, area under cultivable waste lost to net sown area in the previous phase, an indication that the 2008 legislation did meet its objective of preventing the paddy land from getting converted to other uses, but it did not prevent the farmers from leaving their land fallow. By leaving their land fallow, meant that the legislation was an artificial barrier to farmers who were not interested in continuing with paddy cultivation and had no choice but to leave their lands unattended. The promotion of cultivation in the fallow lands continued into this phase, especially in Palakkad under the central government sponsored National Food Security Scheme, which showed a 12.3 per cent probability of current fallow land transitioning to net sown area. As per the DES data, the area under permanent pastures and grazing lands got depleted in 2015-16. At the same time, the area under pastures showed a 93.2 per cent of transitioning to net sown area, an indication that the area under permanent pastures and grazing lands was getting cleared and converted to farm lands. A summary of the retention and transition probabilities of different land-use categories in different growth phases of agriculture in Kerala is summarised in Table 4.33.

Table 4.27: Transition probability matrix for land use classes in Kerala during Period I (1970-71 to 1980-81)

Land use Categories	**Forests**	**Land put to non-agricultural uses**	**Barren and uncultivable land**	**Permanent pastures and grazing lands**	**Land under miscellaneous tree crops**	**Cultivable waste**	**Fallow other than current fallow**	**Current fallow**	**Net area sown**
Forests	**0.99**	0	0		0	0	0	0	0.01
Land put to non-agricultural uses	0	**0.958**	0	0	0	0.042	0	0	0
Barren and uncultivable land	0.012	0	**0.236**	0	0	0	0	0	0.752
Permanent pastures and grazing lands	0	0	0	**0.956**	0	0	0	0	0.044
Land under miscellaneous tree crops	0	0	0	0.001	**0.786**	0	0	0	0.214
Cultivable waste	0.005	0	0.168	0	0	**0.613**	0.006	0.208	0
Fallow other than current fallow	0	0.517	0.196	0	0.287	0	**0**	0	0
Current fallow	0	0	0	0	0	0.466	0.168	**0.366**	0
Net area sown	0.004	0	0.016	0	0.002	0.009	0.008	0	**0.961**

Table 4.28: Transition probability matrix for land use classes in Kerala during Period II (1981-82 to 1987-88)

Land use Categories	**Forests**	**Land put to non-agricultural uses**	**Barren and uncultivable land**	**Permanent pastures and grazing lands**	**Land under miscellaneous tree crops**	**Cultivable waste**	**Fallow other than current fallow**	**Current fallow**	**Net area sown**
Forests	**1**	0	0	0	0	0	0	0	0
Land put to non-agricultural uses	0	**0.212**	0	0	0	0.354	0	0	0.433
Barren and uncultivable land	0	0	**0.476**	0	0.524	0	0	0	0
Permanent pastures and grazing lands	0	0	0	**0**	0	1	0	0	0
Land under miscellaneous tree crops	0	0	0.416	0.082	**0.103**	0.398	0	0	0
Cultivable waste	0	1	0	0	0	**0**	0	0	0
Fallow other than current fallow	0	0	0	0	0	0	**0**	0	1
Current fallow	0	0	0.507	0	0	0.109	0	**0.384**	0
Net area sown	0	0.041	0	0	0	0	0.013	0.012	**0.934**

Table 4.29: Transition probability matrix for land use classes in Kerala during Period III (1981-82 to 1987-88)

Land use Categories	**Forests**	**Land put to non-agricultural uses**	**Barren and uncultivable land**	**Permanent pastures and grazing lands**	**Land under miscellaneous tree crops**	**Cultivable waste**	**Fallow other than current fallow**	**Current fallow**	**Net area sown**
Forests	**1**	0	0	0	0	0	0	0	0
Land put to non-agricultural uses	0	**0.798**	0	0	0.025	0.052	0.055	0.069	0
Barren and uncultivable land	0	0	**0.13**	0.028	0.258	0.585	0	0	0
Permanent pastures and grazing lands	0	0	0	**0**	0	0	0	0	1
Land under miscellaneous tree crops	0	0	0.944	0	**0**	0	0	0.056	0
Cultivable waste	0	0	0.03	0	0	**0.303**	0	0	0.667
Fallow other than current fallow	0	0	0	0.006	0.444	0.55	**0**	0	0
Current fallow	0	0	0.278	0	0	0	0.234	**0.486**	0.002
Net area sown	0	0.028	0	0	0	0	0	0	**0.972**

Table 4.30: Transition probability matrix for land use classes in Kerala during Period IV (1995-96 to 2003-04)

Land use Categories	Forests	Land put to non-agricultural uses	Barren and uncultivable land	Permanent pastures and grazing lands	Land under miscellaneous tree crops	Cultivable waste	Fallow other than current fallow	Current fallow	Net area sown
Forests	**0.738**	0	0	0	0	0	0	0	0.262
Land put to non-agricultural uses	0.099	**0.788**	0.013	0	0	0.004	0.096	0	0
Barren and uncultivable land	0	0	**0**	0	0	0.278	0	0	0.722
Permanent pastures and grazing lands	0	0	0	**0.615**	0.385	0	0	0	0
Land under miscellaneous tree crops	0	0	0.255	0.007	**0.738**	0	0	0	0
Cultivable waste	0	0	0	0	0	**0**	0	0	1
Fallow other than current fallow	0.151	0	0	0.001	0	0.701	**0**	0	0.147
Current fallow	0	0.588	0	0	0	0	0	**0.412**	0
Net area sown	0.109	0.021	0.009	0	0.001	0.014	0	0.019	**0.827**

Table 4.31: Transition probability matrix for land use classes in Kerala during Period V (2004-05 to 2010-11)

Land use Categories	**Forests**	**Land put to non-agricultural uses**	**Barren and uncultivable land**	**Permanent pastures and grazing lands**	**Land under miscellaneous tree crops**	**Cultivable waste**	**Fallow other than current fallow**	**Current fallow**	**Net area sown**
Forests	**0.986**	0	0	0	0	0	0	0	0.014
Land put to non-agricultural uses	0.004	**0.504**	0	0.001	0	0.138	0.062	0	0.143
Barren and uncultivable land	0	0	**0.916**	0	0	0	0	0.084	0
Permanent pastures and grazing lands	0	0	0	**0**	0	0	0	1	0
Land under miscellaneous tree crops	0	0	0	0.003	**0.925**	0	0	0.072	0
Cultivable waste	0.006	0.085	0	0	0	**0.049**	0	0	0.582
Fallow other than current fallow	0	0	0	0	0	0	**0**	1	0
Current fallow	0.005	0.604	0	0	0	0.051	0	**0**	0.34
Net area sown	0.006	0.049	0	0	0	0	0.009	0.012	**0.924**

Table 4.32: Transition probability matrix for land use classes in Kerala during Period VI (2011-12 to 2018-19)

Land use Categories	**Forests**	**Land put to non-agricultural uses**	**Barren and uncultivable land**	**Permanent pastures and grazing lands**	**Land under miscellaneous tree crops**	**Cultivable waste**	**Fallow other than current fallow**	**Current fallow**	**Net area sown**
Forests	**1**	0	0	0	0	0	0	0	0
Land put to non-agricultural uses	0	**1**	0	0	0	0	0	0	0
Barren and uncultivable land	0	0	**0.545**	0	0	0	0	0.455	0
Permanent pastures and grazing lands	0	0	0	**0.068**	0	0	0	0	0.932
Land under miscellaneous tree crops	0	0	0	0	**0**	0	0	1	0
Cultivable waste	0	0.073	0	0	0	**0.409**	0.361	0	0
Fallow other than current fallow	0	0	0	0	0	0.049	**0**	0	0
Current fallow	0	0	0.019	0	0.012	0	0.277	**0.536**	0.123
Net area sown	0	0	0	0	0	0.026	0	0	**0.958**

Table 4.33: Summary of retention and transition probabilities of land use classes in Kerala

Period	Stable land use classes			Land use classes gained	Land use classes lost
Period I (1970-71 to 1980-81)	Forest (0.99)	Net sown area (0.961)	Land put to non-agricultural uses (0.958)	Land put to non-agricultural uses, net sown area	Barren and uncultivable land, fallow other than current fallow, current fallow
Period II (1981-82 to 1987-88)	Net sown area (0.934)			Net sown area, barren land and uncultivable land	Pastures, tree crops, cultivable waste and fallow other than current fallow
Period III (1988-89 to 1994-95)	Net sown area (0.972)	Land put to non-agricultural uses (0.798)		Barren land and uncultivable land, net sown area	Barren and uncultivable land, ,permanent pastures, tree crops, fallow other than current fallow
Period VI (2011-12 to 2018-19)	Land put to non-agricultural uses (0.788)	Permanent pastures and other grazing land (0.615)	Miscellaneous tree crops (0.738)	Land put to non-agricultural uses, Miscellaneous tree crops	Barren land, cultivable waste, fallow other than current fallow and Net sown area
Period V (2004-05 to 2010-11)	Miscellaneous tree crops (0.925)	Net sown area (0.924)	Barren and uncultivable land (0.916)	Net sown area, Land put to non-agricultural uses, Miscellaneous tree crops	Permanent pastures and other grazing land, cultivable waste, fallow other than current fallow and current fallow.
Period VI (2011-12 to 2018-19)	Land put to non-agricultural uses (1.000)	Barren and uncultivable land (0.545)	Current fallow (0.536)	Cultivable waste, current fallow	Miscellaneous tree crops, fallow other than current fallow

4.3.2.2 Transition probabilities of crops

Presented in Table 4.34 is the transition probability matrix for various crops in Kerala obtained from the Markov chain analysis. The diagonal elements of the matrix show the retention probabilities of the crops. In the first phase (1970-71 to 1980-81) paddy, rubber, tapioca and cashew were some of the most stable crops. Cashew had the highest retention probability (83%), followed by tapioca and rubber. The largest gainers in this phase were rubber, coconut and tapioca. While coconut gained 27.1 per cent from paddy, it lost 22.3 per cent in turn to paddy. The largest losers were pulses, black pepper, ginger and banana. Pulses lost almost all its area to coconut at 95.2 per cent probability and the remaining to black pepper. Black pepper also lost some of its area to coconut, while banana had 100 per cent probability of transitioning to area under paddy

The most stable crops in the second phase (1981-82 to 187-88) were rubber, tea, paddy and coconut as shown in Table 4.35. The stability of paddy came from 49.8 per cent transition probability from tapioca. Banana and coffee were some of the most unstable crops since each had 100 per cent transition probability of losing to black pepper and rubber respectively. Other plantains had a 90.4 per cent transition probability in favour of coconut. Another large loser in this phase was pulses which lost most of its area to cashew. Mango gained some area from black pepper and started improving its retention probability in this phase.

The retention probability of paddy declined in the third phase (1988-89 to 1994-95) in comparison to the second phase. As indicated in Table 4.36, much of its area was lost to pulses, ginger, coconut, rubber, tea, tapioca, cashew and mango. Despite that, it gained 41.6 per cent from tapioca. The most stable crop in this phase was coconut, which had 73.3 per cent probability of gaining from black pepper and 56.5 per cent of gaining from other plantain. Both coffee and mango had 100 per chance of losing the area under those crops to rubber, while cashew and tea also had 100 per cent chance of losing the area to paddy. Tapioca was also a major gainer from pulses and ginger which had 100 per cent probability of losing the area under those crops to tapioca.

During the fourth phase (1995-96 to 2003-04), it could be observed from Table 4.37 that paddy, banana, tapioca, coconut and arecanut showed the highest stability in area based on their retention probabilities. Rubber was a major loser in this phase and it had 78 per cent probability of transitioning to coconut cultivation. It also showed probability of losing its land to coffee, tea, other plantain and mango. Therefore, coconut was a major gainer in this phase.

Table 4.34: Transition probability matrix for crops in Kerala during Period I (1970-71 to 1980-81)

Crop	Paddy	Pulses	Black pepper	Small cardamom	Turmeric	Ginger	Coconut	Rubber	Arecanut	Coffee	Tea	Tapioca	Cashew	Banana	Other plantain	Mango
Paddy	0.64	0.034	0.012	0	0	0	0.271	0	0	0	0	0	0	0	0	0.042
Pulses	0	0	0.048	0	0	0	0.952	0	0	0	0	0	0	0	0	0
Black pepper	0.61	0	0.018	0	0	0	0.368	0	0	0	0	0	0	0	0	0
Small cardamom	0	0	0	0.157	0	0	0	0.843	0	0	0	0	0	0	0	0
Turmeric	0	0	0	0	0.194	0	0	0	0	0	0.241	0.566	0	0	0	0
Ginger	0	0	0	0	0	0	0	0.251	0	0	0	0	0	0.32	0	0.429
Coconut	0.223	0	0.133	0	0	0	0.463	0	0	0	0.023	0.034	0	0	0	0
Rubber	0	0	0	0.119	0	0.03	0	0.773	0	0	0	0	0	0	0.012	0
Arecanut	0	0	0	0	0	0	0	0	0.551	0	0	0.449	0	0	0	0
Coffee	0	0	0	0	0	0	0	0	0	0.58	0	0	0.024	0	0	0
Tea	0.085	0	0	0	0	0	0	0.013	0	0	0.148	0	0	0.003	0	0.429
Tapioca	0.111	0.017	0	0	0	0	0.044	0	0.004	0	0	0.78	0	0	0.03	0
Cashew	0	0	0	0	0	0	0	0	0	0.17	0	0	0.83	0	0	0
Banana	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other plantain	0	0	0	0.324	0	0.125	0	0.052	0	0	0.285	0	0	0	0.216	0
Mango	0.287	0.043	0	0	0	0	0	0	0	0	0	0	0	0	0.287	0.098

Table 4.35: Transition probability matrix for crops in Kerala during Period II (1981-82 to 1987-88)

Crop	Paddy	Pulses	Black Pepper	Small Cardamom	Turmeric	Ginger	Coconut	Rubber	Arecanut	Coffee	Tea	Tapioca	Cashew	Banana	Other plantain	Mango
Paddy	0.778	0	0	0	0	0	0	0	0.007	0	0	0.162	0.028	0	0	0
Pulses	0	0	0	0	0	0	0	0	0	0	0.069	0	0.931	0	0	0
Black Pepper	0	0	0.519	0	0	0	0	0	0.062	0	0	0	0	0.042	0	0.307
Small Cardamom	0	0	0.321	0	0	0	0.007	0	0	0	0	0	0	0	0	0
Turmeric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ginger	0	0	0	0.552	0	0	0	0	0	0.148	0	0	0	0.301	0	0
Coconut	0	0	0	0.057	0	0	0.767	0.004	0	0.054	0	0	0	0.005	0.05	0
Rubber	0	0	0.09	0.041	0	0	0	0.842	0	0.013	0	0	0	0.014	0	0
Arecanut	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coffee	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Tea	0	0	0	0	0	0	0	0	0.206	0	0.794	0	0	0	0	0
Tapioca	0.498	0.097	0	0	0	0	0	0	0	0	0	0.405	0	0	0	0
Cashew	0	0	0	0	0.02	0.088	0	0	0	0.148	0	0	0.639	0	0	0
Banana	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Other plantain	0	0	0	0	0	0	0.904	0	0	0	0.096	0	0	0	0	0
Mango	0	0	0	0	0	0	0	0	0.057	0	0	0	0	0	0	0.24

Table 4.36: Transition probability matrix for crops in Kerala during Period III (1988-89 to 1994-95)

Crop	Paddy	Pulses	Black Pepper	Small Cardamom	Turmeric	Ginger	Coconut	Rubber	Arecanut	Coffee	Tea	Tapioca	Cashew	Banana	Other plantain	Mango
Paddy	0.554	0.021	0	0	0	0.004	0.052	0.006	0	0	0.016	0.122	0.132	0	0	0.019
Pulses	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Black Pepper	0	0	0	0	0	0	0.733	0.075	0.056	0	0	0	0	0.091	0	0.046
Small Cardamom	0	0.036	0	0.159	0	0.038	0.13	0	0	0	0.03	0.257	0.103	0	0	0.154
Turmeric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ginger	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Coconut	0.003	0	0.054	0	0	0.012	0.562	0.196	0	0.047	0.015	0	0	0	0	0
Rubber	0	0	0.225	0	0	0	0	0.054	0.064	0.089	0.019	0	0	0	0.078	0.117
Arecanut	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Coffee	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Tea	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tapioca	0.416	0.058	0	0.252	0	0	0	0	0	0	0	0.128	0.146	0	0	0
Cashew	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Banana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other plantain	0	0	0.07	0	0.027	0	0.565	0	0.28	0	0	0	0	0.015	0	0
Mango	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Table 4.37: Transition probability matrix for crops in Kerala during Period IV (1995-96 to 2003-04)

Crop	Paddy	Pulses	Black Pepper	Small Cardamom	Turmeric	Ginger	Coconut	Rubber	Arecanut	Coffee	Tea	Tapioca	Cashew	Banana	Other plantain	Mango
Paddy	0.722	0.015	0	0	0.004	0.02	0.097	0	0	0	0	0.083	0.057	0	0	0.002
Pulses	0.668	0.332	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black Pepper	0	0	0.429	0.007	0	0	0	0	0.195	0	0.036	0	0	0.075	0.052	0
Small Cardamom	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Turmeric	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ginger	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Coconut	0	0	0	0.026	0	0	0.422	0.275	0	0.062	0.004	0	0.034	0	0	0
Rubber	0	0	0.073	0	0	0	0.78	0.056	0	0.009	0.013	0	0	0	0.012	0.058
Arecanut	0	0	0.455	0	0	0	0	0	0.427	0	0	0	0	0	0	0
Coffee	0	0	0	0.021	0	0	0	0.47	0	0	0.112	0	0	0	0	0
Tea	0	0	0	0	0	0	0	0	0	0	0.172	0	0	0	0	0
Tapioca	0	0	0	0	0	0.02	0	0	0	0.131	0	0.585	0.057	0	0	0
Cashew	0	0	0	0	0	0	0.587	0	0	0	0	0	0	0	0	0
Banana	0	0	0	0	0	0	0	0	0.366	0	0	0	0	0.634	0	0
Other plantain	0	0	0.832	0	0	0	0	0	0	0	0	0	0	0.098	0.071	0
Mango	0	0	0	0	0.012	0	0.165	0	0	0	0	0	0	0	0.278	0.148

Table 4.38: Transition probability matrix for crops in Kerala during Period V (2004-05 to 2010-11)

Crop	**Paddy**	**Pulses**	**Black Pepper**	**Small Cardamom**	**Turmeric**	**Ginger**	**Coconut**	**Rubber**	**Arecanut**	**Coffee**	**Tea**	**Tapioca**	**Cashew**	**Banana**	**Other plantain**	**Mango**
Paddy	0	0	0.425	0	0	0	0.484	0	0.039	0	0	0	0	0	0	0
Pulses	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Black Pepper	0	0.014	0.432	0	0.008	0.007	0	0.083	0.014	0	0	0.05	0	0.133	0.092	0.018
Small Cardamom	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Turmeric	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ginger	0	0	0	0	0.082	0.086	0	0	0	0	0	0	0.229	0	0	0
Coconut	0	0	0	0	0	0	0.711	0	0.026	0.019	0	0	0	0	0	0.025
Rubber	0	0	0	0	0	0	0	0.966	0	0	0.009	0	0	0	0	0
Arecanut	0	0	0	0.016	0	0	0.529	0	0.275	0	0	0	0	0	0.14	0
Coffee	0	0	0	0.013	0	0	0	0	0	0.628	0.26	0	0	0	0	0
Tea	0	0	0	0.779	0	0	0	0	0	0	0	0	0	0	0	0
Tapioca	0.89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cashew	0	0	0	0	0	0	0	0	0	0	0	0.112	0.757	0	0	0.132
Banana	0.106	0	0	0.197	0.01	0	0	0	0	0	0	0.129	0	0	0	0.173
Other plantain	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Mango	0.751	0.022	0	0	0	0	0	0	0	0	0	0	0.115	0	0	0.113

Table 4.39: Transition probability matrix for crops in Kerala during Period VI (2011-12 to 2018-19)

Crop	Paddy	Pulses	Black Pepper	Small Cardamom	Turmeric	Ginger	Coconut	Rubber	Arecanut	Coffee	Tea	Tapioca	Cashew	Banana	Other plantain	Mango
Paddy	0	0	0	0.016	0	0	0.78	0.161	0	0.043	0	0	0	0	0	0
Pulses	0	0	0.405	0	0	0.184	0	0	0	0	0	0	0.32	0	0	0.088
Black Pepper	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Small Cardamom	0	0	0	0	0	0	0.85	0	0	0.15	0	0	0	0	0	0
Turmeric	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ginger	0	0	0	0	0.054	0	0	0	0.073	0	0	0.172	0.7	0	0	0
Coconut	0.03	0	0.05	0.021	0	0	0.62	0.106	0	0.023	0	0.063	0.018	0.068	0	0
Rubber	0.098	0	0.033	0	0	0.007	0	0.355	0	0.036	0.038	0	0	0	0.009	0.112
Arecanut	0	0	0	0	0	0	0.522	0	0.454	0.024	0	0	0	0	0	0
Coffee	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tea	0.549	0	0	0.295	0	0	0	0	0.081	0.012	0.062	0	0	0	0	0
Tapioca	0.053	0	0	0.056	0	0	0.082	0	0.719	0.086	0.006	0	0	0	0	0
Cashew	0.288	0.056	0	0	0	0	0	0	0	0	0	0	0.535	0.121	0	0
Banana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.557	0
Other plantain	0	0	0	0	0	0.003	0	0	0	0	0	0	0	0	0.314	0
Mango	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.40: Summary of retention and transition probabilities of crops in Kerala

Period	Stable crops			Crops gained	Crops lost
Period I (1970-71 to 1980-81)	Cashew (0.83)	Tapioca (0.78)	Rubber (0.773)	Coconut, rubber, paddy	Pulses, black pepper, banana, mango
Period II (1981-82 to 1987-88)	Rubber (0.842)	Tea (0.794)	Coconut (0.767)	Rubber, coconut, paddy	Pulses, small cardamom, turmeric, ginger, arecanut, coffee, banana and other plantains.
Period III (1988-89 to 1994-95)	Coconut (0.562)	Paddy (0.554)		Coconut, rubber, paddy, tapioca	Pulses, black pepper, turmeric, arecanut, coffee, tea, cashew, banana, other plantain and mango
Period VI (2011-12 to 2018-19)	Paddy (0.722)	Banana (0.634)	Tapioca (58.5)	Paddy, coconut, tapioca, black pepper	Rubber, small cardamom, turmeric, ginger, coffee, cashew, other plantain and pulses
Period V (2004-05 to 2010-11)	Rubber (0.966)	Cashew (0.757)	Coconut (0.711)	Coconut, rubber, arecanut, cashew, paddy	Paddy, pulses, tapioca, small cardamom, turmeric, ginger, tea, banana and other plantain
Period VI (2011-12 to 2018-19)	Coconut (0.62)	Cashew (0.535)		Coconut, cashew, arecanut, paddy and other plantain	Paddy, pulses, tapioca, small cardamom, turmeric, ginger, coffee, tapioca and mango

In addition to rubber showing 78 per cent probability of transition in its favour, small cardamom also had 100 per cent probability of shift in favour of coconut together with cashew and mango.

In the fifth phase (2004-05 to 2010-11), shown under Table 4.38, the largest losers were food grains and tapioca. All these crops had zero probability of retaining their areas. However, most plantation crops had relatively high retention probabilities. The most stable crop in this phase was rubber, followed by cashew, coconut and coffee. The transition probabilities from paddy area was in favour of black pepper, coconut and arecanut, while pulses had 100 per cent chance of shifting its area to ginger.

Coconut had the highest transition probability in the sixth phase (2011-12 to 2018-19), an indication that it was the most stable crop as shown Table 4.39. It was also a major gainer in this phase with paddy showing 78 per cent transition probability in its favour. Rubber on the other hand, showed a probability of transitioning to several other crops which in turn affected its retention probability. Table 4.40 show the summary of transition probability matrix of the crops.

4.4 Economics, efficiency and profitability of major crops in Kerala

This section studies the dynamics in costs involved in cultivation of paddy (based on seasons), tapioca, coconut, black pepper, ginger, turmeric and, banana and other plantains in Kerala for 17 years from 2000-01 to 2016-17. The results are discussed under the sections on analysis of the cost components in the cost of cultivation of major crops and, returns and profitability. In the analysis of the cost components in the cost of cultivation of major crops, the share of the input-wise cost components over the period are discussed. The results of these analyses are discussed below.

4.4.1 Analysis of cost components in the cost of cultivation of major crops in Kerala

4.4.1.1 Paddy

The share of cost components for paddy are presented from Table 4.41 to Table 4.46. The major component in the cost of the cultivation of paddy across all seasons and landholding sizes was human labour. However, the share of the cost in the total cost showed different trends over the study period. The proportion of human labour in the total cost showed an increase from 59.45 per cent in 2000-01 to 63.42 per cent in 2016-17 for the small holdings, which

4.4.1.1.1 Autumn paddy

Table 4.41: Share of cost components in total cost of cultivation of autumn paddy in small and medium landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Small				Medium			
	2000-01	2003-04	2010-11	2016-17	2000-01	2003-04	2010-11	2016-17
Hired human labour	11745 (49.27)	10839 (46.63)	19541 (44.31)	33390 (44.16)	9382 (48.49)	9799 (48.72)	15912 (43.87)	24974 (42.63)
Family labour	2427 (10.18)	2316 (9.96)	4703 (10.66)	14556 (19.25)	1077 (5.57)	1232 (6.13)	3185 (8.78)	7233 (12.35)
Total Human labour	**14172 (59.45)**	**13155 (56.6)**	**24244 (54.97)**	**47946 (63.42)**	**10459 (54.06)**	**11031 (54.85)**	**19097 (52.65)**	**32207 (54.98)**
Animal labour	1138 (4.77)	610 (2.62)	879 (1.99)	208 (0.28)	539 (2.79)	319 (1.59)	261 (0.72)	1159 (1.98)
Machine labour	1759 (7.38)	2217 (9.54)	4300 (9.75)	8508 (11.25)	1667 (8.62)	2171 (10.79)	4787 (13.2)	7734 (13.2)
Total mechanical cost	**2897 (12.15)**	**2827 (12.16)**	**5179 (11.74)**	**8716 (11.53)**	**2206 (11.4)**	**2490 (12.38)**	**5048 (13.92)**	**8893 (15.18)**
Seed/Seedlings	1086 (4.56)	1187 (5.11)	1379 (3.13)	3119 (4.13)	949 (4.91)	1099 (5.46)	1416 (3.9)	2491 (4.25)
Fertiliser	3113 (13.06)	3037 (13.07)	4307 (9.77)	7010 (9.27)	2355 (12.17)	2742 (13.63)	3535 (9.75)	6332 (10.81)
Plant protection	239 (1)	247 (1.06)	451 (1.02)	444 (0.59)	137 (0.71)	210 (1.04)	408 (1.12)	469 (0.8)
Land tax &irrigation cess	49 (0.21)	57 (0.25)	85 (0.19)	152 (0.2)	53 (0.27)	56 (0.28)	94 (0.26)	373 (0.64)
Total material cost	**4487 (18.82)**	**4528 (19.48)**	**6222 (14.11)**	**10725 (14.19)**	**3494 (18.06)**	**4107 (20.42)**	**5453 (15.03)**	**9665 (16.5)**
Repair and Maintenance	188 (0.79)	363 (1.56)	1373 (3.11)	788 (1.04)	978 (5.06)	162 (0.81)	904 (2.49)	189 (0.32)
Interest on Capital	965 (4.05)	932 (4.01)	1674 (3.8)	2811 (3.72)	767 (3.96)	849 (4.22)	1428 (3.94)	2394 (4.09)
Other expenses	212 (0.89)	499 (2.15)	2620 (5.94)	3548 (4.69)	313 (1.62)	636 (3.16)	2245 (6.19)	4729 (8.07)
Sub total	22921 (96.15)	22304 (95.96)	41312 (93.67)	74534 (98.59)	18217 (94.16)	19275 (95.83)	34175 (94.22)	58077 (99.14)
Interest on fixed capital	918 (3.85)	939 (4.04)	2791 (6.33)	1069 (1.41)	1130 (5.84)	838 (4.17)	2097 (5.78)	503 (0.86)
Total cost	23839 (100)	23243 (100)	44103 (100)	75603 (100)	19347 (100)	20113 (100)	36272 (100)	58580 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.42: Share of cost components in total cost of cultivation of autumn paddy in large and all size landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Large				All Size			
	2000-01	2003-04	2010-11	2016-17	2000-01	2003-04	2010-11	2016-17
Hired human labour	11037 (66.05)	11005 (47.2)	16461 (49.69)	22011 (38.98)	10571 (55.16)	10463 (47.57)	16833 (45.92)	25474 (41.72)
Family labour	236 (1.41)	867 (3.72)	1500 (4.53)	4753 (8.42)	1059 (5.53)	1292 (5.87)	2861 (7.8)	7705 (12.62)
Total Human labour	**11273 (67.46)**	**11872 (50.92)**	**17961 (54.22)**	**26764 (47.4)**	**11630 (60.69)**	**11755 (53.44)**	**19694 (53.73)**	**33179 (54.34)**
Animal labour	64 (0.38)	123 (0.53)	0	0	444 (2.32)	297 (1.35)	286 (0.78)	539 (0.88)
Machine labour	897 (5.37)	2041 (8.75)	7245 (21.87)	8684 (15.38)	1387 (7.24)	2129 (9.68)	5601 (15.28)	8241 (13.5)
Total mechanical cost	**961 (5.75)**	**2164 (9.28)**	**7245 (21.87)**	**8684 (15.38)**	**1831 (9.55)**	**2426 (11.03)**	**5887 (16.06)**	**8780 (14.38)**
Seed/Seedlings	1157 (6.92)	1195 (5.13)	773 (2.33)	2770 (4.91)	1062 (5.54)	1153 (5.24)	1170 (3.19)	2717 (4.45)
Fertiliser	1432 (8.57)	4485 (19.24)	1653 (4.99)	6180 (10.95)	2168 (11.31)	3477 (15.81)	2991 (8.16)	6405 (10.49)
Plant protection	170 (1.02)	401 (1.72)	756 (2.28)	632 (1.12)	173 (0.9)	292 (1.33)	546 (1.49)	526 (0.86)
Land tax &irrigation cess	362 (2.17)	118 (0.51)	238 (0.72)	133 (0.24)	173 (0.9)	80 (0.36)	145 (0.4)	240 (0.39)
Total material cost	**3121 (18.68)**	**6199 (26.59)**	**3420 (10.32)**	**9715 (17.21)**	**3576 (18.66)**	**5002 (22.74)**	**4852 (13.24)**	**9888 (16.2)**
Repair and Maintenance	35 (0.21)	216 (0.93)	488 (1.47)	633 (1.12)	199 (1.04)	228 (1.04)	843 (2.3)	472 (0.77)
Interest on Capital	746 (4.46)	1029 (4.41)	1431 (4.32)	2412 (4.27)	802 (4.19)	934 (4.25)	1478 (4.03)	2481 (4.06)
Other expenses	163 (0.98)	1324 (5.68)	1722 (5.2)	7966 (14.11)	231 (1.21)	879 (4)	2126 (5.8)	5723 (9.37)
Sub total	16299 (97.53)	22804 (97.81)	32267 (97.4)	56174 (99.49)	18269 (95.33)	21224 (96.49)	34880 (95.15)	60523 (99.13)
Interest on fixed capital	412 (2.47)	510 (2.19)	861 (2.6)	288 (0.51)	894 (4.67)	772 (3.51)	1777 (4.85)	531 (0.87)
Total cost	16711 (100)	23314 (100)	33128 (100)	56462 (100)	19163 (100)	21996 (100)	36657 (100)	61054 (100)

Note: Figures in parentheses indicate per cent to column total

showed that the share of the human labour was increasing in the small sized landholdings. While the share of human labour remained stagnant over the period for the medium holdings of paddy, it reduced from 67.46 per cent in 2000-01 to 47.4 per cent in 2016-17 for the large holdings. This showed that the use of human labour, which included hired human labour and family labour was increasing in the small sized holdings of paddy and declining for other holdings. The increase in the share of human labour was more in the small holdings for all the seasons and least for large holdings for all seasons an indication that large holdings were reducing utilisation of human labour for the cultivation of paddy cultivation for all seasons. The decline in human labour cost was highest in winter paddy and least in summer paddy for large holdings. Hired human labour was declining in proportion over the period for all the sizes in paddy cultivation while family labour was increasing in the proportion of the total cost.

The analysis also showed that shares of the hired human labour for all holdings are declining in the cultivation of paddy. Autumn paddy had the highest share increase in use of machine labour over the year of study while winter paddy had the least increase for large holdings. For small holdings, machine labour usages were more in the winter season while lowest in autumn. For all the seasons in the cultivation of paddy, machine use had positive annual growth rates in all holdings. However, the growth was lowest in small holdings and highest in large holdings. Autumn paddy had the highest growth in use of machine labour (6.35%) while winter paddy had the least growth for large holdings (4.42%). For small holdings, machine labour usage's share increased more over the years in winter season while lowest in autumn. This is in line with the human labour use trend an indication that the small farms were working in their farms more in the winter season and less in the autumn season. This was an indication that for the period under study, paddy farmers in the small holdings were increasing the use of human labour and reducing on machine labour. Small holdings, where animal labour was still being used, showed a high annual decline in its use.

The results of paddy cultivation for all seasons and holdings show that the share of cost of materials like seeds, fertilisers, plant protection materials and irrigation cess were declining. For example, the total material cost in for autumn paddy for small holdings had 18.82 per cent of the total cost. However, this reduced to 14.19 per cent by 2016-17. This trend is repeated for other seasons and holdings though in the autumn and summer paddy, the decline in material cost component was highest in small holdings and less in large holdings while the decline was highest in medium holdings and least in large holdings. These decline in cost component of

4.4.1.1.2 Winter paddy

Table 4.43: Share of cost components in total cost of cultivation of winter paddy in small and medium landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	**Small**				**Medium**			
	2000-01	2003-04	2010-11	2016-17	2000-01	2003-04	2010-11	2016-17
Hired human labour	9692 (47.56)	11140 (34.65)	22904 (46.67)	34567 (39.26)	8221 (48.08)	10319 (50.32)	17952 (46.86)	28411 (40.29)
Family labour	1868 (9.17)	2286 (7.11)	5322 (10.84)	16276 (18.48)	942 (5.51)	1170 (5.71)	3751 (9.79)	9387 (13.31)
Total Human labour	**11560 (56.73)**	**13426 (41.76)**	**28226 (57.51)**	**50843 (57.74)**	**9163 (53.58)**	**11489 (56.03)**	**21703 (56.65)**	**37798 (53.61)**
Animal labour	1075 (5.28)	816 (2.54)	430 (0.88)	85 (0.1)	609 (3.56)	613 (2.99)	233 (0.61)	188 (0.27)
Machine labour	1594 (7.82)	2253 (7.01)	4538 (9.25)	11896 (13.51)	1618 (9.46)	2082 (10.15)	4604 (12.02)	10884 (15.44)
Total mechanical cost	**2669 (13.1)**	**3069 (9.54)**	**4968 (10.12)**	**11981 (13.61)**	**2227 (13.02)**	**2695 (13.14)**	**4837 (12.63)**	**11072 (15.7)**
Seed/Seedlings	953 (4.68)	1040 (3.23)	1871 (3.81)	2997 (3.4)	965 (5.64)	1095 (5.34)	1661 (4.34)	2759 (3.91)
Fertiliser	2578 (12.65)	2841 (8.84)	4893 (9.97)	9037 (10.26)	2142 (12.53)	2241 (10.93)	3590 (9.37)	8061 (11.43)
Plant protection	284 (1.39)	270 (0.84)	461 (0.94)	673 (0.76)	268 (1.57)	202 (0.99)	318 (0.83)	755 (1.07)
Land tax &irrigation cess	67 (0.33)	101 (0.31)	94 (0.19)	298 (0.34)	94 (0.55)	89 (0.43)	91 (0.24)	441 (0.63)
Total material cost	**3882 (19.05)**	**4252 (13.22)**	**7319 (14.91)**	**13005 (14.77)**	**3469 (20.29)**	**3627 (17.69)**	**5660 (14.77)**	**12016 (17.04)**
Repair and Maintenance	231 (1.13)	317 (0.99)	1709 (3.48)	2342 (2.66)	230 (1.35)	291 (1.42)	731 (1.91)	518 (0.73)
Interest on Capital	829 (4.07)	9479 (29.48)	1856 (3.78)	3207 (3.64)	709 (4.15)	871 (4.25)	1522 (3.97)	2828 (4.01)
Other expenses	412 (2.02)	630 (1.96)	2018 (4.11)	4881 (5.54)	355 (2.08)	859 (4.19)	2078 (5.42)	5496 (7.79)
Sub total	19583 (96.09)	31173 (96.95)	46096 (93.93)	86259 (97.96)	16153 (94.46)	19832 (96.71)	36531 (95.36)	69728 (98.89)
Interest on fixed capital	796 (3.91)	980 (3.05)	2980 (6.07)	1798 (2.04)	947 (5.54)	674 (3.29)	1777 (4.64)	781 (1.11)
Total cost	20379 (100)	32153 (100)	49076 (100)	88057 (100)	17100 (100)	20506 (100)	38308 (100)	70509 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.44: Share of cost components in total cost of cultivation of winter paddy in large and all size landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Large				All Size			
	2000-01	2003-04	2010-11	2016-17	2000-01	2003-04	2010-11	2016-17
Hired human labour	8482 (46.56)	9018 (44.71)	21122 (41.81)	21073 (35.12)	8615 (47.28)	9784 (46.98)	20202 (44.23)	25234 (37.63)
Family labour	657 (3.61)	924 (4.58)	1874 (3.71)	2775 (4.62)	1019 (5.59)	1202 (5.77)	3125 (6.84)	6693 (9.98)
Total Human labour	**9139 (50.17)**	**9942 (49.29)**	**22996 (45.52)**	**23848 (39.75)**	**9634 (52.87)**	**10986 (52.75)**	**23327 (51.07)**	**31927 (47.61)**
Animal labour	245 (1.34)	209 (1.04)	176 (0.35)	203 (0.34)	610 (3.35)	440 (2.11)	238 (0.52)	183 (0.27)
Machine labour	1786 (9.8)	2165 (10.73)	10029 (19.85)	12244 (20.41)	1677 (9.2)	2147 (10.31)	7115 (15.58)	11743 (17.51)
Total mechanical cost	**2031 (11.15)**	**2374 (11.77)**	**10205 (20.2)**	**12447 (20.74)**	**2287 (12.55)**	**2587 (12.42)**	**7353 (16.1)**	**11926 (17.79)**
Seed/Seedlings	1056 (5.8)	1323 (6.56)	2414 (4.78)	2924 (4.87)	997 (5.47)	1201 (5.77)	2044 (4.48)	2877 (4.29)
Fertiliser	2632 (14.45)	2641 (13.09)	5284 (10.46)	5998 (10)	2418 (13.27)	2524 (12.12)	4581 (10.03)	7073 (10.55)
Plant protection	389 (2.14)	347 (1.72)	567 (1.12)	1583 (2.64)	317 (1.74)	284 (1.36)	456 (1)	1190 (1.77)
Land tax &irrigation cess	94 (0.52)	127 (0.63)	157 (0.31)	405 (0.67)	89 (0.49)	110 (0.53)	122 (0.27)	404 (0.6)
Total material cost	**4171 (22.9)**	**4438 (22)**	**8422 (16.67)**	**10910 (18.18)**	**3821 (20.97)**	**4119 (19.78)**	**7203 (15.77)**	**11544 (17.22)**
Repair and Maintenance	221 (1.21)	281 (1.39)	726 (1.44)	128 (0.21)	228 (1.25)	294 (1.41)	883 (1.93)	538 (0.8)
Interest on Capital	779 (4.28)	871 (4.32)	2246 (4.45)	2675 (4.46)	762 (4.18)	882 (4.23)	1911 (4.18)	2793 (4.17)
Other expenses	982 (5.39)	1725 (8.55)	5332 (10.55)	9483 (15.8)	605 (3.32)	1259 (6.04)	3581 (7.84)	7565 (11.28)
Sub total	17323 (95.1)	19631 (97.33)	49927 (98.82)	59491 (99.15)	17337 (95.15)	20127 (96.63)	44258 (96.9)	66293 (98.86)
Interest on fixed capital	893 (4.9)	538 (2.67)	596 (1.18)	510 (0.85)	884 (4.85)	701 (3.37)	1417 (3.1)	763 (1.14)
Total cost	18216 (100)	20169 (100)	50523 (100)	60001 (100)	18221 (100)	20828 (100)	45675 (100)	67056 (100)

Note: Figures in parentheses indicate per cent to column total

4.4.1.1.3 Summer paddy

Table 4.45: Share of cost components in total cost of cultivation of summer paddy in small and medium landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Small				Medium			
	2000-01	2003-04	2010-11	2016-17	2000-01	2003-04	2010-11	2016-17
Hired human labour	10851 (46.04)	9934 (40.06)	22836 (42.59)	32626 (38.82)	10571 (46.9)	8928 (41.72)	13858 (37.62)	26495 (38.78)
Family labour	2589 (10.98)	3054 (12.31)	6622 (12.35)	16852 (20.05)	1562 (6.93)	1421 (6.64)	3477 (9.44)	7948 (11.63)
Total Human labour	**13440 (57.02)**	**12988 (52.37)**	**29458 (54.95)**	**49478 (58.87)**	**12133 (53.83)**	**10349 (48.36)**	**17335 (47.06)**	**34443 (50.41)**
Animal labour	780 (3.31)	846 (3.41)	332 (0.62)	0	626 (2.78)	332 (1.55)	202 (0.55)	0
Machine labour	1868 (7.92)	2054 (8.28)	548 3(10.2 3)	9513 (11.32)	2165 (9.61)	2229 (10.42)	6294 (17.09)	11219 (16.42)
Total mechanical cost	**2648 (11.23)**	**2900 (11.69)**	**5815 (10.85)**	**9513 (11.32)**	**2791 (12.38)**	**2561 (11.97)**	**6496 (17.63)**	**11219 (16.42)**
Seed/Seedlings	1156 (4.9)	1175 (4.74)	1608 (3)	3059 (3.64)	1043 (4.63)	1187 (5.55)	1673 (4.54)	2773 (4.06)
Fertiliser	2789 (11.83)	3424 (13.81)	5136 (9.58)	9547 (11.36)	2619 (11.62)	2677 (12.51)	3777 (10.25)	7671 (11.23)
Plant protection	550 (2.33)	435 (1.75)	546 (1.02)	945 (1.12)	606 (2.69)	439 (2.05)	811 (2.2)	1129 (1.65)
Land tax &irrigation cess	123 (0.52)	169 (0.68)	356 (0.66)	282 (0.34)	370 (1.64)	200 (0.93)	390 (1.06)	643 (0.94)
Total material cost	**4618 (19.59)**	**5203 (20.98)**	**7646 (14.26)**	**13833 (16.46)**	**4638 (20.58)**	**4503 (21.04)**	**6651 (18.05)**	**12216 (17.88)**
Repair and Maintenance	385 (1.63)	213 (0.86)	1415 (2.64)	1719 (2.05)	372 (1.65)	714 (3.34)	669 (1.82)	349 (0.51)
Interest on Capital	927 (3.93)	964 (3.89)	1930 (3.6)	3021 (3.59)	923 (4.1)	859 (4.01)	1457 (3.96)	2785 (4.08)
Other expenses	551 (2.34)	1421 (5.73)	2650 (4.94)	4720 (5.62)	839 (3.72)	1382 (6.46)	2518 (6.84)	6413 (9.39)
Sub total	22569 (95.75)	23689 (95.52)	48914 (91.24)	82284 (97.91)	21696 (96.26)	20368 (95.18)	35126 (95.35)	67425 (98.69)
Interest on fixed capital	1002 (4.25)	1111 (4.48)	4699 (8.76)	1760 (2.09)	843 (3.74)	1031 (4.82)	1712 (4.65)	894 (1.31)
Total cost	23571 (100)	24800 (100)	53613 (100)	84044 (100)	22539 (100)	21399 (100)	36838 (100)	68319 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.46: Share of cost components in total cost of cultivation of summer paddy in large and all size landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Large				All Size			
	2000-01	2003-04	2010-11	2016-17	2000-01	2003-04	2010-11	2016-17
Hired human labour	10712 (50.44)	9583 (45.34)	17750 (42.17)	17734 (34.04)	10686 (48.14)	9359 (42.74)	17211 (40.99)	25234 (37.63)
Family labour	436 (2.05)	869 (4.11)	1375 (3.27)	2656 (5.1)	1174 (5.29)	1386 (6.33)	2742 (6.53)	6693 (9.98)
Total Human labour	**11148 (52.49)**	**10452 (49.45)**	**19125 (45.44)**	**20390 (39.14)**	**11860 (53.42)**	**10745 (49.07)**	**19953 (47.52)**	**31927 (47.61)**
Animal labour	407 (1.92)	205 (0.97)	59 (0.14)	0)	543 (2.45)	342 (1.56)	141 (0.34)	183 (0.27)
Machine labour	1766 (8.32)	2359 (11.16)	7233 (17.18)	10752 (20.64)	1921 (8.65)	2265 (10.34)	6702 (15.96)	11743 (17.51)
Total mechanical cost	**2173 (10.23)**	**2564 (12.13)**	**7292 (17.32)**	**10752 (20.64)**	**2464 (11.1)**	**2607 (11.91)**	**6843 (16.3)**	**11926 (17.79)**
Seed/Seedlings	1123 (5.29)	1325 (6.27)	2505 (5.95)	3175 (6.09)	1101 (4.96)	1248 (5.7)	2123 (5.06)	2877 (4.29)
Fertiliser	2762 (13)	2590 (12.25)	4021 (9.55)	6291 (12.08)	2720 (12.25)	2736 (12.49)	4094 (9.75)	7073 (10.55)
Plant protection	767 (3.61)	541 (2.56)	1203 (2.86)	1315 (2.52)	676 (3.05)	485 (2.21)	992 (2.36)	1190 (1.77)
Land tax &irrigation cess	178 (0.84)	103 (0.49)	858 (2.04)	269 (0.52)	236 (1.06)	152 (0.69)	643 (1.53)	404 (0.6)
Total material cost	**4830 (22.74)**	**4559 (21.57)**	**8587 (20.4)**	**11050 (21.21)**	**4733 (21.32)**	**4621 (21.1)**	**7852 (18.7)**	**11544 (17.22)**
Repair and Maintenance	55 (0.26)	58 (0.27)	208 (0.49)	29 (0.06)	268 (1.21)	390 (1.78)	515 (1.23)	538 (0.8)
Interest on Capital	958 (4.51)	945 (4.47)	1878 (4.46)	2331 (4.47)	941 (4.24)	912 (4.16)	1752 (4.17)	2793 (4.17)
Other expenses	1623 (7.64)	2300 (10.88)	4783 (11.36)	7355 (14.12)	1178 (5.31)	1805 (8.24)	3784 (9.01)	7565 (11.28)
Sub total	20787 (97.88)	20878 (98.78)	41873 (99.48)	51907 (99.63)	21444 (96.59)	21080 (96.26)	40699 (96.93)	66293 (98.86)
Interest on fixed capital	451 (2.12)	258 (1.22)	219 (0.52)	192 (0.37)	756 (3.41)	818 (3.74)	1291 (3.07)	763 (1.14)
Total cost	21238 (100)	21136 (100)	42092 (100)	52099 (100)	22200 (100)	21898 (100)	41990 (100)	67056 (100)

Note: Figures in parentheses indicate per cent to column total

material cost could be attributed to reduction in prices of these materials over the period that made their resultant proportions in the total cost to decline. Government subsidy could have also had the same effect. This could be true however, if this was the case, then the pattern of decline should be almost the same. Therefore, the question could be why the decline was more in small paddy holdings in autumn and summer and highest for medium holdings in winter and why was the decline lower in larger holdings. This could be due to, small holdings were minimising on input costs and thereby reducing on their usage, this then over time made the growth in the costs to decline. We established earlier that the small holdings were more active in the winter and thus this confirms that the small holdings deliberately reduced on their material use in the other seasons and increased in the winter (medium holdings had highest decline in share of the total cost in this season).

4.4.1.2 Tapioca

The shares of cost components for tapioca are presented under Table 4.47 and Table 4.48. Total human labour constituted the largest cost component (more than 54%) in all holdings in the cultivation of tapioca and was increasing under all holdings other than in the large holdings where there was decline. As opposed to paddy cultivation where the share of cost of human labour component was declining in the large holdings, in tapioca it was largely increasing. Hired human labour had higher share of the total cost in human labour, however, it was declining for all the holdings. The decline in hired labour share of the total cost was higher in small holdings and least in large holdings. Instead, there was an increase in share of cost of family labour all the holdings. Analysis of materials cost share of the total cost in paddy showed that paddy farmers are decreasing on materials usage based on the declines on their share in the total cost. However, for tapioca other than land tax and irrigation cess, all were increasing. The proportion of machine use in the cultivation of tapioca was found to be increasing for all the holdings.

Table 4.47: Share of cost components in total cost of cultivation of tapioca in small and medium landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Small			Medium		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	17393 (37.87)	33060 (38.27)	50684 (33.37)	15376 (41.51)	32242 (53.13)	52964 (40.6)
Family labour	8889 (19.36)	18758 (21.72)	50294 (33.11)	4658 (12.57)	9682 (15.95)	29344 (22.49)
Total Human labour	**26282 (57.23)**	**51818 (59.99)**	**100978 (66.48)**	**20034 (54.08)**	**41924 (69.08)**	**82308 (63.09)**
Animal labour	0	0	0	0	0	0
Machine labour	52 (0.11)	93 (0.11)	622 (0.41)	427 (1.15)	113 (0.19)	1808 (1.39)
Total mechanical cost	**52 (0.11)**	**93 (0.11)**	**622 (0.41)**	**429 (1.16)**	**113 (0.19)**	**1808 (1.39)**
Seed/Seedlings	1264 (2.75)	2929 (3.39)	5847 (3.85)	977 (2.64)	1457 (2.4)	6189 (4.74)
Fertiliser	7515 (16.36)	9377 (10.86)	17722 (11.67)	7240 (19.54)	7123 (11.74)	18053 (13.84)
Plant protection	115 (0.25)	105 (0.12)	114 (0.08)	48 (0.13)	97 (0.16)	204 (0.16)
Land tax &irrigation cess	71 (0.15)	496 (0.57)	316 (0.21)	46 (0.12)	142 (0.23)	215 (0.16)
Total material cost	**8965 (19.52)**	**12907 (14.94)**	**23999 (15.8)**	**8311 (22.44)**	**8819 (14.53)**	**24661 (18.9)**
Repair and Maintenance	337 (0.73)	2069 (2.4)	2437 (1.6)	260 (0.7)	994 (1.64)	497 (0.38)
Interest on Capital	2793 (6.08)	4903 (5.68)	8265 (5.44)	2640 (7.13)	4350 (7.17)	8933 (6.85)
Other expenses	1594 (3.47)	3462 (4.01)	7661 (5.04)	2329 (6.29)	2464 (4.06)	10107 (7.75)
Sub total	40023 (87.15)	75252 (87.12)	143962 (94.78)	34003 (91.79)	58664 (96.66)	128314 (98.36)
Interest on fixed capital	5901 (12.85)	11126 (12.88)	7921 (5.22)	3040 (8.21)	2026 (3.34)	2142 (1.64)
Total cost	45924 (100)	86378 (100)	151883 (100)	37043 (100)	60690 (100)	130456 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.48: Share of cost components in total cost of cultivation of tapioca in large and all size landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Large			All Size		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	22386 (55.3)	28915 (56.11)	42704 (39.82)	17445 (43.74)	31293 (49.2)	50285 (38.09)
Family labour	634 (1.57)	4664 (9.05)	15495 (14.45)	4735 (11.87)	10101 (15.88)	32630 (24.71)
Total Human labour	**23020 (56.87)**	**33579 (65.16)**	**58199 (54.27)**	**22180 (55.61)**	**41394 (65.08)**	**82915 (62.8)**
Animal labour	0	0	0	0	0	0
Machine labour	1571 (3.88)	935 (1.81)	3700 (3.45)	600 (1.5)	390 (0.61)	1841 (1.39)
Total mechanical cost	**1571 (3.88)**	**935 (1.81)**	**3700 (3.45)**	**601 (1.51)**	**390 (0.61)**	**1841 (1.39)**
Seed/Seedlings	1106 (2.73)	1319 (2.56)	4326 (4.03)	1073 (2.69)	1757 (2.76)	5723 (4.33)
Fertiliser	6968 (17.21)	4217 (8.18)	18771 (17.5)	7226 (18.12)	6658 (10.47)	18099 (13.71)
Plant protection	5 (0.01)	202 (0.39)	516 (0.48)	54 (0.14)	135 (0.21)	240 (0.18)
Land tax &irrigation cess	40 (0.1)	25 (0.05)	100 (0.09)	50 (0.13)	185 (0.29)	221 (0.17)
Total material cost	**8119 (20.06)**	**5763 (11.18)**	**23713 (22.11)**	**8403 (21.07)**	**8735 (13.73)**	**24283 (18.39)**
Repair and Maintenance	144 (0.36)	1856 (3.6)	183 (0.17)	251 (0.63)	1543 (2.43)	992 (0.75)
Interest on Capital	3399 (8.4)	3678 (7.14)	8259 (7.7)	2846 (7.14)	4250 (6.68)	8608 (6.52)
Other expenses	1958 (4.84)	1193 (2.31)	12569 (11.72)	2060 (5.16)	2263 (3.56)	9890 (7.49)
Sub total	38211 (94.39)	47004 (91.21)	106623 (99.43)	36341 (91.11)	58575 (92.09)	128529 (97.35)
Interest on fixed capital	2269 (5.61)	4531 (8.79)	610 (0.57)	3544 (8.89)	5032 (7.91)	3500 (2.65)
Total cost	40480 (100)	51535 (100)	107233 (100)	39885 (100)	63607 (100)	132029 (100)

Note: Figures in parentheses indicate per cent to column total

4.4.1.3 Coconut

The proportion of cost components of coconut are given under Table 4.49 and Table 4.50. Coconut presented an interesting case other than the crops discussed so far. Coconut had increasing proportions in hired human labour at the same time increase in share of the family labour in the total cost. Consequently, the total human labour was increasing in proportion from 2006-07 to 2016-17 for all the holdings an indication that farmers are intensifying in the operations in their farms over the study period. The largest increase in share of hired human labour, household labour and the total human labour was highest in large holdings and lowest in small holdings. Use of machine labour was generally low and declining in the small holdings and medium holdings but was increasing in the large holdings in its share of the total cost. Seedlings cost share of the total cost was largely increasing for all the holdings within the study period while the total cost of materials was declining in its share of the total cost in small holdings more followed by medium holdings while for large holdings it was increasing.

4.4.1.4 Banana and other plantains

The proportion of cost components for banana and other plantains is presented under Table 4.51 and Table 4.52. Human labour and fertiliser consumption accounted for the highest cost component in banana and other plantains cultivation in 2006-07. In 2006-07, the cost of human labour accounted for 43.4 per cent in small holdings, 38 per cent in medium holdings and 27.12 per cent in large holdings. In the same year, fertiliser proportion in the total cost was higher than human labour in large holdings (27.94%). In 2016-17, the proportions of fertiliser cost in the total cost declined while that of the human labour increased. Hired human labour accounted for most of the human labour and was increasing. Just as in coconut, human labour components (hired and family) cost share in the total cost were higher in large holdings and lowest in small holdings. Out of all the material costs, only seedlings costs was increasing in its share of the total cost while the rest declined. The largest decline in share of individual material cost component was in plant protection related costs in the cultivation of banana and other plantains.

Table 4.49: Share of cost components in total cost of cultivation of coconut in small and medium landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Small			Medium		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	14819 (43.37)	19677 (37.02)	45007 (45.1)	11501 (43.11)	22105 (46.65)	41776 (50.3)
Family labour	3280 (9.6)	7272 (13.68)	17512 (17.55)	1952 (7.32)	4391 (9.27)	11760 (14.16)
Total Human labour	**18099 (52.98)**	**26949 (50.7)**	**62519 (62.64)**	**13453 (50.42)**	**26496 (55.92)**	**53536 (64.46)**
Animal labour	0	0	0	0	0	42 (0.05)
Machine labour	82 (0.24)	142 (0.27)	92 (0.09)	159 (0.6)	264 (0.56)	86 (0.1)
Total mechanical cost	**82 (0.24)**	**142 (0.27)**	**92 (0.09)**	**159 (0.6)**	**264 (0.56)**	**128 (0.15)**
Seed/Seedlings	41 (0.12)	109 (0.21)	683 (0.68)	45 (0.17)	142 (0.3)	519 (0.62)
Fertiliser	6546 (19.16)	7282 (13.7)	17334 (17.37)	5358 (20.08)	7722 (16.3)	14834 (17.86)
Plant protection	38 (0.11)	162 (0.3)	119 (0.12)	41 (0.15)	101 (0.21)	95 (0.11)
Land tax &irrigation cess	92 (0.27)	162 (0.3)	297 (0.3)	84 (0.31)	104 (0.22)	258 (0.31)
Total material cost	**6717 (19.66)**	**7715 (14.52)**	**18433 (18.47)**	**5528 (20.72)**	**8069 (17.03)**	**15706 (18.91)**
Repair and Maintenance	841 (2.46)	1874 (3.53)	1213 (1.22)	636 (2.38)	819 (1.73)	844 (1.02)
Interest on Capital	2263 (6.62)	3046 (5.73)	6698 (6.71)	1812 (6.79)	3241 (6.84)	6056 (7.29)
Other expenses	1106 (3.24)	3086 (5.81)	3749 (3.76)	1020 (3.82)	2078 (4.39)	3207 (3.86)
Sub total	29108 (85.2)	42812 (80.55)	92704 (92.89)	22608 (84.73)	40967 (86.46)	79477 (95.7)
Interest on fixed capital	5057 (14.8)	10337 (19.45)	7098 (7.11)	4073 (15.27)	6413 (13.54)	3575 (4.3)
Total cost	34165 (100)	53149 (100)	99802 (100)	26681 (100)	47380 (100)	83052 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.50: Share of cost components in total cost of cultivation of coconut in large and all size landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Large			All Size		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	11789 (49.45)	18159 (51.71)	39103 (53.24)	11939 (46.24)	19750 (47.8)	40918 (50.78)
Family labour	1128 (4.73)	2303 (6.56)	6153 (8.38)	1631 (6.32)	3536 (8.56)	9838 (12.21)
Total Human labour	**12917 (54.18)**	**20462 (58.26)**	**45256 (61.62)**	**13570 (52.56)**	**23286 (56.36)**	**50756 (62.99)**
Animal labour	34 (0.14)	0	9 (0.01)	18 (0.07)	0	22 (0.03)
Machine labour	79 (0.33)	264 (0.75)	654 (0.89)	110 (0.43)	253 (0.61)	351 (0.44)
Total mechanical cost	**113 (0.47)**	**264 (0.75)**	**663 (0.9)**	**128 (0.5)**	**253 (0.61)**	**373 (0.46)**
Seed/Seedlings	12 (0.05)	420 (1.2)	800 (1.09)	27 (0.1)	289 (0.7)	669 (0.83)
Fertiliser	4945 (20.74)	6937 (19.75)	15007 (20.43)	5240 (20.29)	7258 (17.57)	15212 (18.88)
Plant protection	26 (0.11)	80 (0.23)	52 (0.07)	33 (0.13)	96 (0.23)	78 (0.1)
Land tax &irrigation cess	91 (0.38)	75 (0.21)	251 (0.34)	88 (0.34)	94 (0.23)	260 (0.32)
Total material cost	**5074 (21.28)**	**7512 (21.39)**	**16110 (21.94)**	**5388 (20.87)**	**7737 (18.73)**	**16219 (20.13)**
Repair and Maintenance	451 (1.89)	451 (1.28)	211 (0.29)	556 (2.15)	720 (1.74)	594 (0.74)
Interest on Capital	1773 (7.44)	2748 (7.82)	5812 (7.91)	1830 (7.09)	295 7(7.16)	6019 (7.47)
Other expenses	843 (3.54)	1620 (4.61)	2493 (3.39)	934 (3.62)	1926 (4.66)	2939 (3.65)
Sub total	21171 (88.8)	33057 (94.13)	70545 (96.06)	22406 (86.78)	36879 (89.26)	76900 (95.43)
Interest on fixed capital	2671 (11.2)	2063 (5.87)	2896 (3.94)	3414 (13.22)	4437 (10.74)	3679 (4.57)
Total cost	23842 (100)	35120 (100)	73441 (100)	25820 (100)	41316 (100)	80579 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.51: Share of cost components in total cost of cultivation of banana and other plantains in small and medium landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Small			Medium		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	34114 (30.8)	54987 (30)	82553 (30.33)	30539 (28.69)	42669 (33.65)	71723 (32.28)
Family labour	13962 (12.6)	29403 (16.04)	61419 (22.56)	9915 (9.31)	18910 (14.91)	39535 (17.79)
Total Human labour	**48076 (43.4)**	**84390 (46.04)**	**143972 (52.89)**	**40454 (38)**	**61579 (48.56)**	**111258 (50.07)**
Animal labour	28 (0.03)	0	67 (0.02)	0	0	0
Machine labour	476 (0.43)	594 (0.32)	656 (0.24)	107 (0.1)	400 (0.32)	2249 (1.01)
Total mechanical cost	**504 (0.45)**	**594 (0.32)**	**723 (0.27)**	**107 (0.1)**	**400 (0.32)**	**2249 (1.01)**
Seed/Seedlings	9728 (8.78)	14383 (7.85)	24533 (9.01)	8767 (8.24)	12292 (9.69)	22165 (9.97)
Fertiliser	24000 (21.67)	30821 (16.82)	44237 (16.25)	24859 (23.35)	21332 (16.82)	36864 (16.59)
Plant protection	1181 (1.07)	853 (0.47)	1097 (0.4)	896 (0.84)	514 (0.41)	1349 (0.61)
Land tax &irrigation cess	89 (0.08)	158 (0.09)	457 (0.17)	59 (0.06)	175 (0.14)	270 (0.12)
Total material cost	**34998 (31.59)**	**46215 (25.22)**	**70324 (25.83)**	**34581 (32.49)**	**34313 (27.06)**	**60648 (27.29)**
Repair and Maintenance	607 (0.55)	3143 (1.71)	2819 (1.04)	146 (0.14)	1009 (0.8)	735 (0.33)
Interest on Capital	8173 (7.38)	11826 (6.45)	17596 (6.46)	8385 (7.88)	9264 (7.31)	16150 (7.27)
Other expenses	12206 (11.02)	16619 (9.07)	22818 (8.38)	18677 (17.55)	15433 (12.17)	27148 (12.22)
Sub total	104564 (94.39)	162787 (88.82)	258252 (94.87)	102350 (96.15)	121998 (96.21)	218188 (98.18)
Interest on fixed capital	6211 (5.61)	20493 (11.18)	13968 (5.13)	4094 (3.85)	4804 (3.79)	4034 (1.82)
Total cost	110775 (100)	183280 (100)	272220 (100)	106444 (100)	126802 (100)	222222 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.52: Share of cost components in total cost of cultivation of banana and other plantains in large and all size landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Large			All Size		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	16044 (20.43)	31977 (29.77)	70883 (33.18)	27330 (27.51)	40388 (31.43)	73597 (32.1)
Family labour	5262 (6.7)	11078 (10.31)	31331 (14.67)	9655 (9.72)	17491 (13.61)	41159 (17.95)
Total Human labour	**21306 (27.12)**	**43055 (40.08)**	**102214 (47.85)**	**36985 (37.23)**	**57879 (45.04)**	**114756 (50.05)**
Animal labour	0	0	0	7 (0.01)	0)	13 (0.01)
Machine labour	0	0	3167 (1.48)	175 (0.18)	269 (0.21)	2237 (0.98)
Total mechanical cost	**0**	**0**	**3167 (1.48)**	**182 (0.18)**	**269 (0.21)**	**2250 (0.98)**
Seed/Seedlings	10176 (12.95)	11197 (10.42)	25201 (11.8)	9367 (9.43)	12200 (9.49)	23645 (10.31)
Fertiliser	21947 (27.94)	23999 (22.34)	31677 (14.83)	23699 (23.86)	24052 (18.72)	36606 (15.96)
Plant protection	818 (1.04)	833 (0.78)	964 (0.45)	946 (0.95)	703 (0.55)	1171 (0.51)
Land tax &irrigation cess	133 (0.17)	407 (0.38)	818 (0.38)	87 (0.09)	267 (0.21)	489 (0.21)
Total material cost	**33074 (42.11)**	**36436 (33.92)**	**58660 (27.46)**	**34099 (34.32)**	**37222 (28.96)**	**61911 (27)**
Repair and Maintenance	222 (0.28)	862 (0.8)	178 (0.08)	288 (0.29)	1314 (1.02)	964 (0.42)
Interest on Capital	6363 (8.1)	8510 (7.92)	16330 (7.64)	7727 (7.78)	9393 (7.31)	16497 (7.19)
Other expenses	14640 (18.64)	17092 (15.91)	31405 (14.7)	15745 (15.85)	16317 (12.7)	27702 (12.08)
Sub total	75605 (96.25)	105955 (98.63)	211954 (99.22)	95026 (95.65)	122394 (95.24)	224080 (97.72)
Interest on fixed capital	2944 (3.75)	1467 (1.37)	1669 (0.78)	4319 (4.35)	6120 (4.76)	5223 (2.28)
Total cost	78549 (100)	107422 (100)	213623 (100)	99345 (100)	128514 (100)	229303 (100)

Note: Figures in parentheses indicate per cent to column total

4.4.1.5 Black pepper

Shares of cost components involved in the cultivation of black pepper are provided under Table 4.53 and Table 4.54. The share of human labour in the total cost accounts for more than 50 per cent in all the landholding sizes in the cultivation of black pepper. The share of hired human labour component in the total cost for black pepper cultivation was increasing for all the landholding sizes. The increase was more in the small holdings and least in medium holdings. Small holdings also had increase in share of the family labour in the total cost shown by increase from 18.82 per cent to 29.89 per cent during the period from 2000-01 to 2016-17. The share of family labour increased for the medium holdings too. However, for the large holdings, it showed a decline over the period. Overall, the cost of human labour share in the total cost was found to be increasing for all the holdings but the large holdings. The reason for low increase in the cost of human labour share of the total cost in the large holdings in black pepper cultivation could be due to economies of scale. With time, the large holdings were possibly able to operate efficiently by incorporating inputs at large scale. By doing so, the per unit cost declines compared the costs used in the small and medium holdings. In all the holdings in under black pepper cultivation, the material cost share in the total cost was increasing. The increase was derived from fertiliser and seedlings costs while the irrigation cess/ land tax declined.

4.4.1.6 Ginger

The proportions of components in the total cost of ginger cultivation are given under Table 4.55 and Table 4.56. Human labour, seeds and fertiliser costs take a major share of the total cost in the cultivation of ginger. However, the share of hired labour showed a decline in all sizes other than the large holding size while household labour was increasing in its share of the total cost for all the holdings. Consequently, the total human labour cost increased for all the holdings. While the proportion of seedlings cost increased for all the holdings in cultivation of ginger, the proportion of other material cost components like fertiliser costs declined. Comparing 2006-07 and 2016-17, there was increasing proportion of machine labour generally for all the holdings in the cultivation of ginger. It was more in the large holdings. It could be concluded that, the large holdings were replacing the hired human labour with the machine labour.

Table 4.53: Share of cost components in total cost of cultivation of black pepper in small and medium landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Small			Medium		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	12693 (35.95)	24340 (35.7)	50699 (36.98)	10858 (47.58)	19902 (35.55)	45911 (48.67)
Family labour	6644 (18.82)	11526 (16.91)	40984 (29.89)	2619 (11.48)	8398 (15)	15992 (16.95)
Total Human labour	**19337 (54.76)**	**35866 (52.61)**	**91683 (66.88)**	**13477 (59.06)**	**28300 (50.55)**	**61903 (65.63)**
Animal labour	0	0	0	0	0	0
Machine labour	16 (0.05)	0	70 (0.05)	93 (0.41)	0	116 (0.12)
Total mechanical cost	**16 (0.05)**	**0**	**70 (0.05)**	**93 (0.41)**	**0**	**116 (0.12)**
Seed/Seedlings	65 (0.18)	1633 (2.4)	766 (0.56)	53 (0.23)	739 (1.32)	3229 (3.42)
Fertiliser	4206 (11.91)	7336 (10.76)	16595 (12.1)	3167 (13.88)	6719 (12)	14654 (15.54)
Plant protection	237 (0.67)	134 (0.2)	326 (0.24)	52 (0.23)	23 (0.04)	317 (0.34)
Land tax &irrigation cess	72 (0.2)	87 (0.13)	244 (0.18)	52 (0.23)	87 (0.16)	169 (0.18)
Total material cost	**4580 (12.97)**	**9190 (13.48)**	**17931 (13.08)**	**3324 (14.57)**	**7568 (13.52)**	**18369 (19.47)**
Repair and Maintenance	1128 (3.19)	3961 (5.81)	2542 (1.85)	174 (0.76)	2250 (4.02)	392 (0.42)
Interest on Capital	1786 (5.06)	3545 (5.2)	7144 (5.21)	1455 (6.38)	2912 (5.2)	6636 (7.04)
Other expenses	639 (1.81)	2004 (2.94)	2982 (2.18)	325 (1.42)	1740 (3.11)	2134 (2.26)
Sub total	27486 (77.84)	54566 (80.04)	122352 (89.25)	18848 (82.6)	42770 (76.39)	89550 (94.94)
Interest on fixed capital	7825 (22.16)	13605 (19.96)	14742 (10.75)	3971 (17.4)	13216 (23.61)	4773 (5.06)
Total cost	35311 (100)	68171 (100)	137094 (100)	22819 (100)	55986 (100)	94323 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.54: Share of cost components in total cost of cultivation of black pepper in large and all size landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Large			All Size		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	7110 (40.74)	24962 (47.39)	36084 (41.23)	10632 (41.12)	22465 (38.1)	46279 (42.17)
Family labour	3681 (21.09)	4974 (9.44)	8057 (9.21)	4231 (16.36)	8553 (14.51)	24410 (22.24)
Total Human labour	**10791 (61.84)**	**29936 (56.83)**	**44141 (50.44)**	**14863 (57.48)**	**31018 (52.61)**	**70689 (64.41)**
Animal labour	0	0	0	0	0	0
Machine labour	32 (0.18)	0	452 (0.52)	53 (0.2)	0	149 (0.14)
Total mechanical cost	**32 (0.18)**	**0**	**452 (0.52)**	**53 (0.2)**	**0**	**149 (0.14)**
Seed/Seedlings	0	19 (0.04)	9657 (11.04)	45 (0.17)	844 (1.43)	3245 (2.96)
Fertiliser	3455 (19.8)	5891 (11.18)	18435 (21.07)	3586 (13.87)	6714 (11.39)	15967 (14.55)
Plant protection	132 (0.76)	1343 (2.55)	700 (0.8)	133 (0.51)	369 (0.63)	377 (0.34)
Land tax &irrigation cess	77 (0.44)	198 (0.38)	600 (0.69)	65 (0.25)	113 (0.19)	262 (0.24)
Total material cost	**3664 (21)**	**7451 (14.15)**	**29392 (33.59)**	**3829 (14.81)**	**8040 (13.64)**	**19851 (18.09)**
Repair and Maintenance	352 (2.02)	1827 (3.47)	331 (0.38)	540 (2.09)	2676 (4.54)	1209 (1.1)
Interest on Capital	1100 (6.3)	3329 (6.32)	6882 (7.86)	1487 (5.75)	3206 (5.44)	6868 (6.26)
Other expenses	266 (1.52)	1078 (2.05)	3491 (3.99)	419 (1.62)	1665 (2.82)	2663 (2.43)
Sub total	16205 (92.87)	43621 (82.82)	84689 (96.78)	21191 (81.96)	46605 (79.05)	101429 (92.42)
Interest on fixed capital	1245 (7.13)	9051 (17.18)	2822 (3.22)	4665 (18.04)	12352 (20.95)	8313 (7.58)
Total cost	17450 (100)	52672 (100)	87511 (100)	25856 (100)	58957 (100)	109742 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.55: Share of cost components in total cost of cultivation of ginger in small and medium landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	**Small**			**Medium**		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	20856 (28.93)	49920 (30.15)	70966 (26.96)	19791 (32.82)	35419 (28.02)	86984 (29.98)
Family labour	9038 (12.54)	19495 (11.77)	64402 (24.47)	3415 (5.66)	12096 (9.57)	38132 (13.14)
Total Human labour	**29894 (41.46)**	**69415 (41.92)**	**135368 (51.43)**	**23206 (38.48)**	**47515 (37.59)**	**125116 (43.13)**
Animal labour	4 (0.01)	0	0	0	0	0
Machine labour	188 (0.26)	1500 (0.91)	796 (0.3)	1192 (1.98)	2645 (2.09)	5398 (1.86)
Total mechanical cost	**192 (0.27)**	**1500 (0.91)**	**796 (0.3)**	**1192 (1.98)**	**2645 (2.09)**	**5398 (1.86)**
Seed/Seedlings	16097 (22.33)	31884 (19.26)	55876 (21.23)	13856 (22.98)	26538 (21)	76396 (26.33)
Fertiliser	11342 (15.73)	20776 (12.55)	29173 (11.08)	10710 (17.76)	22082 (17.47)	39386 (13.58)
Plant protection	413 (0.57)	705 (0.43)	1205 (0.46)	633 (1.05)	531 (0.42)	2103 (0.72)
Land tax &irrigation cess	53 (0.07)	91 (0.05)	202 (0.08)	50 (0.08)	67 (0.05)	270 (0.09)
Total material cost	**27905 (38.7)**	**53456 (32.28)**	**86456 (32.85)**	**25249 (41.87)**	**49218 (38.94)**	**118155 (40.73)**
Repair and Maintenance	1621 (2.25)	2927 (1.77)	3030 (1.15)	678 (1.12)	1254 (0.99)	787 (0.27)
Interest on Capital	5108 (7.08)	10838 (6.55)	16630 (6.32)	4834 (8.02)	9387 (7.43)	22573 (7.78)
Other expenses	2175 (3.02)	3590 (2.17)	8282 (3.15)	2162 (3.58)	6651 (5.26)	15465 (5.33)
Sub total	66895 (92.78)	141726 (85.59)	250562 (95.2)	57321 (95.05)	116670 (92.31)	287494 (99.09)
Interest on fixed capital	5202 (7.22)	23857 (14.41)	12644 (4.8)	2988 (4.95)	9720 (7.69)	2629 (0.91)
Total cost	72097 (100)	165583 (100)	263206 (100)	60309 (100)	126390 (100)	290123 (100)

Note: Figures in parentheses indicate per cent to column total

Table 4.56: Share of cost components in total cost of cultivation of ginger in large and all size landholdings (₹ per hectare)

Holding size class/Year/ Cost Component	Large			All Size		
	2006-07	2010-11	2016-17	2006-07	2010-11	2016-17
Hired human labour	35357 (35.19)	31891 (26.61)	114490 (36.42)	21848 (31.92)	38333 (28.31)	87076 (30.55)
Family labour	3643 (3.63)	7564 (6.31)	14252 (4.53)	5200 (7.6)	12551 (9.27)	43063 (15.11)
Total Human labour	**39000 (38.81)**	**39455 (32.93)**	**128742 (40.95)**	**27048 (39.52)**	**50884 (37.58)**	**130139 (45.66)**
Animal labour	0	0	0	0	0	0
Machine labour	1543 (1.54)	4612 (3.85)	12831 (4.08)	913 (1.33)	3053 (2.25)	5312 (1.86)
Total mechanical cost	**1543 (1.54)**	**4612 (3.85)**	**12831 (4.08)**	**914 (1.34)**	**3053 (2.25)**	**5312 (1.86)**
Seed/Seedlings	17314 (17.23)	26455 (22.08)	73759 (23.46)	14913 (21.79)	28072 (20.73)	67447 (23.66)
Fertiliser	21851 (21.75)	24854 (20.74)	38035 (12.1)	12153 (17.76)	22747 (16.8)	34923 (12.25)
Plant protection	6285 (6.25)	1916 (1.6)	2296 (0.73)	1211 (1.77)	1105 (0.82)	1786 (0.63)
Land tax &irrigation cess	77 (0.08)	13 (0.01)	106 (0.03)	54 (0.08)	54 (0.04)	203 (0.07)
Total material cost	**45527 (45.31)**	**53238 (44.43)**	**114196 (36.33)**	**28331 (41.4)**	**51978 (38.39)**	**104359 (36.62)**
Repair and Maintenance	259 (0.26)	706 (0.59)	338 (0.11)	925 (1.35)	1537 (1.14)	1589 (0.56)
Interest on Capital	8607 (8.57)	10014 (8.36)	27015 (8.59)	5338 (7.8)	10048 (7.42)	21228 (7.45)
Other expenses	3721 (3.7)	10408 (8.69)	28743 (9.14)	2338 (3.42)	7174 (5.3)	15732 (5.52)
Sub total	98657 (98.18)	118433 (98.83)	311865 (99.21)	64894 (94.82)	124674 (92.09)	278359 (97.67)
Interest on fixed capital	1830 (1.82)	1397 (1.17)	2485 (0.79)	3542 (5.18)	10715 (7.91)	6654 (2.33)
Total cost	100487 (100)	119830 (100)	314350 (100)	68436 (100)	135389 (100)	285013 (100)

Note: Figures in parentheses indicate per cent to column total

4.2 Returns and profitability of crops

This section analyses the net returns from the cultivation of various crops in Kerala. In continuation to the previous section, the values of net returns obtained here cannot be used to compare across years since these values are represented in current prices. However, for the same year, different classes can be compared based on their net returns. To ensure a better measure that gives output value based on the per unit input value, an output/input index ratio was worked out. This ensures comparability across different years and the results can also be used to compare profitability across different sizes of landholdings despite the difference in output and input values. The results of the analysis for paddy are presented from 2000-01 to 2016-17. The data on the value of output for various holding sizes other than all sizes are available for coconut, ginger, tapioca, banana and other plantains, and black pepper from 2006-07 and therefore the respective results are presented from 2006-07 to 2016-07. For all the crops, the results will be presented for the first year and the last year, in addition to any year in between that coincides with the growth phases identified though trend break analysis.

4.4.2.1 Paddy

From the analysis of the shares of different cost components, it was found that paddy cultivation in 2016-17 was more active in the winter season in the small holdings. Consequently, as shown in Table 4.57, it had the highest cost of ₹ 88,057 per hectare compared to the other seasons and the second-best value of output of ₹ 89,794 per hectare. Due to the high cost incurred in the cultivation of paddy, net returns were affected and the season despite being the most intensive in operation, had the lowest profitability while the autumn paddy which recorded the lowest costs and value of output, had the best returns especially due to relatively low cost of cultivation and hence the highest profitability. This result was different from the previous presented years where each had its own season of profitability. Compared to the other holding sizes, the small sized holding showed losses in most years and seasons. In 2000-01, for the autumn paddy, the most profitable holding size was medium holding, while the smallholding was the least profitable. The large holdings showed the highest profitability for both winter and summer paddy in this year. In 2003-04, the medium sized holdings were the most profitable for both summer and winter paddy, while the large sized holdings were found to be profitable in autumn. Large sized paddy holdings were found to be profitable in raising autumn as well as summer paddy in 2010-11, while medium holdings were profitable while raising the winter paddy. In 2016-17, for all the seasons, profitability was found to be the highest in large holdings.

Table 4.57: Net returns and profitability of paddy for all seasons in small holdings

Year	Season	Total Cost (Per ha)	Value of Output (Per ha)	Net Returns (Per Ha)	O/I Ratio
2000-01	Autumn	23839	21554	-2285	0.904
	Winter	20379	20531	152	1.007
	Summer	23571	24131	560	1.024
2003-04	Autumn	23243	25577	2334	1.100
	Winter	32153	24613	-7540	0.765
	Summer	24800	24250	-550	0.978
2010-11	Autumn	44103	40582	-3521	0.920
	Winter	49076	46589	-2487	0.949
	Summer	53613	53861	248	1.005
2016-17	Autumn	75603	87454	11851	1.157
	Winter	88057	89794	1737	1.020
	Summer	84044	89945	5901	1.070

Note: O/I denote output/input ratio

Table 4.58: Net returns and profitability of paddy for all seasons in medium holdings

Year	Season	Total Cost (Per ha)	Value of Output (Per ha)	Net Returns (Per Ha)	O/I Ratio
2000-01	Autumn	19347	18636	-711	0.963
	Winter	17100	18807	1707	1.100
	Summer	22539	25422	2883	1.128
2003-04	Autumn	20113	24831	4718	1.235
	Winter	20506	22879	2373	1.116
	Summer	21399	23394	1995	1.093
2010-11	Autumn	36272	36964	692	1.019
	Winter	38308	45792	7484	1.195
	Summer	36838	50660	13822	1.375
2016-17	Autumn	58580	85852	27272	1.466
	Winter	70509	83578	13069	1.185
	Summer	68319	90237	21918	1.321

Note: O/I denote output/input ratio

Several studies had delved into the matter of farm size versus yield. Most studies argue that small sized farms are able to realise high levels of yields and hence increased profitability

Table 4.59: Net returns and profitability of paddy for all seasons in large holdings

Year	Season	Total Cost (Per ha)	Value of Output (Per ha)	Net Returns (Per Ha)	O/I Ratio
2000-01	Autumn	16711	18545	1834	1.110
	Winter	18216	24433	6217	1.341
	Summer	21238	24871	3633	1.171
2003-04	Autumn	23314	30090	6776	1.291
	Winter	20169	20524	355	1.018
	Summer	21136	16837	-4299	0.797
2010-11	Autumn	33128	47328	14200	1.429
	Winter	50523	69246	18723	1.371
	Summer	42092	59831	17739	1.421
2016-17	Autumn	56462	85883	29421	1.521
	Winter	60001	94194	34193	1.570
	Summer	52099	84120	32021	1.615

Note: O/I denote output/input ratio

Table 4.60: Net returns and profitability of paddy for all seasons in all size holdings

Year	Season	Total Cost (Per ha)	Value of Output (Per ha)	Net Returns (Per Ha)	O/I Ratio
2000-01	Autumn	19163	19271	108	1.006
	Winter	18221	21298	3077	1.169
	Summer	22200	24943	2743	1.124
2003-04	Autumn	21996	27021	5025	1.228
	Winter	20828	22018	1190	1.057
	Summer	21898	20521	-1377	0.937
2010-11	Autumn	36657	41517	4860	1.133
	Winter	45675	56819	11144	1.244
	Summer	41990	56145	14155	1.337
2016-17	Autumn	61054	86172	25118	1.411
	Winter	67056	90072	23016	1.343
	Summer	67056	86612	19556	1.292

Note: O/I denote output/input ratio

due to ability to have mixed cropping and use family labour intensively resulting in increasing per unit output. However, according to Mahesh (1999), he pointed out that most studies carried out in this regard contradicted themselves since the relationship exists for some types of farms and cannot be generalised. He added that a complex mix of factors may be contributing to more profitability in certain farms such as timely administration of inputs, correct management of activities related to the crop, employment of labour etc, which could make the difference and that on this basis, the assertions cannot be generalised. Similarly, in this case, the reason for higher profitability in large holding could be due to higher input use and improvement in efficiency through use of machine. These two components were higher in large holdings. Large holdings had the largest annual increase in machine use at 6.35 per cent, 4.42 per cent and 4.58 per cent for autumn, winter and summer seasons of paddy cultivation. While the cost of material use cost declined for all the holdings, the decline was lowest in large holdings compared to the other holdings. This could imply that large holdings were able to apply the required inputs like fertiliser and plant protection measures optimally which helped to improve the yield and finally the profitability.

4.4.2.2 Returns and profitability from other crops

In 2006-07 and 2010-11, profitability of tapioca was highest in the medium holdings as shown in Table 4.61. However, in 2016-17, the profitability was highest in the large holdings. In all the years studied, profitability was lowest in the small holdings. However, for coconut, the profitability was highest in large holdings and lowest in the small holdings. This was the case for banana and other plantains other than in 2006-07, when profitability was lowest in the large holdings and highest in the medium holdings and pepper in 2016-17. Ginger presented an inverse of the pattern shown in many crops in which small holdings were the least profitable. In 2016-17, profitability in ginger was highest in the small holdings while medium holdings were the least profitable. This could be attributed to complexities in managing large ginger farms which is prone to diseases. Overall, profitability improved over the period under study for all the crops other than ginger. Improvement in profitability could be due to increased use of high yielding varieties and efficient fertilisers that improved the productivity as the years progressed. Efficiency in these crops is further discussed in section 4.5.

Table 4.61: Net returns and profitability of tapioca in different sized holdings

Year	Holding size class	Total Cost	Value of Output (Per Ha)	Net Returns (Per Ha)	Input/output Ratio
2006-07	Small	45924	68437	22513	1.49
	Medium	37043	65048	28005	1.756
	Large	40480	62616	22136	1.547
	All Size	39885	65298	25413	1.637
2010-11	Small	86378	172487	86109	1.997
	Medium	60690	136878	76188	2.255
	Large	51535	113936	62401	2.211
	All Size	63607	137407	73800	2.16
2016-17	Small	151883	308686	156803	2.032
	Medium	130456	315754	185298	2.42
	Large	107233	295677	188444	2.757
	All Size	132029	309762	177733	2.346

Note: O/I denote output/input ratio

Table 4.62: Net returns and profitability of coconut in different sized holdings

Year	Holding size class	Total Cost	Value of Output (Per Ha)	Net Returns (Per Ha)	Input/output Ratio
2006-07	Small	34165	48686	14521	1.425
	Medium	26681	41018	14337	1.537
	Large	23842	40799	16957	1.711
	All Size	25820	41573	15753	1.61
2010-11	Small	53149	72912	19763	1.372
	Medium	47380	62421	15041	1.317
	Large	35120	64350	29230	1.832
	All Size	41316	64447	23131	1.56
2016-17	Small	99802	133927	34125	1.342
	Medium	83052	132646	49594	1.597
	Large	73441	123333	49892	1.679
	All Size	80579	128467	47888	1.594

Note: O/I denote output/input ratio

Table 4.63: Net returns and profitability of banana and other plantains in different sized holdings

Year	Holding size class	Total Cost	Value of Output (Per Ha)	Net Returns (Per Ha)	Input/output Ratio
2006-07	Small	110775	158245	47470	1.429
	Medium	106444	174480	68036	1.639
	Large	78549	103774	25225	1.321
	All Size	99345	150007	50662	1.51
2010-11	Small	183280	290716	107436	1.586
	Medium	126802	275221	148419	2.17
	Large	107422	264643	157221	2.464
	All Size	128514	273531	145017	2.128
2016-17	Small	272220	496927	224707	1.825
	Medium	222222	466827	244605	2.101
	Large	213623	549606	335983	2.573
	All Size	229303	500319	271016	2.182

Note: O/I denote output/input ratio

Table 4.64: Net returns and profitability of black pepper in different sized holdings

Year	Holding size class	Total Cost	Value of Output (Per Ha)	Net Returns (₹. Per Ha)	Input/output Ratio
2006-07	Small	35311	51945	16634	1.471
	Medium	22819	46902	24083	2.055
	Large	17450	27090	9640	1.552
	All Size	25856	44389	18533	1.717
2010-11	Small	68171	86895	18724	1.275
	Medium	55986	70477	14491	1.259
	Large	52672	56381	3709	1.07
	All Size	58957	72206	13249	1.225
2016-17	Small	137094	314660	177566	2.295
	Medium	94323	319247	224924	3.385
	Large	87511	322608	235097	3.686
	All Size	109742	317987	208245	2.898

Note: O/I denote output/input ratio

Table 4.65: Net returns and profitability of ginger for all holdings

Year	Holding size class	Total Cost	Value of Output (Per Ha)	Net Returns (Per Ha)	Input/output Ratio
2006-07	Small	72097	92903	20806	1.289
	Medium	60309	83050	22741	1.377
	Large	100487	141353	40866	1.407
	All Size	68436	92919	24483	1.358
2010-11	Small	165583	218131	52548	1.317
	Medium	126390	220638	94248	1.746
	Large	119830	208938	89108	1.744
	All Size	135389	215483	80094	1.592
2016-17	Small	263206	331377	68171	1.259
	Medium	290123	297169	7046	1.024
	Large	314350	331064	16714	1.053
	All Size	285013	319149	34136	1.12

Note: O/I denote output/input ratio

4.5 Total factor productivity of major crops in Kerala

Total factor productivity (TFP) explains the growth in output which is more than the growth in inputs such as labour and capital. In other words, TFP is the proportion of index of combined output to an index of combined input. This objective therefore sought to understand the total factor productivity changes among selected crops in Kerala.

To undertake this, eight input values and one output of the selected crops from the cost of cultivation data published by DES were used for data envelopment analysis. The crops which were studied for TFP analyses were paddy (autumn), paddy (winter), paddy (summer), coconut, ginger, black pepper, turmeric, tapioca and banana. These were purposively selected since only for these crops the data was available sufficiently longer period, which was from 2000-01. The inputs used for this study were human labour (hired and family labour), machine labour, seeds, fertiliser, plant protection, irrigation and the interest on working capital, as the dummy for capital component. The output from the crop was estimated as the summation of the value of product and by product and was used for the analysis.

4.5.1 Decomposition of total factor productivity changes

To interpret the results, the displayed value is multiplied by one hundred to obtain percentages. The excess of 100 per cent is taken as a positive TFP change, while the difference with which the percentage value falls short of 100 per cent is the percentage decline in TFP.

4.5.2 Total factor productivity changes for major crops (2000-01 to 2016-17)

Total factor productivity changes for autumn paddy fluctuated over the study period mainly because of changes in technical efficiency changes and technological changes as shown in Table 4.66. Despite 39.5 per cent increase technological changes for autumn paddy, the crop

Table 4.66 Decomposition of change in total factor productivity for autumn paddy (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	0.711	1.395	0.993
2002-03	1.666	0.959	1.598
2003-04	1.000	0.790	0.790
2004-05	1.000	0.985	0.985
2005-06	0.951	1.236	1.175
2006-07	0.823	1.327	1.092
2007-08	0.943	0.875	0.825
2008-09	1.220	1.179	1.438
2009-10	1.111	0.952	1.057
2010-11	0.845	1.083	0.916
2011-12	1.019	1.076	1.097
2012-13	0.791	1.135	0.898
2013-14	0.998	1.085	1.082
2014-15	1.157	0.921	1.065
2015-16	0.636	1.233	0.784
2016-17	1.502	0.782	1.175

had a 0.7 per cent decline in TFP changes in 2001-02 mainly due to 28.9 per cent decline in technical efficiency changes. The TFP improved in the following year mainly due to improvement in technical efficiency but again declined in 2003-04 mainly due to decline in technological changes since there was no change in technical efficiency. In 2010-11, the crop registered 8.4 per cent decline in TFP mainly due to less proportionate decline in technical efficiency. However, in the last year of the study, 2016-17, autumn paddy had an improvement in TFP by 17.5 per cent mainly driven by impressive increase in technical efficiency. Overall, autumn paddy had the largest TFP increase in 2002-03 of 59.8 per cent and largest TFP decline in 2015-16 which was 21.6 per cent decline.

Winter paddy's TFP change decomposition is shown in Table 4.67. Winter paddy registered 6.8 per cent decline in TFP in 2001-02 and one per cent decline in 2003-04. Just as in the case of autumn paddy. The change in 2001-02 and 2003-04 were mainly influenced by technical and technological changes respectively. In 2010-11, winter paddy had an increase in TFP by 3.9 per cent mainly driven by improvements in technical efficiency. In the last year of

Table 4.67 Decomposition of change in total factor productivity for winter paddy (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	0.612	1.523	0.932
2002-03	1.340	0.791	1.060
2003-04	1.373	0.721	0.990
2004-05	1.000	1.016	1.016
2005-06	1.000	1.297	1.297
2006-07	0.675	1.325	0.894
2007-08	1.386	0.729	1.011
2008-09	0.938	1.185	1.111
2009-10	0.930	0.952	0.885
2010-11	1.072	0.969	1.039
2011-12	0.986	1.072	1.057
2012-13	0.759	1.132	0.859
2013-14	1.126	1.042	1.173
2014-15	1.056	0.957	1.011
2015-16	0.733	1.479	1.084
2016-17	1.221	0.773	0.944

the study, 2016-17, the TFP declined by 5.6 per cent mainly due to decline in technological changes. Overall, winter paddy had the largest decline in TFP of 11.5 per cent in 2009-10 while the largest increase in TFP was 29.7 per cent in the year 2005-06. Both the decline and increase in TFP in winter paddy were majorly influenced by changes in technology in the cultivation of the crop.

Summer paddy's TFP results are presented in Table 4.68. The crop had 2.4 per cent improvement in TFP in 2001-02 mainly due to impressive improvement in technological changes and less due to changes in technical efficiency. This was the same case with paddy grown in autumn and winter seasons. The same trend was depicted in TFP changes in 2003-04 for the summer paddy where TFP declined by 26.6 per cent. In 2010-11, there was 16.6 per cent increase in TFP mainly due to improvements in technical efficiency and technology. In

Table 4.68 Decomposition of change in total factor productivity for summer paddy (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	0.713	1.437	1.024
2002-03	1.292	0.801	1.035
2003-04	1.075	0.683	0.734
2004-05	1.126	1.101	1.240
2005-06	0.962	1.223	1.177
2006-07	1.040	1.119	1.164
2007-08	0.721	0.400	0.289
2008-09	1.173	1.180	1.384
2009-10	0.973	0.949	0.924
2010-11	1.150	1.014	1.166
2011-12	0.846	1.093	0.924
2012-13	0.864	1.137	0.982
2013-14	1.077	1.017	1.095
2014-15	1.059	0.954	1.011
2015-16	1.228	1.078	1.324
2016-17	0.692	0.954	0.660

2016-17, summer paddy had the largest decline in its TFP by 34 per cent mainly due to decline in technical efficiency and technological change. Summer paddy had the largest increase in TFP in 2008-09 at 38.4 per cent mainly due to increase in both technological change and technical efficiency.

Tapioca had 9.4 per cent decline in TFP in 2001-02 mainly due to decline in technological change. TFP of the crop improved the following year in 2002-03 but declined further in 2003-04 by 22.2 per cent. In 2010-11, tapioca had 4.2 per cent improvement in TFP while 2016-17 experienced decline of 49.5 per cent. Overall, tapioca had the largest decline in TFP of 63.2 per cent in 2012-13 while the largest increase was in the following year in 2013-14 at 72.9 per cent. Since technical efficiency changes were constant, the changes in TFP for tapioca were mostly due to technological changes.

For the first few years of the study, coconut showed decline in TFP mainly due to decline in technology inherent in the cultivation of the crop. The crop showed 13.6 per cent and 21.3 per cent decline in 2001-02 and 2003-04 respectively. In 2010-11, there was further decline in TFP in the production of coconut showed by 58.6 per cent decline. Generally, coconut showed decline in TFP all over the period since it is a perennial crop and the input use

Table 4.69 Decomposition of change in total factor productivity for tapioca (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	1.000	0.906	0.906
2002-03	1.000	1.228	1.228
2003-04	1.000	0.778	0.778
2004-05	1.000	1.055	1.055
2005-06	1.000	1.439	1.439
2006-07	1.000	1.052	1.052
2007-08	1.000	0.538	0.538
2008-09	0.802	1.564	1.254
2009-10	1.247	1.123	1.401
2010-11	1.000	1.042	1.042
2011-12	1.000	1.520	1.520
2012-13	1.000	0.368	0.368
2013-14	1.000	1.729	1.729
2014-15	1.000	0.705	0.705
2015-16	1.000	1.209	1.209
2016-17	1.000	0.505	0.505

level would result in little improvement in production levels of the crop when the crop is already established. Coconut had the largest positive change in TFP in 2011-12 where it showed 62.4 per cent increase in TFP while the largest decline was 54.1 per cent in 2012-13. The technical efficiency of the crop was generally stagnant due to the crop being a perennial crop and minor scale improvements in area would have little impact on the state's average for the crop's cultivation.

Banana and other plantains had 38.6 per cent decline in TFP in 2001-02 as shown in Table 4.71. The crop in 2003-04 again had 17 per cent decline in TFP mainly due to decline technological changes. However, in 2010-11, banana and other plantains registered an improvement in TFP by showing 32.5 per cent increase in TFP mainly due to increase in technological changes. In 2016-17, banana and other plantains registered a 7.4 per cent decline in TFP mainly due to 20 per cent decline in technical efficiency. Banana and other plantains

Table 4.70 Decomposition of change in total factor productivity for coconut (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	1.000	0.864	0.864
2002-03	1.000	0.855	0.855
2003-04	1.000	0.787	0.787
2004-05	1.000	0.554	0.554
2005-06	1.000	1.176	1.176
2006-07	1.000	0.659	0.659
2007-08	1.000	0.569	0.569
2008-09	1.000	1.524	1.524
2009-10	1.000	1.409	1.409
2010-11	1.000	0.414	0.414
2011-12	1.000	1.624	1.624
2012-13	1.000	0.459	0.459
2013-14	1.000	1.198	1.198
2014-15	1.000	0.919	0.919
2015-16	1.000	0.938	0.938
2016-17	1.000	1.489	1.489

was one of the crop that was found to be improving in area from the analysis of growth performance of crops and trend break analysis. This was mainly due to impressive improvement in the prices of the crop. Banana and other plantain was also found to be having crops transitioning to it especially in the later phases of the transition and retention probability matrices. This explains why the crop registered positive improvements in technical efficiency that led to increase in TFP. In overall, banana and other plantains had the largest decline in TFP of 84.7 per cent in 2012-13 while the largest improvement in TFP was in 2008-09 where the crop registered 42.5 per cent increase in TFP growth mainly driven by technical efficiency and technological change.

As shown in Table 4.72, black pepper had 55.5 per cent decline in TFP in 2001-02 mainly due to decline in technological change. The TFP improved thereafter and by 2003-04, the decline reduced to 6.2 per cent. In 2004-05, the TFP declined further by 81.6 per cent. This was the largest decline in TFP change of the crop. In 2010-11, the crop registered positive improvement in TFP of 37.2 per cent while in 2016-17, there was a 25.1 per cent decline in

TFP. The largest increase in TFP for black pepper was in 2015-16 when the crop had 59.8 per cent improvement in TFP. The technical efficiency of the crop was majorly stagnant for the

Table 4.71 Decomposition of change in total factor productivity for banana and other plantains (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	0.543	1.132	0.614
2002-03	1.923	0.709	1.363
2003-04	1.000	0.830	0.830
2004-05	0.660	1.215	0.802
2005-06	1.344	0.881	1.184
2006-07	1.128	1.220	1.376
2007-08	0.794	0.732	0.582
2008-09	1.259	1.132	1.425
2009-10	1.000	0.919	0.919
2010-11	1.000	1.325	1.325
2011-12	0.773	1.604	1.240
2012-13	0.665	0.231	0.153
2013-14	1.171	1.190	1.393
2014-15	0.787	0.914	0.719
2015-16	1.374	0.964	1.325
2016-17	0.800	1.158	0.926

entire period of the study whereas technological change was the main driver for TFP change in the increase in productivity of the crops.

Ginger had 52 per cent decline in TFP in 2001-02 as shown in Table 4.73. The TFP improved afterwards till 2004-05 when there was a decline the following year in 2005-06. Therefore, TFP change in 2003-04 (-4.5%) was an improvement in the decline of the TFP in 2001-02. The largest decline in TFP in the production of ginger was in 2006-07 which was 96.1 per cent. The crop registered 13.6 per cent improvement in TFP in the year 2010-11 and 23.9 per cent improvement in TFP in 2016-17. The changes in the TFP in all the years under the study of productivity of ginger was driven by technological changes since technical efficiency was stagnant. The largest increase in TFP in the production of ginger was 27.8 per cent in 2013-14.

The productivity of turmeric was determined by both technical efficiency changes and technological changes as shown in Table.4.74 contrary to the results of ginger productivity.

Table 4.72 Decomposition of change in total factor productivity for black pepper (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	1.000	0.445	0.445
2002-03	1.000	0.753	0.753
2003-04	1.000	0.938	0.938
2004-05	1.000	0.184	0.184
2005-06	1.000	1.126	1.126
2006-07	1.000	1.202	1.202
2007-08	1.000	0.784	0.784
2008-09	1.000	0.906	0.906
2009-10	1.000	1.139	1.139
2010-11	1.000	1.372	1.372
2011-12	1.000	1.464	1.464
2012-13	1.000	0.356	0.356
2013-14	1.000	1.027	1.027
2014-15	1.000	0.620	0.620
2015-16	1.000	1.598	1.598
2016-17	1.000	0.749	0.749

Table 4.73 Decomposition of change in total factor productivity for ginger (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	1.000	0.480	0.480
2002-03	1.000	0.686	0.686
2003-04	1.000	0.955	0.955
2004-05	1.000	1.160	1.160
2005-06	1.000	0.748	0.748
2006-07	1.000	0.039	0.039
2007-08	1.000	1.195	1.195
2008-09	1.000	0.960	0.960
2009-10	1.000	0.798	0.798
2010-11	1.000	1.136	1.136
2011-12	1.000	0.708	0.708
2012-13	1.000	1.206	1.206
2013-14	1.000	1.278	1.278
2014-15	1.000	0.833	0.833
2015-16	1.000	0.942	0.942
2016-17	1.000	1.239	1.239

Table 4.74 Decomposition of change in total factor productivity for turmeric (2000-01 to 2016-17)

Year	Technical efficiency change	Technological change	Total factor productivity change
2001-02	1.022	0.647	0.661
2002-03	0.698	0.924	0.645
2003-04	1.028	0.909	0.934
2004-05	1.128	1.116	1.259
2005-06	0.637	0.805	0.513
2006-07	1.408	0.741	1.044
2007-08	1.115	0.885	0.987
2008-09	0.943	1.598	1.507
2009-10	0.378	1.053	0.398
2010-11	1.921	0.772	1.484
2011-12	0.541	1.959	1.059
2012-13	0.813	0.221	0.180
2013-14	1.387	1.102	1.529
2014-15	1.108	0.837	0.928
2015-16	1.260	1.227	1.546
2016-17	0.729	0.993	0.724

Turmeric had 33.9 per cent decline in TFP in 2001-02 followed by 6.6 per cent decline in 2003-04. In 2010-11, turmeric had 48.4 per cent improvement in TFP. The largest improvement in TFP of turmeric was in 2015-16 where the crop had 54.6 per cent increase in TFP. The largest decline in TFP in the productivity of turmeric was 82 per cent in 2012-13.

4.5.3 Mean total factor productivity changes for crops from 2000-01 to 2016-17

The summary of technical efficiencies and technological changes that determined the total factor productivities of various crops in Kerala are presented below. Banana and other plantains, autumn paddy and coconut had the largest TFP change of 7.2 per cent, 4.4 per cent and 3.4 per cent respectively for the entire study period. The TFP growth in these crops were majorly driven by increases in their technological components. The winter paddy and summer paddy also had a slight increment in their TFPs at about 1 per cent mainly driven by growth in the technological changes and hindered by decline in technical efficiencies. Turmeric also was buoyed by 4 per cent technological change and in turn recorded 1.9 per cent TFP growth.

Tapioca, black pepper and ginger recorded negative changes or decline in their TFPs. There was 5.2 per cent decline in TFP in tapioca, 2.2 per cent TFP decline in black pepper and 2 per cent TFP decline in ginger. These three crops on an average had stagnant technical

Table 4.75: Mean total factor productivity changes for crops from 2000-01 to 2016-17

Crop	Technical efficiency change	Technological change	Total factor productivity change
Paddy (Autumn)	0.993	1.051	1.044
Paddy (Winter)	0.985	1.025	1.009
Paddy (Summer)	0.982	1.028	1.009
Tapioca	1.000	0.948	0.948
Coconut	1.000	1.034	1.034
Banana	1.019	1.052	1.072
Black pepper	1.000	0.978	0.978
Ginger	1.000	0.980	0.980
Turmeric	0.979	1.040	1.019
Mean	0.995	1.015	1.010

efficiencies for the period under study. The decline in TFP in these crops was majorly due to decline in the technological changes.

5. SUMMARY AND CONCLUSION

This study on ‘structural transformation and spatio-temporal variations of agriculture in Kerala was done with the objectives, to analyse the growth of agriculture and assess the disparities among the districts in agricultural development in Kerala, examine the dynamics in land use and cropping patterns, study the dynamics in economics, efficiency and profitability of cultivation of major crops and estimate the total factor productivity and its determinants for major crops in Kerala.

The entire agriculture GSVA series was subjected to Bai and Perron (1998) structural break methodology. Five break points were obtained leading to six growth periods from which the study was based. These periods were Period I (1970-71 to 1980-81), Period II (1981-82 to 1987-88), Period III (1988-89 to 1994-95), Period IV (1995-96 to 2003-04) Period V (2004-05 to 2010-11) and Period VI (2011-12 to 2018-19). Compound annual growth rates (CAGRs) and Cuddy-Della Valle Instability Indices (CDVIs) were used to analyse the growth performance of crops in Kerala. The CAGRs showed that pulses (-6.58%), paddy (-3.89%), tapioca (-3.71%) and cashew (-2.44%) had the largest loss in area throughout the phases. This loss in area could be attributed to the decline in prices, rising cost of inputs and increasing prices of other crops. Rubber had the largest annual increase in area (2.56%) among all the crops in the entire period of the study. Other crops that were found to have performed well were coconut and banana and other plantains. These improvements were attributed to the prices of these crops which increased favourably and due to relatively low labour requirements, the crops were found to be profitable by farmers. Arecanut and small cardamom had the highest increase in yield of 6.29 per cent each per annum among all the crops. The positive productivity growth was also found for all the crops except for cashew. In general, food grains and tapioca had their areas declining all through the study period (1970-71 to 2018-19), while the area under fruits and plantation crops were generally increasing during most of the period. The crop with the highest stability in area was tea (4.63%), while black pepper was the most unstable (30.57%). It was established that profitability was a major factor that determined the annual growth and instability of the area under various crops.

The trend break analysis was also used to study the growth performance of crops in Kerala. The (Bai and Perron, 1998) methodology was used to compute the trend breaks in area under crops and to find out the reasons behind the breaks. It was established that the main reason for the break in area under most of the crops was related to profitability. The farmers were found to be prioritising profits in the cultivation of various crops and it was noted that with increase in prices, especially of plantation crops and spices, coincidentally the areas under those crops also increased. However, this was not entirely true for food grains like paddy. It was observed that at some instances when it had price increase, the area did not improve but continued declining. It was established that despite the increase in price, it could not offset the increasing input costs like wage rates and fertiliser prices and hence the farmers were realising decline in their net returns. Paddy was much affected since it is a labour-intensive crop and an increase in the wages of field labour impacted it negatively. The plantation crops on the other hand were less labour intensive and the growth in prices was an incentive for the farmers to expand the acreage under the crop, which also enticed more farmers into the cultivation of the crops. In turn, the area under rubber and coconut increased tremendously especially from late 1980s. Thus, the changes in prices could be attributed as the major cause for the breaks in trend for most of the crops grown in the State.

Another significant factor found to be contributing to the trend breaks in crops was the price of rubber. Under many instances, the price of rubber was found to be affecting the break in area under crops, especially the upward movements in prices. The increase in the price of rubber encourage the farmers of crops such as paddy to leave their land fallow, possibly in anticipation of converting to rubber later. The government policies and interventions in the agricultural sector were also found to be major contributor to the trend breaks. The introduction of policies that promoted the cultivation of crops such as paddy led to increase in the area, which led to breaks. The government policies that positively influenced the breaks in area under paddy were the introduction of the group farming scheme in 1988-89, promotion of paddy cultivation in the fallow lands in 2004-05 and the enactment of the Conservation of paddy land and wetland act of 2008.

The Seemingly Unrelated Regression (SUR) model was used to understand the determinants of the growth in GSDP from agriculture in Kerala. The model revealed that the largest contributor to agricultural GSVA was gross cropped area irrigated and was followed by the area under the high value crops. This was a confirmation that the increased cultivation of high value crops was the key to improvement in earnings from agriculture in Kerala State. The fertiliser consumption was also found to be important in improving the earnings realised from agriculture. While gross fixed capital formation was found to be positively influencing GSVA from agriculture, its contribution to the rise in per capita earnings in agriculture was low. The gross area irrigated area was found to be significantly contributed by the development expenditure and cropping intensity. In most instances, the Government of Kerala (GoK) met the cost of energy used in running the irrigation systems. Thus, it found validity in the model that development expenditure by the GoK was significantly one of the determinants of area irrigated in gross cropped area. The enhanced as well as dedicated cropping intensity and development expenditure were found to lead to more earnings in the agricultural sector by increasing the total area irrigated, which in turn spurred the growth in agricultural income.

The fertiliser consumption was found to be majorly affected by the development expenditure. From the model, it was found out that more development expenditure to the agricultural as well as the primary sector leads to more fertiliser consumption per hectare. The institutional credit was also found to be a major driver for encouraging fertiliser consumption among the farmers. The fertiliser prices affected earnings realised from the agricultural sector negatively, while development expenditure and institutional credit were instrumental in improving the earnings realised from the agriculture GSVA.

To analyse the inter-district variations in crops, CAGR and CDVI were used to find out the best performing districts in terms of area, production and productivity for 33 years from1985-86 to 2017-18. The area under paddy was found to be declining in all the districts of Kerala. Kollam (-10.92%), Ernakulam (-9.71%) and Thiruvananthapuram (-9.36%) had the largest annual declines in area. Alappuzha, Palakkad, Kottayam, Wayanad and Thrissur experienced the lowest decline in area under paddy compared to other districts. The largest instability of 24.41 per cent for area under paddy was observed in Thiruvananthapuram, while Palakkad had the lowest instability in area (10%). The highest mean yields of 2.54 tonnes per hectare and 2.5 tonnes per hectare in paddy were found in Pathanamthitta and Kottayam respectively. Kozhikode had the lowest mean productivity of 1.31 tonnes per hectare among all the districts in the state. While the State's average yield of paddy was 2.14 tonnes per hectare for the 33-year period of the study, it was found that Thiruvananthapuram, Kollam, Kasaragod, Malappuram, Ernakulam, Kannur and Kozhikode had mean productivity lower than the State average.

The area under coconut declined in some of the districts, while it registered positive annual growth rates in most of them. The highest CAGR of 3.54 per cent in area was observed in Wayanad, while Pathanamthitta had showed the largest decline of -2.16 per cent. All the districts other than Thiruvananthapuram, Kollam, Ernakulam, Alappuzha and Pathanamthitta exhibited positive annual growth rates in area under coconut. The highest mean productivity of

6940 nuts per hectare during the 33-year period of study was found in Kasaragod, while the lowest was in Wayanad, which reported 3299coconuts per hectare. The State's long-term average productivity was 5,748 nuts per hectare and therefore Ernakulam, Palakkad, Alappuzha, Kottayam, Idukki and Wayanad had mean productivity below the State average for the entire period of the study.

The analysis of area under rubber found that all the districts experienced positive annual growth rates in area. However, the growth rates in some of the districts like Kollam, Kottayam, Ernakulam and Idukki were comparatively low. The highest annual growth in area under rubber was observed in Wayanad (3.26%), while the highest instability in area was found in Thrissur, which recorded an instability of 10.07 per cent. Kannur showed the most stable area under rubber. The State's average productivity of rubber for the period under study was worked out as 1.09 tonnes per hectare. The districts of Thrissur, Kozhikode, Kollam, Alappuzha, Pathanamthitta, Kottayam and Ernakulam had higher mean productivity than the state average, while the rest of the districts reported lower productivity than the state average during the period under the study.

Most districts were reporting decline in areas under tapioca. Kasaragod had the largest annual decline in area of -8.07 per cent and Wayanad was the only district which had increasing area under the crop with a CAGR of 0.35 per cent. As a result of the higher decline in area under tapioca in Kasaragod, a comparatively greater instability was also witnessed in the district (42.62%). Wayanad, Idukki, Ernakulam and Pathanamthitta were the only districts which exhibited growth in production of tapioca. Despite some districts having negative annual growth rates in area and production of tapioca, all the districts showed a growth in productivity. The mean productivity in tapioca was found to be highest in Wayanad at 36.19 tonnes per hectare, while the lowest was in Kozhikode (20.9 T/ha). Thrissur, Kollam, Palakkad, Alappuzha, Thiruvananthapuram, Kasaragod and Kozhikode were the districts with productivity of tapioca lower than the State average for the period.

The only districts that exhibited growth in area of black pepper were Idukki and Palakkad, while the other districts registered negative growth rates. Kannur had the lowest annual decline of -6.07 per cent per annum for area under black pepper. The instability in area was relatively high in all the districts and none of the districts showed lower instability. In line with the positive annual growth rates in area, only Palakkad and Idukki had positive annual growth rates in production. The mean productivity of black pepper was highest in Idukki (0.43

T/ha), while Alappuzha reported the lowest (0.16 T/ha) productivity. The average for Kerala State was found to be 0.25 tonnes per hectare and it was found that Kottayam, Thrissur, Palakkad, Ernakulam, Kozhikode, Malappuram and Alappuzha were having lower mean productivity as compared to the State average.

The area under banana and other plantains registered an impressive annual growth in most of the districts. The decline in area under banana was observed only in Alappuzha, Kannur, Wayanad, Pathanamthitta and Kottayam. Palakkad had the highest annual growth rate in area of 4.56 per cent. Kottayam, Pathanamthitta, Idukki, Kollam, Kozhikode, Ernakulam and Thiruvananthapuram showed low instability for area under banana and other plantains, while the rest of the districts showed medium instability. The growth in production was observed in all the districts which was an indication that because of the increase in area banana was showing increased production in all the districts. Idukki showed the highest average productivity of 8.84 tonnes per hectare for banana and other plantains during the entire period under study, while Kannur had the lowest (4.33 T/ha). The average for the State was worked out as 6.46 tonnes per hectare and Alappuzha, Malappuram, Kasaragod, Thrissur, Kozhikode and Kannur were found to be yielding lower than the State average.

The study on land use and cropping pattern changes revealed through transition probability matrices obtained from the Markov chain analyses showed that the area under forests, area put to non-agricultural uses and, permanent pastures and grazing lands were the most stable land use classes in the first phase (1970-71 to 1980-81). This phase marked the beginning of shift from various crops to plantation crops and large tracts of lands in which other crops were grown were converted to the cultivation of plantation crops like rubber due to increasing prices and profitability. This shift in land use helped to increase the net sown area. The net sown area also had 4.4 per cent probability of receiving land from permanent pastures and grazing lands, and a probability 21.4 per cent from area under miscellaneous tree crops. In the second phase (1981-82 to 1987-88) the increase in area under rubber and other plantation crops resulted in the increase of net sown area. Thus, net sown area was the most stable by having a probability of 93.4 per cent of retaining its area in the current use.

The fifth phase from 2004-05 to 2010-11 was an important period for paddy since several projects were initiated for promoting paddy cultivation in the state. In 2004, GoK launched a project to promote the cultivation of paddy in the fallow lands and towards the latter half of the phase, GoK enacted Kerala Conservation of Paddy Land and Wetland Act, 2008.

While the promotion of cultivation in the fallow lands could have led to the increasing probability in the shift of cultivable waste and current fallow to net sown area, the 2008 act played an important role in ensuring that there would be no further loss and possible conversion as well as reversion of paddy land. This could explain the reason for the net sown area gaining from land put to non-agricultural uses, cultivable waste and current fallow, which showed transition probabilities of 14.3 per cent, 58.2 per cent and 34 per cent in favour of the net sown area. Consequently, the largest losers in this phase were cultivable waste, fallow other than current fallow and current fallow possibly due to GoK intervention. The permanent pastures and other grazing land was also a loser in this phase. The area under non-agricultural uses which got a stimulus in the fifth phase, showed a 100 per cent probability of holding to its share in the sixth phase (2011-12 to 2018-19). The cultivable waste drew gains from net sown area. The area under pastures showed a 93.2 per cent of shift to net sown area, an indication that the area under permanent pastures and grazing lands was getting cleared and converted to farm lands.

In the computation of economics, efficiency and profitability of major crops in Kerala, the share of cost components was analysed to find out their contribution to the total cost every year. The major component in the cost of the cultivation of all the crops across all the landholding sizes was human labour. However, the share of the cost in the total cost showed different trends for each crop over the study period. The proportion of human labour in the total cost for paddy showed an increase from 59.45 per cent in 2000-01 to 63.42 per cent in 2016-17 for the small holdings, which showed that the share of the human labour was increasing in the small sized landholdings. While the share of human labour remained stagnant over the period for the medium holdings of paddy, it reduced from 67.46 per cent in 2000-01 to 47.4 per cent in 2016-17 for the large holdings. This showed that the use of human labour, which included hired human labour and family labour was increasing in the small sized holdings of paddy and declining for other holdings. As opposed to paddy cultivation where the share of cost incurred for human labour component was declining in the large holdings, in tapioca it was largely increasing. The hired human labour had higher share in the total cost of human labour, however, it was declining for all the holdings. The decline in the share of hired labour in the total cost was higher in small holdings and least in large holdings for tapioca. Instead, there was an increase in share of cost of family labour in all the holdings. The analysis of the input cost in the total cost of cultivation of paddy showed that paddy farmers were decreasing the use of inputs.

The shares of hired human labour and family labour in the total cost of cultivation were found to be increasing. The use of machine labour was found to be generally low and declining in the small holdings and medium holdings but was increasing in the large holdings in its share of the total cost. The share of costs incurred for seedlings in the total cost was mostly increasing for all the holdings in coconut cultivation. The share of hired human labour component in the total cost for black pepper cultivation was increasing for all landholding sizes. The increase was more in the small holdings and least in medium holdings. Overall, the cost of human labour share in the total cost was found to be increasing for all the holdings, except the large holdings. In all the holdings under black pepper cultivation, the share of input cost in the total cost was increasing.

The study on economics, efficiency and profitability revealed that profitability of growing paddy, tapioca, coconut and black pepper in Kerala were found to be highest in large and medium holdings. This was also the case for banana and other plantains. Ginger presented an inverse of the trend witnessed in many of the crops in which small holdings were the least profitable. This was attributed to complexities in managing large ginger farms which were prone to diseases. Overall, the profitability improved over the period under the study for all the crops other than ginger. The improvement in profitability could be due to increased use of high yielding varieties and efficient fertilisers that improved the per unit yield as the years progressed.

Banana and other plantains, autumn paddy and coconut had the largest Total Factor Productivity (TFP). The growth of TFP in these crops were majorly driven by improvement in their technological components. The winter paddy and summer paddy also had a slight increment in their TFP, mainly driven by growth in their technological changes and hindered by decline in their technical efficiencies. Turmeric also was buoyed by a four per cent technological change. Tapioca, black pepper and ginger recorded negative changes in the corresponding TFPs. These three crops on an average had stagnant technical efficiencies for the period under the study. The decline in TFP in these crops was majorly due to decline in the technological changes.

Policy Suggestions

- The study revealed that development expenditure by the government is important in improving the gross cropped area irrigated and fertiliser consumption, which would sequentially improve per capita income realised from GSVA agriculture. Therefore, there is a need to enhance public investment to the agricultural sector which will provide incentives and favourable environment for agricultural development. Improved public investment to the agricultural sector will also promote private investment in potential areas of the state, which will consecutively help further growth in the agricultural and primary sectors.

- The study on the inter-district disparities revealed that the districts are endowed with varied capabilities that cause variations in production of the crops. These variations include agroclimatic variation and opportunities. Therefore, to improve and lower the inter-district variations in agricultural development, the development initiatives should target indicators specific to the areas of each district. Thus, in case of collective project for the whole state, there is a need to develop the framework of implementation of the project based on the local needs, capabilities and by taking into account peculiarities inherent to the specific area of the district like weather, soil etc.
- The enactment of the act to protect the paddy land and wetlands seems to have not solved the problem of losing paddy land since more land continue to get lost to other competing uses based on the analysis of land use dynamics. Therefore, a suitable policy intervention needs to be taken up to help reverse the continuing trend in conversion of paddy land. The analysis also showed that the enactment of the act brought some artificial barrier to the farmers on what they can do with their land. With little options, most who are not able to transfer the land to other uses are increasingly leaving their lands fallow, an indication that they would rather leave it fallow than take up non-remunerative paddy cultivation. A suitable government intervention can also put in place to solve this disenfranchisement and help put the states resources to full employment.
- In addition, to ensure better land utilisation, a comprehensive land use plan at the lowest level should be prepared to enhance better utilisation of the resources and to have uniform growth among all sectors of the state.

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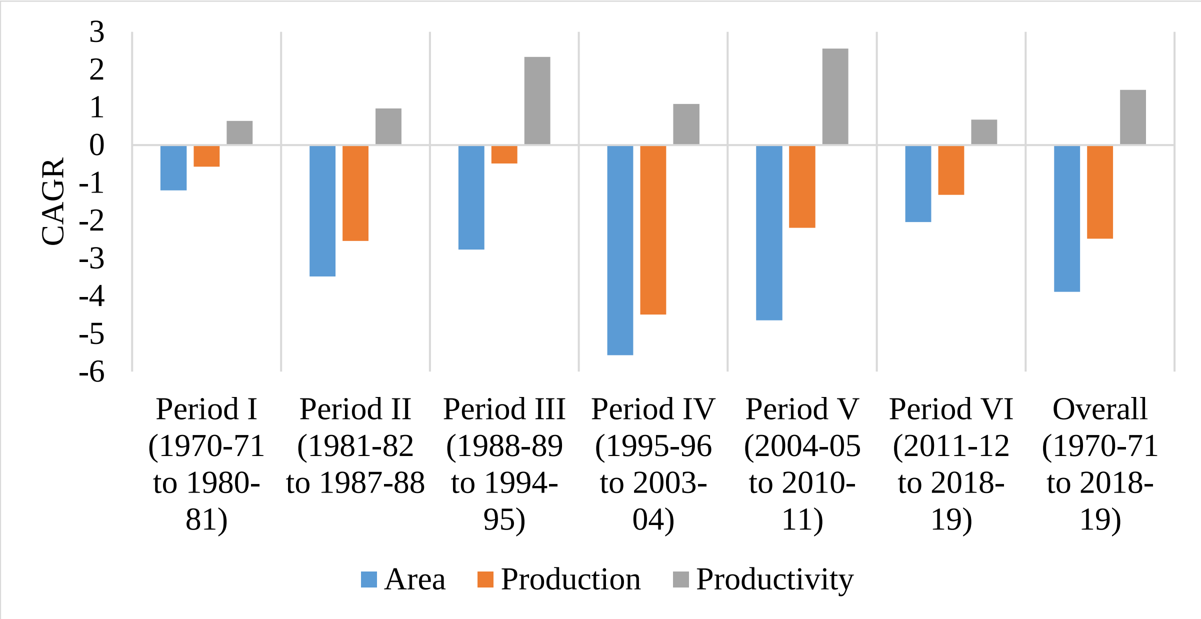
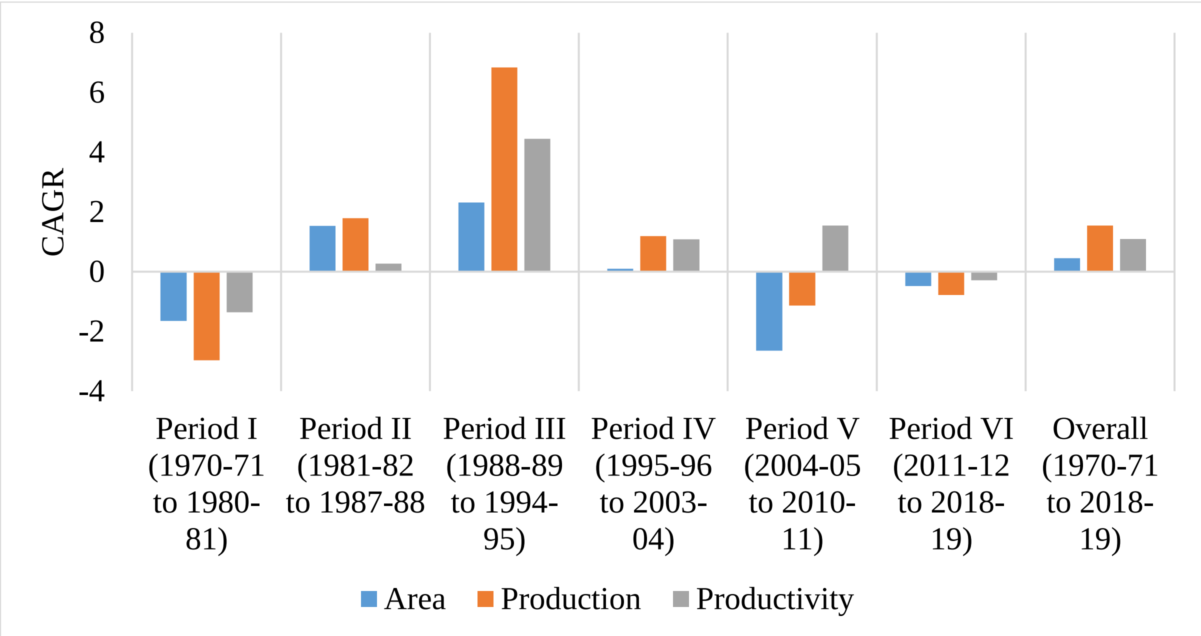
APPENDIX

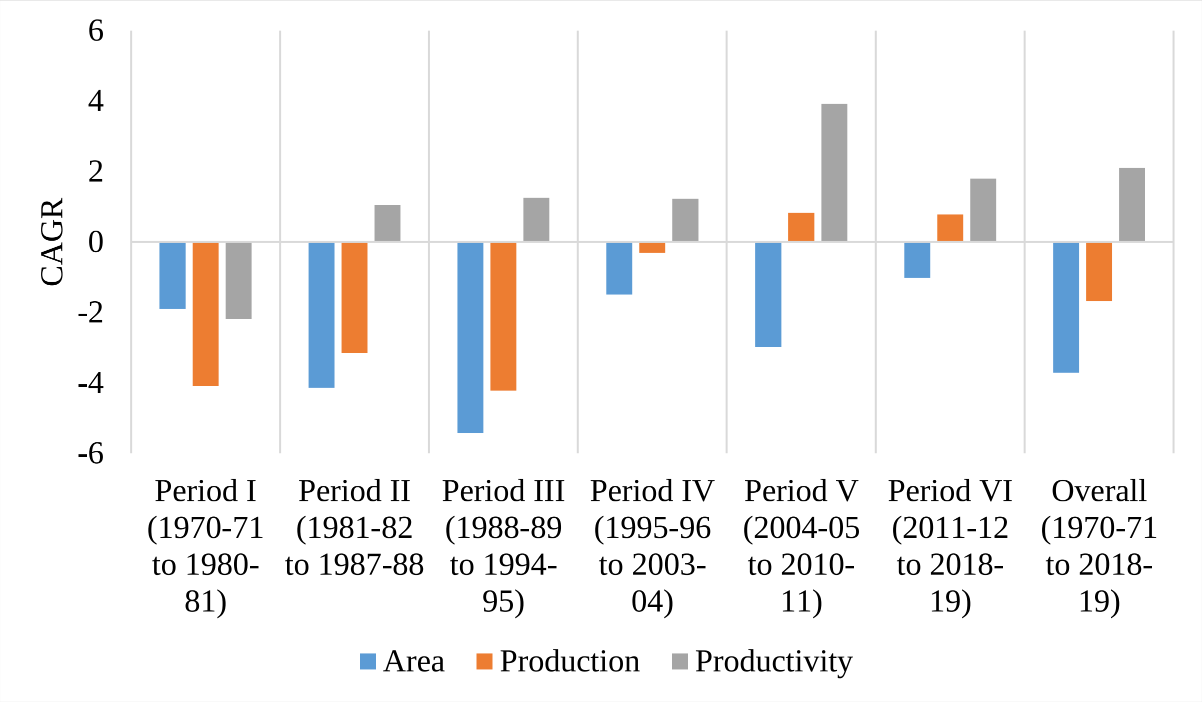
Appendix 1: Growth in area, production and productivity of paddy in Kerala



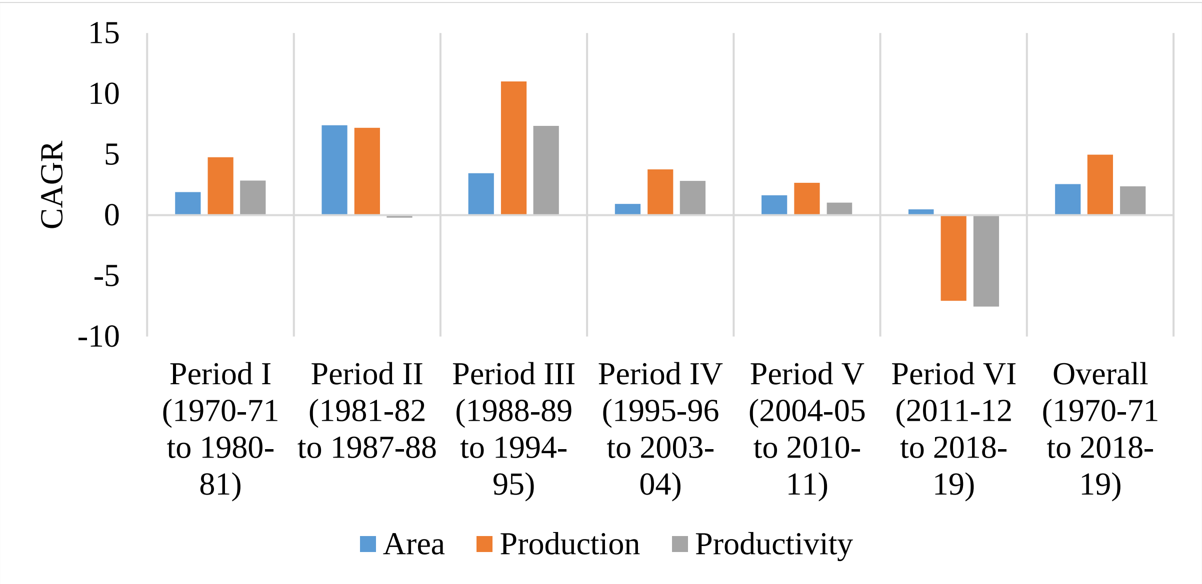
Appendix 2: Growth in area, production and productivity of coconut in Kerala



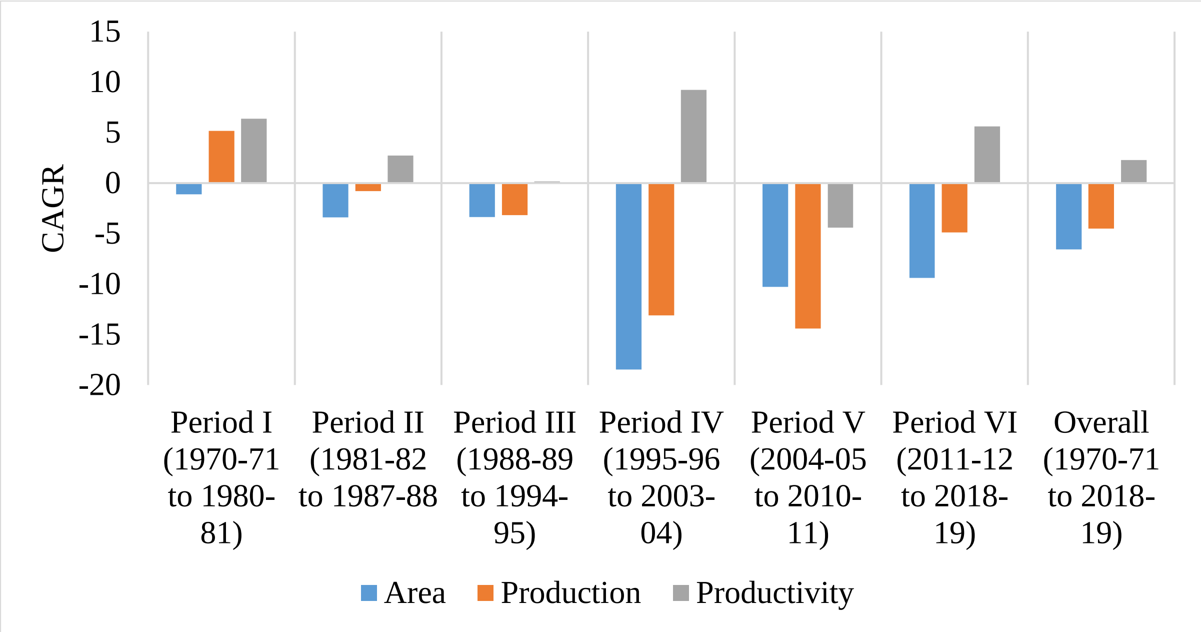
Appendix 3: Growth in area, production and productivity of tapioca in Kerala



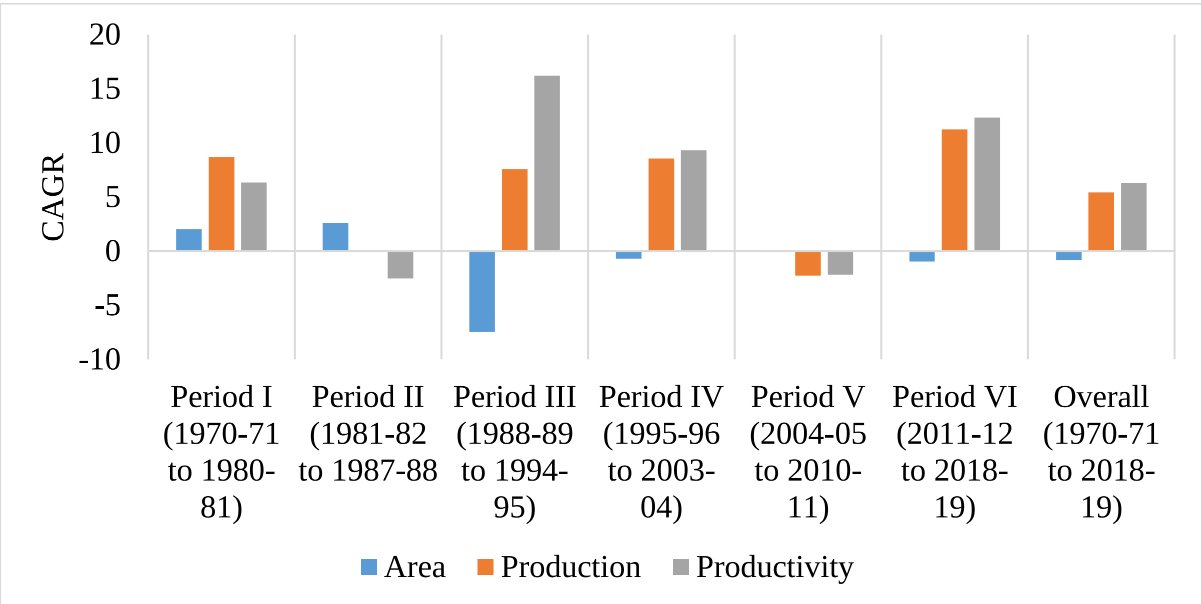
Appendix 4: Growth in area, production and productivity of rubber in Kerala



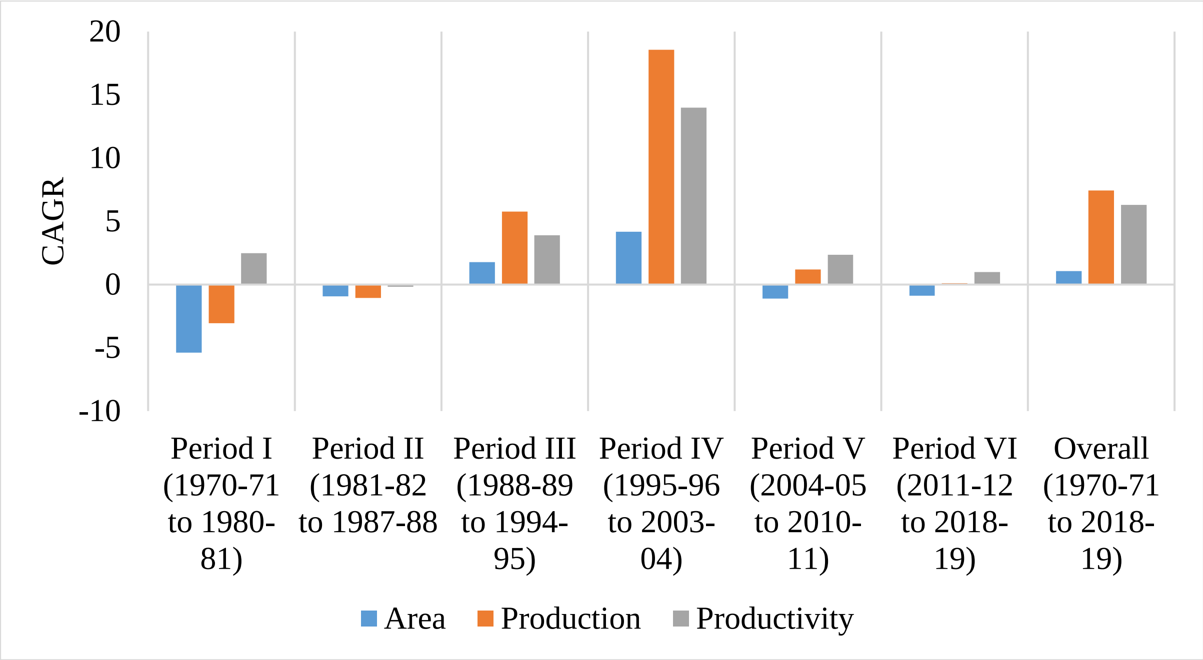
Appendix 5: Growth in area, production and productivity of pulses in Kerala



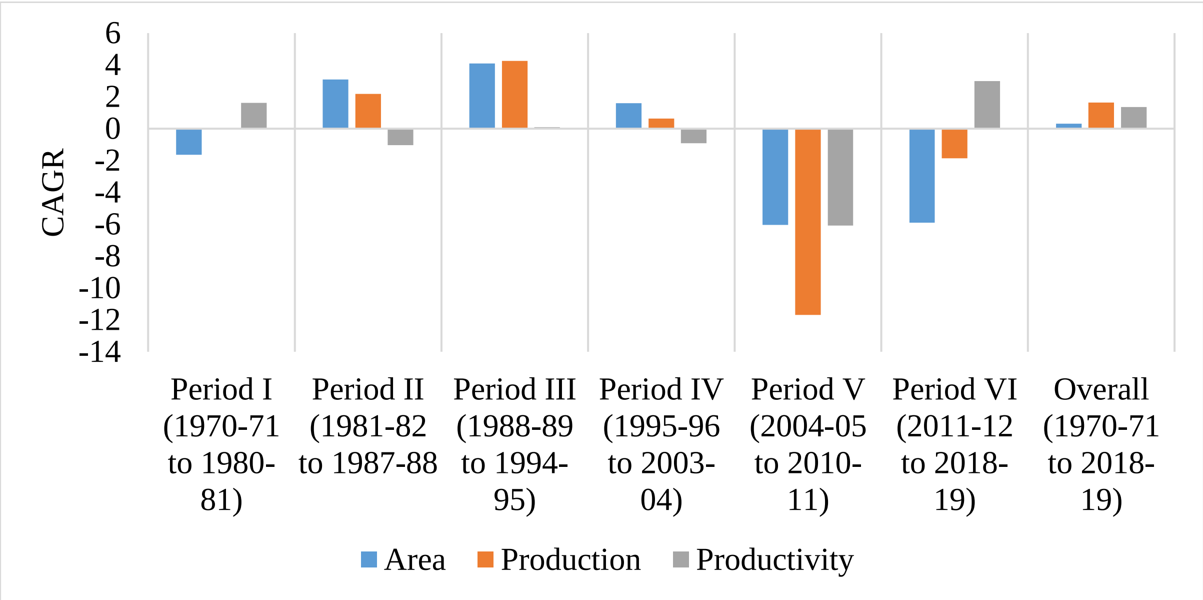
Appendix 6: Growth in area, production and productivity of small cardamom in Kerala



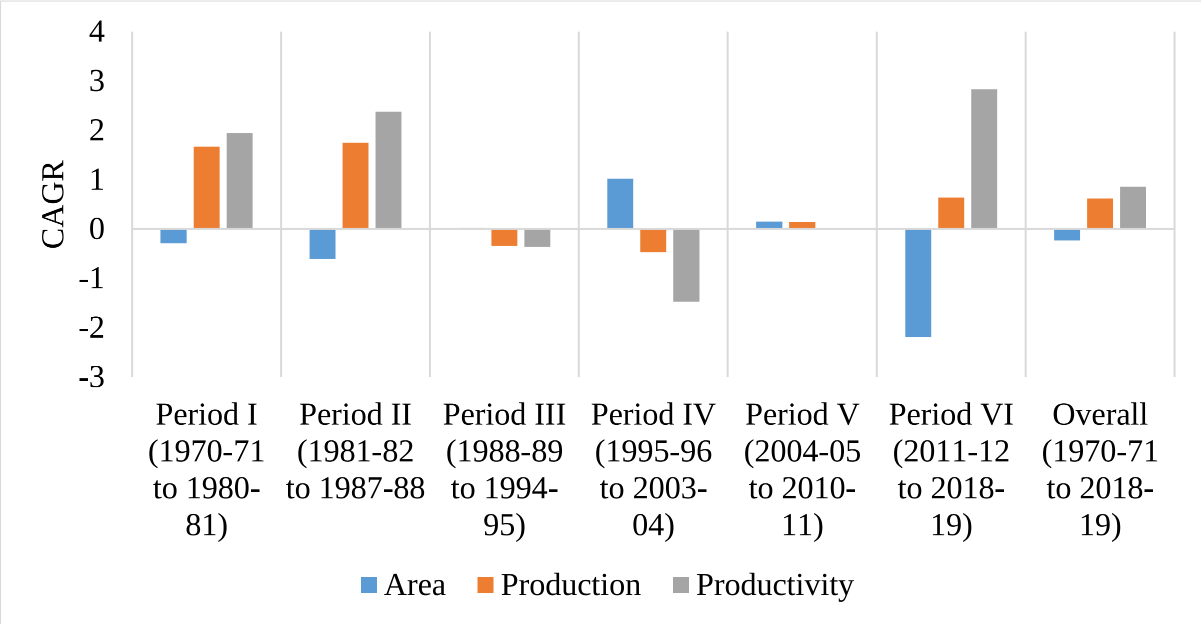
Appendix 7: Growth in area, production and productivity of arecanut in Kerala



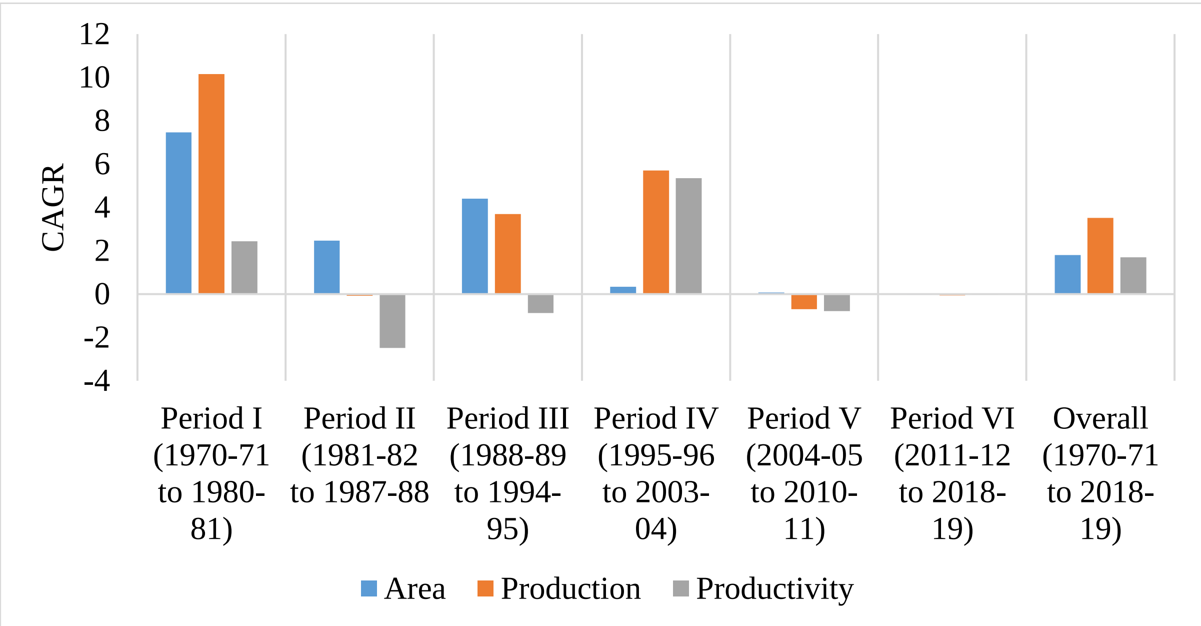
Appendix 8: Growth in area, production and productivity of black pepper in Kerala



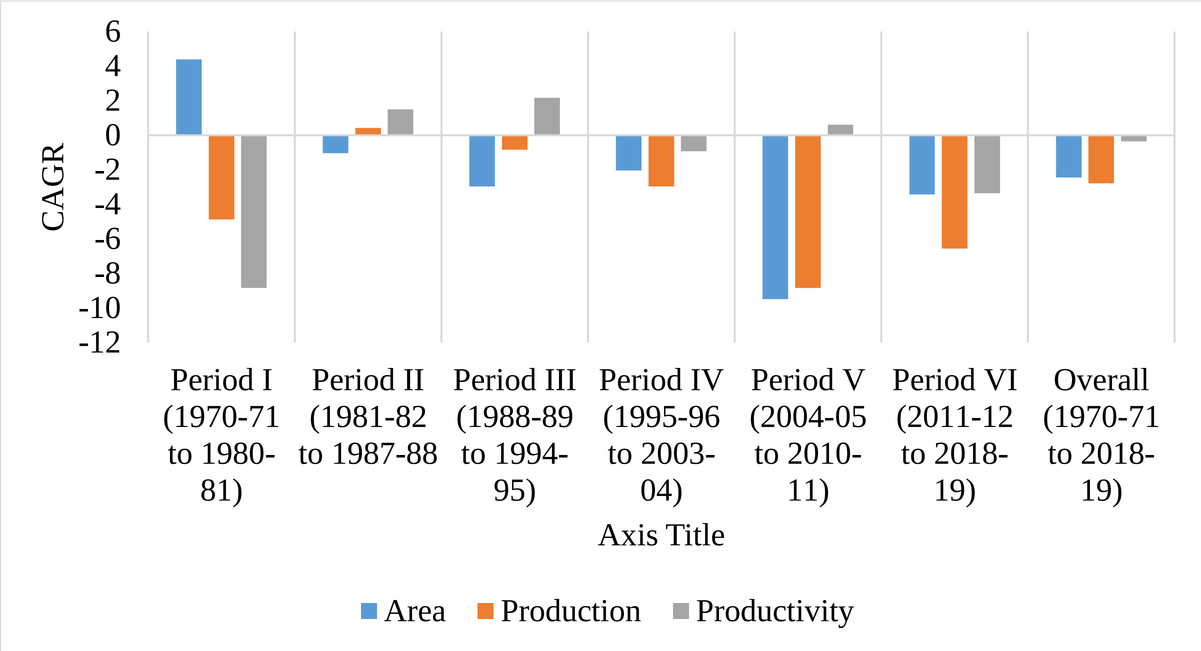
Appendix 9: Growth in area, production and productivity of tea in Kerala



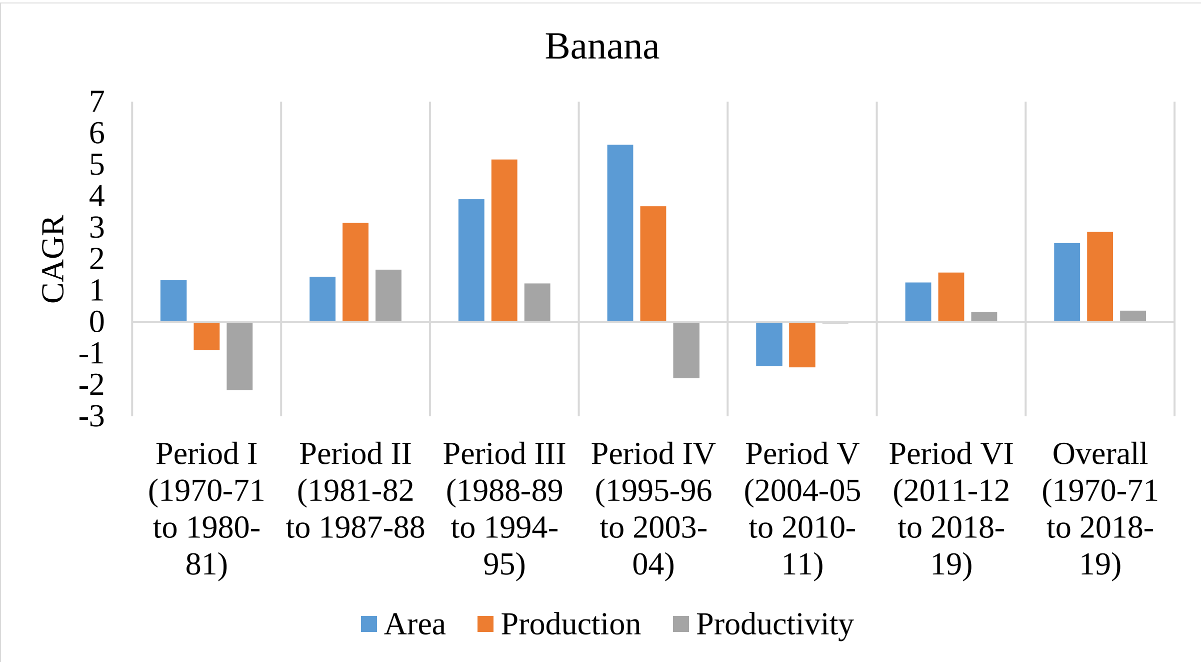
Appendix 10: Growth in area, production and productivity of coffee in Kerala



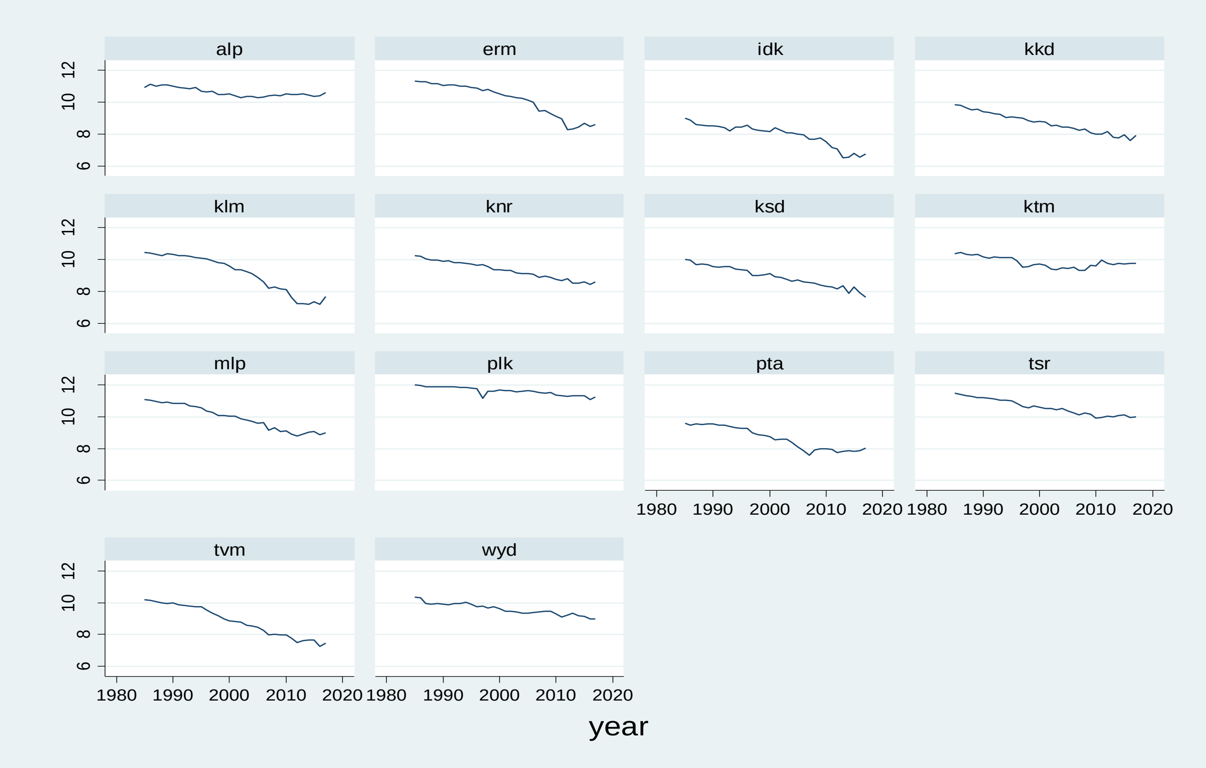
Appendix 11: Growth in area, production and productivity of cashew in Kerala



Appendix 12: Growth in area, production and productivity of banana and other plantains in Kerala

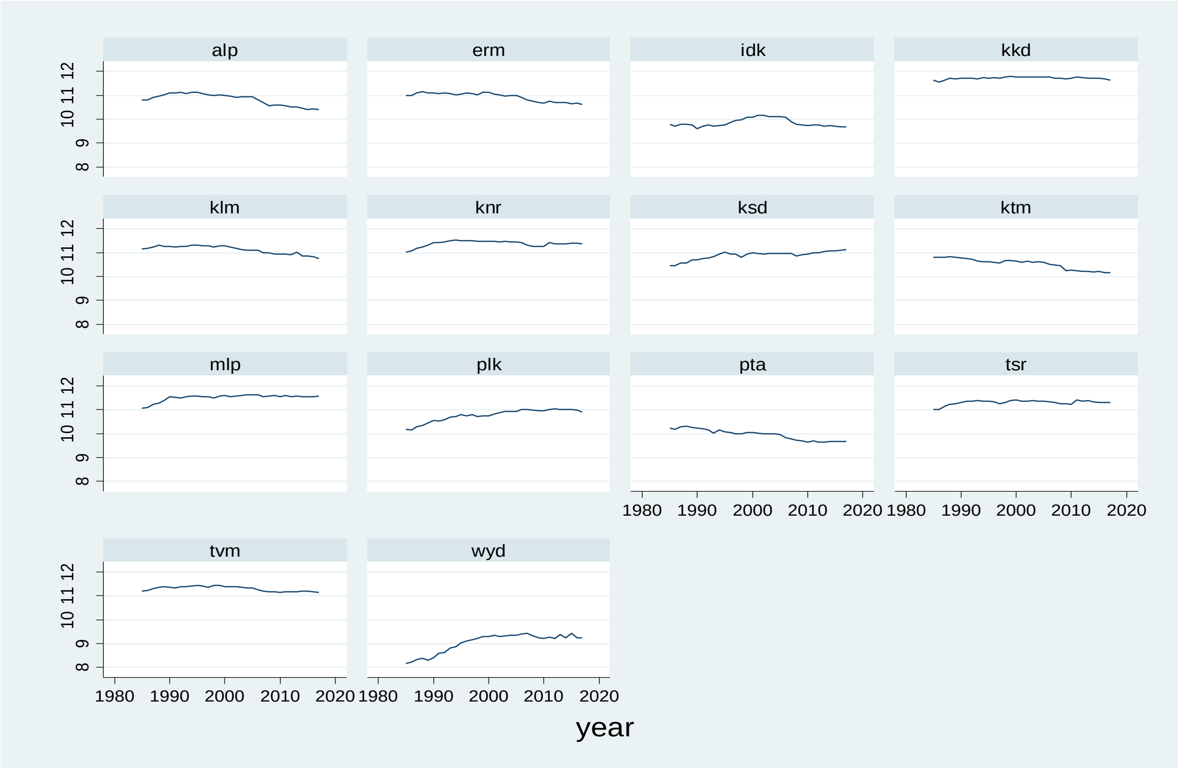


Appendix 13: District-wise trend in area under paddy in Kerala

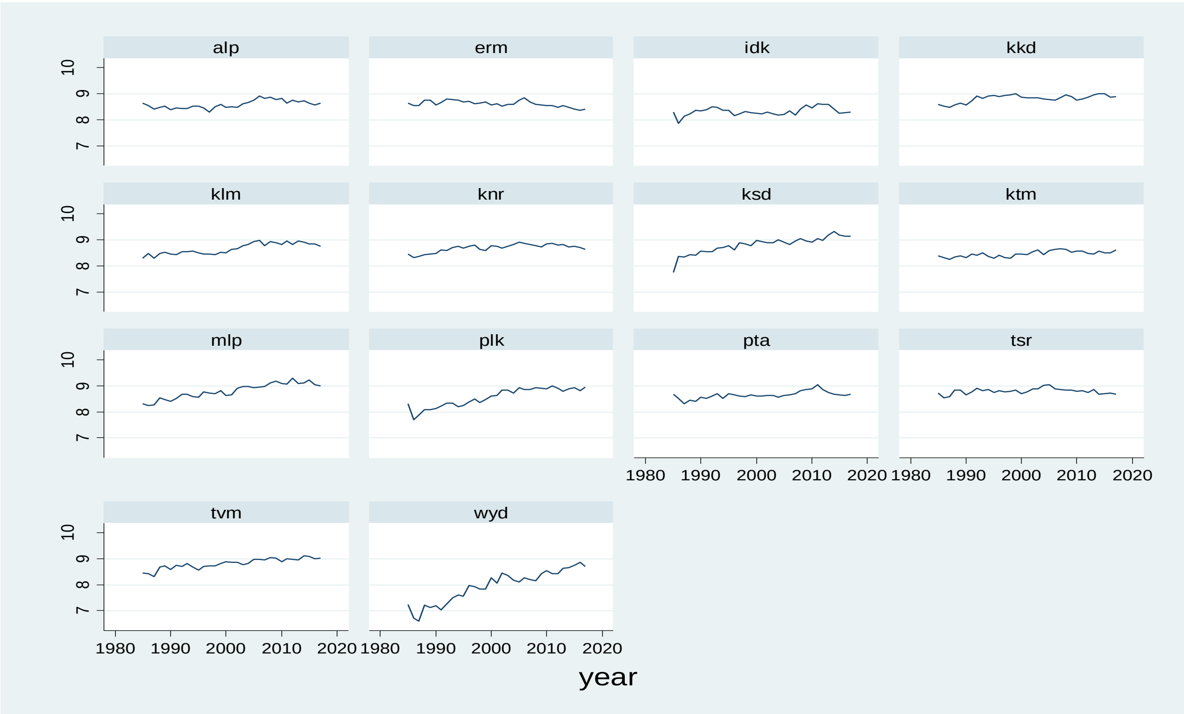


Appendix 14: District-wise trend in productivity of paddy in Kerala

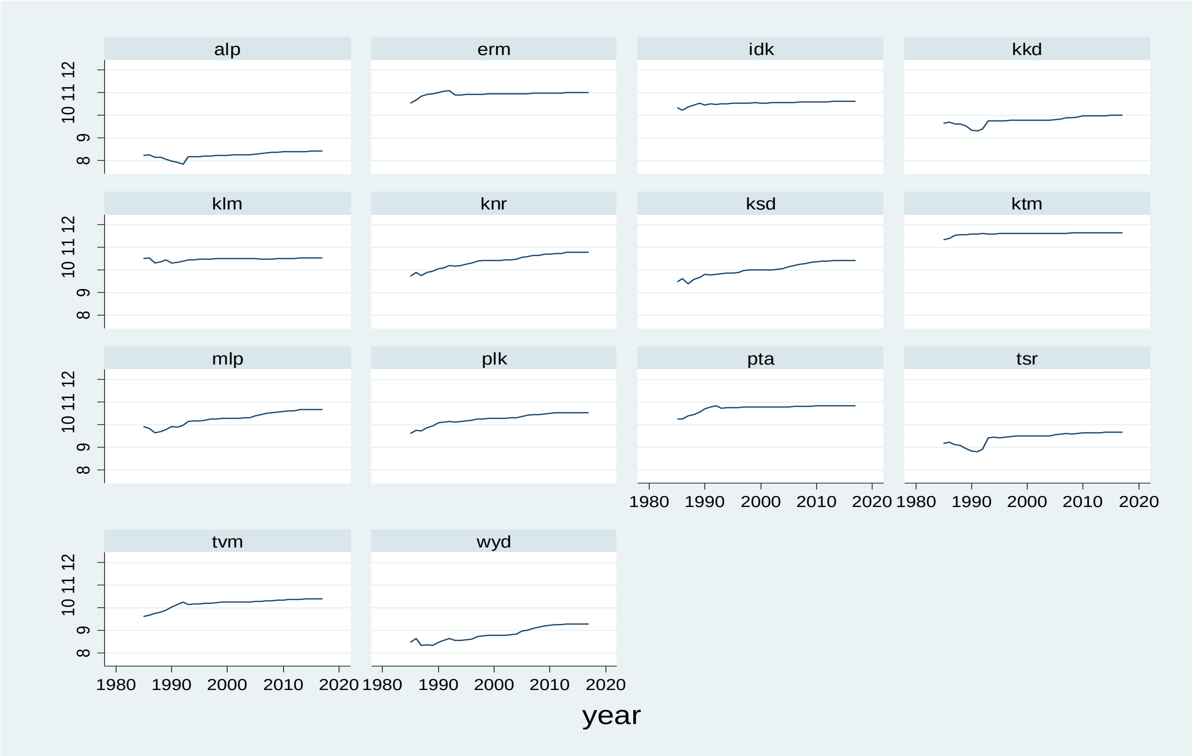
Appendix 15: District-wise trend in area under coconut in Kerala



Appendix 16: District-wise trend in productivity of coconut in Kerala

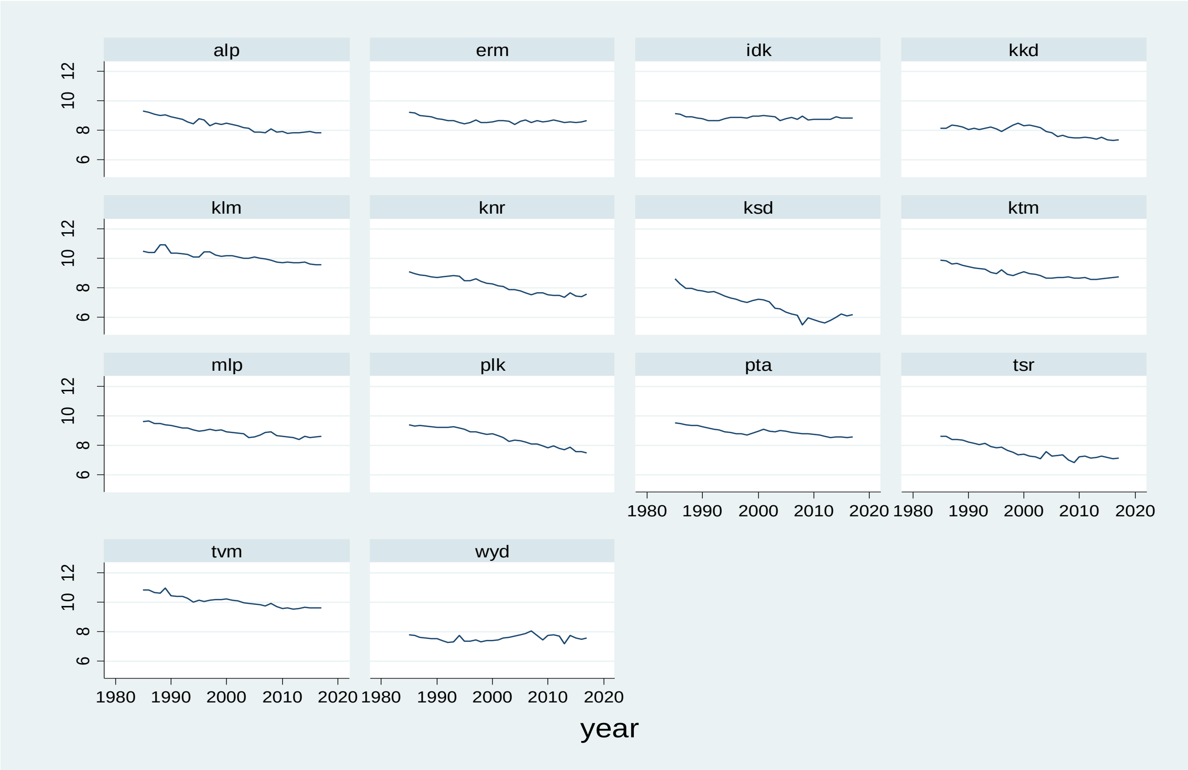


Appendix 17: District-wise trend in area under rubber in Kerala



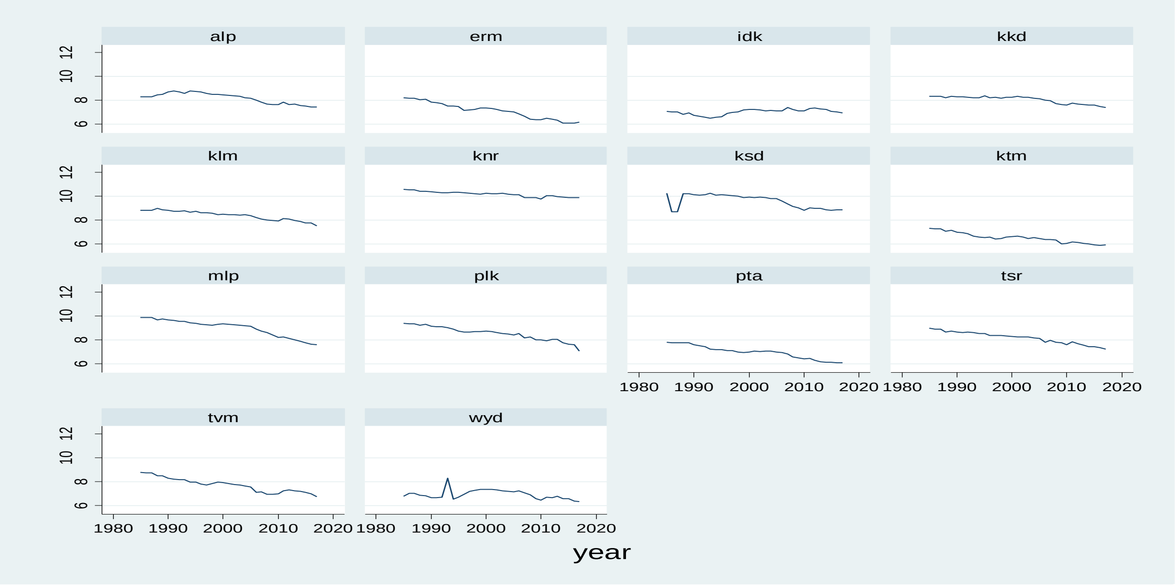
Appendix 18: District-wise trend in productivity of rubber in Kerala

Appendix 19: District-wise trend in area under tapioca in Kerala

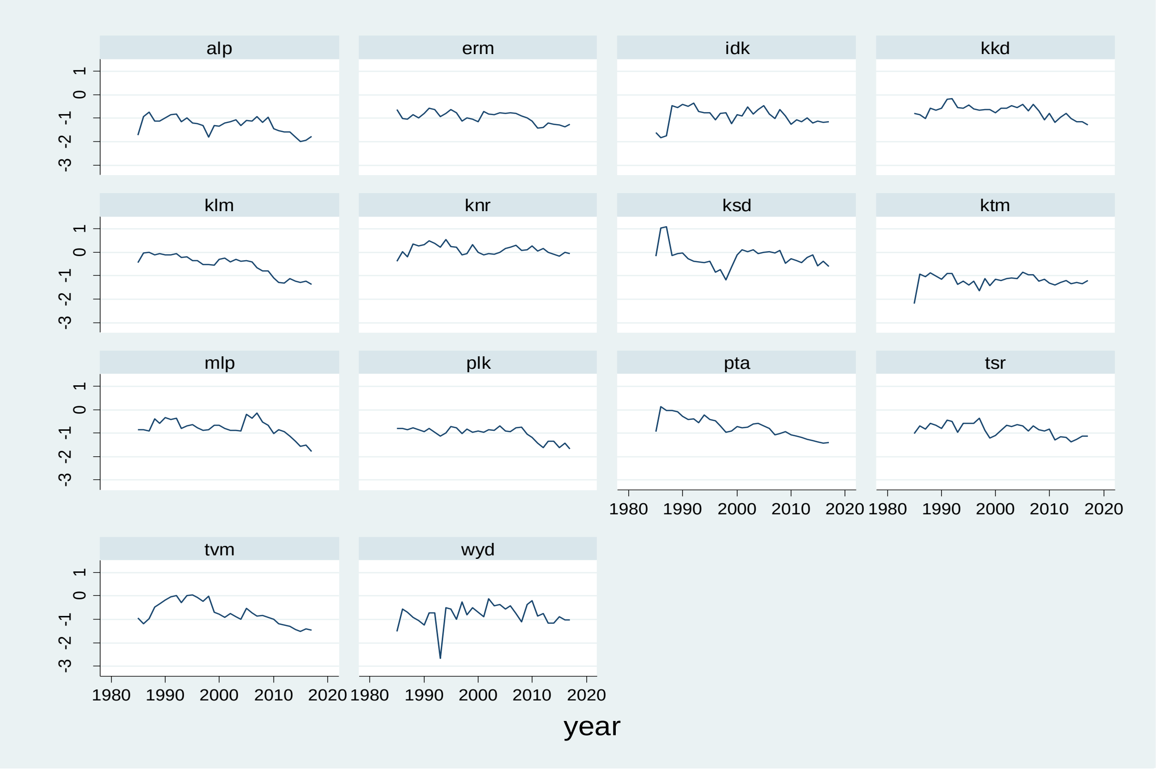


Appendix 20: District-wise trend in productivity of tapioca in Kerala

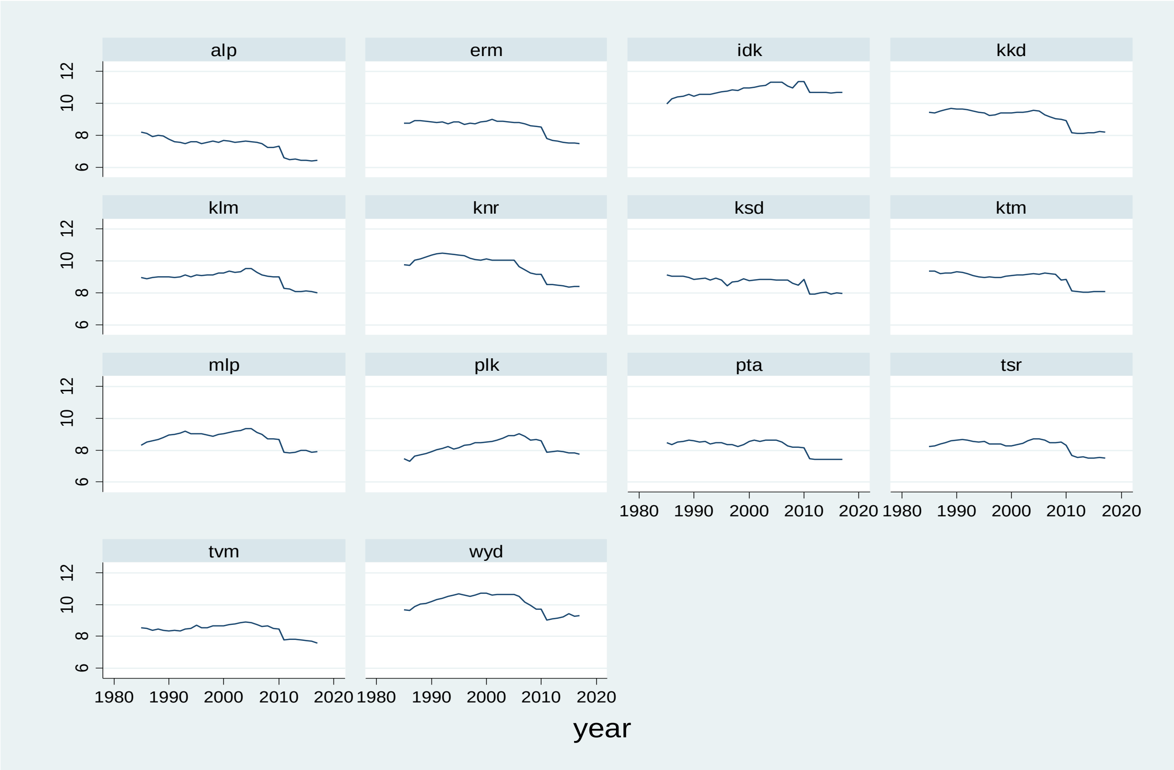
Appendix 21: District-wise trend in area under cashew in Kerala



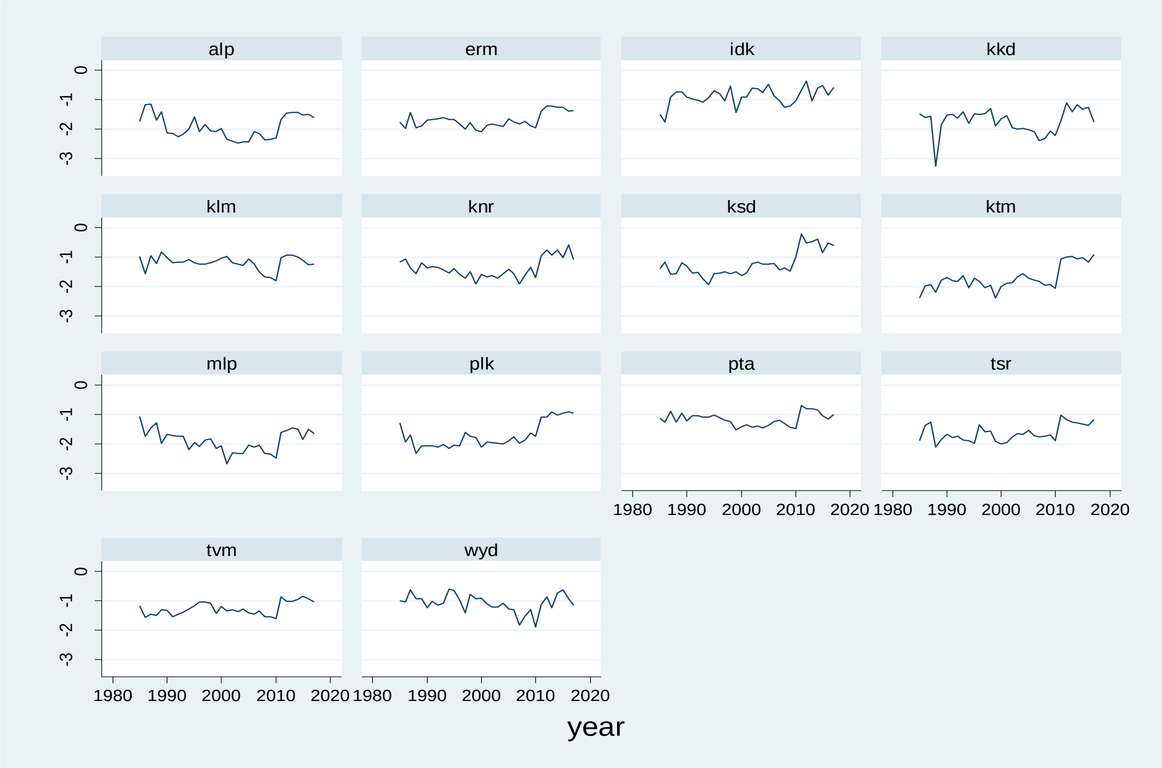
Appendix 22: District-wise trend in productivity of cashew in Kerala



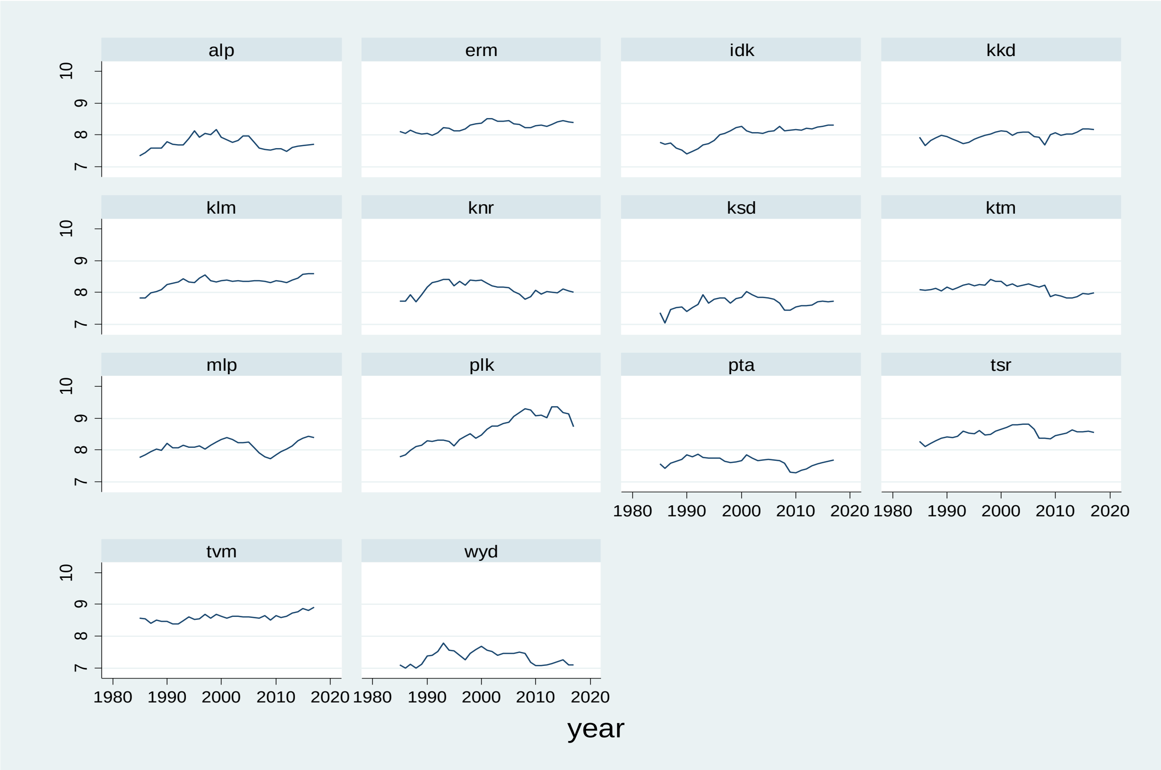
Appendix 23: District-wise trend in area under black pepper in Kerala



Appendix 24: District-wise trend in productivity of black pepper in Kerala

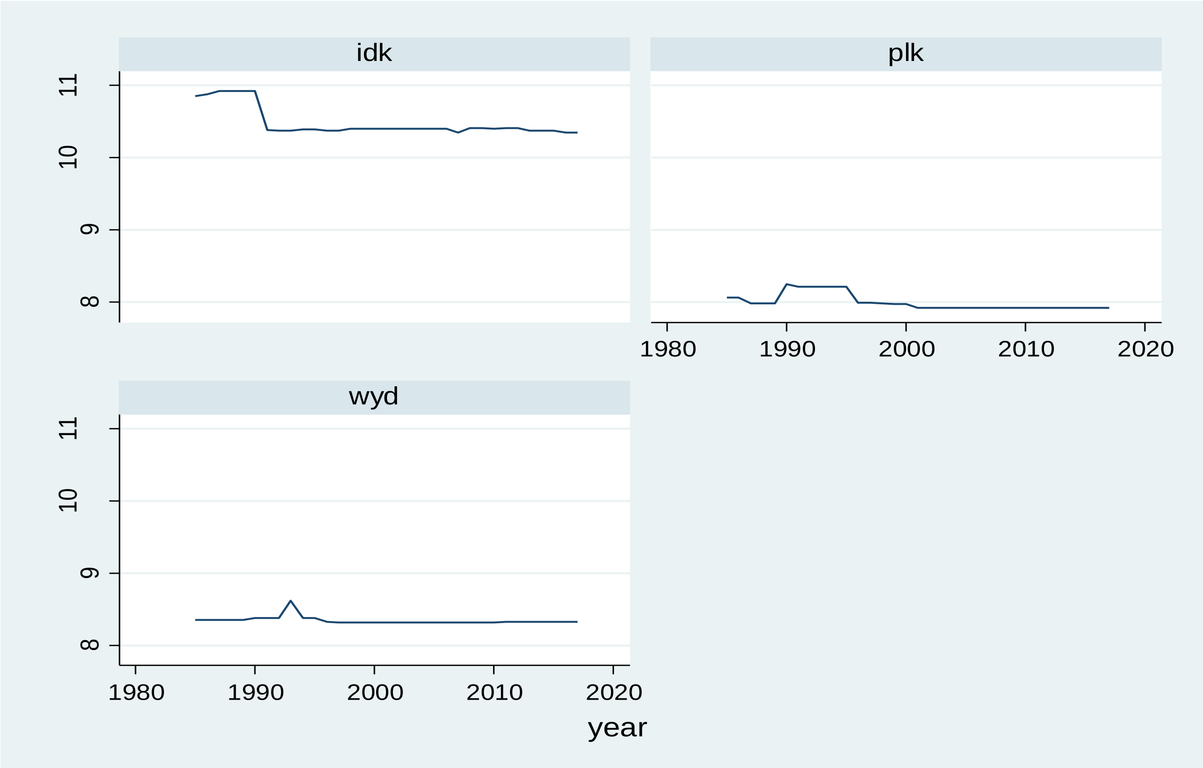


Appendix 25: District-wise trend in area under banana and other plantains in Kerala

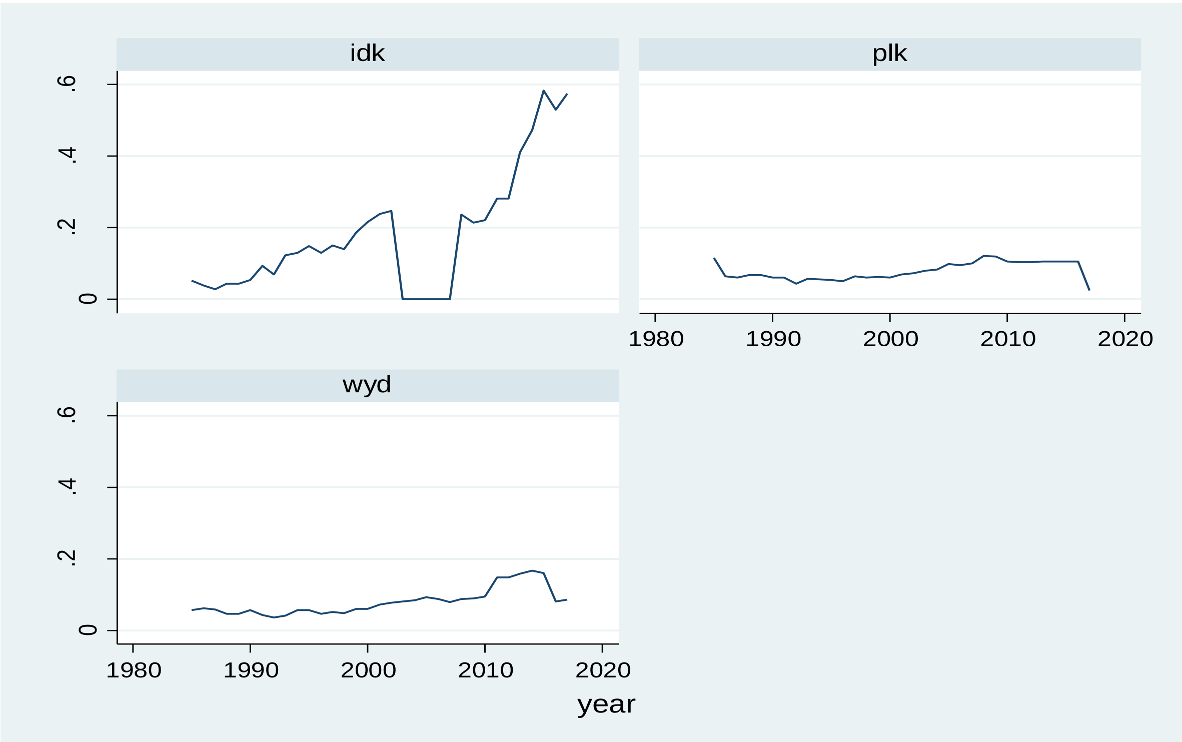


Appendix 26: District-wise trend in productivity of banana and other plantains in Kerala

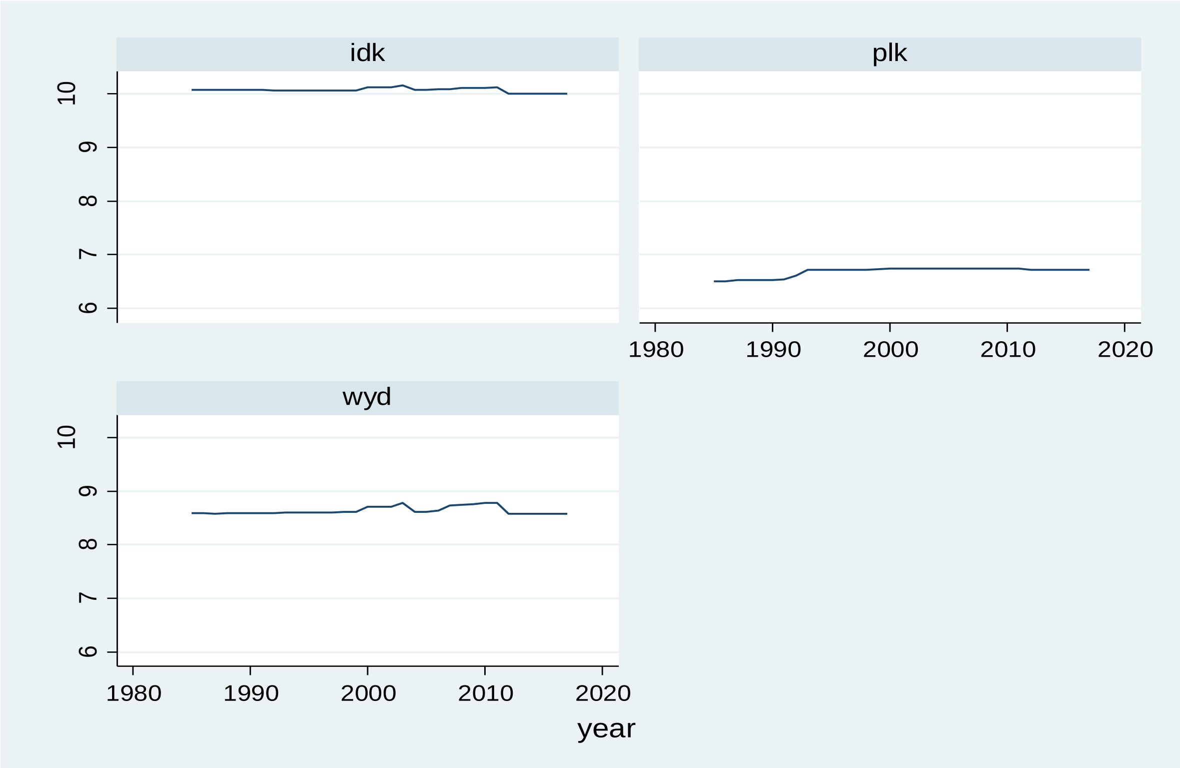
Appendix 27: District-wise trend in area under small cardamom in Kerala



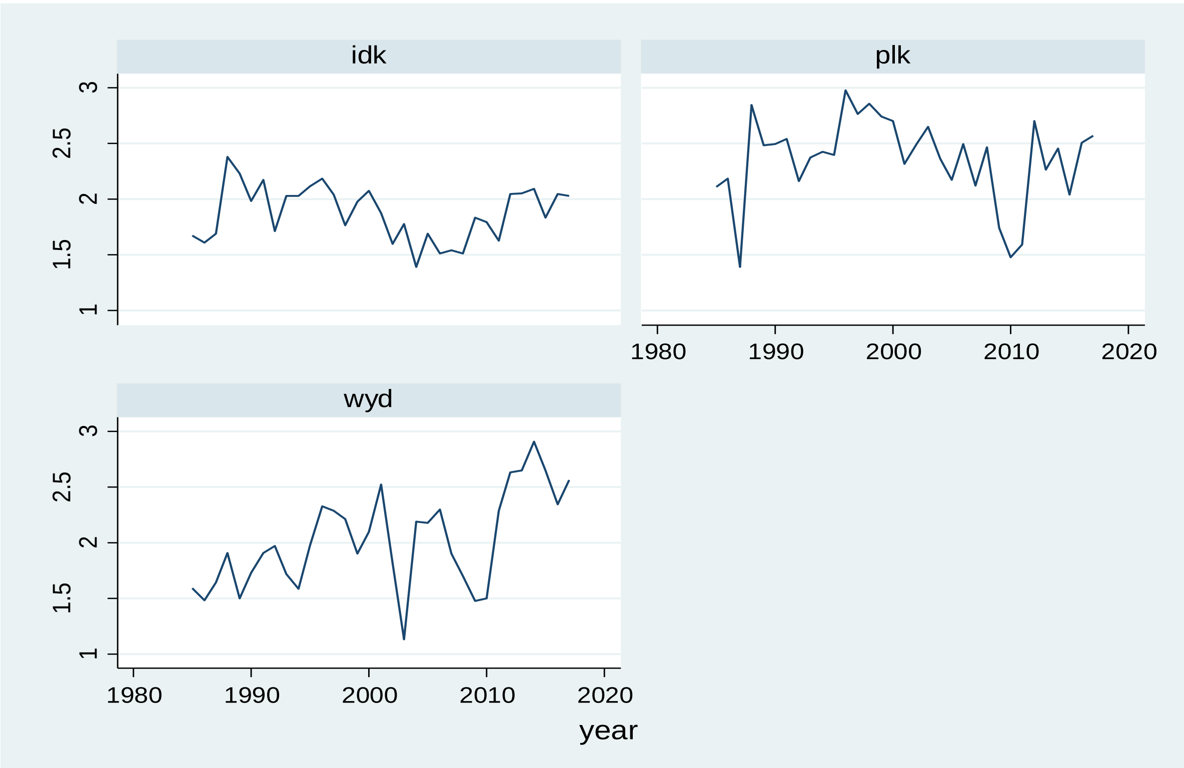
Appendix 28: District-wise trend in productivity of small cardamom in Kerala



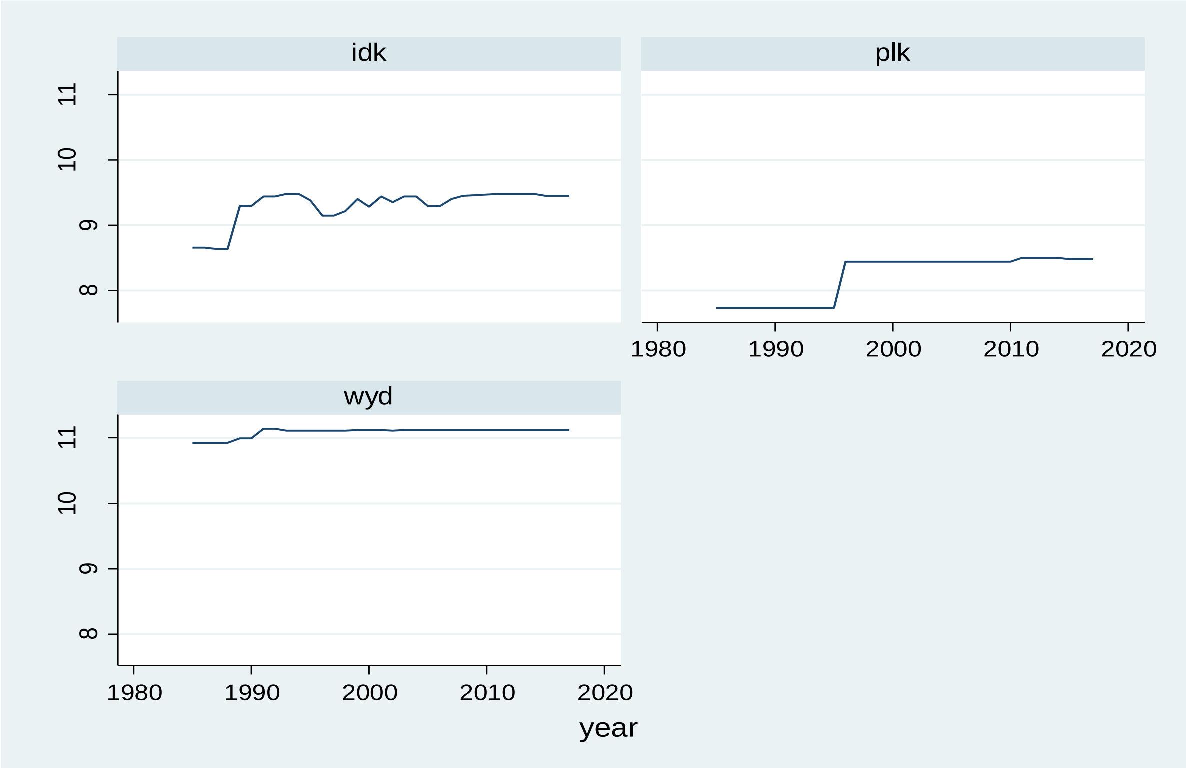
Appendix 29: District-wise trend in area under tea in Kerala



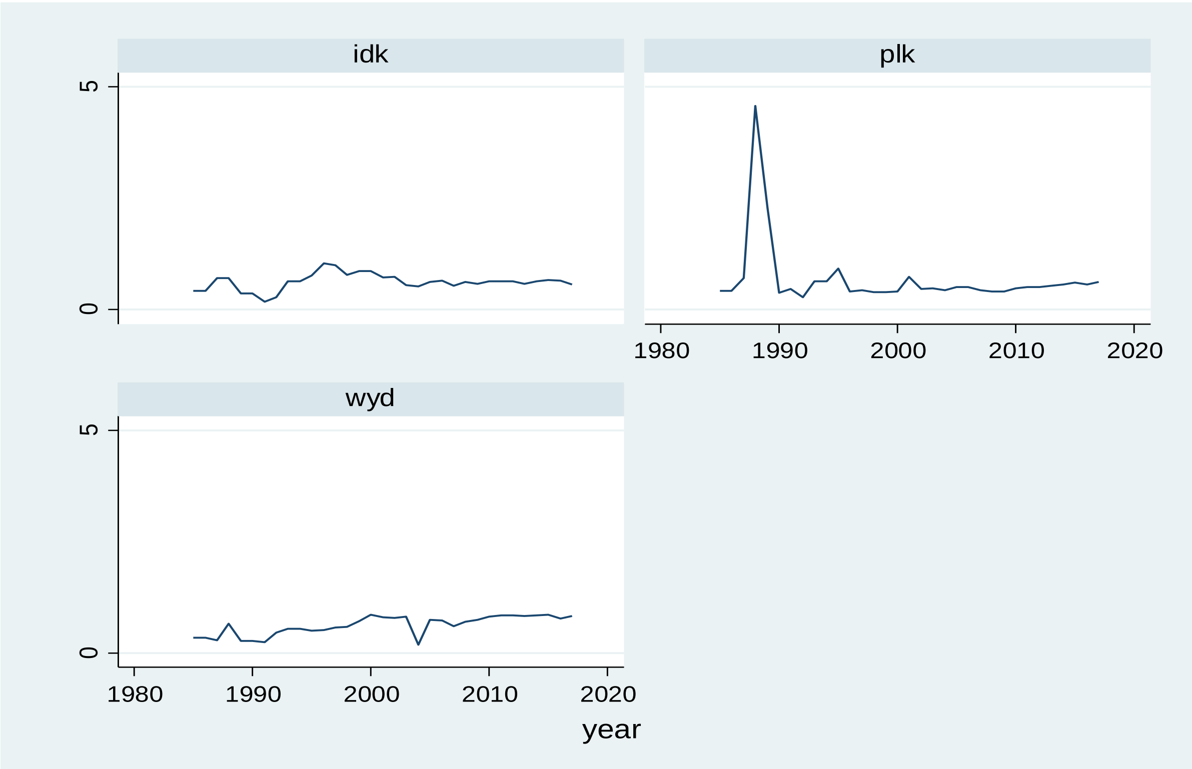
Appendix 30: District-wise trend in productivity of tea in Kerala



Appendix 31: District-wise trend in area under coffee in Kerala



Appendix 32: District-wise trend in productivity of coffee in Kerala



Appendix 33: Results of fixed effects model to estimate the determinants of income variability among districts of Kerala

Fixed-effects (within) regression Number of obs = 462

Group variable: dists Number of groups = 14

R-sq: Obs per group:

within = 0.8455 min = 33

between = 0.5407 avg = 33.0

overall = 0.4277 max = 33

F (10,438) = 239.70

Corr (u_i, Xb) = -0.7967 Prob > F = 0.0000

nddpa	**Coef.**	**Std. Err.**	**t**	**P>|t|**
Gross irrigated area	0.1468	0.0785	1.87	0.062
rainfall	-0.3993	0.1207	-3.31	0.001
Ferterliser consumption	0.3943	0.0797	4.94	0.000
prod_paddy	-0.3778	0.0645	-5.85	0.000
prod_rubber	1.0075	0.0889	11.32	0.000
prod_coconut	-0.0278	0.0788	-0.35	0.724
prod_plantain	0.5047	0.0741	6.80	0.000
prod_cashew	-0.4831	0.0517	-9.33	0.000
prod_tapioca	0.1743	0.0807	2.16	0.031
prod_black pepper	-0.1442	0.0637	-2.26	0.024
Intercept of nddpa	0.3489	2.1448	0.16	0.871

sigma_u 1.3358

sigma_e 0.4729

rho 0.8886 (fraction of variance due to u_i)

F test that all u_i=0: F(13, 438) = 41.61 Prob > F = 0.0000

Appendix 34: Results of random effects model to estimate the determinants of income variability among districts of Kerala

Random-effects GLS regression Number of obs= 462

Group variable: dists Number of groups = 14

R-sq: Obs per group:

within = 0.8455 min = 33

between = 1.0000 avg = 33.0

overall = 0.8515 max = 33

Wald chi2(23) = 2512.24

corr(u_i, X) = 0 (assumed) Prob > chi2 = 0.0000

nddpa	Coef.	Std. Err.	z	P>|z|
Gross irrigated area	0.1468	0.0785	1.87	0.062
rainfall	-0.3993	0.1207	-3.31	0.001
Ferterliser consumption	0.3943	0.0797	4.94	0.000
prod_paddy	-0.3778	0.0645	-5.85	0.000
prod_rubber	1.0075	0.0889	11.32	0.000
prod_coconut	-0.0278	0.07880	-0.35	0.723
prod_plantain	0.5047	0.0741	6.80	0.000
prod_cashew	-0.4831	0.0517	-9.33	0.000
prod_tapioca	0.1743	0.0807	2.16	0.031
prod_black pepper	-0.1442	0.0637	-2.26	0.024
Districts				
Ernakulam	-3.0500	0.2741	-11.12	0.000
Idukki	-2.5538	0.4540	-5.62	0.000
Kk	-1.4656	0.3211	-4.56	0.000
Kollam	-1.7957	0.3747	-4.79	0.000
Kannur	0.0171	0.3392	0.05	0.960
Kasagode	-0.0812	0.317	-0.26	0.798
Kottayam	-4.180	0.3891	-10.74	0.000
Malappuram	-1.2227	0.2294	-5.33	0.000
Palakkad	-1.4058	0.2628	-5.35	0.000
Pathanamthitta	-3.0098	0.3490	-8.62	0.000
Thrissur	-1.1324	0.1770	-6.40	0.000
Thiruvananthapuram	-2.4992	0.3121	-8.01	0.000
Wayanad	0.0709	0.3472	0.20	0.838
Intercept of nddpa	1.9424	2.1292	0.91	0.362

sigma_u | 0

sigma_e | 0.4729

rho | 0 (fraction of variance due to u_i)

Appendix 35: Results of Hausman Test for deciding on fixed versus random effects (Basis for rejecting fixed effects model)

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fe	re	Difference	S.E.
girr	0.1468	0.2637	-0.1169	0.0516
rain	-0.3993	0.3350	-0.7344	
fert	0.3943	0.4572	-0.0628	
prod_paddy	-0.3778	-0.6690	0.2913	0.0473
prod_rubber	1.0075	0.0849	0.9225	0.0754
prod_coconut	-0.0278	-0.0858	0.0579	0.0503
prod_plant~n	0.5047	0.9026	-0.3979	
prod_cashew	-0.4831	-0.0649	-0.4181	0.0304
prod_tapioca	0.1743	-0.1978	0.3721	0.0631
prod_black pepper	-0.1442	-0.2483	0.1041	0.0404

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 13.30

Prob>chi2 = **0.2075**

(V_b-V_B is not positive definite)

Appendix 36: Breusch and Pagan Lagrangian multiplier test for deciding on random effects versus panel OLS

(basis for rejecting random effects model in this document**)**

nddpa[dists,t] = Xb + u[dists] + e[dists,t]

Estimated results:

nddpa	1.4314	1.1964
e	0.2236	0.4729
u	0	0

Test: Var(u) = 0

chibar2(01) = 0.00

Prob > chibar2 = 1.000

STRUCTURAL TRANSFORMATIONS AND SPATIO-TEMPORAL VARIATIONS OF AGRICULTURE IN KERALA

By

OTIENO FELIX OWINO

(2018-11-115)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement

for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ECONOMICS

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR – 680656

KERALA, INDIA

2020

ABSTRACT

Kerala had been undergoing several transformations in its agricultural sector. This was caused by the shift of resources like labourers from the agricultural sector to the secondary and tertiary sector. The transformation could also be seen where ever the rising agricultural wages affected the profitability of major crops due to the increase in the cost of production. The shortage of farm labourers coupled with other factors like uneconomic size of land holdings, sustained conversion of agricultural lands to non-agricultural uses and low profitability in agriculture had hampered the growth in the sector. The structural adjustments could also be observed in the state income in which there was an increase in share of income from the tertiary sector and decline in share from the primary sector.

The decline in the share of agriculture in the state income was due to an aggregation of factors. Thus, the present study sought to find out the reasons leading to the transformations in Kerala agriculture by analysing the growth of agriculture and assessing the disparities among the districts in agricultural development in Kerala, examining the dynamics in land use and cropping patterns, studying the dynamics in economics, efficiency and profitability of cultivation of major crops and estimating the total factor productivity and its determinants for major crops in Kerala. The time series data for the period from 1970-71 to 2018-19 was used to understand the objectives of this study. The entire series was subjected to (Bai and Perron, 1998) methodology and six phases of growth were obtained, on which the entire study was based. These periods were Period I (1970-71 to 1980-81), Period II (1981-82 to 1987-88), Period III (1988-89 to 1994-95), Period IV (1995-96 to 2003-04), Period V (2004-05 to 2010-11) and Period VI (2011-12 to 2018-19).

The Compound annual growth rates and Cuddy-Della Instability Indices were used to understand the growth performance of the crops. The results of the analyses of growth in crops revealed that food grains, tapioca, ginger and cashew had the largest loss in area throughout the period under study. Pulses, paddy, tapioca, cashew and ginger exhibited annual declines of -6.58 per cent, -3.89 per cent, -3.71 per cent, -2.44 per cent and -2.12 per cent in their area. These crops also had the lowest growth in productivities which affected the production. This was found to be due to fall in the prices of these crops, rising cost of inputs and rising prices of other crops. Rubber had the largest annual rise in area of 2.56 per cent in the entire period of the study. Other crops that were found to have performed well were coconut and banana and other plantains.

The trend break analysis was also used to study the growth performance of crops in Kerala. It was established that the main reason for breaks in areas under most crops was related to profitability. It was noted that with increases in prices, especially for plantation crops, the areas under the crops also increased. Several crops had breaks in their areas exactly at the time when rubber was recording its best prices in 1995 and from 2007-08 to 2009-10. Due to the sustained rise in prices of rubber, crops like paddy were much affected, since it is a labour-intensive crop and an increase in the wages of field labour impacted it negatively. Plantation crops on the other hand were less labour intensive and the increases in prices were an incentive for the farmers to expand the area under the cultivation of those crops. In turn, the area under rubber and coconut increased tremendously especially from late 1980s. Thus, changes in prices was a major cause for most breaks in most of the crops. The government policies and interventions in the agricultural sector were found to be the major contributor to the trend breaks. The introduction of policies that promoted the cultivation of crops such as paddy led to increase in their areas and these led to the breaks. These include the group farming scheme implemented in 1988-89, promotion of paddy cultivation in the fallow lands of 2004-05 and the enactment of the conservation of paddy land and wetland act of 2008.

Seemingly Unrelated Regression (SUR) model was used to understand the determinants of the growth in the GSDP from agriculture. The model revealed that the largest contributor to per capita agricultural GSVA was gross cropped area irrigated. This meant that for every additional hectare of land brought to irrigation every year, it added 75.3 per cent of the value of the output per hectare from the crop to the per capita income from agriculture. The area under high value crops was also found to be significant and positively influencing per capita GSVA from agriculture and this was a confirmation that increased cultivation of high value crops was key to growth in earnings from agriculture in Kerala State. The fertiliser consumption was also found to be important in improving the earnings realised from agriculture. The use of fertilisers improved the contribution from crops to the agriculture per capita income by 24 per cent, while rainfall improved the earnings by 10.5 per cent.

The study on the land use and cropping pattern changes revealed through transition probability matrices obtained from Markov chain analyses showed that various land use classes apart from forest were not stable throughout, but had seasons of loss and gain to and from other different land use classes, which was also the same case for crops. For instance, area put to non-agricultural uses and, permanent pastures and grazing lands were the most stable land use classes in the first phase of the study (1970-71 to 1980-81). This phase was the beginning of shift from various crops to plantation crops and large tracts of lands in which other crops were grown were converted to the cultivation of plantation crops like rubber due to increasing prices and profitability. This shift in land use helped to increase the net sown area. The net sown area also had 4.4 per cent probability of receiving land from permanent pastures and grazing lands, and a probability of 21.4 per cent from area under miscellaneous tree crops. However, in contrast to the first phase, in the last and sixth phase from 2011-12 to 2018-19, the area under non-agricultural uses which got a stimulus in the fifth phase, showed a 100 per cent probability of holding to its share in the sixth phase. The cultivable waste drew gains from net sown area. The area under pastures showed a 93.2 per cent of probability of transition to net sown area, an indication that the area under permanent pastures and grazing lands was getting cleared and converted to farm lands.

The study on economics, efficiency and profitability of crops revealed that the profitability of tapioca, coconut and black pepper were highest in the large and medium holdings. Ginger presented an inverse of the trend shown in many crops in which small holdings were the least profitable. This was attributed to complexities in managing large ginger farms which were prone to diseases. Overall, the profitability improved over the period under study for all the crops other than ginger, which could be attributed to increased use of high yielding varieties and efficient fertilisers that improved the productivity.

Banana and other plantains, autumn paddy and coconut had the largest TFP. The TFP growth in these crops were majorly driven by increases in their technological components. Winter paddy and summer paddy also had a slight increment in their TFP mainly driven by growth in their technological changes and hindered by decline in their technical efficiencies. Tapioca, black pepper and ginger recorded negative changes in their TFPs. The decline in TFP of these crops was majorly due to the decline in the technological changes in these crops. Therefore, there is need for increased public investment in the agricultural sector. The increased public investment will in turn promote private investment in potential areas of the state, which will sequentially help to provide incentives and favourable environment for agricultural development.