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IMPACT OF CLIMATE CHANGE ON AGROFORESTRY SYSTEMS OF HIGH RANGE LANDSCAPES OF KERALA

by

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(2012 - 20 - 106)

THESIS

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DECLARATION

I, hereby declare that the thesis entitled **"IMPACT OF CLIMATE CHANGE ON THE AGROFORESTRY SYSTEMS OF HIGH RANGE LANDSCAPES OF KERALA"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that the thesis entitled **"IMPACT OF CLIMATE CHANGE ON THE AGROFORESTRY SYSTEMS OF HIGH RANGE LANDSCAPES OF KERALA"** is a record of research work done independently by **Ms. Anjaly George** under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Anjaly George

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CHAPTER 1
INTRODUCTION

Climate change is unequivocal. All through the world, huge impacts of climate change are being felt and are now being observed and recorded carefully, pointing clearly to a future that is frightening if not disastrous (Pachauri, 2012). The fifth assessment report of the IPCC has brought out that the impacts of climate change could cause untold hardship and misery to a very large number of people, if we do not take action. Climate change is a complex phenomenon that has numerous and wide-ranging impacts on the environment and livelihoods. While a host of global trends in climate and impacts thereof have been explained, locally-relevant analyses are hardly any in number and are appalling in quality (Kumar and Srinath, 2011). Climate change is recognized as a key environmental problem worldwide and global assessments have classified South Asia as the region that is most vulnerable to the impacts of climate variability and change (Nagabhatla *et al.*, 2015).

The global environmental balance is modified at multiple scales by the shift of ecological and socioeconomic systems towards critical thresholds in due course, leading to rate of change of climatic processes (UNEP, 2009). At the same time, the increased occurrence of unusual climate events in the near past has invigorated the scientific community to explore their impact on the stability of earth systems (FAO, 2008). Many researchers agree that critical tipping points has been crossed by some climate parameters, in a process that is irreversible and raises serious concerns for the future of human civilization (Kriegler *et al.*, 2009; Lemoine and Traeger, 2011). Climate change is a major overriding environmental issue of our time and particularly a great challenge facing conservation and development managers. It is a mounting crisis in multiple dimensions such as health, economics and food production/security, said Ban Ki Moon, former U.N Secretary General.

Developing countries are the major bearers of the brunt of climate change and suffers most from its negative impacts. We now accept that the primary drivers of climate change are not going to stop because the global conventions are not sufficiently effective to halt the increase of atmospheric greenhouse gases (GHG) concentrations. In developing countries, large percentages of the population derive their livelihoods from agriculture and are therefore particularly vulnerable to climate change (Verchot *et al.*, 2007).

Anthropogenic climate change has significant consequences for the sustainability and productivity of agroforestry ecosystems upon which millions of smallholders in the tropics depend and that provide valuable global services (Dawson *et al.*, 2011).

Increased emissions of greenhouse gases causing global climate change is likely to affect agro ecosystems in many ways, but for instance, the outcome, as a shift in productivity, depends on the combined effects of climate (temperature, precipitation) and other global change components. Agricultural ecosystems or agro ecosystems— comprise polycultures, monocultures, and mixed systems, including crop–livestock systems, agroforestry, agro–silvo–pastoral systems, aquaculture, as well as rangelands, pastures and fallow lands. They are found all over the world from wetlands and lowlands to drylands and mountains, and their interactions with human activities are determinant. Even though the effects of climate change on agroecosystems have received considerable research attention (Parry, 1990; Rosenzweig and Hillel, 1998) the sensitivity of many of the types of ecosystems listed above have not been studied in detail. Most studies focused on cropping systems, and projected effects include changes in yield and spatial shifts of production potentials (Reilly and Schimmelpfennig, 1999) or altered insect pest occurrence (Porter *et al.*, 1991).

Changing temperature or rainfall alters the local suitability for specific crops (Rotter and Geijn, 1999) and grasslands (Roosevelt *et al.*, 1996) and the need for irrigation and fertilization (Adams *et al.*, 1990).

As the west coast and southern India are projected to shift to a new high temperature climatic regime under 4°C warming, climate change significantly impacts agriculture in India. The livelihood of small farm holders (those owning less than 2.0 ha of farmland) that comprise 78% of the country's farmer population, is mostly affected by climate change (Radhakrishnan and Gupta, 2017). Climate change impact differs from region to region, country to country, sector to sector and community to community.

Majority of livelihood in much of rural India is directly dependent on climate and are highly vulnerable to climate variability, with climatic changes having intense direct and indirect impacts. The small size of land-holdings of most farmers in high elevations and the large tribal population render the people and the livelihood of these areas highly vulnerable to climate change and variability, apart from the general climate-dependent nature of the economy. Agroforestry practices increase productivity and provide economic benefits and thus farmers typically adopt it. But agroforestry practices may also provide significant ecological effects, which many consider to be equally or more important than the potential agricultural and economic benefits.

Agriculture sector is the primary sector whose growth acts as a catalyst to the growth of other sectors. Since the last seventies, agriculture development experience of Kerala, in the share of agriculture and allied sectors in gross state domestic product (GSDP) and area under food crops and the substantial expansion in the area under nonfood crops has been characterized by sharp decline (Karunakaran and Gangadharan, 2013). Agricultural trends such as land utilization pattern, cropping pattern and the area, production and productivity growth, particularly of plantation crops like rubber, coconut, coffee, cardamom and tea etc. is subjected to drastic changes causing a threat to the food security and structural transformation in the state's economy.

From the realm of indigenous knowledge, agroforestry was brought to the frontline of agricultural research and was promoted widely as a sustainability enhancing practice that integrates the best attributes of forestry and agriculture (Sanchez, 1995). Crop productivity and fertility of soil and environment can be improved if agriculture and forestry is developed in an integrated way in the form of farm forestry and agroforestry. These two sectors are ecologically and economically inseparable. Agroforestry practices are of increasing importance in both sustainable food production and safeguarding environmental services such as biodiversity conservation and carbon sequestration.

Agroforestry combines agriculture and forestry technologies to create diverse, profitable, and sustainable land-use systems (Rietveld, 1995). Agroforestry systems are complex assemblages of ecosystem components, each of which responds to climate. Whereas climate change impacts on crops grown in monocultures can reasonably well be projected with process-based crop models, robust models for complex agroforestry systems are not available. Yet impact projections are needed because of the long planning horizons required for adequate management of tree-based ecosystems (Luedeling *et al.*, 2014).

Agricultural and natural ecosystems around the world is projected to affect by climate change and there is no reason to expect that agroforestry systems will be spared. Like all other plants and animals, those existing within agroforestry systems will be exposed to temperatures that are higher than those of the past, to higher carbon dioxide concentrations, and they may also experience changes in precipitation. These changes will affect all system components, and they may even modulate interactions between components probably.

The present study is focused on the impact of climate change von agroforestry systems of high range landscapes of Kerala with the following specific objectives:

1. To study the shift in patterns of agroforestry systems in the high range landscapes of Kerala on a temporal scale.

2. To analys e the changes in the climate variables (i.e., temperature and precipitation) in the study area.

3. To assess the drivers of change in the agroforestry systems in the high range landscapes in Kerala.

4. To analyse whether climate change made an impact on production, pattern and processes of agroforestry systems.

REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

Agroforestry systems are complex collection of ecosystem services that responds to climate. They are more compound than monoculture situations that consists of annual and perennial plants, which are often combined with livestock. All organisms involved in an agroforestry system is affected by temperature, humidity and ambient CO_2 concentration possibly in very different ways, and climate change is projected to alter all of these factors (Luedeling *et al.*, 2014).

From the realm of indigenous knowledge, agroforestry was brought to the frontline of agricultural research and was upheld widely as a sustainability-enhancing method that combines the best features of forestry and agriculture (Sanchez, 1995). Agriculture and forestry should be developed in a unified way in the form of farm forestry and agroforestry under which crop productivity and fertility of soil and environment improve. These two sectors are ecologically and economically inseparable and are of increasing importance in both sustainable food production and protecting environmental services such as biodiversity conservation and carbon sequestration.

Deliberate use of trees in the agricultural landscape, i.e. agroforestry practices such as multi-strata forest gardens, mixed tree crop systems and home gardens, is widespread in the tropics (Verchot *et al.*, 2007). According to Noordwijk *et al.* (2011), trees in the landscape, under various forms and types of management play a critical role in reducing vulnerability to unpredictable and changing climates. Also, trees can buffer microclimates, regulate water flows, reserve carbon, provide habitat for plants and animals in protected areas and corridors, and supply food for people.

High potential of agroforestry for food security, climate change adaptation and mitigation, results in high promotion of tree-based agricultural systems in many part of

Africa, and they have successfully been established in many regions. Trees that are introduced in the system are long-lived species that are expected to grow for several decades on farmer's fields. These long planning horizons make discussion of climate change impacts on trees particularly important (Luedeling *et al.*, 2014).

2.1. CLIMATE CHANGE

IPCC defines 'Climate change' as the change in the state of the climate that can be identified (may be using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2011).

Global warming and climate change is the major concern of mankind in the 21st century. Under changing climatic scenarios crop failures, reduction in yields, reduction in quality and increasing pest and disease problems are common and they render the cultivation unprofitable (IPCC, 2007).

The term 'Climate' has variety of meaning. To a geologist, climate is an external agent which forces many phenomena of interest. To an agriculturist, it is an influencing crop growth parameter which shows year to year variability. In general climate is the thought of as the average weather conditions at a given location over long time.

Climate change is real. Ill effects of climate change on various sectors like agriculture, socio economy and health and so on are found from several studies. Frequency of extreme events like flood, drought, heat waves, cyclones, storm surges etc. are also increasing (IPCC, 2014).

Climate change is a complex phenomenon that has countless and wide-ranging effects on the environment and sustenance. Global trends in climate and impacts thereof have been elucidated appreciably but locally-relevant analyses are far fewer in number and remain poorer in quality (Gopakumar, 2011).

Over the last century, atmospheric concentrations of carbon dioxide increased from a pre-industrial value of 278 parts per million to 379 parts per million in 2005, and the average global temperature rose by 0.74°C. Climate change will have widespread effects on the environment, socioeconomic and related sectors, including water resources, agriculture, food security, human health, terrestrial ecosystems, biodiversity and coastal zones (UNFCCC, 2009).

Anthropogenic climate change caused by greenhouse gas emissions changes the mean, range and seasonality of a series of climatic variables which in turn resulting in rapid temperature increases, significantly different rainfall patterns and a greater frequency of extreme weather events in many regions (Dawson *et al.*, 2011).

Human activities are changing the Earth's climate causing impact on all ecosystems. The regional agricultural systems are altered by the expected changes in climate with consequences for food production.

2.2. CLIMATE CHANGE IMPACTS

Southeast Asia, with a population of more than 600 million mostly dependent on agriculture and forests, is ranked high on measures of vulnerability to the impact of climate change. According to Finlyson (2016) the list of impacts of climate change is long extending from shifting seasons that affect planting and growing periods; extreme heat, droughts, increased aridity and water shortages that reduce or wipe out yields; erratic rainfall that makes farm planning difficult if not impossible; storms, floods and landslides that destroy crops, livestock and homes; rising sea levels that salinate farm land; increased human, plant and livestock diseases; to lowered productivity of livestock, including fisheries.

Increasing frequency, intensity and duration of severe weather events are causing major threat to global food security and livelihoods of rural people. The effects of climate change on agriculture have long been identified and negative impacts on food production have frequently been reported (Lobell *et al.*, 2008; Parry and Carter 1985; Pautasso *et al.*, 2012).

Climate change impacts are high in agriculture land use. For the normal growth of a crop there are normal temperature and rainfall pattern. If the temperature and rainfall pattern is deviated from the normal pattern for the normal growth of crops, crop production is decreased. Farmers usually change the land use by modification of agriculture, if the temperature increases continuously. Further, the farmers may migrate from the area as well if the production is not satisfied (IPCC, 2011).

2.3. CROPPING SYSTEMS AND CROPPING PATTERNS

According to Luedeling *et al.*, 2014, millions of smallholders in the tropics depend on sustainability and productivity of agroforestry ecosystems that provide valuable global services. Anthropogenic climate change has significant impact on these systems. However, introduction of agroforestry practices that are either entirely new, or new to particular regions, is risky, because like all other agricultural systems, agroforestry systems will respond to climate change. Climate change is projected to affect agricultural and natural ecosystems around the world and there is no reason to expect that agroforestry systems will be spared.

Home gardens are agrisilvipastural system which is highly productive and sustainable one in which woody perennial is produced along with annuals and pastures whose primary function is food production. Here, trees, shrubs, vegetables, and other herbaceous plants are grown in profuse and animals are also included for which fodder grasses and legumes are planted (Manikandan and Prabhu, 2016).

Cropping system includes all components mandatory for the production of a particular crop and the interrelationships among crop and environment. It is an amalgamation of crops in time and space. Combination in time occurs when crops occupy different growing period and combinations in space occur when crops are inter planted.

Cropping pattern is the yearly sequence and spatial arrangement of crops or of crops and fallow on a given area and it indicates the proportion of area under different crops at a point of time (Gautam, 2015).

Cropping pattern is the extent of area under different crops at a particular period of time (Ministry of Agriculture). It is a dynamic concept as it changes over space and time which is denoted using crop statistics. Agricultural Commission, Government of India, determined cropping pattern according to relative acreage of various crop in a district or group of district. It include the recognition of the most efficient crops of the region which is considered in a homogenous soil and climate belt, the rotation in which the crop fits and the intensity of cropping. Geoclimatic, socio – cultural, economic, historical and political factors closely influence the cropping pattern of a region. The physical environment (physiographic, climatic, soils, and water) enforce restrains on the growth and distribution of plants and animals (Subrata, 2007).

2.4. CHANGES IN CROPPING SYSTEMS AND PATTERNS

Gopinath and Sundaresan (1990) observed that the rice economy of Kerala declined to a considerable extent followed by tapioca. Also, the major change was from food crops to cash crops especially from rice and tapioca to rubber and coconut. Since 1975, rubber played the dominant role among the plantation crops by commanding the largest area increase.

Traditional agroforestry system such as home garden has been subjected to conversion linked to socio economic changes, despite the ecological and socio economic importance of agroforestry systems (Guillerme *et al.*, 2011).

From Jose and Shanmugaratnam (1993), fragmentation of land holdings due to population pressure steering land use intensification and declining traditional agroforestry system and monoculture is prevailing in Kerala, with increasing emphasis on industrial model of agricultural development.

2.5. DRIVERS OF CHANGES IN CROPPING PATTERN

Efforts have been made globally (Hertel, 2011; Lambin *et al.*, 2001; Lambin *et al.*, 2014; Vliet *et al.*, 2015) as well as for the Indian context (Saikia *et al.*, 2013; Islam *et al.*, 2015) to address the land-use transitions and changes with the major focus has been towards land-use and land-cover changes in agriculture-forest ecotones (Jose and Padmanabhan, 2016).

Physical characteristics such as soil and climatic conditions have a direct influence on the cropping pattern in agriculture. Cropping pattern of a region vary on the basis of terrain, topography, slope, temperature, amount and reliability of rainfall, soils and variability of water for irrigation and so on from region to region.

Agricultural activities has to be adjusted depending on region's climatic conditions since weather and climatic conditions have a definite influence on cropping pattern in particular regions. Regions with less physical diversities have less diversified cropping pattern. For example, in the rainfall deficient area, the farmer grow drought resistant crop.

The cropping pattern may change with better implements, improved seeds and finance for getting fertilizers. These facilities enable farmers to go in for better technology in farm management and a rapid change in the cropping pattern for better income and profitable agriculture.

According to Gautam (2015) both climatic factors and resources of the farmers determine the cropping pattern on a farm. Economic consideration of farmer such as irrigation water, cost of inputs and prices of the products is a major factor that determines the cropping pattern of an area, though climate plays most vital part in crop selection and the area under crop. Scarcity of land resources is another driver of cropping systems which is solved by adopting integrated farming system. This will increases the income level and improve the nutrition standard of small-scale farmers with limited resources. Also, seasonal conditions or attack of pests and diseases causes failure of crops and mixed-cropping systems were adopted as an insurance against this.

Land use change is a matter of serious worry which is debatably the most pervasive socio-economic power, driving changes and degradation of ecosystems. Most of the fundamental causes leading to land use change are endogenous, such as resource shortage, increased vulnerability, and changes in social organization. Other important causes include changing market opportunities, and policy intervention which are mostly exogenous. But the response of land users to these external forces is strongly mediated by local factors (Lambin *et al.,* 2003).

2.6. CHANGES IN CLIMATE VARIABLES

Pant and Kumar (1997) have shown that there has been an increasing trend of mean annual temperature over India at the rate of 0.57°C/100 years. The trend and magnitude of global warming over Indian sub-continent over last century is broadly consistent with the global trend and magnitude.

Hingane *et al.* (1985); Kumar and Hingane (1988); Pant and Hingane (1988); Kumar and Parikh (1998); Sanghi *et al.* (1998); Kumar *et al.* (2002); Gadgil and

Dhorde (2005); Kothawala and Kumar (2005); Ramakrishna (2007) studied time to time temperature variability within the nation and inferred that depending upon the data set, location, region and season, the rate of increase in temperature varied. Though some locations showed cooling trend, the rate of increase in temperature was high in recent years and in an overall, a warming trend is evident across the country.

It is expected to get good rainfall in the wake of warming scenario, but it does not happens. Indian monsoon is showing vagaries due to increasing global warming and associated climate change. It is reported that there was a decrease of 4.51 per cent of all India summer monsoon rainfall by since 1964-65 (Singh, 2013).

Studies have shown that, while post monsoon rainfall declines there is an increase in the annual rainfall as well as southwest monsoon rainfall over Kerala (Krishnakumar *et al.*, 2008; 2009).

Mini *et al.* (2017) analyzed 146 years of rainfall data and confirmed there is significant decrease (10.9 mm in 10 years) in southwest monsoon rainfall while increase (7.5 mm in 10 years) in post monsoon season.

2.7. CROPS AND CLIMATE

An overview of impact of climate variability on agriculture was given by Sikka and Pant (1990).

Kumar and Kumar (2011) opined that the crop yield is significantly influenced by the cumulative effect of ecological variables, which are independent.

Rao *et al.* (2009b) reported an increase in pepper yield than a year which received good monsoon.

According to Santiago (1967), an average rainfall of 1500 mm – 2500 mm is ideal for cardamom growth and development. George (1976) reported that the years of low production of cardamom were those in which there were inadequate timely rainfall and prevailing prolonged dry summers.

Studies conducted by Amma *et al.* (2005) indicated that during 2004, annual yield of cocoa is declined by 39% due to the disastrous summer drought when compared to 2003.

Jeeva *et al.* (2005) reported that there was a significant and positive correlation of nut yield per tree with maximum temperature and rainfall in cashew.

Depending upon thermal distribution, tea, coffee, cardamom, cocoa and black pepper are grown across the highlands of the State. All these crops are thermo-sensitive as they respond quickly to variations in ambient air temperature which is more so, in the case of cardamom, tea, coffee and black pepper which are grown across the high ranges.

According to Rao *et al.* (2008) crops such as cocoa, black pepper, coffee, cardamom and tea grown under the influence of typical forest-agro-ecosystems, need special attention as temperature range is likely to increase and rainfall is likely to decline in addition to deforestation. Rao, *et al.* (2009a) highlighted the climate change/variability studies in the State, reporting that climate variability in the high ranges of Kerala is likely to affect the thermo sensitive crops like tea, coffee, and cardamom, cocoa adversely.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY AREA

Wayanad, the so called 'Green Paradise' is a high altitude valley in the South Indian state of Kerala which had got its name from the Malayalam words 'Vayal Nadu' meaning the land of paddy fields. It enjoys a unique local climate and culture and its economy is driven by a diverse system of agro-plantations, cash crops and rice cultivation – all of which are directly dependent on climate and are vulnerable to climate variability and climate change.

Wayanad District is situated in the north-eastern portion of Kerala. It lies between the north latitudes $11^0 25'$ and $12^0 0'$and the east longitudes $75^0 45'$and $76^0 20'$. The district is bounded on the north by Kodagu district of Karnataka state, on the east by Mysore district of Karnataka state and Nilgiri district of Tamilnadu state, on the south by Ernad taluk of Malappuram district and Kozhikode taluk of Kozhikode district, on the west by Koyilandi and Vadakara taluk of Kozhikode district and Thalassery taluk of Kannur district.

Wayanad covers an area of 2132 km^2 on the southern edge of the Deccan plateau at an altitude ranging from 700 to 2100 m and is located in the margin of the Western Ghats, one of the world's most important biodiversity hotspots and a UNESCO world heritage site. It is geographically remote from the coastal plains and is characterized by low hills, with rice fields located in the valleys and spices on the hill slopes.

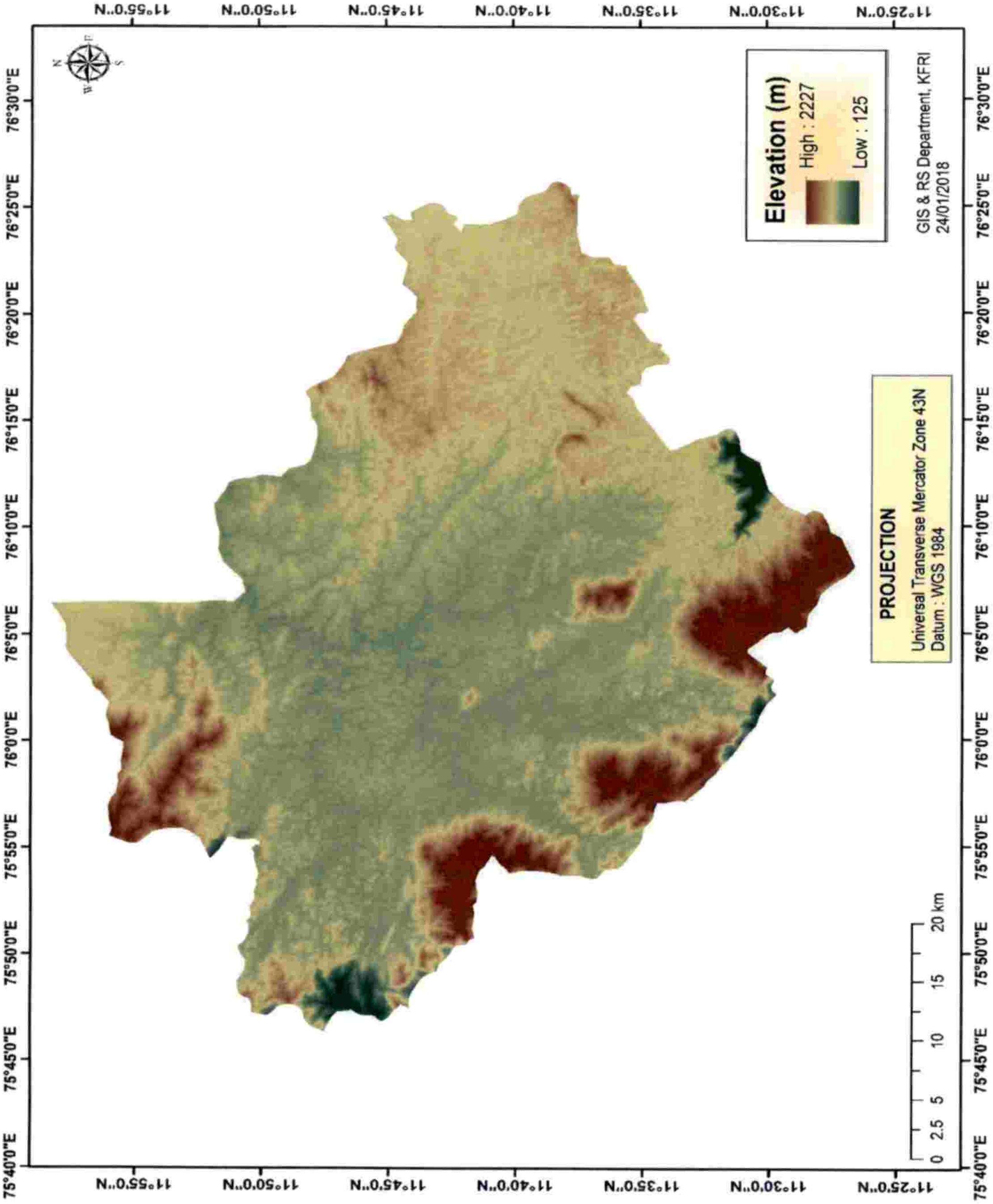


Figure 1. Elevation of Wayanad derived from the SRTM (Shuttle Radar Topographic Mission) Satellite data

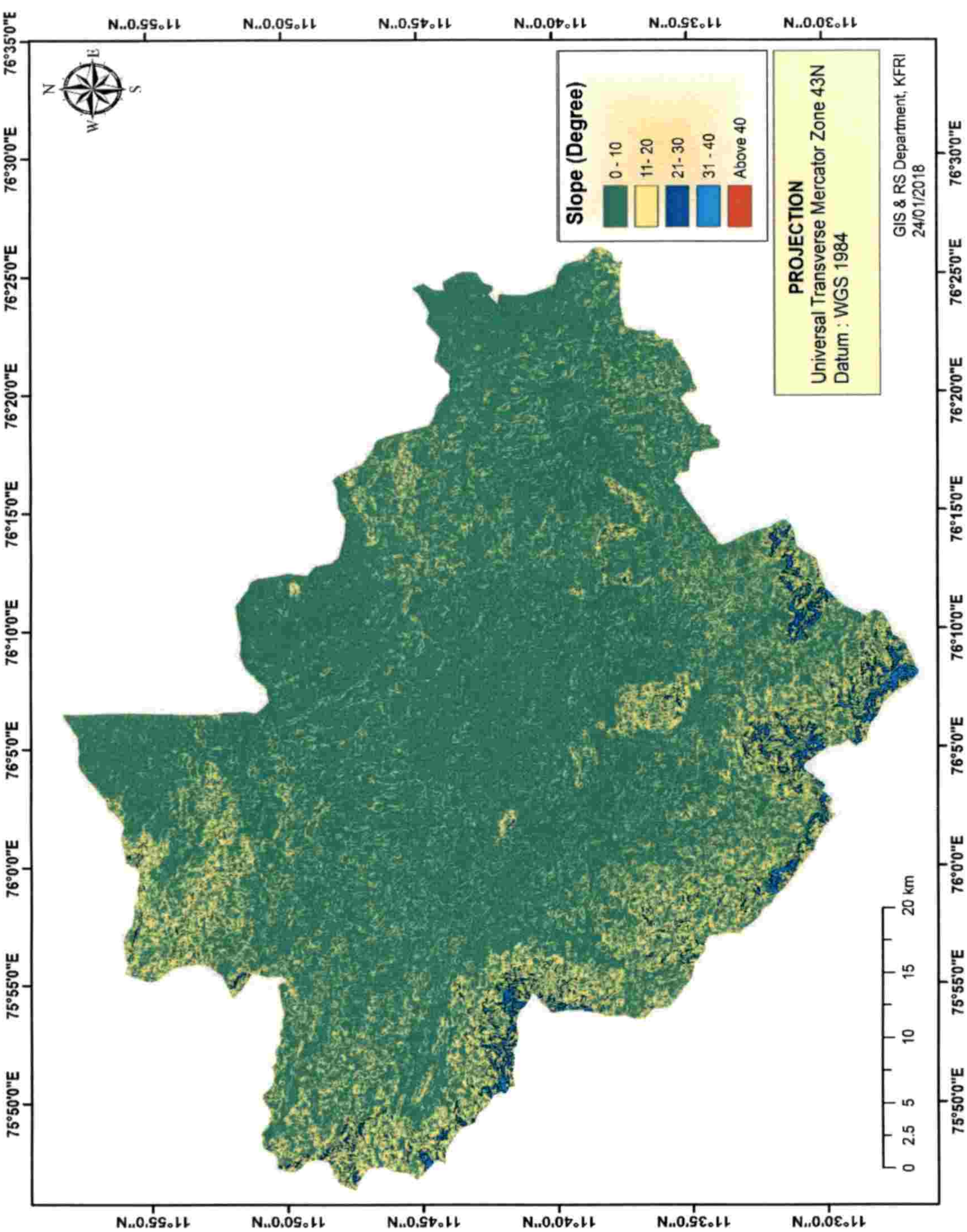


Figure 2. Slope of Wayanad derived from the SRTM (Shuttle Radar Topographic Mission) Satellite data

Agriculture is the predominant livelihood, with most farmers cultivating high value crops such as coffee, pepper, tea and others, mostly as agroforestry combinations. Given the small size of most land holdings, most people grow home gardens or follow traditional homestead farming, growing a large variety of seasonal and annual crops together, along with shade-giving trees and fruit trees. The home gardens are characterised by multi-storey combinations of crops and trees and provide many products for the household including food, fuel, fruits and fodder, apart from generating income and employment. Here a subsistence wet-paddy integrated agro-ecosystem has given way for more lucrative cash crops, such as banana and ginger, or even to nonagricultural uses causing homogenization of the landscape, resulting in unsustainable land use and agro biodiversity loss (Nagabhatla & Kumar, 2013; Padmanabhan, 2011). It is one of the most agriculturally productive districts in India with a productivity of Rs. 82,600 per hectare (Chand *et al.,* 2009).

As per the 2011 census, Wayanad has a population of 8,16,588 spread over an area of 2,132 square kilometers. It is one of the less-densely populated districts in the state, having 2.45 per cent of the Kerala's total population and 5.48 per cent of the area with 383 persons per square kilometer, compared to the state average of 859 persons per sq. km. Wayanad has the largest proportion of indigenous population (18.53%) among the districts of Kerala. Having a small local population that goes back centuries, the majority of Wayanad's residents today are migrants from the rest of Kerala who moved into the district in the last century, especially since the 1940s. Between 1941 and 1991, Wayanad showed an extremely high population growth rate, with the population growing six-fold over the period (Jose and Padmanabhan, 2016). This rapid growth transformed Wayanad irrevocably, bringing ever-greater areas under cultivation, changing land use.

3.2 CLIMATE

The topography of Wayanad is responsible for its unique climate that is quite distinct from the climate of neighboring regions. It is responsible for a strong gradient in rainfall within the district as well. The south-west monsoon period is the primary rainfall season of the region. Moisture-laden winds rush into Wayanad through the Thamarassery ghat pass in the south-west of Wayanad, which in turn receives copious amounts of rainfall (Simon and Mohankumar, 2004). This phenomenon is so severe on the pass that the hill-top location of Lakkidi is one of the wettest places in India.

The mean annual temperature is 23.8^0C. During December-January temperature lowers to 15^0C experiencing severe cold and during summer season the temperature go up to 35^0C. The mean average annual rainfall in the district is 2322 mm.

The climate of Wayanad is tropical humid, which is typical to hilly tracts. The south west monsoon season starts from June and ends by August-September, and around 80% of total rainfall is received during this period. North-East monsoon starts by September and ends in November. High velocity winds are common during the south-west monsoon and dry winds blow in March – April. The climate shows unpredictable variations, causing severe damage to crops.

The distance from the sea and surrounding forests create a salubrious climate. Generally the year is classified in four seasons namely, Winter season (December – February) with hovering mist in the evening or otherwise receiving little rainfall, Summer season (March – May) which is partially dry, but interspersed with sharp premonsoon showers in the afternoon, and associated lightning, high velocity winds and infrequent hail, Southwest monsoon (June – September) with torrential daily showers and Northeast monsoon (October – November) with intermittent rain and high humidity since it is the secondary rainfall season.

3.3 LAND USE

As the district is located completely at the highland region, its climate and land use pattern shows significant difference from all other districts of Kerala. The major portion of total land area of the district is coming under three major categories, viz forest land (39.26%), plantation land (39.02%) and agricultural land (10.94%).

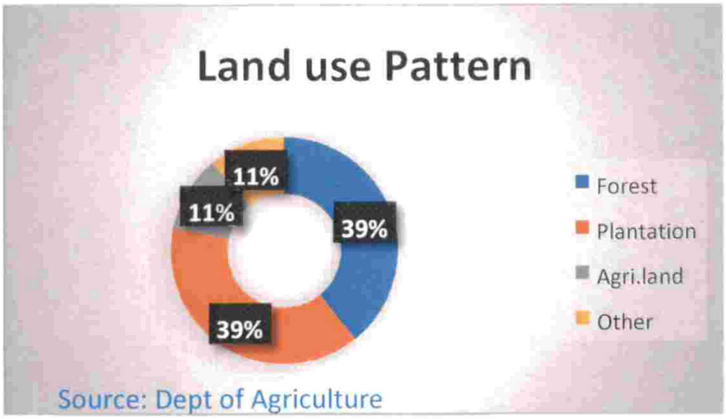


Figure 3. Land use pattern in Wayanad

Climate change and other drivers such as increasing population has led to significant changes in land use among the farming communities. Since its formation, the district has experienced major land-use transitions. In the past, paddy rice was the major wet crop and the staple food, while finger millet (ragi) was the main dry crop consumed mainly by the indigenous communities (Nair, 1911). The hilly interior forests were inhabited by communities which exchanged collected forest products for their living. Later, crops such as coffee (in 1830), tea (in 1892), cardamom, pepper and rubber were introduced to the region, mainly popularized by the British planters (Nair, 1911) making Wayanad a highland plantation economy. The agricultural potential of Wayanad attracted large numbers of Christians from Central Travancore. These Christian immigrants introduced new methods of agriculture and crops, such as banana, ginger, arecanut and tapioca. The general process of land-use change follows a sequence which begins with traditional paddy cultivars being replaced by modern cultivars, followed by annual crops, such as banana, ginger or tapioca, and later by arecanut, coffee or non-agricultural use.

People began cultivating food crops including grains, tapioca and other tuber crops during the initial years of immigration only to satisfy their hunger. Introduced by the in-migrant farmers the first cash crop cultivated in the area was lemon grass. Households which made a surplus first from cultivation of lemon grass and tapioca later turned to cultivation of other cash crops like coffee and pepper by 1970s. Many families had developed good gardens of pepper by the end of the decade. In the early 1980s pepper prices were high and pepper cultivation yielded handsome returns causing pepper cultivation to spread fast. Pepper were grown in abundance in Wayanad and farmers capitalised on its price hike. Onslaught of diseases on pepper and changes in climate gradually weekend this phase. Also, crops like coconut and rubber, which were once considered as not adaptable to the local environment, have also found a place in many local homesteads due to shift in local climate.

Tree cover map and tree cover loss map of Wayanad is derived from the Hansen data (Hansen *et al.*, 2013). Figure 4 shows that Wayanad has areas with sparse tree cover, moderate tree cover and dense tree cover. Majority of the land area of the district is under dense tree cover with 31 – 100% trees in it. While the region with 0 - 10% and 11 – 30 % are categorized under sparse tree cover areas and moderate tree cover areas. Figure 5 shows the tree cover loss map derived from Hansen data over the years 2001-2016 and the tree cover loss data over the district of Wayanad during 2001-2016 is given in Table 1. Tree cover loss has been evidently increasing over the years with the highest loss being observed at 2007 and the lowest at 2002 with 446.67 ha and 21.15 ha respectively.

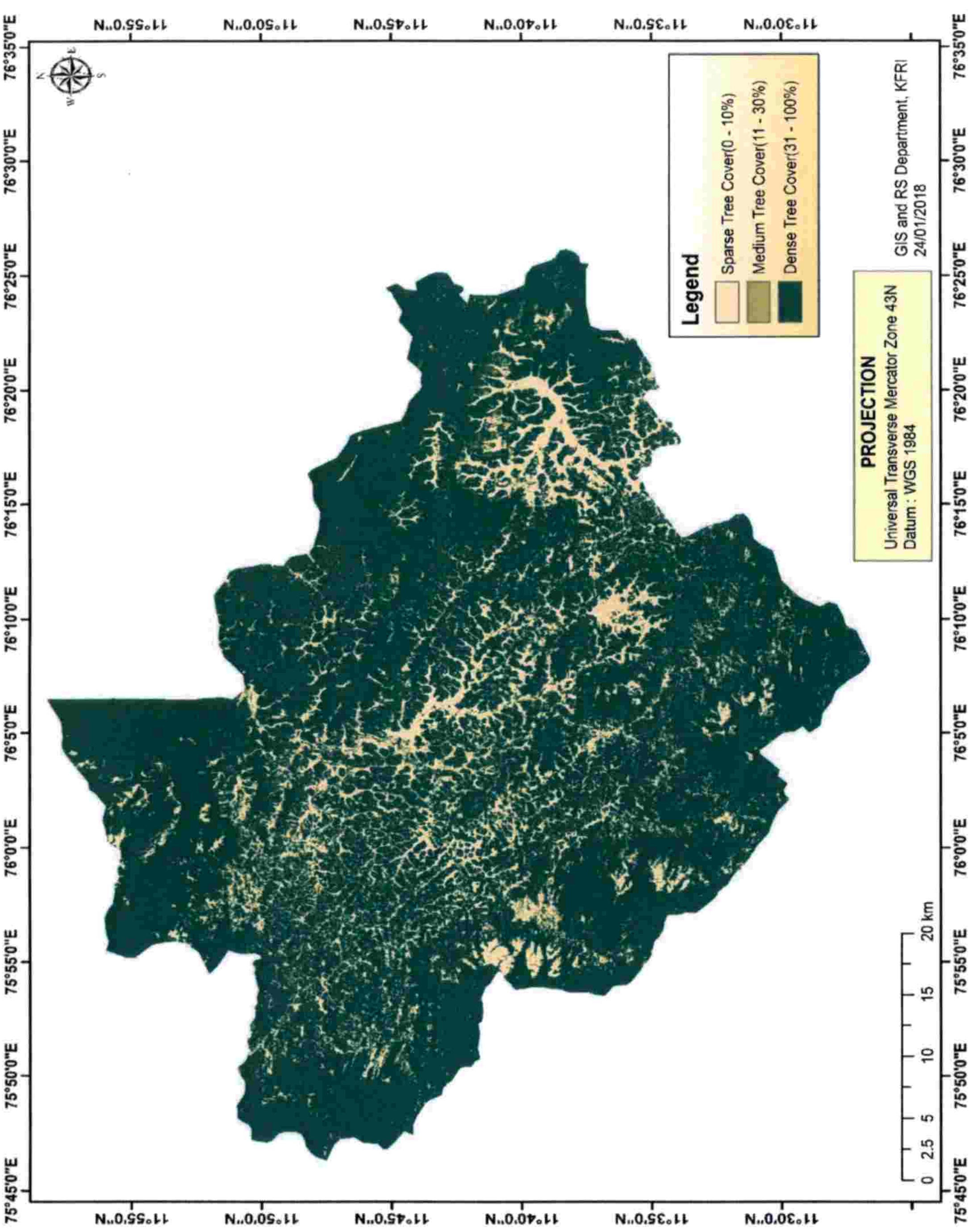


Figure 4. Tree cover map of Wayanad derived from the Hansen data (Hansen et al., 2013)

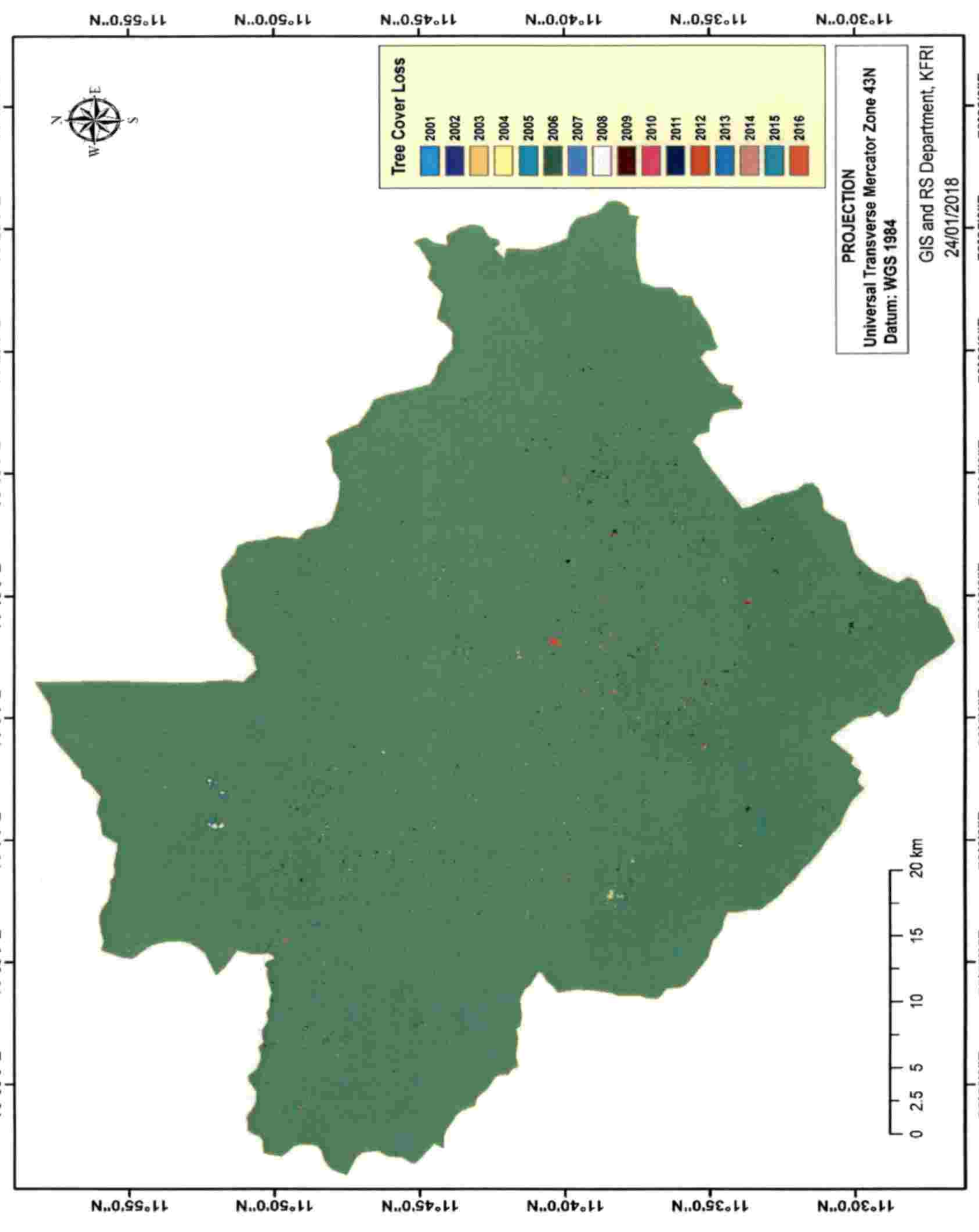


Figure 5. Tree cover loss map of Wayanad derived from the Hansen data (Hansen et al., 2013)

Table 1. Tree cover loss data of Wayanad from 2001-2016 derived from the Hansen data (Hansen et al., 2013)

OBJECT ID	Year	Area(ha)
1	2001	25.83
2	2002	21.15
3	2003	51.39
4	2004	64.71
5	2005	103
6	2006	64.35
7	2007	446.67
8	2008	203.94
9	2009	71.55
10	2010	56.7
11	2011	219
12	2012	183.6
13	2013	132.66
14	2014	185.31
15	2015	65.52
16	2016	246.78
	TOTAL	2142.16

The most commonly and widely seen transformation more recently in Wayanad is paddy to banana plantation. The bunds raised for banana plantation caused the increased runoff of water leading to soil erosion and reduced groundwater recharge (Jose and Padmanabhan, 2016). The same process is followed for planting ginger and tapioca. Banana is replaced by either arecanut or coffee, causing further compaction of the soil and thus making it suitable for non-agricultural use. Declining productivity of banana over the years due to pest incidence and soil degradation induced further landuse change. The final stage of land-use change from agricultural to non-agricultural purpose is more related to the nature of urbanization in Kerala and the increasing demand for residential plots.

3.4 METHODOLOGY

3.4.1. Data collection

3.4.1.1. Agriculture data

In order to understand the changes in productions, patterns and processes of agricultural systems, both quantitative and qualitative data were used. The quantitative data such as area (in hectares) and production (in tonnes) of major crops over the past two and half decades were obtained from the Agricultural Statistics records of the Department of Economics and Statistics at the district headquarters in Wayanad. Data which were not available at the district headquarters were then collected from the State Headquarters in Thiruvananthapuram. The qualitative data were obtained through systematic survey of the scientific literatures, and also by conducting one-to-one interview's with major stakeholders. The literature survey included national journals, conference proceedings, scientific reports, ISI publications and academic theses. The available historical documents, records and gazetteers were also consulted. Subject experts from government (primarily principal agricultural officer), scientific institutes, universities, NGOs, and other research groups were also consulted to understand the changes in productions, patterns and processes of cropping systems over the last couple of decades.

3.4.1.2. Selection of intensive study area

Based on the above, the sampling sites were selected for the intensive survey. There are four administrative blocks in the Wayanad district, i.e., Kalpetta, Mananthavady, Panamaram and Sulthan Bathery. There are 25 Panchayaths in four blocks. From each block, two panchayaths were selected after interacting with experts and other traditional farmers. The eight panchayaths selected for the study were Meppady and Padinharethara from Kalpetta block, Edavaka and Thavinjal from Mananthavady block, Mullankolly and Pulpally from Panamaram block and Meenangaday and Noolpuzha from Sulthan Bathery block. List of major farmers from these selected panchayats were collected from the respective Krishibhavans (agricultural offices) and Panchayat Offices. Of these, 120 home gardens were randomly picked for the intensive survey on how agri and agroforestry practices have changed over the last couple of decades. The spatial distribution of Panchayats, and the home gardens selected were given in Fig.6.

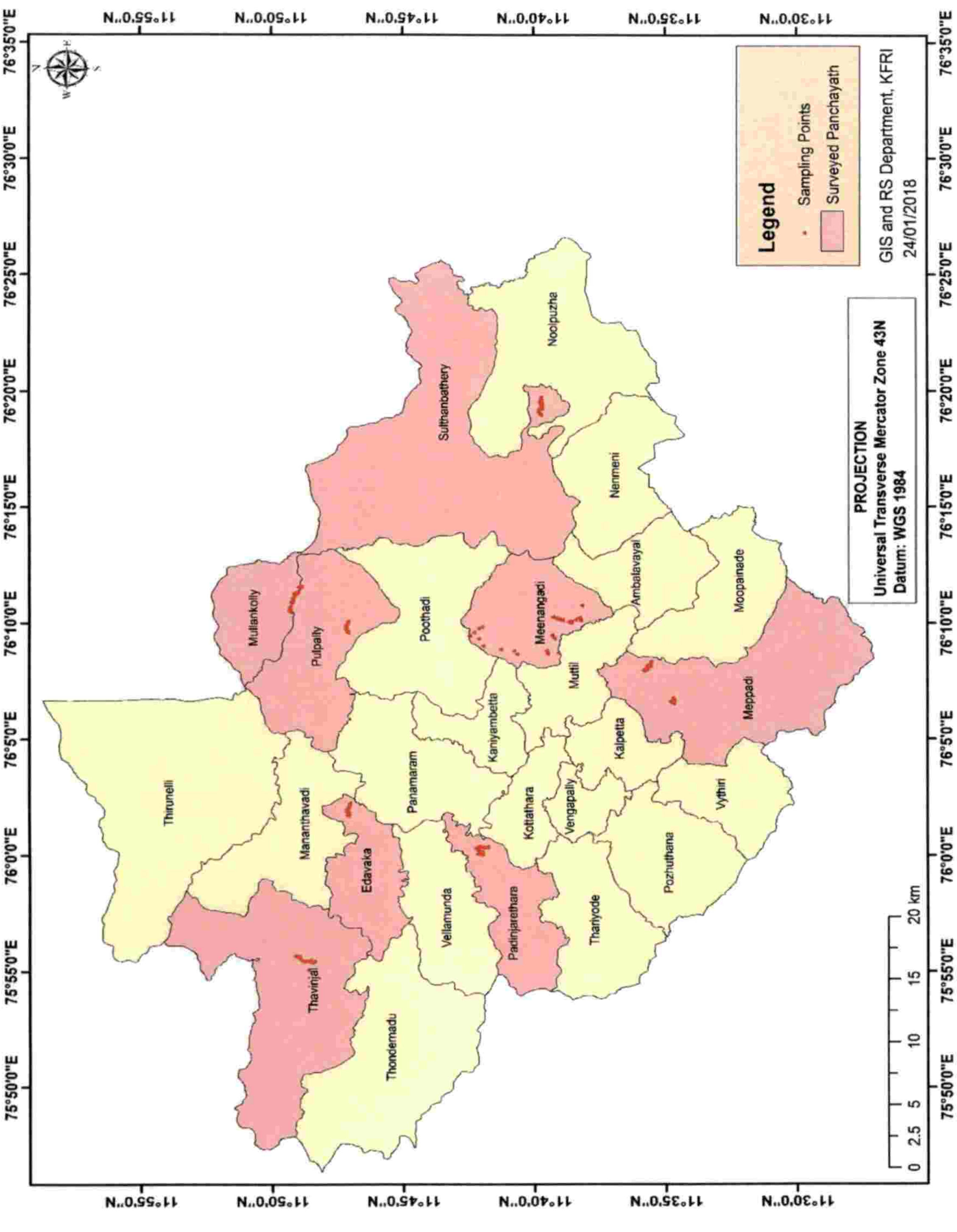


Figure 6. Spatial distribution of panchayaths and homegardens selected for the study

3.4.1.3. Semi structured Interview

Semi-structured interviews were conducted at the homes of respondents during May - June, 2017. For each of the 120 home gardens visited, the semi structured interview lasted about 60-90 minutes with the head of household, but in many cases the entire family contributed.

The semi structured interview were designed to elucidate land-use histories by comparing the primary crops produced on the homestead before 1990s, 1990-2000, 2000-2010 and after 2010 which consisted of a set of questions on cultivation histories of major crops grown in the area such as rice, banana, coffee, pepper, coconut and so on, its percentage contribution and approximate productivity before 1990s to 2016. We also collected demographic data (e.g. size of family, primary source of income), size of home gardens and its location using GPS.

It sought primarily to explore the shift in patterns of agroforestry systems, the drivers of change in agroforestry systems and the changes in climate variables between 1990 and 2016. Our leading question was "Has cropping patterns on your land changed over the past 25 years?" classifying the time period at an interval of 10 years from 1990-2016. Following this question, our interviews developed freely in various directions, but were guided generally by questions such as "What has caused changes in the cropping patterns?" And "what were the climate variabilities experienced during the past and the present" and "Is there any agro entrepreneurial migration (both geographical and sectorial)?", if yes, "what were the reasons for the migration in and out of the district?" A copy of the questionnaire survey is given in Appendix I. The answers were recorded on paper and then entered separately in excel worksheets for further analyses.

Plate 1. Semi-Structured interview with farmers

Plate 2. Rice tracts of Wayanad

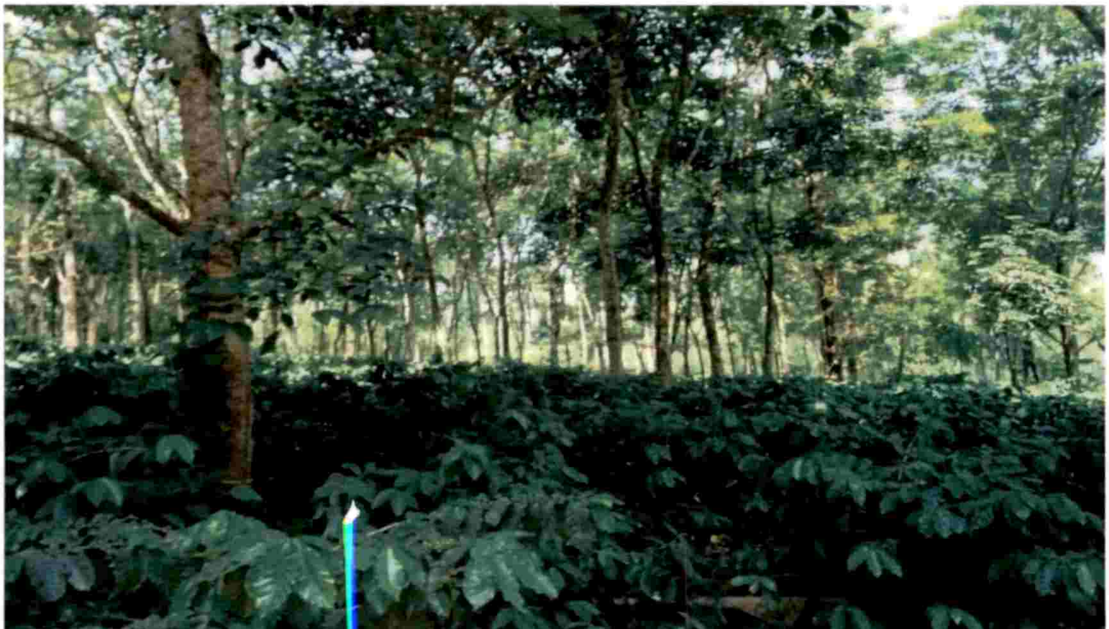


Plate 3. Coffee grown under the shade of Rubber plantation

Plate 4. Paddy field converted into banana plantation

3.4.1.4. Climate data

Climate data of the area over the past two and half decades were collected from different agencies such as Regional Agricultural Research Station (RARS) of the Kerala Agricultural University, and India Meteorological Department, Pune. The daily rainfall data was available from stations Vythiri, Kuppady and Mananthavady from IMD, Pune and Ambalavayal from RARS. The daily temperature data was available only from RARS, KAU. Ordinary least square regression equations were fitted in the temperature and rainfall data to analyse the changes in trends. Monthly and annual changes were analyzed to assess the seasonal and overall shifts in rainfall and temperature.

3.4.2. Factor analysis

Multivariate statistical techniques are powerful tools for analysing large numbers of samples collected in surveys, classifying assemblages and assessing human impacts on ecosystem conditions (Gauch 1982; Digby and Kempton 1987; Reynoldson *et al.*, 2001; Cao *et al.*, 2002). Factor analysis is a multivariate statistical techniques used to understand the correlation structure of shift in agroforestry systems and identify the most important factors contributing to the structure. It was carried out for data reduction to represent a number of questions with a small number of hypothetical factors. To understand the degree of mutually shared variability between individual pairs of factors that caused changes in agroforestry systems, a correlation matrix was generated. The next step was the estimation of the Eigen values and factor loadings for the correlation matrix. Since lower Eigen values contribute only a little to the explanatory capability of the data, only a few factors were taken into account. The Eigen values >1 were considered as prominent factors as per the Kaiser criterion. Multicollinearity test was also conducted for each variable and then Principle component analysis was carried out again after removing the multicollinearity in the samples. The observations were divided into three time periods namely 1990-2000, 2000-2010 and 2010 onwards to understand the drivers of change in the landscape. Also, a cumulative analysis was also conducted to understand the major drivers of change in the landscape for the last two and half decades. After the correlation and Eigen values were obtained, factor loadings were used to measure both the correlations and regression weights between factors and variables.

RESULTS

CHAPTER 4
RESULTS

4.1 TRENDS IN THE AREA OF MAJOR CROPS

The results show that the Wayanad has underwent major changes in the land use in the last two and half decades. During 1991-2015, the area of crops such as arecanut, coconut, rubber and banana increased considerably whereas the area of rice, ginger and pepper has declined. The area of crops such as coffee, tea, cardamom, cocoa and turmeric however remains almost steady from 1991-2015.

The cultivated area under rice was 19,582 ha in Wayanad in the year 1991 which is reduced to its half (9,204 ha) by 2015. Similarly, in the year 1991, the area of Pepper was 30,543 ha which is decreased to 12,498 ha in 2015. Another crop that showed decline in area is ginger, which covered about 8,053 ha in 1991 and declined to one-fourth (2,125 ha) in 2015. The major crops that showed a decreasing trend over the study period is given in Fig. 7. In the case of arecanut, coconut, rubber and banana, the area under cultivation showed an increasing trend (Fig. 8). Area under arecanut, coconut, rubber and banana recorded an increase of 1,765 ha to 13,461 ha (eight times), 5,347 ha to 12,403 ha (two times), 5,177 ha to 10,790 ha (two times) and 1,396 ha to 9,739 ha (seven times) respectively from 1991-2015.

The Fig. 9. shows that the area under cultivation of coffee, cocoa, cardamom, turmeric and tea followed more or less stable trend.

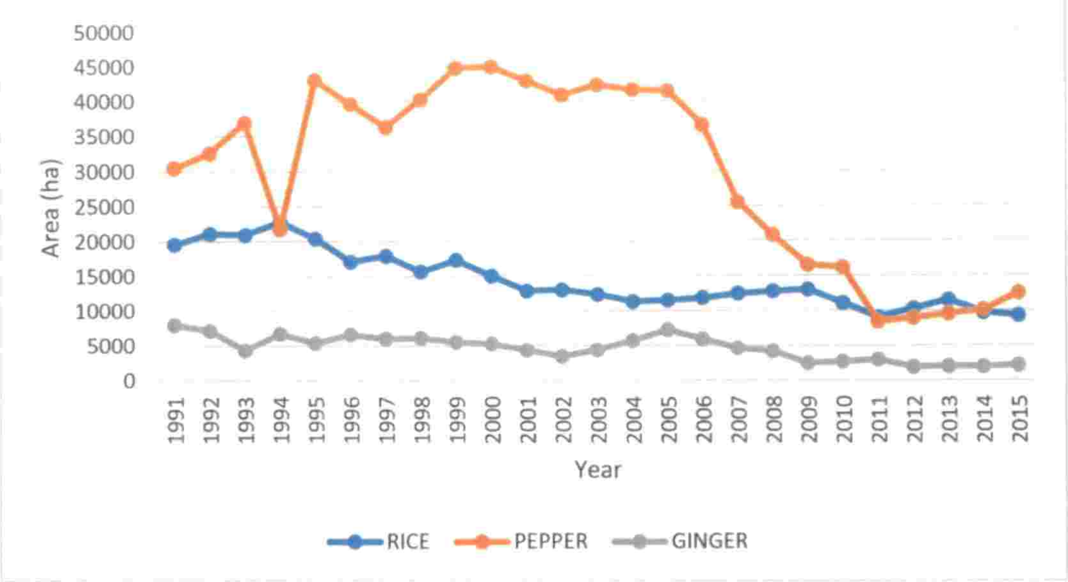


Figure 7. Area (ha) of major crops of Wayanad such as Rice, Pepper and Ginger during 1991-2015

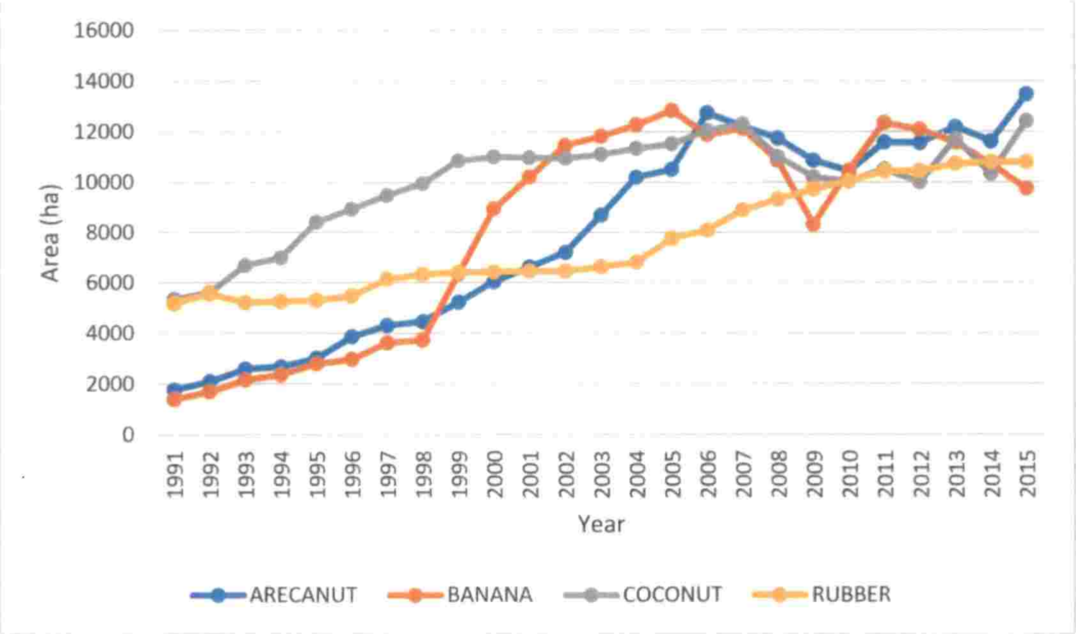


Figure 8. Area (ha) of major crops of Wayanad such as Arecanut, Banana, Coconut and Rubber during 1991-2015

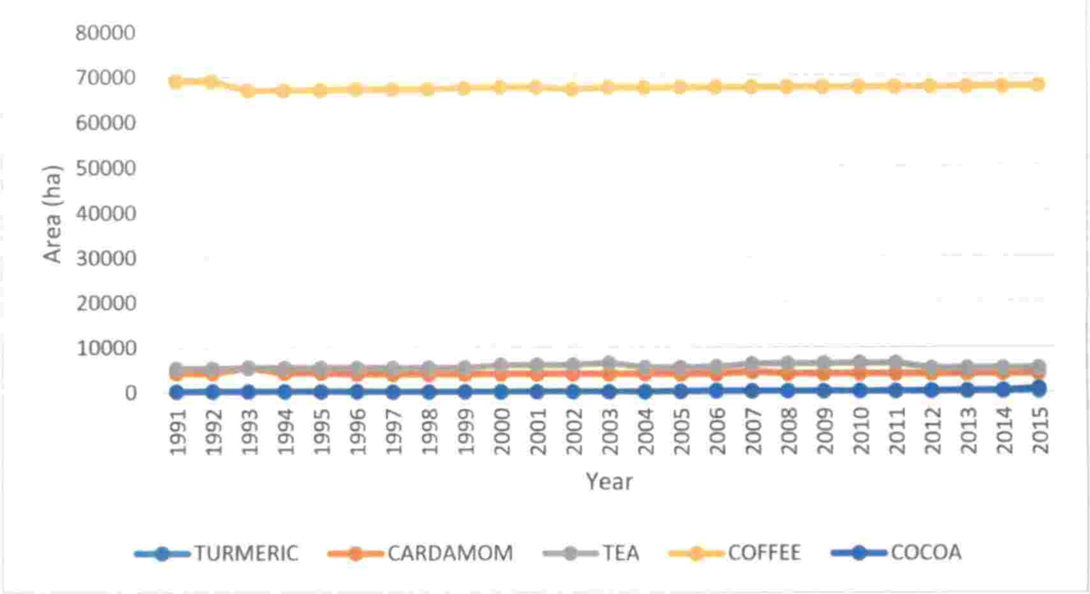


Figure 9. Area (ha) of major crops of Wayanad such as Turmeric, Cardamom, Tea, Coffee and Cocoa during 1991-2015

4.2 TRENDS IN THE YIELD OF MAJOR CROPS

In similar lines with area under cultivation, the production of pepper, rice and ginger showed a decreasing trend during the past two and half decades in Wayanad (Fig.10-12). The production of pepper was 10,954 tons in 1991 which has significantly reduced to 6,593 tons in 2015. Likewise the production of ginger was 28,978 tons in 1991 and is declined to 9,959 tons in 2015. Also the production of rice, 42,803 tons, in 1991 is reduced to 23,704 tons by 2015 (Fig.12). Whereas, crops such as arecanut, banana, tea, rubber, coconut, cocoa, cardamom, turmeric and coffee showed an increase in production during the study period. These crops were increased from 343 tons, 21,658 tons, 10,198 tons, 2,426 tons, 6 million nuts, 73 tons, 163 tons, 461 tons and 16,730 tons at the beginning of the study to 7,428 tons, 92,295 tons, 14,050 tons, 6,206 tons, 77 million nuts, 636 tons, 660 tons, 577 tons and 57,850 tons by 2015 respectively.

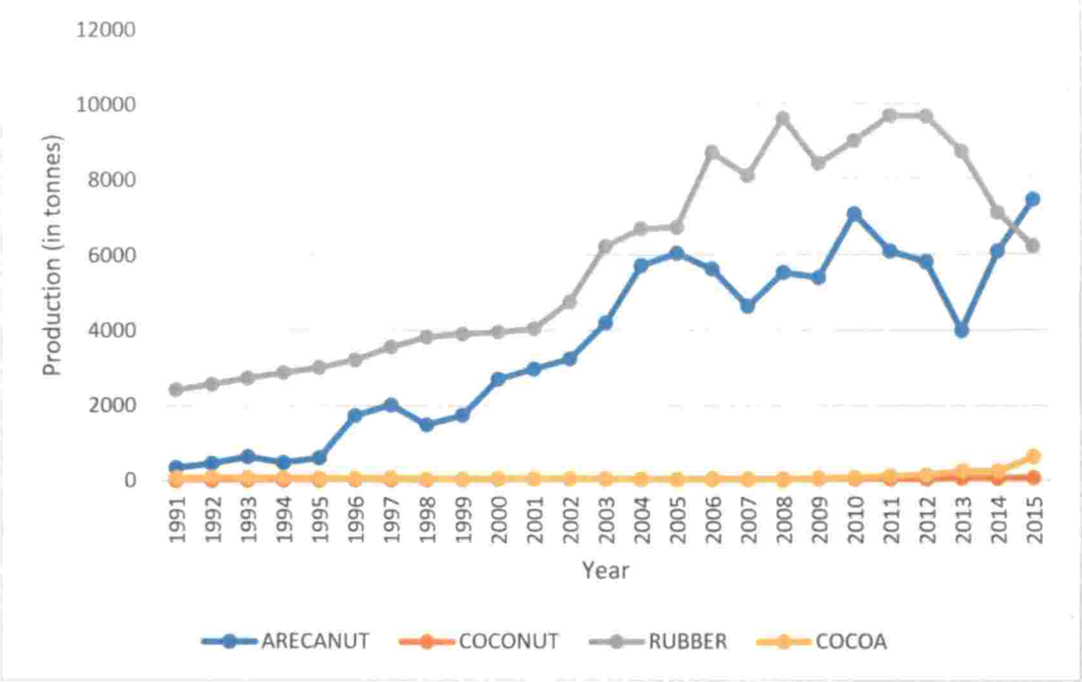


Figure 10. Yield (tons) of major crops of Wayanad such as Arecanut, Coconut, Rubber and Cocoa during 1991-2015

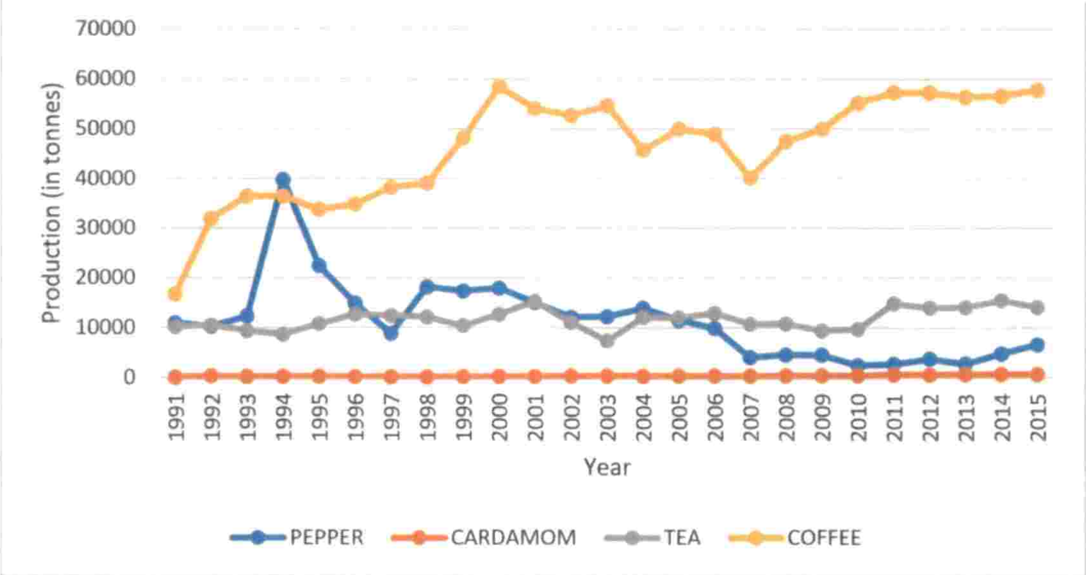


Figure 11. Yield (tons) of major crops of Wayanad such as Pepper, Cardamom, Tea and Coffee during 1991-2015

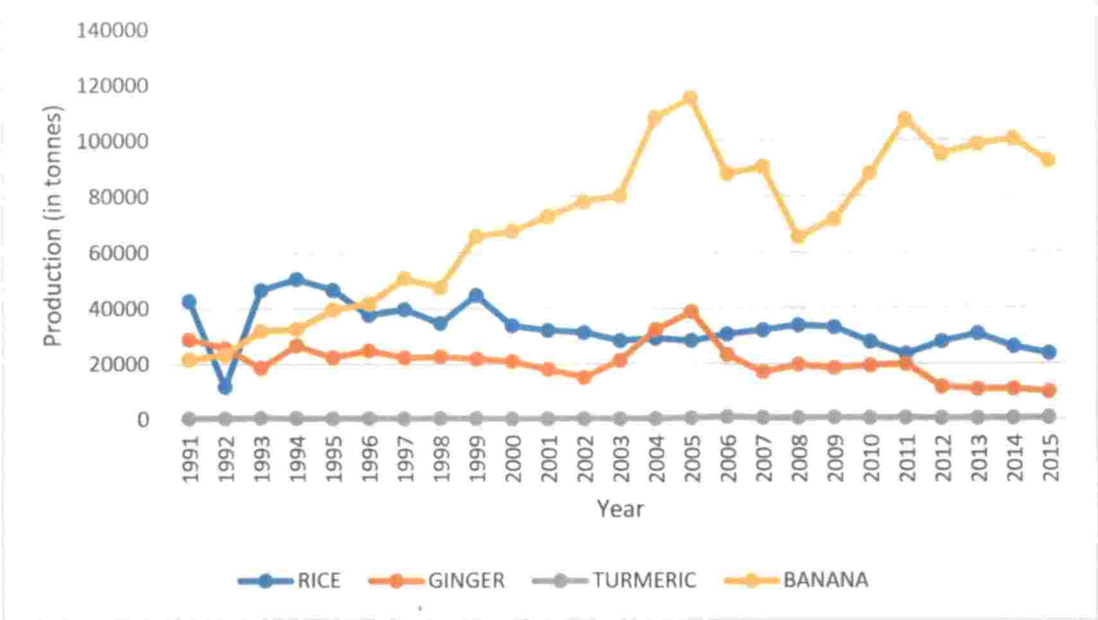


Figure 12. Yield (tons) of major crops of Wayanad such as Rice, Ginger, Turmeric and Banana during 1991-2015

The results obtained from the economic and statistics department were in concordance with the socio-economic survey. The 120 participants who participated in the survey responded that the cultivation of rice, pepper, and ginger in their homesteads have considerably reduced in the last couple of decades. In the survey, respondents were asked about the percentage contribution of each crop grown in their total land area in different time periods such as before 1990s, 1990-2000, 2000-2010 and after 2010, and the result is given in Fig.13. Before 1990s, rice, pepper and ginger were in abundance in Wayanad which was then replaced by arecanut, coconut, coffee, rubber and banana. Severe decline was recorded in the percentage contribution of rice and pepper grown in the fields from about 43.54% and 33.43% before 1990s to 13.75% and 12.51% after 2010. Likewise, tremendous increase in the percentage of arecanut, coconut, coffee, rubber and banana from 8.86%, 14.25%, 30.19%, 5.48% and 7.92% to 29.5%, 22.60%, 38.31%, 18.61% and 15% was also noticed from 1990 to 2015.

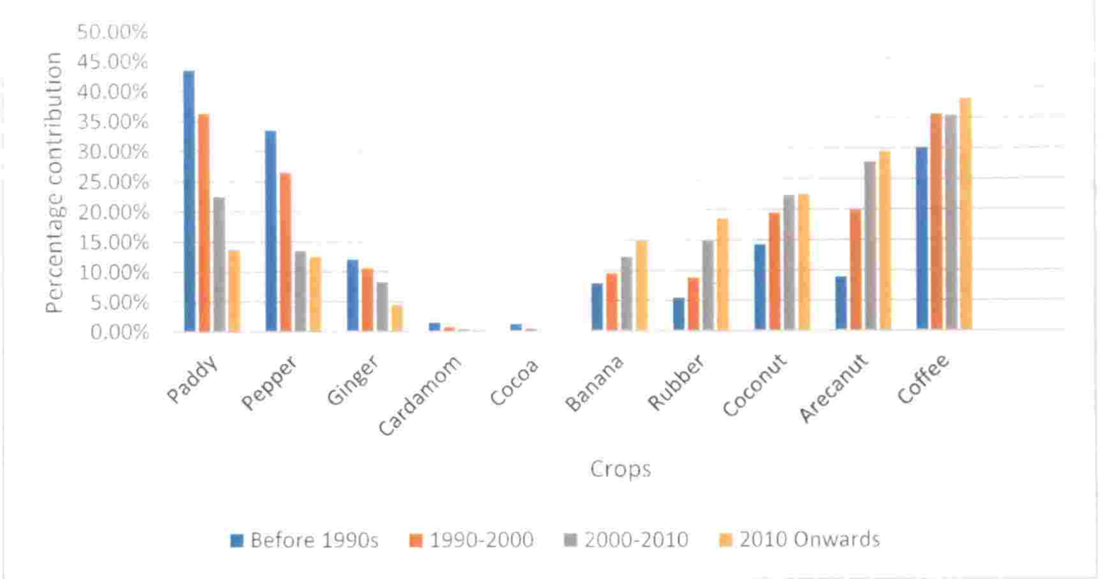


Figure 13. Percentage contribution of major crops grown in Wayanad before 1990s, 1990-2000, 2000-2010 and 2010 onwards

4.3 TRENDS IN CLIMATE VARIABLES

4.3.1. Annual rainfall

A decreasing trend is noticed in the amount of rainfall received in the district during 1991-2015. Annual rainfall varies from 3000 to 4000 mm in these areas. Fig. 14 clearly defines 1994 as the year that received highest rainfall (4445.4 mm) and 2003 that has experienced the lowest rainfall (1327.1 mm) for past 25 years. From 1991-1997, though the trend in annual rainfall is observed to be varying, the rainfall average has not dropped below 2400 mm. But since 1997, the rainfall average has been showing a decreasing trend until 2003, where the annual rainfall average fell below 2000 mm. Since 2003, the rainfall amounts have shown an alternate increase and decrease with the average ranging 2000-3500 mm, until 2012. 2013 and 2014 were the years that experienced rainfall simultaneously for two consecutive years and then the rainfall pattern again showed a decreasing trend the subsequent years, with 2016 being the year that received least annual rainfall.

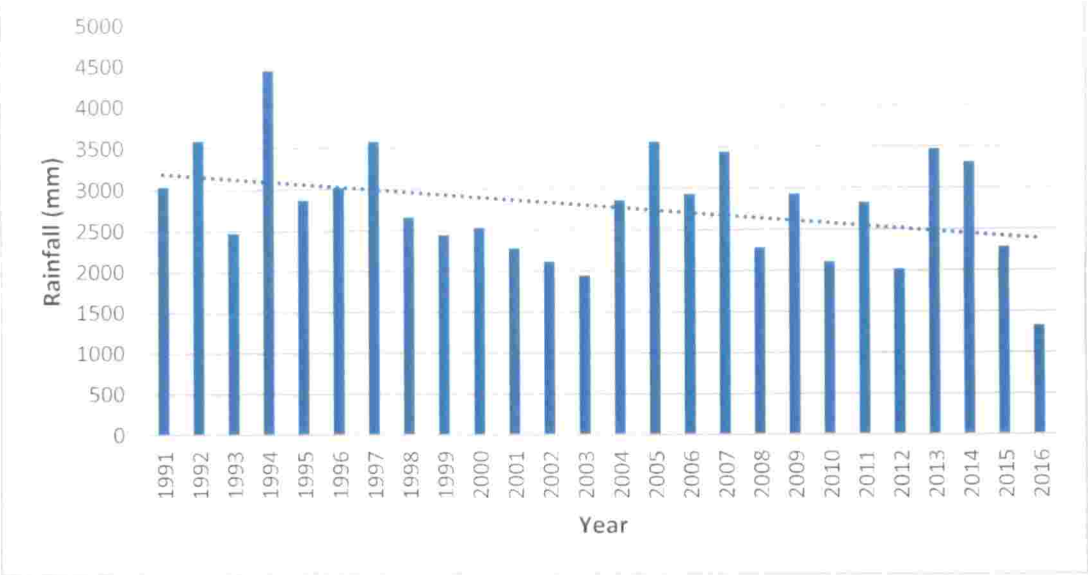


Figure 14. Annual variation of rainfall (1991-2016)

4.3.2. Annual temperature

The annual variation of temperature for the past two and half decades is shown in Fig.15. The maximum annual temperature was experienced in the recent year, 1998 (23.23°C) and the minimum annual temperature in 1995 (21.5°C). Except for the initial year of the study (1991), when the temperature was 22.7°C, then until 1996, the temperature values remained well within 22.5°C. The figure establishes a consistent increase in the annual temperature during the four year period between 1995- 1998. From 21.6°C in 1995, the temperature value hiked to 23.2°C in 1998. Since 1999 until 2001 the value remained almost consistent. 2003- 2007 showed a decreasing trend. From 2008- 2016, though it appears to be varying, a closer look establishes an increasing trend, where even the lowest noted temperature valued above 22.3°C with the highest of the value, recorded against 2016 (23.4°C).

58

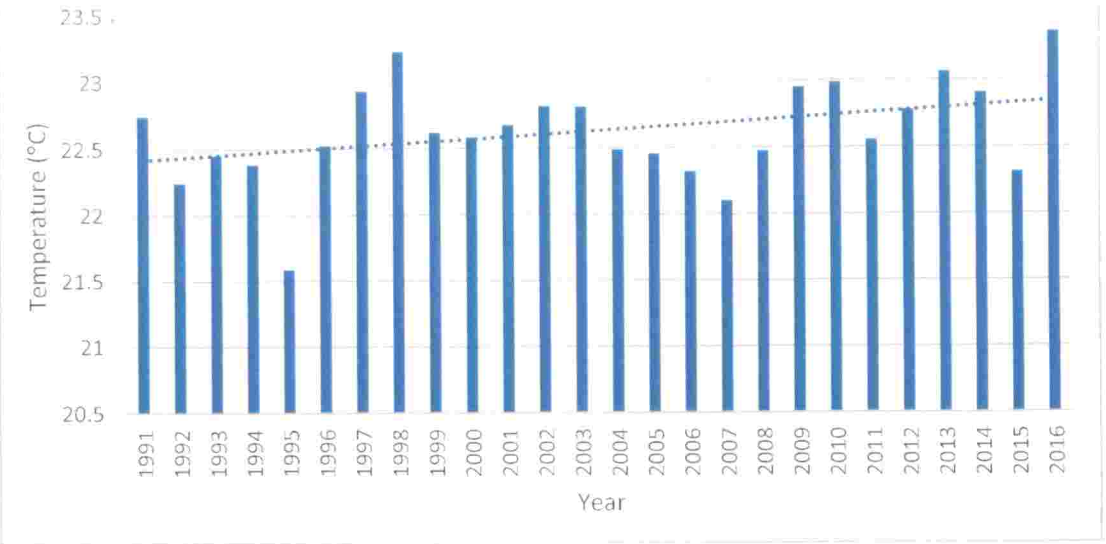


Figure15. Annual variation of temperature (1991-2016)

4.3.3. Rainfall anomalies

Fig. 16 shows the percentage anomaly in rainfall during 1991-2016. It is observed that there is random anomaly of rainfall during each year. The most prominent anomalies were observed in the years of 1992, 1994, 1997, 2005 with 25.1%, 54.7%, 24.5% and 24.1% and in the years 2002, 2003, 2010, 2012 and 2016 with -26.3%, -32.3%, -26.7%, -29.8% and -53.8% respectively. 1995 and 2004 recorded the least anomalies while the largest anomaly was recorded in 2016 with -53.8%.

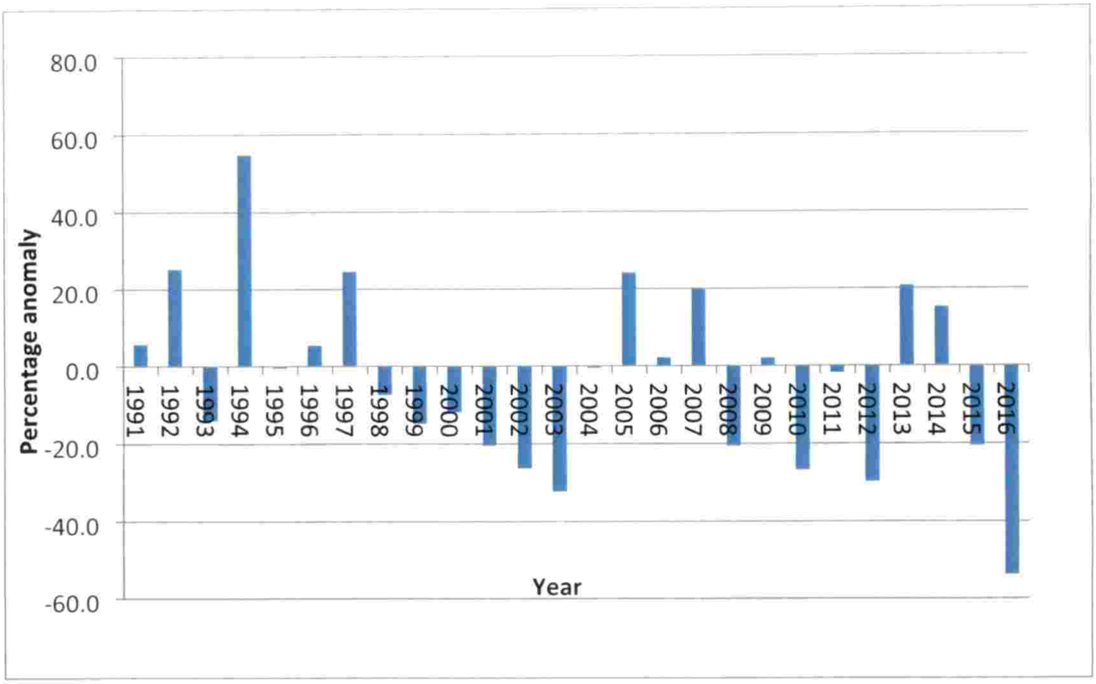


Figure16. Percentage anomaly in rainfall

4.3.4. Temperature anomalies

Fig.17. shows the percentage anomaly in temperature during 1991-2016. The anomalies over the period shows random positive and negative trends. The year 1991 witnessed an increase of 0.5 % from the normal followed by consecutive negative anomalies for the next five years. The most prominent anomalies were observed in the years of 1995, 1998, 2007 and 2016 with anomalies of -4.59%, 2.64%, -2.33% and 3.23% respectively. Least deviation from the normal was recorded in the years 1999, 2000 and 2001 with anomalies of -0.1%, -0.19% and 0.2%. Also, 2002 and 2003 had almost similar variation from the mean followed by a sudden drift to decrease in anomalies for the next four years (2004-2008). Later on from 2009 to 2016, there was a positive variation from the normal except for 2011 and 2015 with -0.3% and -1.39% anomalies. The warmest temperature was recorded in 2016 with a positive anomaly of 3.23% and the coolest temperature was recorded in 1995 with a negative anomaly of - 4.6%.

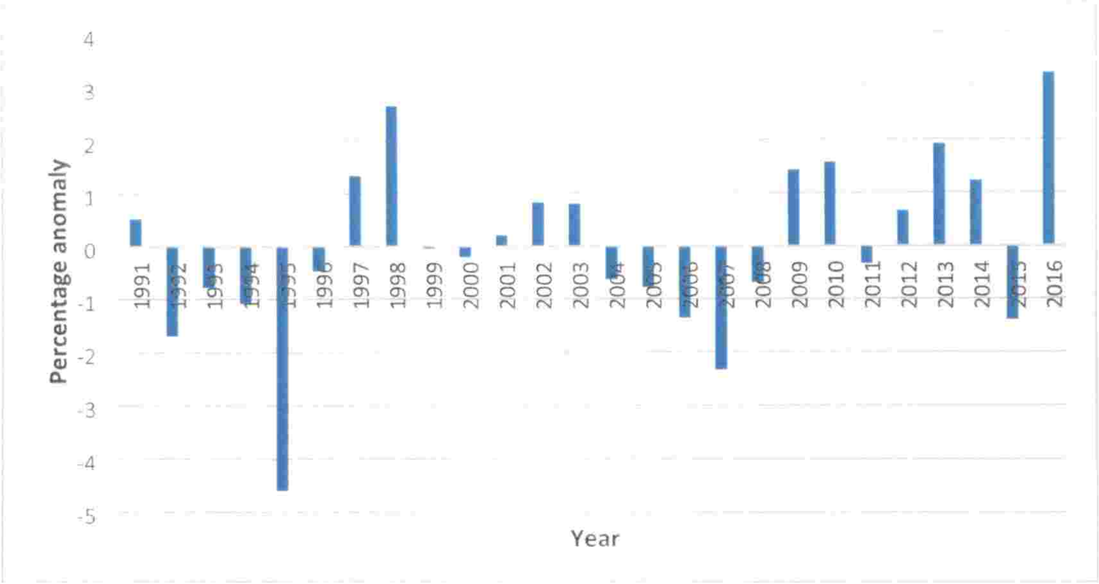
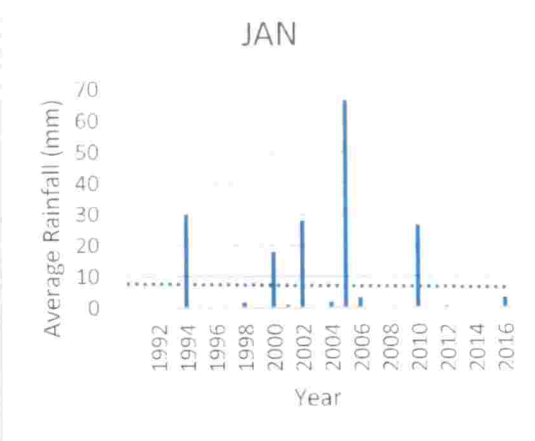
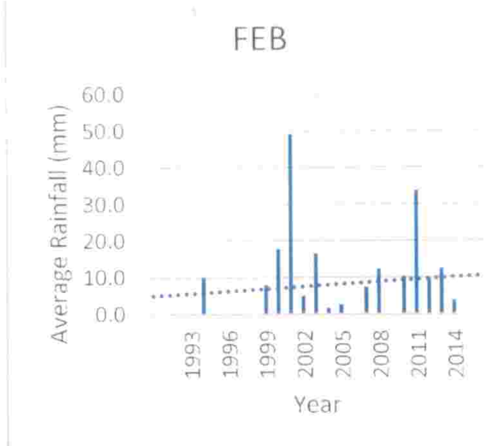


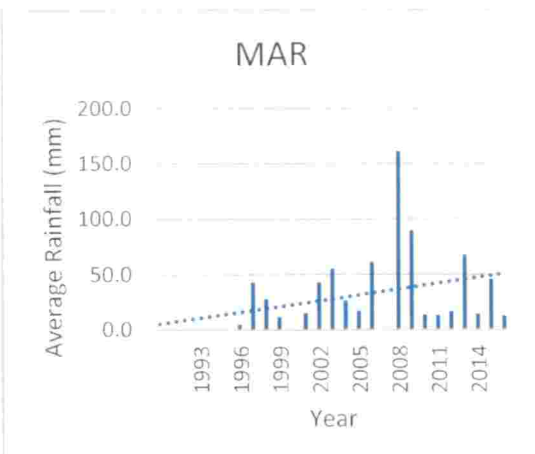
Fig. 17. Percentage anomaly in temperature

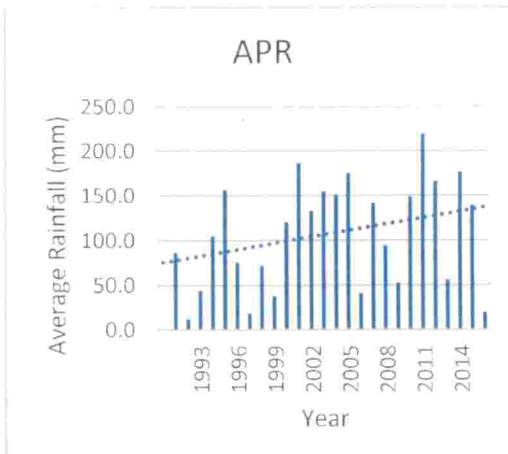
4.3.5. Monthly rainfall

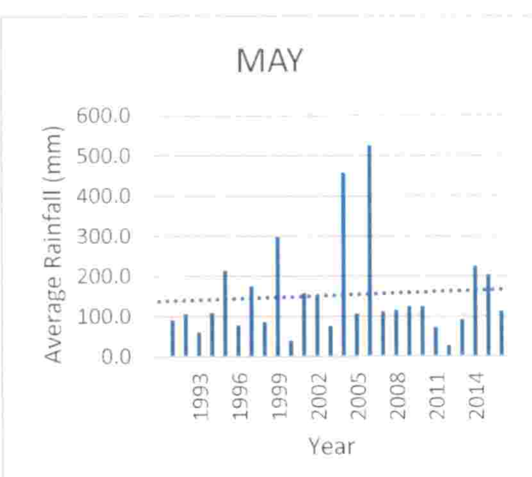
A closer look at the monthly rainfall pattern revealed a seasonal shift in the Wayanad for the last two and half decades (Fig.18). The south west monsoon showers from June to August found to be decreasing over the study period. A sharp decline was observed in June and July months, and thereafter a slight decline in August followed by a slight increase in September. The north-east monsoon in October and November also showed a slight decreasing trend from 1991 to 2015. It is also found that the offset of north-eastern monsoon slowly advancing to December in the study period. The shift in the rainfall intensity was also prominent in pre-monsoon period. The months of March and April showed a sharp increase in the rainfall intensity.

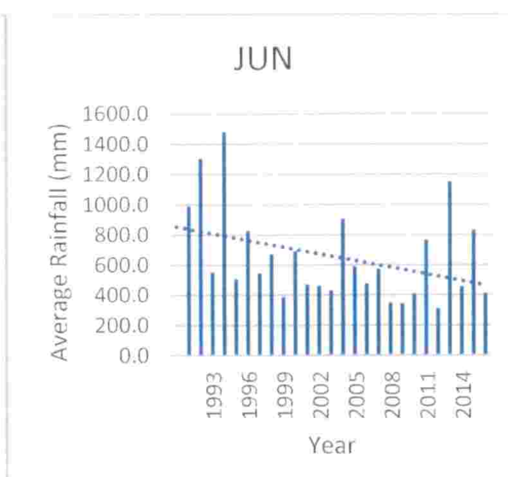

JAN
Average Rainfall (mm)
70
60
50
40
30
20
10
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Year


FEB
Average Rainfall (mm)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1993
1996
1999
2002
2005
2008
2011
2014
Year


MAR
Average Rainfall (mm)
200.0
150.0
100.0
50.0
0.0
1993
1996
1999
2002
2005
2008
2011
2014
Year


APR
Average Rainfall (mm)
250.0
200.0
150.0
100.0
50.0
0.0
1993
1996
1999
2002
2005
2008
2011
2014
Year


MAY
Average Rainfall (mm)
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1993
1996
1999
2002
2005
2008
2011
2014
Year


JUN
Average Rainfall (mm)
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
1993
1996
1999
2002
2005
2008
2011
2014
Year

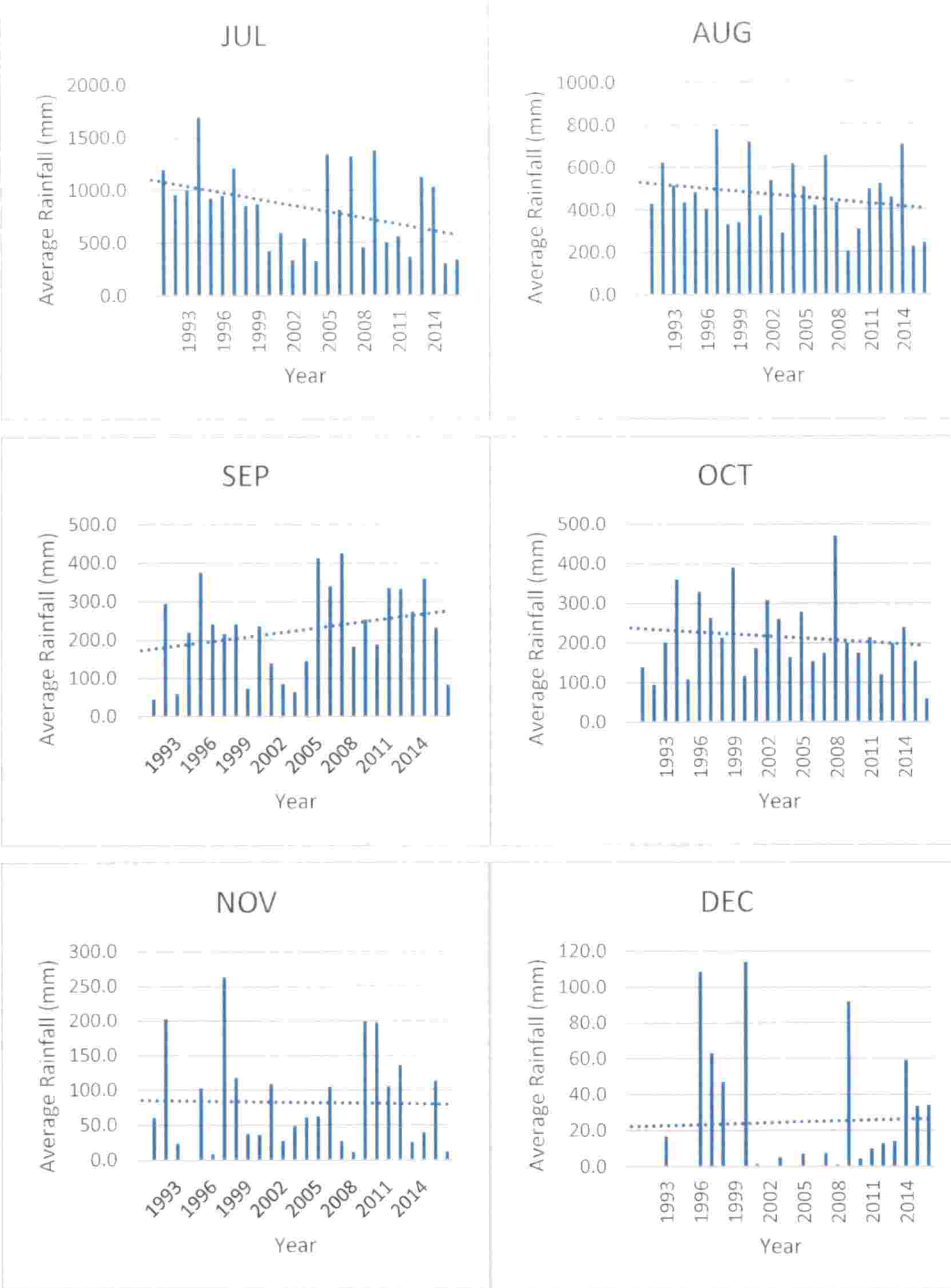


Figure 18. Monthly average rainfall of Wayanad from 1991-2016

4.4 FACTOR ANALYSIS

Factor analysis on drivers of change extracted four Principal Components explaining 71% variation in the trends. The first factor explained 25% of the variation, the second 18%, the third 15% and the fourth 13% of the variation (Table 2). The remaining Eigen values were less than one, and were of less interpretability in the total variance observed. The first PC had high factor loadings for high demand of certain crops (-0.878) and the increase in price of crops (-0.851) which can be certainly attributed to the market driven shift in agricultural practices (Table 3). The second PC had high factor loadings for the absence of labors (-0.862) and the less investment and production cost for new crops (-0.736), indicated an adaptive strategy of farmers to maximize the profits on context of challenges. The third PC had high factor loadings for disease threat (0.821) and climate change (0.557) which certainly related to the climate variability experienced in the region, and the resultant outbreak of pests and diseases that affects the crop production. The fourth PC had high factor loadings for land conversion (-0.785) and decrease in productivity of crops (0.722) which may be attributed to the booming expansion of tourism industry in recent times especially in those areas where agriculture production is not profitable.

Table 2. Factor analysis based on Principal component analysis in Agroforestry systems in Wayanad (1990-2016)

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.604	26.041	26.041	2.514	25.139	25.139
2	2.022	20.219	46.259	1.750	17.501	42.640
3	1.407	14.072	60.331	1.482	14.819	57.458
4	1.059	10.594	70.926	1.347	13.467	70.926
5	.898	8.982	79.908			
6	.713	7.131	87.039			
7	.512	5.124	92.163			
8	.491	4.912	97.075			
9	.273	2.735	99.810			
10	.019	.190	100.000			

Table 3. Factor loadings of Principal components

Rotated Component Matrix[a]

	Component			
	1	2	3	4
Productivity decreased	.111	.287	.093	.722
Price hike	-.851	.229	-.302	.018
High demand	-.878	.142	-.015	.108
Less investment cost	-.184	-.736	-.299	-.170
Absence of labours	.255	-.862	.078	.005
Disease threat	.004	.040	.821	.020
Climate change	.020	.380	.557	.290
Animal Attack	.656	.315	-.254	-.215
Loss of soil fertility	.612	.219	-.487	.194
Land Conversion	.319	.128	-.022	-.785

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

DISCUSSION

CHAPTER 5
DISCUSSIONS

5.1 SHIFT IN PATTERNS OF AGROFORESTRY SYSTEMS

Agroforestry systems of high range landscapes, in particular Wayanad has undergone major shift in its area, production and productivity over the past two and half decades.

A considerable decrease in the area under rice and increase in the area under arecanut, coconut, rubber and banana is observed during 1990-2015. The production of major crops had undergone considerable variation over time. Crops such as rubber, coffee, banana, arecanut and tea showed an increase in production and crops such as pepper, rice and ginger showed a decreasing trend in production during the past two and half decades in Wayanad. This was in agreement with Jose and Padmanabhan (2016) that reported conversion of extensive areas of paddy fields and other wetlands to dry lands for growing cash crops which are less labour intensive and highly profitable as paddy cultivation became increasingly unprofitable. Mani (2004), noted a significant decrease in area under rice and increase in area under coconut and rubber and opined that farmers of Kerala were shifting the area under rice to coconut and rubber.

Chattopadhyay and Franke (2006) analysed the land use variations in Kerala and the shift in cropping pattern from rice and tapioca to coconut and rubber from 1957-58 to 1996-97. A clear shift from food crops (mainly rice and tapioca) in favour of tree crops (mainly rubber and coconut) was noticed. It was found that while rice lost the maximum area, rubber gained the maximum area. The overall process of land use changes was mentioned as: coconut replaces rice in the lowland and upland valleys, rubber replaces coconut in the upland valleys, tapioca replaces rice in the valleys, rubber replaces tapioca and coconut in the midlands and highlands and rubber replaces wastelands and natural vegetation in the foothills.

5.2 CHANGES IN CLIMATE VARIABLES

A decreasing trend in the amount of rainfall and increasing trend of temperature is noticed in the district during 1991-2015. Monsoon rainfall across the district is found to be decreasing since years, while there is an increase in temperature. Also, there is a delay in the onset of monsoon and an advance in the offset of monsoon in Wayanad for the past two and half decades.

Mini *et al.* (2017) analysed 146 years of rainfall data and concluded that the temperature of an area is affected directly by any variation in the rainfall and its characteristics and number of rainy days and it may effect the climate system as a whole. She also confirmed that there is significant decrease (10.9mm in 10 years) in southwest monsoon rainfall while increase (7.5 mm in 10 years) in post monsoon season rainfall. With respect to temperature, AR5 of Intergovernmental Panel on Climate Change (IPCC, 2014), point out that warming of the climate system is unequivocal.

Semi–structured interview explored questions on how temperature, precipitation, mist, humidity, solar insolation, wind speed and other weather parameters changed over time in Wayanad. Farmers provided numerous information on the changes in climate variables that they have experienced over years such as the increase in temperature, decrease in precipitation, changes in rainfall pattern, occurrence of erratic rainfall, disappearance of fog and mist and so on. They also said that the foggy days of the past are no more. There used to be a time when the farmers go out to the fields early in the morning and complete the day's work by noon because the cold would hit in around four in the afternoon and that they sit around a fire at that time. Now, there is no trace of mist and nip in the air. Also, changing climate in the area has resulted in the shift of harvests during the season from three to one or two.

According to Kumar and Srinath (2012), climate change is usual to bring about gradual changes such as the shift of climatic zones, increased temperature and changes in precipitation patterns along with increase in the frequency and magnitude of extreme weather events such as droughts, floods, and storms. A likely impact of climate change is also greater climate variability. Livelihoods of Wayanad are under the threat of existing climate variability in the form of drought and floods and climate change might upsurge jeopardies manifold.

5.3 DRIVERS OF CHANGES IN AGROFORESTRY SYSTEMS

Farmers provided numerous explanations for the changes in agroforestry systems in the area. Data collected from the semi structured interview and qualitative survey shows that there is a gradual shift from food crops to cash crops. Most common causes for the decline in agriculture in the district were market driven shift, adaptive strategy of farmers to maximize the profits on context of challenges, climate variability experienced in the region and booming expansion of tourism industry in recent times especially in those areas where agriculture production is not profitable. This was in conformity with the study of Fox *et al.* (2017) that reported the drivers of change in agricultural land use as changing weather and climate, decreased access to labour, declining profit margins, poor access to pesticides and fertilizers, increased problems with pests and disease, a stigma against agriculture and construction competing for land use.

Thomas (1999) conducted a detailed investigation of changes in the cropping pattern in Kerala 1990's. The study found that the main reasons for the transformation of land from cultivating food crops to other purposes were low growth rate in the price of rice, low price of land under food crops, migration of people to urban areas, shortage of farm labourers and rapid increase in their wages.

Factor analysis technique was used to understand the correlation structure of shift in agroforestry systems and identify the most important factors contributing to the structure during the study period 1990-2016 and three sub periods of the study period such as 1990-2000, 2000-2010 and 2010 onwards. It was found that four principle components were driving the changes in cropping pattern of the area which were found to be the market driven shift in agricultural practices, adaptive agriculture management strategy adopted by the stakeholders, impact of climate change on crops that led to outbreak of pest and diseases and thus decrease in productivity and the booming expansion of tourism industry in recent times especially in those areas where agriculture production is not profitable.

According to Karunakaran (2011), since 1960 the statistical profile of Kerala agriculture clearly established the changes of cropping pattern in the state. The changes in the cropping pattern were mainly based upon the farmer's decisions in Kerala. Agro climatic conditions, cost of cultivation, price levels, soil fertility, irrigation facilities, profitability, labour availability, mechanisation, and so on are major factors which encouraged the farmers to allocate their land for agricultural purposes such as selection of crops to cultivate, area to allocate and for non-agricultural purposes.

Farmers in the study area revealed that the output of rice was decreased due to unavailability of water. Climate has played a major role in shift in productivity of crops and cropping patterns of a region. Traditional monsoon and Njattuvela have been changed in recent time. The production of pepper was considerably decreased due to this change from 2000 onwards. This was further accelerated with the attack of pests and diseases. Like pepper, arecanut and coconut also faced threat of disease in Wayanad. Before 1990s, Wayanad was characterized by homestead farming and plantations. Paddy based cropping system involved paddy and vegetables. The upland area adjoining with wetlands is characterized by coffee – based cropping system; involving coffee, pepper and so on along with many trees. Paddy wetlands are now converted into fields of arecanut, coconut, banana, tapioca and so on. Coffee and pepper is also grown along with rubber.

Climate change has very significant influence on pepper and rice production. Before 1990s, climatic condition was very much suitable for coffee and pepper but not for rubber (it need hot climate). People preferred pepper as a permanent source of income because of certain limitations in the marketing of coffee. Before 1990s pepper was trailed on native tree *Erythrina indica*. After 1995, severe dryness combined with disease has decreased production of pepper and complete loss of *Erythrina indica*. Increasing price of certain crops and high demand of certain crops has also significant effect on cropping pattern of a region. This has encouraged farmers to grow more of such crops such as vanilla, rubber and cashew.

With respect to panchayaths, Panamaram and Sulthan Bathery showed huge decline in rice fields leading to nearly zero percent by 2017, whereas, there was an increase in the percentage contribution of arecanut, coconut and banana. Most of the paddy land is converted for planting banana, coconut and arecanut because of the less investment for arecanut, coconut and banana. Absence of labour and high labour wage are also influencing the changing pattern of cropping systems.

5.4 CROPS AND CLIMATE

According to Rao (2017), decline in cropped area, production, productivity, quality of crop produce and food price could be seen as the threat from global warming and climate change. There was a time when oranges were in plenty in Wayanad and is now completely disappeared. Most of the paddy lands in Wayanad is now converted into arecanut and banana gardens.

Agriculture in Wayanad is heavily dependent on climate. Major crop of Wayanad is Paddy. Rice can be cultivated under a variety of climatic and soil conditions. Rice cultivation is conditioned by temperature parameters at the different phases of growth. The critical mean temperature for flowering and fertilization ranges from 16 to 20^0C, whereas, during ripening, the range is from 18 to 32°C. Temperature beyond 35^0C affects grain filling. Unlike other parts of Kerala, Wayanad has two paddy seasons, namely Nancha (July-Nov, Dec) and Puncha (Dec, Jan-May). Over the past two and half decades the production of rice in Wayanad showed a decreasing trend with the lowest production of 11738 tons in 1992. Rainfall variability along with other considerations such as lack of water availability due to increase in runoff and reduced groundwater recharge, forced farmers to transform rice fields to other profitable crops.

The second major crop of Wayanad is Pepper. The area under cultivation of pepper in the district has reduced from 30,543 ha to 12,498 ha since 1990's bringing down its production from 10,950 tons to 6,593 tons. In 1994, there was a sudden decline in the production of pepper to 39,814 tons preceded and followed by 12,290 tons in 1993 and 22,385 tons in 1995. Major causes for this reduced yield is found to be pest attacks and diseases. Also, Climatic factors further foster faster multiplication of Phytophthora, which attacks the fibrous root of pepper vine causing the quick wilt disease in pepper. Pepper requires a warm and humid climate. Long normal rainy season and fairly high temperatures with partial shade are best for its growth. It is the distribution pattern of monsoon rainfall and its timely occurrence that determines the yield of Pepper. During 1990s, there were heavy incidence of disease and pest attack due to varying soil temperature and excessive rainfall increasing the soil acidity due to leaching of calcium and magnesium components in the soil which in turn killed the favorable microbes in the soil.

Coffee, which is the primary crop of Wayanad remained almost steady in its area during 1991-2016 whereas its production showed an overall increasing trend. Highest production of 58,500 tons was recorded in the year 2000. After that till 2007, the production of coffee was on a lean with slight increase in 2003 and 2005. From 2007 to 2011 showed an increase in the trend. From 2011, the production remained almost constant.

In general, coffee needs an annual rainfall of 1500-3000 mm and it is the most important weather element influencing flowering and yield of coffee. The growth of coffee is affected when exposed and hence it requires certain degree of shade. It is a tropical plant where temperature, rainfall, sunlight, wind and soil are important for its ideal growth with slight variation according to the variety. Arabica is more sensitive to weather than Robusta. Average temperature of 15 to 24°C is ideal for Arabica and 24 to 30°C for Robusta. The agro-climatic changes in the area is found to cause leaf rust disease in the crop. Even though the area under Coffee in Wayanad remains steady, increase in production as well as productivity is observed. This is due to the influence of blossom and backing showers. In recent years, early maturity of crops and decline in berry weight is noticed. This is attributed to global warming and climate change. Blossom showers of 20-40 mm is ideal for the flower buds and backing showers of 5075 mm for fruit development and retention. Any failure in this lead to poor yield.

In case of coffee, highest production of 58,500 tons was recorded in the year 2000 and lowest production of 16,730 tons was recorded in the year 1991. There was not much variations in the area under coffee cultivation, but an increase both in production as well as its productivity. In 1991, absence of rain in March might have resulted in decreased production, since blossom showers are very important in coffee. This is similar to the finding of Rao *et al.* (2017) that the productivity of coffee increased in recent decades though inter annual variation in coffee production is significant due to blossom and backing showers.

During 1991-2015, both area as well as the production of arecanut in Wayanad showed a linear positive trend. Area under cultivation of arecanut increased from 1,396 ha in 1991 to 13,461 ha in 2015. Likewise the production which was 343 tons in 1991 raised to 7,428 tons in 2015 which was the highest recorded value. From 1991 till 2005, the trend in production was on increase which then declined for the next two years and then again increasing till 2010. The lowest of the production over the last ten years was recorded in the year 2013 with 3,985 tons followed by an increase.

The rice fields and other wetlands in the district are converted into arecanut and banana plantations. Many of the arecanut gardens were adversely affected by yellowing due to heavy monsoon rains which led to waterlogging. Floods in August/September 2014 across Wayanad district adversely affected rice and arecanut fields. Yellowing in arecanut devastated large number of palms in Wayanad district in 2014 (Rao, 2017).

Production of cardamom showed a consistent increase from 163 tons in 1991 to 660 tons in 2015 whereas the area under cultivation of cardamom remained steady during 1991-2016. Cardamom grows well at an optimum temperature of 10 -35°C and rainfall of 1500-4000 mm. Cardamom production is highly dependent on the availability of showers. The important physiological stages such as panicle initiation and subsequent growth is dependent on receipt of showers from January to May. Any failure in this lead to poor growth and yield. There is a close relationship between cardamom production and rainfall distribution during summer. Production of cardamom was recorded highest in the year 2014 with 690 tones when there was a temperature of 23°C and rainfall of 3307 mm.

Climatic conditions for the optimum growth of ginger include temperature of 25 -32°C and rainfall of 1500- 3000 mm. Production of ginger was on a decreasing trend over the past 25 years. Highest production of ginger over the last two and half decades was recorded in the year 2005(38,823 tons) and lowest in 2015(9,959 tons).

The production of coconut increased slightly during the study period whereas there was a noticeable increase in the trend of area under cultivation of coconut from 1991-2015. Temperature optimum for coconut production is 27°C and rainfall is 1300-2300 mm. Temperature and rainfall conditions optimum for the growth of cocoa are 10- 38°C and 1000- 1500 mm. A linear constant trend was noticed in the production and area under cultivation of cocoa over the last 25 years in Wayanad.

During the past two and half decades there was an increasing trend, in both area and production of Banana in Wayanad. During the initial years of the study, area under cultivation of banana were 1396 ha with a production of 21,658 tons which further increased to 9739 ha with a production of 92,295 tons. From 1991 till 2005, the production was consistently increasing reaching 1,15,160 tons and then followed by a decrease in trend for the next three years. Similarly, 2008 – 2011 marked another increasing trend followed by decrease in the following years. Banana grows optimum at a temperature of 27°C (25-32°C) and a rainfall of 1500- 3000 mm.

Rubber tree grows optimum only when a rainfall of 2000 to 3000 mm is evenly distributed without any marked dry season and with 125 to 150 rainy days per annum is received. A maximum temperature of about 29°C to 34°C and minimum of about 20°C or more with a monthly mean of 25 to 28°C is also essential.

From 1990s, the area, production and productivity of rubber have been increasing in Wayanad. Rubber production shoot up to 2,426 tons in 1991 to 6,206 tons in 2015. Likewise area under rubber cultivation expanded from 5,177 ha in 1991 to 10,790 ha in 2015, which is almost twice the area in the initial years of the study. Growth and productivity of rubber is often affected by the climate change in the form of climate variability, such as unpredictable, irregular and deficient rainfall pattern. Fungal infection of leaves usually triggered by changes in rainfall pattern adversely affects the productivity.

The rubber board has once declared Wayanad is not suited for rubber cultivation, since it requires hot climate. But over the past two and half decades there was tremendous increase in area, production and productivity of rubber in Wayanad indicating the climatic conditions of Wayanad has changed over years in favour of hot and dry conditions.

5.5 AGRO-ENTREPRENEURIAL MIGRATION

Out migration of farmers from Wayanad was also addressed at different time periods such as 1990-2000, 2000-2010 and 2010 onwards. It was noticed that since 1990s both sectorial as well as geographical migration has occurred in the study area. For each of the 120 home gardens visited, questions such as "Is there any agro entrepreneurial migration (both geographical and sectorial)?", if yes, "what were the reasons for the migration in and out of the district?" were addressed. It was noted that 2000-2010 period witnessed intense migration than the period before and after. Out of 120 respondents, 13 were forced to migrate to nearby states of Karnataka and Tamilnadu during 1990-2000. Later on, in 2000-2010 number of respondents migrated raised to 19 followed by a decrease to 6 after 2010. All these migration were either sectorial, geographical or both. The prominent reason for migration was found to be raising agriculture in places such as Coorg and Shimoga of nearby state of Karnataka because of better availability of resources, less cost of cultivation in those areas, suitable climate for growing certain crops, high returns and better policies available in those areas.

According to Lambin *et al.* (2003) migration in its various forms is the most important demographic feature affecting land-use change at timescales of a couple of decades. The semi structured interview conducted among the households of the study area highlighted the outmigration of farmers since 1990s from Wayanad both sectorially and geographically. States such as Tamil Nadu and Karnataka witnessed intense immigration of farmers to the districts of Kodaku, Shimoga and so on from Wayanad for cultivation of ginger in early 2000s and now banana as well as ginger because of several reasons such as better availability of land and water resources, less cost of cultivation in those areas, favorable climatic conditions, high returns and better policies available for promoting agricultural activities.

This was in conformity to the study of Srinath and Kumar (2012), that in Wayanad, an agro-entrepreneurial outmigration of ginger farmers was observed in the late 2000s. The study found that In the late 2000s, enterprising ginger cultivators from Wayanad and other parts of Kerala responded to the uncertainty and variability in climate by taking land on lease in the neighbouring state of Karnataka (and to a lesser extent, Tamil Nadu) to cultivate ginger there.

To move out of poverty within their own communities, many individuals and families migrate from rural areas for monetary reasons as they see no possible option. Migration is part of the process of development. War, risky weather events and political instability are among the core causes of migration. The movement of people in search of better employment openings within and across countries is unavoidable, as economies suffer structural transformation. Migrants can be agents of development, contribute to economic growth and improve food security and rural livelihoods (FAO, 2016).

According to Jose and Padmanabhan (2016), migration's effect on land-use change in Wayanad can be divided into two sub-categories. First, is the seasonal migration of agricultural skilled labour to bordering areas such as Kodagu district in Karnataka for the cultivation of ginger (Steur, 2011) and second, is the movement of the younger generation of landowners to other southern districts of Kerala and to Gulf countries for better employment opportunities (Kannan and Hari, 2002).

SUMMARY AND CONCLUSION

CHAPTER 6
SUMMARY AND CONCLUSION

A study was carried out in the high range landscapes of Kerala to determine the impact of climate change on agroforestry systems. The objectives of the study included, studying the shift in patterns of high range landscapes on a temporal scale, assessing the drivers of change in agroforestry systems of high range landscapes, analyzing the changes in climate variables in the study area and correlating the relationship between climate variables with agroforestry production and pattern systems over years.

In order to understand the changes in productions, patterns and processes of agricultural systems, both quantitative and qualitative data were used. The quantitative data such as area (in hectares) and production (in tonnes) of major crops over the past two and half decades were obtained from the Agricultural Statistics records of the Department of Economics and Statistics at the district headquarters in Wayanad. The qualitative data were obtained through systematic survey of the scientific literatures, and also by conducting one-to-one interview's with major stakeholders. Based on this, sampling sites were selected for the intensive survey. From each block, two panchayaths were selected after interacting with experts and other traditional farmers. 120 home gardens were randomly picked for the intensive survey on how agri and agroforestry practices were changed over the last couple of decades. Semi-structured interviews were conducted at the homes of respondents which were designed to elucidate land-use histories by comparing the primary crops produced on the homestead before 1990s, 1990-2000, 2000-2010 and after 2010. It sought primarily to explore the shift in patterns of agroforestry systems, the drivers of change in agroforestry systems and the changes in climate variables between 1990 and 2016. Climate data of the area over the past two and half decades were collected from different agencies to study the shift in climate variables in the study area. Factor analysis technique was used to understand the correlation structure of shift in agroforestry systems and identify the most important factors contributing to the structure during the study period 1990-2016.

The salient findings are summarized as:

Agroforestry systems of high range landscapes, in particular Wayanad has undergone severe shift in its area, production and productivity over the past two and half decades.

A clear shift from food crops (mainly rice) in favour of tree crops (mainly rubber and coconut) was noticed.

Data collected from the semi structured interview shows that there is a gradual shift from food crops to cash crops. Most common causes for the decline in agriculture in the district were decrease in the productivity of certain crops, climate change, threat of diseases, absence of labours, increase in the market price of certain crops, increase in the demand of certain crops, less investment cost of certain crops, animal attack, overuse of chemical fertilizers and land conversions.

Factor analysis resulted that 71% of the changes in cropping pattern of the area is driven by four principle components which were found to be the market driven shift in agricultural practices (25.13%), adaptive agriculture management strategy adopted by the stakeholders (17.50%), impact of climate change on crops that led to outbreak of pest and diseases (14.81%) and the booming expansion of tourism industry (13.46%).

A decreasing trend in the amount of rainfall and increasing trend of temperature is noticed in the district during 1991-2016. Monsoon rainfall across the district is found to be decreasing since years, while there is an increase in temperature. Also, there is a

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delay in the onset of monsoon and an advance in the offset of monsoon in Wayanad for the past two and half decades.

There used to be a time when the farmers go out to the fields early in the morning and complete the day's work by noon because the cold would hit in around four in the afternoon and that they sit around a fire at that time. Now, there is no trace of mist and nip in the air. Also, changing climate in the area has resulted in the shift of harvests during the season from three to one or two.

Farmers in the study area revealed that the output of rice was decreased due to unavailability of water and absence of labours. Climate has played a major role in shift in productivity of crops and cropping patterns of a region.

The rice fields and other wetlands in the district are converted into arecanut, coconut and banana plantations. Many of the arecanut gardens were adversely affected by yellowing due to heavy monsoon rains which led to waterlogging.

Even though the area under Coffee in Wayanad remains steady, increase in production as well as productivity is observed due to the influence of blossom and backing showers.

Climate change has very significant influence on pepper and rice production. Before 1990s, climatic condition was very much suitable for coffee and pepper but not for rubber (it need hot climate).

The rubber board has once declared Wayanad is not suited for rubber cultivation, since it requires hot climate. But over the past two and half decades there was tremendous increase in area, production and productivity of rubber in Wayanad indicating the climatic conditions of Wayanad has changed over years in favour of hot and dry conditions.

The semi structured interview conducted among the households of the study area highlighted the outmigration of farmers since 1990s from Wayanad both sectorially and geographically. States such as Tamil Nadu and Karnataka witnessed intense immigration of farmers to the districts of Kodaku, Shimoga and so on from Wayanad for cultivation of ginger in early 2000s and later on banana as well as ginger because of several reasons such as better availability of land and water resources, less cost of cultivation in those areas, favorable climatic conditions, high returns and better policies available for promoting agricultural activities.

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IMPACT OF CLIMATE CHANGE ON AGROFORESTRY SYSTEMS OF HIGH RANGE LANDSCAPES OF KERALA

by

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(2012 - 20 - 106)

ABSTRACT

Submitted in partial fulfilment of the requirements for the degree of

B.Sc. – M.Sc. (Integrated) Climate Change Adaptation

Faculty of Agriculture

Kerala Agricultural University

ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH

VELLANIKKARA, THRISSUR – 680 656

KERALA, INDIA

2017

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ABSTRACT

Much of rural India, has a majority of its livelihood directly dependent on climate and are highly vulnerable to climate variability, with climatic changes having profound direct and indirect impacts. Apart from the general climate-dependent nature of the economy, the small size of land-holdings of most farmers in high elevations and the large tribal population render the people and the livelihood of these areas highly vulnerable to climate change and variability. Climate change is projected to affect agricultural and natural ecosystems around the world, and there is no reason to expect that agroforestry systems will be spared. This study was done to identify the impact of climate change on agroforestry systems of high range landscapes of Kerala, in particular Wayanad.

In this study we employ mixed methods, including remote sensing, semi-structured interviews and statistical techniques to unravel the complex shift in agroforestry systems occurring in Wayanad. The study was done with the compilation of secondary literature on various agroforestry systems in the high range landscapes of Kerala followed by the selection of intensive study area and a detailed socio-economic survey among various stakeholders to understand the patterns, productions and processes of various agroforestry systems in the landscape and climate variables. The quantitative data such as area (in hectares) and production (in tonnes) of major crops over the past two and half decades were obtained from the Agricultural Statistics records of the Department of Economics and Statistics The *in situ* measured temperature and rainfall data were collected from India Meteorological Department and Regional Agricultural Research Station of the Kerala Agricultural University. Ordinary least square regression equations were fitted in the temperature and rainfall data to analyse the changes in trends. Monthly and annual changes were analyzed to assess the seasonal and overall shifts in rainfall and temperature. Factor analysis based on principal components was used to disentangle the impacts of various drivers in the shifts the agricultural patterns, productions, and processes.

The results showed that Wayanad has underwent major changes in the land use in the last two and half decades. Data from Economics and statistics department showed that, the area and production of crops such as arecanut, coconut, rubber and banana increased considerably whereas the area and production of rice, ginger and pepper has declined over the last couple of decades.

Variables showed that monsoon rainfall across the district is found to be decreasing over the years, while there is an increase in temperature during the same period. Also, there is a delay in the onset of monsoon and an advance in the offset of monsoon in Wayanad during 1991-2015. The factor analysis indicated four principal components that drives the shifts in the agricultural practices. The first factor explained 25% of the variation, attributed to the market driven shift in agricultural practices . The second principal component explained 18% of the variation driven by the adaptive management strategies of the farmers to maximize the profits on context of absence of labors and less investment and production cost for new crops. The third factor contributed 15% in the overall shift in agricultural practices, and it was driven by the changes in climate. The fourth component was responsible for a shift of 13% in the agricultural practices driven by the expansion of tourism industry in recent times. The study also indicated the out-migration of farmers since 1990s from Wayanad to nearby regions where similar climatic conditions exists in search of better availability of land and water resources, and less cost of cultivation among others.

The study conclude that there are changes in pattern, production and processes of agroforestry systems of high range landscapes of Kerala, particularly in Wayanad, and climate change contribute 15% of the shift in agricultural practices. The present study contribute to our existing knowledge on the effect of climate change on crop production and agricultural dynamics, and sheds light into the programs related to the agro-forestry based climate change mitigation where climate variability and other factors need to be accounted before making policy decisions that aimed to mitigate the impact of climate change by means of agroforestry systems.

APPENDIX I

KERALA AGRICULTURAL UNIVERSITY

ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH

&

KERALA FOREST RESEARCH INSTITUTE

GIS AND REMOTE SENSING DEPARTMENT

QUESTIONNAIRE ON AGROFORESTRY AND CLIMATE SYSTEM DYNAMICS IN WAYANAD DISTRICT

Instructions

1. Introduce yourself.
2. Explain why we are doing this research.
3. Explain the objective of the study.
4. Explain the outcome of the study.
5. Explain the guarantees of anonymity and confidentiality.
6. Ask for consent to conduct the interview.

I. Basic Information

Date:	
Questionnaire No:	
Name of the Surveyor:	Ms. Anjaly George
Area:	
Panchayath:	
Block:	
GPS Location:	

II. Individual Details:

Name of Respondent:	
Age:	
Address:	

Education of the Respondent:	
Occupation of the Respondent:	
Family Size:	

Members of the family:

Grandfather	Grandmother	Father	Mother	Children	Others

III. Introductory questions

1. Are you a native of Wayanad?

Native ☐ Migrant ☐

If migrant, where do you originally belong?

2. When did you arrive here and what was the reason for migration?

Year / Period:

Specify reasons:

i. In search of more agriculture lands
ii. In search of business opportunities
iii. As a result of displacement from developmental activities
iv. To escape from famine, and poverty
v. To avoid communal and social unrest
vi. Any other reasons?

2. How much land did you own/acquire when you came here, and what was the price of land per acre?

3. What was the land use/land cover at the time of your arrival here (in percentage)?

☐ Forest

- ☐ Agriculture
- ☐ Open and fallow lands
- ☐ Any other land types

4. If agriculture, what were the major crops grown (in percentage)?

Sl.No	Crops	% contribution	Approx. Productivity / acre
1	Paddy		
2	Banana		
3	Pepper		
4	Coffee		
5	Tea		
6	Tapioca		
7	Elephant Foot Yam		
8	Colocassia		
9	Yam		
10	Coconut		
11	Arecanut		
12	Rubber		
13	Ginger		
14	Turmeric		
15	Galanga (Kacholam)		
16	Cardamom		
17	Vegetables		
18	Others		

5. Have you observed any major changes in the agricultural pattern before 1990's?

IV. Repetitive Questions

(Now we are going to ask how patterns of agriculture changed over years, and whether climate change is a reason for change. Starting with 1990s and repeated in every five years. Please choose starting year based on the questions in III. Introductory Questions)

1. 1990-2000 Period

1.1 What were the major crops cultivated during 1990-2000? Have you introduced any new crops or changed into any other crops?

Sl.No	Crops	% contribution	Approx. Productivity / acre
1	Paddy		
2	Banana		
3	Pepper		
4	Coffee		
5	Tea		
6	Tapioca		
7	Elephant Foot Yam		
8	Colocassia		
9	Yam		
10	Coconut		
11	Arecanut		
12	Rubber		
13	Ginger		
14	Turmeric		
15	Galanga (Kacholam)		
16	Cardamom		
17	Vegetables		
18	Others		

1.2 What were the major changes in the cropping patterns?

1.3 If there were changes,what were the reasons for changes (Rank if required)?

i. The productivity of the crops decreased (specify the crop).
ii. The price of the certain crops increased.
iii. There was a high demand for certain crops.
iv. The investment cost for the new crops was less.
v. Absence of labours for certain crops.

vi. Market accessibility increased.
vii. Government programs (eg:subsidies) & promotions were higher for certain crops.
viii. The crops were under the threat of diseases.
ix. Climate has changed and the crop was not suitable to be cultivated in that climate.
x. Any other reasons?

1.4 Have you experienced any of the following during this period?

- ☐ Increase in Temperature
- ☐ Decrease in Temperature
- ☐ Increase in Rainfall
- ☐ Decrease in Rainfall
- ☐ Increase of Mist
- ☐ Decrease of Mist
- ☐ Changes in rainfall pattern(Advanced rainfall)
- ☐ Changes in rainfall pattern(Delayed rainfall)
- ☐ Increase in atmospheric moisture(Humidity)
- ☐ Decrease in atmospheric moisture(Humidity)
- ☐ Increase in dry periods
- ☐ Decrease in dry periods
- ☐ Increase in solar insolation
- ☐ Decrease in solar insolation
- ☐ Increase in wind speed
- ☐ Decrease in wind speed

1.5 Have you experienced any migration during this period?

Yes ☐ No ☐

1.6 Was it a sectorial or geographical migration?

- ☐ Sectorial
- ☐ Geographical

1.7 In case of sectorial migration, what was the preferred sector?

- ☐ Agriculture
- ☐ Working as labour on daily wages
- ☐ Government and Non-governmental fixed income salary
- ☐ Business

☐ Others (specify)

1.8 In case of geographical migration, what were the preferred destinations?

☐ Nearby Panchayaths
☐ Nearby Districts
☐ Other states (Karnataka, Maharashtra, Goa, Tamil Nadu etc…)
☐ Other countries (Malaysia, Indonesia, Philippines)

1.9 What were the reasons for geographical migration?

☐ Less cost of cultivation
☐ Better availability of resources
☐ Suitable climate
☐ Better policies
☐ High returns
☐ Others

2. 2000-2010 Period

2.1 What were the major crops cultivated during 2000-2010? Have you introduced any new crops or changed into any other crops?

Sl.No	Crops	% contribution	Approx. Productivity / acre
1	Paddy		
2	Banana		
3	Pepper		
4	Coffee		
5	Tea		
6	Tapioca		
7	Elephant Foot Yam		
8	Colocassia		
9	Yam		
10	Coconut		
11	Arecanut		
12	Rubber		
13	Ginger		
14	Turmeric		
15	Galanga (Kacholam)		
16	Cardamom		
17	Vegetables		
18	Others		

2.2 What were the major changes in the cropping patterns?

2.3 If there were changes,what were the reasons for changes (Rank if required)?

i. The productivity of the crops decreased (specify the crop).
ii. The price of the certain crops increased.
iii. There was a high demand for certain crops.
iv. The investment cost for the new crops was less.
v. Absence of labours for certain crops.
vi. Market accessibility increased.
vii. Government programs (eg:subsidies) & promotions were higher for certain crops.
viii. The crops were under the threat of diseases.
ix. Climate has changed and the crop was not suitable to be cultivated in that climate.
x. Any other reasons?

2.4 Have you experienced any of the following during this period?

- ☐ Increase in Temperature
- ☐ Decrease in Temperature
- ☐ Increase in Rainfall
- ☐ Decrease in Rainfall
- ☐ Increase of Mist
- ☐ Decrease of Mist
- ☐ Changes in rainfall pattern(Advanced rainfall)
- ☐ Changes in rainfall pattern(Delayed rainfall)
- ☐ Increase in atmospheric moisture(Humidity)
- ☐ Decrease in atmospheric moisture(Humidity)
- ☐ Increase in dry periods
- ☐ Decrease in dry periods
- ☐ Increase in solar insolation
- ☐ Decrease in solar insolation
- ☐ Increase in wind speed
- ☐ Decrease in wind speed

2.5 Have you experienced any migration during this period?

Yes ☐ No ☐

2.6 Was it a sectorial or geographical migration?

- ☐ Sectorial
- ☐ Geographical

2.7 In case of sectorial migration, what was the preferred sector?

- ☐ Agriculture
- ☐ Working as labour on daily wages
- ☐ Government and Non-governmental fixed income salary
- ☐ Business
- ☐ Others (specify)

2.8 In case of geographical migration, what were the preferred destinations?

- ☐ Nearby Panchayaths
- ☐ Nearby Districts
- ☐ Other states (Karnataka, Maharashtra, Goa, Tamil Nadu etc…)
- ☐ Other countries (Malaysia, Indonesia, Philippines)

2.9 What were the reasons for geographical migration?

- ☐ Less cost of cultivation
- ☐ Better availability of resources
- ☐ Suitable climate
- ☐ Better policies
- ☐ High returns
- ☐ Others

3. 2010 Onwards

3.1 What were the major crops cultivated after 2010? Have you introduced any new crops or changed into any other crops?

Sl.No	Crops	% contribution	Approx. Productivity / acre
1	Paddy		
2	Banana		
3	Pepper		
4	Coffee		
5	Tea		
6	Tapioca		
7	Elephant Foot Yam		
8	Colocassia		
9	Yam		
10	Coconut		
11	Arecanut		
12	Rubber		
13	Ginger		
14	Turmeric		

15	Galanga (Kacholam)		
16	Cardamom		
17	Vegetables		
18	Others		

3.2 What were the major changes in the cropping patterns?

3.3 If there were changes,what were the reasons for changes (Rank if required)?

i. The productivity of the crops decreased(specify the crop).
ii. The price of the certain crops increased.
iii. There was a high demand for certain crops.
iv. The investment cost for the new crops was less.
v. Absence of labours for certain crops.
vi. Market accessibility increased.
vii. Government programs (eg:subsidies) & promotions were higher for certain crops.
viii. The crops were under the threat of diseases.
ix. Climate has changed and the crop was not suitable to be cultivated in that climate
x. Any other reasons?

3.4 Have you experienced any of the following during this period?

- ☐ Increase in Temperature
- ☐ Decrease in Temperature
- ☐ Increase in Rainfall
- ☐ Decrease in Rainfall
- ☐ Increase of Mist
- ☐ Decrease of Mist
- ☐ Changes in rainfall pattern(Advanced rainfall)
- ☐ Changes in rainfall pattern(Delayed rainfall)
- ☐ Increase in atmospheric moisture(Humidity)

- ☐ Decrease in atmospheric moisture(Humidity)
- ☐ Increase in dry periods
- ☐ Decrease in dry periods
- ☐ Increase in solar insolation
- ☐ Decrease in solar insolation
- ☐ Increase in wind speed
- ☐ Decrease in wind speed

3.5 Have you experienced any migration during this period?

Yes ☐ No ☐

3.6 Was it a sectorial or geographical migration?

- ☐ Sectorial
- ☐ Geographical

3.7 In case of sectorial migration, what was the preferred sector?

- ☐ Agriculture
- ☐ Working as labour on daily wages
- ☐ Government and Non-governmental fixed income salary
- ☐ Business
- ☐ Others (specify)

3.8 In case of geographical migration, what were the preferred destinations?

- ☐ Nearby Panchayaths
- ☐ Nearby Districts
- ☐ Other states (Karnataka, Maharashtra, Goa, Tamil Nadu etc…)
- ☐ Other countries (Malaysia, Indonesia, Philippines)

3.9 What were the reasons for geographical migration?

- ☐ Less cost of cultivation
- ☐ Better availability of resources
- ☐ Suitable climate
- ☐ Better policies
- ☐ High returns
- ☐ Others

V. Concluding Remarks

1. Do you like to add anything more to this questionnaire?

VI. Thanks