WEATHER EXTREMES PREPAREDNESS OF NUTMEG (*Myristica fragrans)* FARMERS IN KERALA

by

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(2015-20-018)

THESIS

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DECLARATION

I, Adharsh, C.J. (2015-20-018) hereby declare that this thesis entitled **"Weather extremes preparedness of nutmeg (*Myristica fragrans)* farmers in Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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EXTERNAL EXAMINER

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1. INTRODUCTION

Nutmeg (*Myristica fragrans*) is an important tree spice belonging to the family Myristicaceae. It is unique, as it produces two separate and distinct spices, the nutmeg and mace, among spice plants. Mace is the bright red webbing that surrounds the pit's shell, while nutmeg is the dried seed. The mace is removed, dried, and ground into a coarse red powder. Nutmeg can be dried, fresh, and processed for grating, or it can be dried and grated fresh. Between the two spices mace is more expensive. The spice is commonly used as a condiment, and in medicine too. In India, because of its strong medicinal properties, nutmeg and mace are more used as medicines than condiments. It is the commercial source for nutmeg butter and essential oil. Mace is commonly chewed to avoid foul breath (Pruthi, 1979).

In the food processing industry, the spice is used in ground form, particularly as a standard flavor in numerous dishes. Nutmeg is used as a medicine in various nations owing to its properties like stimulant, carminative, astringent and aphrodisiac effects. Grenada and Indonesia contribute around 80 percent of the world's nutmeg output while India, Malaysia, Papua New Guinea and Srilanka account the rest (Miniraj and Nybe, 2015).

Nutmeg, a native of the eastern Moluccas islands, was introduced to India and other tropical countries during the 18th century. The crop's shade-loving nature makes it suitable for intercropping in coconut plantations, and is commonly cultivated in homesteads of India. The total area under this crop was estimated to be 23,480 ha in India during 2018-19 with an output of 15,470 tons of which Kerala represents 96 and 94 percent area and production respectively. The area under nutmeg in Kerala grew from 6,950 ha in 2000-01 to 22,771 ha in 2018-19, while the production over the period increase to 14,598 tonnes from 1,731 tonnes (Spice board, 2019). The cultivation in the country is limited primarily to southern states like Kerala, Karnataka and Tamil Nadu. Among the districts in Kerala, Thrissur and

Ernakulam, together contribute around 60 and 65 percent respectively in area and production during 2018-19.

While the area and production in Kerala has showed considerable growth over the years, there has been a varying pattern of productivity. The key reason for low nutmeg productivity in Kerala was primarily due to low quality planting material and non-adoption of advanced production technologies (Thangaselvabai et al., 2011).

Indonesia holds the position of top exporter in 2016 with 19,957 tonnes, followed by Guatemala and India with 16,714 and 10,629 tonnes of nutmeg exported, respectively. India was the highest-valued nutmeg exporting country, with Indonesia and Guatemala coming in second and third, respectively. Indonesia and Guatemala received US$ 96672 thousand and US$ 95,505 thousand, respectively, while India received US$ 107,906 thousand. That means Indian nutmeg is more valuable than the rest of the world's nutmeg producers. It also means that Indian nutmeg can be of greater quality (Pakpahan et al., 2020).

Nutmeg needs a wet, humid climate with no extreme dry season. The soil should be well drained and rich in organic matter. It is grown and produces satisfactorily within 24-29°C annual temperature range with a humidity of 75-90 percent. With a dry period of 2-3 months, it can be successfully grown as a rainfed crop within the range of 1500-3000 mm. The tree takes preference for partial shade. Its best suited to sheltered valleys. With clay loam soils, sandy loam and red laterite with high humus content, it can be grown up to about 900 m above MSL regions is ideal for its production. Nutmeg doesn't like both dry and water-logged environments (Haldankar and Rangwala, 2009). Rising temperatures, reduced supply of irrigation water, floods, and salinity would be significant limiting factors in maintaining and increasing agricultural productivity. Extreme weather conditions would also have a negative impact on soil productivity and contribute to soil erosion. The response of plants to environmental stresses is determined by their developmental stage, as well as the duration and severity of the stress (Bray, 2002).

Similarly, plants can react to one or more stresses through morphological or biochemical mechanisms (Capiati et al., 2006).

As a shallow rooted crop, Nutmeg is susceptible to water logging, moisture stress and drought. The nutmeg crop will be badly affected if the dry spell continues for a long period until the onset of the monsoon in the first week of June. Irrigation is necessary if the delay of the monsoon is up to 30 days to avoid nut drops leading to a reduction in yield. Mulching can be provided in order to conserve moisture and thus avoid stresses on the palms during dry periods. In Thrissur and Ernakulam districts, heavy rainfall, lack of drainage in fields and inadequate space between plants aggravate the increased spread of dieback disease in nutmeg trees. Proper drainage is recommended during heavy rainfall (Ajithkumar et al., 2015).

Crop insurance policies in India need to be enhanced for better adaptation and called on the Indian government to consider crop insurance schemes as climate adaptation schemes immediately, with government guarantee coverage for all farmers in these schemes, improved crop loss monitoring systems, and timely payments covering the entire loss for farmers (Pande, 2018).

The impacts of climate change on the global biosphere are expressed in diverse ways and have an immense effect on the global agro-economy. The effects of climate change are felt most in the tropics because of its threats to biodiversity and human life. It is well known that rapidly changing climate places severe limits on tropical agricultural production affecting the well-being and survival of millions of small and marginal tropic farmers. Climate change causes many stressors and interacts with other stressors that are not triggered by the environment. In general, it is difficult to predict climate change outcomes other than certain current threats to agricultural growth, such as deforestation, pests and diseases, which are most likely to be intensified by changing climate (Field et al. 2007; USGCRP 2009).

Due to growing global warming, both by natural means and by human activity, the climate of the whole world is changing considerably. All the modifications have an immense effect on the people's lives and ecosystems. As a result, sea levels rise, floods, droughts, weather changes, summer season increases, winter season decreases, glaciers are melting, mortality rates are increasing, the number of illnesses is increasing, the ozone layer is decreasing, and so many other consequences. This affects the lives of humans, plants and animals, and has endangered many species.

With a hot summer and seasonally excessive rainfall, Kerala experiences tropical monsoons. Western ghats are the main reason for the state's prevailing climatic conditions. Kerala's main seasons viz., summer, Southwest monsoon, Northeast monsoon and winter season. The state is experiencing higher humidity due to the presence of the Arabian sea. Kerala economy depends solely on monsoon rainfall for its water needs but recently, due to climate change and the shift in monsoon wind pattern over the region, a large spread shift can be seen in rain spell. Continued rain in August 2018 and 19 caused severe damage to nutmeg farmers in Kerala, resulting in a sudden rise in water levels in rivers and other bodies of water. Kerala economy depends solely on monsoon rainfall for its water needs but recently, due to climate change and the shift in monsoon wind pattern over the region, a large spread shift can be seen in rain spell. According to data from the India Meteorological Department, Kerala recorded 2346.6 mm of rain from June 1 to August 19, 2018, compared to an estimated 1649.5 mm.

In international trade, dried nutmeg and mace are of considerable significance and are used in the preparation of their extractives and volatile oil. The pale-yellow essential oil obtained by steam distillation, which is a volatile fraction, is used as a flavoring essence and in perfumery. A prerequisite for long storage and better price is drying to optimum moisture level without losing the inherent qualities, particularly colour. Colour plays an important role in assessing the market value of mace and its scarlet red colour has been showed to be due to pigment lycopene (Gopalakrishnan et al., 1980). The quality of spices is highly dependent on drying and the content of moisture should be preserved between 10 and 12 percent for most spices for better storage (Pruthi and Krishnamurthy, 1985). Just one percent more than a critical level of humidity will affect mace quality. The temperature and time of exposure are the most important parameter in drying and this can vary with the end use of the product. The mace loses about 60 percent of its weight as moisture during drying (Gopalakrishnan, 1992). When the drying is delayed, mace is particularly prone to contamination with moulds and insects.

With the above background, the overall objective of the present thesis research was to analyse the weather extremes preparedness of nutmeg farmers in Thrissur and Ernakulam districts of Kerala.

The specific objectives of the study are

1) To analyse the crop weather relationship of nutmeg farming in Kerala
2) To study the socio-economic characteristics of nutmeg farmers
3) To study the behavioural pattern and strategies of nutmeg farmers for mitigating weather extreme conditions

2. REVIEW OF LITERATURE

The review of literature is a critical analysis and description of the literature in a specific field of study that aids in the justification of the methodology proposed for the study. In this chapter, an attempt has been made to review previous studies that are applicable to the current research, both in terms of objectives and methodology.

2.1 Influence of weather on nutmeg yield

2.2. Growth and harvesting studies on nutmeg

2.3 Socio-economic characteristics of farmers

2.4 Attitude, knowledge and adoption behaviour of farmers

2.5 Studies on impact of climate change on spice crops

2.6 Climate change adaptation and mitigation strategies of farmers

2.1 INFLUENCE OF WEATHER ON NUTMEG YIELD

A study by Marcelle (1995) showed that there were an estimated 400-450 thousand nutmeg trees in Grenada, with the majority assuming they were under 40 years of age, while the rest were over 100 years of age but productive. Except for a few isolated patches of pure nutmeg trees on a small plot of land, most fields are heavily intercropped, with varying numbers of trees planted per acre (Marcelle, 1995). Except for a few diseases of varying importance, the nutmeg tree in Grenada is free of serious insect pests (Cruickshank, 1973, as Marcelle cited, 1995). However, due to its shallow root system, its tree is easily uprooted or blown down by strong winds. The island's Hurricane reports show that 80 percent of the nutmeg tree population was damaged during hurricane Janet (Marcelle, 1995).

The geographical location in an area vulnerable to natural disasters such as hurricanes and floods adds to the susceptibility to the climate. Flood rains can wreak havoc on degraded hillside agricultural areas, causing widespread soil erosion, landslides, and other forms of mass movement (McGregor, 1995).

In addition, an Organization of Eastern Caribbean States (OECS, 2005) report showing hurricane Ivan destroyed 70 percent of trees (equivalent to 8,400 acres out of 12,000 acres) and left-wing hurricane Emily destroyed 11.6 acres out of 3,200 acres. The nature of the destruction ranged from trees were uprooted to mature nutmeg was lost and blooms were set.

We may recognize stresses and shocks associated with economic trade liberalization, as well as the effects of environmental hazards. A significant increase in extreme weather (particularly erratic periods of prolonged drought and heavy rainfall) is a potential indicator of climate change in the latter case. Agricultural exports and domestic food production have both been impacted by these forces across the country. The Caribbean region's small island developing states (SIDS) and their fragile agricultural sectors are especially vulnerable to global change (Deep-Ford and Rawlins, 2007).

In recent years, there has been an increase in the number of farmer suicides. Suicide is a multifaceted and dynamic phenomenon, so the risks are identified either in a neurobiological or socioeconomic sense. The former are predisposing factors that are internal to the individual, while the latter are precipitating factors that are external to the individual. Farmers commit suicide at a higher rate than non-farmers, reflecting a greater malaise in the economy. This agricultural crisis has two dimensions: an agrarian crisis that threatens the livelihoods of those who rely on agriculture, especially small and marginal farmers and landless agricultural laborers; and an agricultural development crisis manifested by declining productivity and decreasing profitability due to neglect in program design and implementation (Government of India, 2007). Mishra (2008) assessed the frequency of farmers' suicides in India has risen in recent years. The farmers are, according to him, price-takers in both the commodity and the input markets. Such a situation may result in higher production costs and lower export prices, resulting in lower profitability and crop yields.

The relationship of black pepper with weather parameters was studied by Srinivasan and Aipe (2011). For the six years from 1992-93 to 1997-98, weather variables such as maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, rainfall, evaporation, bright sunshine hours and wind speed data were taken along with the fresh black pepper spike yield. The fresh yield was strongly correlated with maximum relative humidity, rainfall, mean temperature, maximum temperature, bright sunshine hours, wind speed, minimum relative humidity, and finally evaporation, according to the regression results.

Krishnamurthy et al. (2011) collected the weather parameters and black pepper yield data. The trend analysis was carried for both. The production of black pepper showed a negative trend and a decreasing trend was showed by weather variables including rainfall and a positive trend was showed by temperature. The correlation analysis carried out between yield and weather variables found that there was more correlation between the minimum and maximum temperature than between rainfall and rainy days. The correlation between monthly rainfall and black pepper productivity showed the adverse effect of rainfall from December to January and the positive effect of rainfall from April to May.

In a period of global change, Barker (2012) studied at national and local scales of analysis, researchers looked at the environmental and developmental effects of climate change and economic globalization on Caribbean agriculture. Small-scale farming systems' ability to cope with and adapt to external changes, based on their traditional knowledge, is one area of focus. Economic change is rapidly affecting agricultural patterns in the insular Caribbean. Two elements, globalization and environmental change, are characteristic of global change.

Every year, disasters such as drought, hailstorm, heavy rain, flood, frost, cyclone, and other abiotic stresses that are listed as impacts of climate change impact various regions and provinces. High and low temperature regimes, as well as increased variability in rainfall, have posed a threat to agricultural production as a result of changing weather patterns caused by climate change (Eduardo et al., 2013, Malhotra and Srivastava, 2014).

Sangadji et al. (2015) outlined that the high rainfall, humidity and rainy days contribute to a lowering of the fruit collection, while the rise in air temperature and solar radiation raises the nutmeg collection. Multiple regression model is highly significant ($R^2 = 0.90$) for male sexual expression and significant ($R^2 = 0.82$) for female sexual expression only for Appangala. Bisexual mode of sexual expression at Kozhikode location was found to be significant ($R^2 = 0.85$).

Aarthi et al., (2018) studied the influence of weather parameters on the flowering pattern of nutmeg in Kerala and Karnataka states of India. The climatic variables play a significant role in nutmeg sex expression. The study population consists of 52 and 20 nutmeg trees randomly selected from Kozhikode and Appangala germplasm including male, female and monoecious species respectively. Between January to December 2015 the monthly flowering pattern and sex expression of individual trees was observed. The study, based on the phenological observations made, showed a prominent difference in nutmeg flowers sex expression at two locations throughout the month in one year. The male flowers were usually seen at two locations throughout the year, with differences in the time of their lean production. The peak female flower development was observed at Kozhikode in the month of September whereas it was in December and March at Appangala. The bisexual flowers were observed at Kozhikode in July and August, and at Appangala in June and November. There is thus a qualitative variation in nutmeg 's flowering pattern at both places. The possible reason for the variations in the flowering pattern of nutmeg male and female trees may be due to the presence of large quantities of reserved food, which in turn is used for fruit production, whereas for non-productive male trees, which receive similar cultural practices as female, there is a tendency for increased flowering. The regression model developed using multiple regression analysis emphasized that maximum and minimum temperatures had a significant impact on the production of male flower under Appangala conditions while minimum temperature and relative humidity played a significant role in the development of female flora. At Kozhikode, maximum temperature along with rainfall had a significant effect on the production of bisexual flora.

2.2 GROWTH AND HARVESTING STUDIES ON NUTMEG

A slow grower may be considered Nutmeg. Development continued for very long periods of between 60 and 80 years. The growth, vigour, productivity, sex of flowers, size, and shape of leaves varied greatly among plants. Flach (1966) found a strong correlation (r = + 0.05) between tree girth at 40 cm above ground level and fruit production. He observed a small difference between the females and the male trees in tree size.

According to Flach (1966) in Grenada, average yield of 1500 fruits per tree was showed at the best plantations. The production reached 700 kg of nutmeg and 140 kg of mace per annum in a new and adequately spaced plantation (the number of trees per hectare = 100 females).

According to Flach and Cruickshank (1969), a good growing plantation in New Guinea reached an average height of three metres in four years and a girth of 15.7 cm above ground level at 40 cm in height.

Two distinct production peaks occur in Grenada: January-April and September-October (Cruickshank, 1973). Shanmughavelu and Rao (1977) claimed that a 10-year-old tree could yield between 500 and 800 fruits, and a 20-year-old tree, between 2000 and 3000 fruits in India.

Nazeem (1979) studied the growth, flowering, fruit set and fruit development in nutmeg. This study showed that during September, followed by May and June, maximum shoot growth and during July, followed by October, maximum flowering occurs. The total number of days between the bud emergence and the flower opening was 154. New flushes had begun on the same shoot by the time the flower opened. A month after flowering, the fruiting begins. Fruit development was found to steadily increase from the second week after the set. During the time between week six and sixteenth, the growth was faster. After fruit set, the fruits begin to split in 206 to 237 days. The peak harvesting month is July and the harvesting season is from June to August.

According to Marcelle (1995), production can begin in 5-8 years, gradually increase to 25-30 years, peak at 70 years, and then decline. A good growing tree on Grenada can produce 30-50 lbs (14-22 kg) of green nutmegs per year (15-25 lbs or 7-11 kg of shelled, dry nutmegs).

The study by McCarthy (2000) showed nutmeg starts fruiting at 7-10 years of age, and increases production for around 25 years, its peak. Also important for perennial crops are age of trees and number of trees per acre, because yield depends on age of the tree. After 7-10 years, nutmeg starts to bear fruit, increases production for about 25 years, and then retains this rate twice a year until 65-70 years.

Upon splitting, the fruits may be collected from the tree, but more commonly they are gathered once in a few days upon falling on the ground. If it is permitted to lie on the ground for several days, the kernel's underside can become dark and discoloured, raising the risk of mouldiness. Nutmeg loses about 25 percent of the weight during drying (Koshy, 2003).

When a seedling tree is five to eight years old it starts to bear fruit. Yield rises steadily with the plant's age up to 15 years or more, and goes on for 30 to 40 years and there after it stabilizes. The fruit matures in around six to nine months after flowering, usually with two peaks of fruiting per annum, although some fruits also mature. Harvesting starts in June and continues till August. When the pericarp splits open the fruits are ripe and ready for harvest. Usually harvesting is achieved via a knife attached to a stick known as a bill hook. Individual fruits weigh an average of 60 g, of which the seed weighs (6-7 g), mace weighs (3-5 g), and pericarp is the rest (Mathew, 2008).

Climate change and its instability present the major challenges affecting agricultural production including annual and perennial horticultural crops. A short growing period, which will have a negative impact on growth and development due, in particular, to terminal heat stress and reduced water availability, is likely to cause a reduction in fruit and vegetable production. Rainfed agriculture would be affected the most as a result of rainfall fluctuations and a decrease in the number of rainy days (Venkateswarlu and Shanker, 2012).

Aarthi et al. (2015) investigated the floral diversity in monoecious type nutmeg, which revealed three types of flowers: staminate, pistillate, and hermaphrodite flowers. These three flower types, including cymes and solitary flowers on the same tree, are borne on the leaf axil. In the population surveyed, the incidence in monoecious tree of hermaphrodite flower ranged from 0 percent to 10 percent.

2.3 SOCIO-ECONOMIC CHARACTERISTICS OF FARMERS

Vijayakumar and Gowda (1998) observed that education encourages a better perception and understanding of technical information by a person, and it is also likely that educated farmers will have a knowledge fund that will allow them to acquire all relevant information.

Rai and Srivastava (2001) stated that the majority of large-scale farmers were in the younger age group and had a high degree of socio-personal status, education, family size, socio-economic status, attitude, risk orientation and innovation, whereas the majority of small-scale farmers were approximately socio-personal in the older age group.

Madhava and Surendran (2016) conducted a field survey in two districts to identify the major factors influencing farmers' adoption of drip irrigation and draw conclusions that will aid in the development of policies and institutional initiatives to encourage adoption. The findings showed that farmers' adoption index is higher in Kozhikode compared to the district of Thrissur. Nevertheless, the adoption index is not statistically relevant with respect to the different crops. Farmers' adoption index for drip irrigation is positively influenced by socioeconomic factors such as age, education, experience, land holding size, and so on. Farmers have increased yields by 13 to 47 percent when using drip irrigation instead of surface irrigation for arecanut, coconut, and nutmeg. High productivity and income from cultivating crops such as coconut, arecanut, and nutmeg have created an opportunity for farmers in Kozhikode and Thrissur to use the costly drip irrigation system.

2.4 ATTITUDE, KNOWLEDGE AND ADOPTION BEHAVIOUR OF FARMERS

Poor farmers need to be aware of climate change adaptation strategies because failure to do so could result in social problems and displacement (Downing et al., 1997).

According to Maddison (2007), perceiving change and then determining whether or not to implement a specific measure is mechanism in adaptation to climate change. As a response to perceived changes in weather conditions, farmers tend to adopt new variety of measures or innovations whenever they have the opportunity. Help from extension workers, knowledge acquired, and available technology can greatly influence their capacity to adapt and respond. Farmers, for example, use water conservation methods if the patterns of rainfall change and the amount of rain decreases. They prefer to plant various types of crops and use short-term crops with planting dates changed. Such modifications are made as they observe rainfall decreases and shifts in the onset and offset of rainy seasons.

To tackle climate change concerns effectively, knowledge and perception of climate change by local communities or farmers is a deciding factor. Climate change is seen by farmers as having a powerful moral, mental, and physical aspect (Apata et al., 2009).

Understanding the concerns of farmers and the way they perceive climate change is critical for having effective policies to promote positive agricultural sector adaptation. As a result, accurate knowledge of the existence and scope of the adaptation methods used by farmers, as well as the need for further improvement in existing adaptation setups, is also needed. Understanding how farmers view climate change and what factors influence their adaptive behavior is therefore significant (Mertz et al., 2009; Weber, 2010).

Benedicta et al., (2010)'s study showed Farmers are aware of climate change, but few seem to be taking effective measures to change their farming practices. According to Temesgen et al., (2011), the majority of farmers have been able to realize that temperatures have risen and the amount of rainfall has been decreased, but few farmers' lack the knowledge of change in their area's climatic situation to take measures to modify their farming activities. Farmers' understanding of climate change is often influenced by its effect on their wellbeing, as well as their social, institutional, and economic circumstances. It varies and is primarily determined by its educational level, livelihood activity, geographic location, and age.

Perceiving climate change is the first step in agricultural climate change adaptation (Temesgen et al., 2011).

Jodha et al., (2012) concentrated on the adaptation strategies of farmers in arid and semi-arid regions of India against climate variability. Farmers' attitudes and coping mechanisms are primarily affected by factors at the village level, which are influenced by weather conditions. The paper is based on a synthesis of village, farm, and plot level data gathered over nearly three decades by various studies in India's arid and semi-arid regions. This paper examines possible climate change adaptation approaches and interventions in the agricultural sector of India's arid and semi-arid tropical regions. According to the Intergovernmental Panel on Climate Change (IPCC, 2007) these are likely to have very significant climate change consequences around the globe. Vulnerabilities were discovered through a combination of studies in various dry region areas that looked at behavioural responses to severe climatic events (such as droughts and floods) as well as daily interactions (repeated revisits) with farmers. Data on long-term farm and village levels could be used to understand perception-related elements of adaptation / adjustment strategies for farmers in India's dry tropical regions facing drought and uncertainty. This will help in determining the role of farmers' attitudes in influencing their adaptation strategies. As a result, this paper discusses a range of possible solutions and options for promoting climate change adaptation strategies in India's drylands. The attention is on the primary issues that are central to dryland agriculture, such as crop technology, natural resource management, and rural development projects that include community-based and infrastructure-related programs. Interventions and options that resolve these concerns have the potential to greatly assist dryland farmers in dealing with the negative consequences of climate change.

Abid et al. (2015) examined farmers' perspectives on climate change and adaptation strategies, as well as their determinants, in Pakistan's Punjab province. The findings revealed that climate change is well-understood in the area, and that farm households are making adjustments to adapt their agriculture to the climate changes.

Minwuye (2017) researched how farmers view and respond to climate change strategies. The aim of this study is to look into farmers' perceptions of climate change and their adaptation strategies in Ethiopia's Woreillu district. Data collected from primary and secondary sources, both qualitative and quantitative. The quantitative data was gathered through five focus group discussions, while the primary data was gathered through interviews with 155 randomly selected respondents. For the period 1993-2016, secondary temperature and rainfall data were obtained from the National Meteorological Agency's Kombolcha Sub-office. To determine farmers' attitudes and identify strategies for climate change adaptation, descriptive statistics and the Likert scale were used. The Multivariate Probit (MVP) model was used to classify factors influencing farmers' decisions on climate change strategies. The descriptive statistics reported that 87.74 percent of respondents and 83.22 percent of respondents, respectively, believed in climate change and its characteristics of temperature and rainfall. Farmers' chances of changing planting date, agroforestry, drought-tolerant crops, soil and water conservation practices, and irrigation were 54.1 percent, 38.9 percent, 47.8 percent, 63.4 percent, and 59.6 percent, respectively, according to the MVP model. The combined likelihood of adopting and failing to follow all adaptation methods was 9.9 percent and 6.3 percent, respectively, according to the report. Agro-ecological settings, gender, educational level, landholding, farm income, non-farm income, livestock ownership, access to credit, extension visits, farmer-to-farmer extension, climate information, and average distance from home to farm all have a significant impact on climate adaptation strategies. As a result, future policy initiatives should concentrate on strengthening farmers' awareness of climate change and adaptation strategies by using extension programs, facilitating farmer-to-farmer extension, and using multiple climate knowledge sources such as the media. To improve farmers' adaptive ability, focus should also be put on improving literacy, expanding the sources and quantity of farm and non/off farm income, and improving credit accessibility.

Roy et al., (2018) examined the understanding of smallholder farmers about the effect on crop production of climate change. The research is from Bangladesh's drought prone regions. Because of its vulnerability, the agricultural sector is vulnerable to climate change and it is witnessing many extreme climatic events such as droughts, flooding, natural disasters and intrusion into salinity. Coping with climate change events and mitigating their impact on crop production needs to evaluate the perception of the farmers. The goal of the study was to assess the perception of smallholder farmers about the effect of climate change on crop production in Bangladesh's drought prone areas. Mixed approaches to analysis were employed including quantitative and qualitative data. During September and October 2017 primary data were gathered using a standardized questionnaire via household survey. The respondents to the study were 100 smallholder farmers in Bangladesh's drought prone regions. Data were analysed using descriptive statistics, correlation coefficient and step by step regression. The main findings show that climate change 's perceived impacts on crop production were extreme followed by mild effects. Among the twelve statements concerning the impact of climate change on crop production, increased pest infestations were perceived as the most significant impact. Greater frequency of incidents of drought was viewed as the second most important effect of climate change. Perhaps the least noticeable effect of climate change has been increased flood severity. Among the respondents' socio-economic characteristics, age, year of schooling, farming experience, exposure to knowledge sources and training experience were significantly linked to their understanding of the impacts of climate change on crop production. Moreover, the most influential factors which affected the perception of smallholder farmers were the year of schooling, farming experience and training experience. The report identified key concerns to tackle and suggested effective interventions for policy-makers and other development practitioners. The methods used in this study and the findings could be used in other districts of Bangladesh with similar socio-economic and regional context.

2.5 STUDIES ON IMPACT OF CLIMATE CHANGE ON SPICE CROPS

The rising CO_2 and other greenhouse gases (GHGs) in the atmosphere leads to rise earth surface temperature as these are radiative forcing gases and absorb heat in their vibrating bonds from the sunlight. There are also risks of lower temperature occurring as an unusual occurrence in certain areas. In 2008, frost occurred in Rajasthan as an extreme event and there was significant crop loss including seed spices, and kali-jeeri (*Centeratherum antihelmenthese*) was completely wiped out of the field. While most seed spices are adaptive to low temperature but sudden rise and fall in temperature leads to crystallization of apoplastic water resulting in loss of integrity of the cell membrane and eventually cell death. Plant life cycles are seasonal indicators, and changes in the timing of these cycles provide some of the most convincing proof that global climate change affects plants and ecosystems (Walther et al., 2002 and Cleland et al., 2007).

Temperature rises by more than 1°C would have changed a considerable portion of the potential suitable regions. Many suitable spice areas will become moderately suitable, or new areas, which are currently inadequate, will become highly suitable for spice cultivation, according to studies conducted at the Indian Institute of Spices Research in Calicut, India, using GIS models. The geographic information system (GIS) was used at the Indian Institute of Spices Research in Calicut to investigate the impact of climate change parameters on black pepper and ginger. Most of the areas where these crops are grown would become unsuitable with a 2°C increase, according to the DIVA GIS Eco-crop model, while some new areas might become suitable for cultivation (Krishnamurthy et al., 2010). Seed spices are winter crops that are commonly grown in arid and semi-arid areas of Rajasthan and Gujarat. They need specific periods of low temperatures for optimal vegetative growth. The arid zone environment is very fragile and even with the slightest disruption, is vulnerable to severe imbalances. Drought is a recurring phenomenon in an arid zone, and seed spices are affected by abiotic stress, water stress and low temperature occurrence during critical growth stage. Many seed spices are vulnerable to the condition of water logging. Water logging or submerged conditions can however be used to grow *Acorus calamus*, while cardamom (*Elettaria cardamomum*) is best suited for its ideal growth in swampy areas. Clove can tolerate water logging conditions for a shorter time span.

Significant changes in weather elements were observed in the studies, which had a direct impact on crop spice production, such as small cardamom, seed spices, and black pepper (Muthusami et al., 2012). Over the past 10 years, Indian pepper production has declined rapidly due to the impact of climate change. It has dropped by more than 50 percent from nearly one lakh of annual production. According to a recent study conducted by Kerala Agricultural University's Agricultural Market Intelligence Centre, the region under pepper farming has decreased by 24 percent in the last nine years, while production has decreased by nearly half due to decreasing productivity and rising production costs. Pepper is primarily grown in irrigated coffee plantations in Karnataka, and it is thought to be less susceptible to monsoons (Ravi, 2012).

Das and Sharangi (2018) studied that climate change's effect on spice crops, and it was found that spice crops face the brunt of climate change. Abiotic factors such as temperature, rainfall, photoperiod, sunshine hours, wind, and others affect various physiological growth stages such as flowering, fruit setting, fruit development, seed setting, and final spice crop reproductive or vegetative yield directly or indirectly. Arid conditions and violent winds are detrimental to the growth of vanilla plants, and high temperatures cause spike shedding in black pepper. A prolonged dry season can lead to reduced pollination and cardamom flower abortion. Onion bolting occurs when the temperature drops suddenly during the early vegetative stage. Many seed spices, such as coriander, fenugreek, cumin, and others, attract pests such as aphids and diseases such as powdery mildew due to high rainfall and humidity. The impact of environmental stress on spice crop seed production and storage life is also important.

Gulati et al., (2018) reported that the quantity and quality of farm product harvested at the end of an agricultural cycle is referred to as yield risk. Rainfall distribution that is erratically distributed has a negative impact on agricultural production. Natural disasters and adverse weather conditions annually damage crops on 12 million hectares of land in the country (Jain and Parshad, 2007). There have been several years in the last fifteen years when a rainfall deficiency has adversely affected agricultural production. Due to a loss of 38 million tonnes of food grains in 2002, the rainfall deficit was 19 percent. The drought in 2009 was the third worst since 1901, when there was an 18 percent rainfall deficit and a production loss of about 16 million tonnes of food grains.

2.6 CLIMATE CHANGE ADAPTATION AND MITIGATION STRATEGIES OF FARMERS

The AVRDC's efforts to improve flood tolerance in tomatoes by grafting eggplant rootstocks could be expanded to include water stress and temperature stress tolerance (AVRDC, 1990). Under conditions of climate change, more heat-tolerant cultivars are needed and these cultivars must perform in non-stress conditions on a par with traditional varieties.

The knowledge and skills of farmers underpin livelihood strategies although they have extremely limited financial resources. Mulching techniques, an adaptation to dry conditions that helps to conserve soil moisture by, among other things, reducing evapotranspiration, were an key feature of farming systems in southern St. Elizabeth. Mulching is an important part of farmers' traditional knowledge, skills, and creativity when it comes to dealing with risk. Traditional knowledge has also assisted Caribbean farmers in sustaining and adapting to change and adversity during the region's turbulent past and present (Barker and Beckford, 2006; Beckford and Barker, 2007).

Krishnamurthy (2008) studied with the objective of identifying species of Myristica that can withstand water scarce condition and can be used as rootstock for grafting. Water stress has been imposed on potted plants aged one year by withholding irrigation until the plants wilted. There was a substantial positive correlation between the relative water content, chlorophyll content and protein content, while membrane leakage had a significant negative correlation with days taken for wilting. Species / genus grouping viz., *Myristica fragrans*, *M. Domeii*, *M. Malabarica*, *Knema andamanica* and *Gymnocranthera canerica* were rendered on the basis of these associated criteria, and the days taken for wilting were also taken. *M. Malabarica* ranked first in terms of tolerance to water stress, and *M. Fragrans*, *G. Canerica* was last ranked, and was named susceptible. Study findings indicate that the *M. Malabarica* can be used as a nutmeg rootstock for combating drought.

Crop management practices such as crop residue mulching and plastic mulching help to conserve moisture from the soil. In certain cases, excessive soil moisture caused by heavy rain can be a major issue, which can be alleviated by growing crops in raised beds. Clear plastic rain shelters may be used to grow vegetables, minimizing direct effects on fruit growth and reducing field water logging during the rainy season. During the rainy season, planting vegetables on elevated beds would increase yields due to improved drainage and decreased root system anoxic stress. Soil-related environmental stresses such as drought, salinity, low soil temperature, and flooding will be tolerated by scion cultivars cultivated on tolerant rootstocks (Chieri et al., 2008).

Agricultural insurance is one of the methods by which farmers can stabilise farm incomes and savings against the catastrophic effects of natural risks and low market prices, according to Raju and Chand (2008). Crop insurance also helps farmers start a farming business after a poor agricultural year, helping farmers overcome the impact of crop losses by offering a minimum amount of protection.

It allows farmers to spread crop losses in space and over time and encourages farmers to invest more in the production of crops.

While farmers are vulnerable, in the face of adversity they are not passive; they are trying to adjust and cope with changing conditions; they are experimenting and improvising, but not always effective. During Hurricane Dean, Campbell hunkered down with farmers in an effort to learn best farming practices during storms, and reported on what they did on the farm immediately before and after the storm (Campbell and Beckford, 2009).

Zeweldi (2010) studied the evaluation of alternative agricultural insurance designs suited for the production of nutmeg and cocoa in Grenada. The aim of this research was to evaluate the performance of farm yield, area yield, and weather index-based insurance schemes for nutmeg and cocoa production in Grenada and find the best match. It's part of a pre-feasibility study of Grenada's agricultural insurance schemes, which looks at three aspects: identifying crop insurance schemes that account for a significant portion of household income, mainly nutmeg and cocoa, access to contract results, and willingness to pay. Farmers and financial institutions have expressed a desire to develop insurance products that cover major cash crops like nutmeg and cocoa in order to broaden lending in these areas. This study focuses on identifying appropriate insurance schemes for cocoa and nutmeg cultivation. The principal objective of this analysis is to determine the efficacy of: a. allowance insurance (farm yield insurance) and b. index insurance: area yield and weather index insurances. Multi-Peril Crop Insurance (MPCI) (or farm yield from now on in this report) insurance, also known as indemnity-based insurance, offers allowances when crop yields fall below a specified level due to various natural causes. This guards against yield losses on the farm.

The experiences of farmers and efforts to cope with drought also represent restricted options, so it's not surprisingly the practice to mitigate risk. Scaling back on production after a hurricane, and even during a drought, is a typical adaptive response. Scaling back includes a reduction of as much as 25 percent in a drought in the number and variety of crops grown and in the size of the cultivated field.

Another technique is to use dry season to plant drought-tolerant crops (such as scallion or sweet potato). Some farmers employ a thicker mulch layer. Over 63 percent of farmers shared water with family or friends during the 2008 drought, a form of social capital during the 2008 drought (Campbell et al. 2011).

Climate change could lead to higher prices of fruits and vegetable crops. The challenges ahead are sustainability and competitiveness, as well as achieving targeted production to meet the rising environmental demands of diminishing land, water, and climate change risks, which necessitate climate-smart horticulture interventions that are highly location-specific and knowledge-intensive in order to increase production in the challenged environment (Malhotra and Srivastava, 2014, Malhotra, 2015).

In addition to implementing updated crop management methods, developing resistant varieties may address the challenges raised by climate change. Several organizations have developed hybrids and varieties that are heat and drought tolerant, with the ability to mitigate the effects of climate change.

To improve water efficiency and adjust to hot and dry environments, focus should be placed on using recommended production systems. To combat the anticipated rise in temperature and water stress cycles during the crop growing season, strategies such as adjusting sowing or planting dates should be implemented. Modifying the application of fertilizers to increase the supply of nutrients and the use of soil modifications to boost soil fertility and increase nutrient absorption (Srivastava et al., 2014, Malhotra and Srivastava, 2015). Irrigation during critical stages of crop growth and soil moisture conservation are the most effective strategies (Malhotra, 2016).

According to Sarangi and Panigrahi (2016), a government's duty would be to compensate farmers for a disaster, however if the state can take out insurance before a disaster happens, the cost of disaster expenditure will decrease. Farmers will be left at a relatively moderate risk if governments were to insure for a catastrophic risk, so the premium they have to pay would decrease and the crop insurance plan will become affordable for them.

Malhotra (2017) studied the horticultural crops and climate change and found that although agriculture is the key stay in climate change-induced greenhouse gas emissions, horticultural crops have a far greater role to play in combating the negative effects of climate change by providing better carbon exchange and carbon sinks. Some of the most alarming physiological reactions to climate change is the shortened growing period, which triggers distinctive declines in fruit and vegetable production. Due to terminal heat stress and the deprived availability of soil water, these responses may leave negative impact on growth and production of horticultural crops. Therefore, interventions pursuing climate-smart horticulture are felt as an unwarranted requirement to incorporate location-specific and knowledge-intensive premise in order to increase production in such challenging environment. Adaptation strategies based on crops are required taking into consideration the nature of the crop, its level of sensitivity and the agro-ecological zone. Around the same time, keeping an eye on the carbon sink potential of various horticultural crops vis-à - vis annual field crops would further assist in creating a blue print to tackle issues related to climate change.

Das and Sharangi (2018) stated that for the regulation of the weather effects, water conservation, irrigation, environmental management, mulching, and situation-specific cropping schemes, among other aspects of crop management, have all been updated. It has also been shown that proper shade tree maintenance will reduce the impact of hail, frost, and snow, as well as serve as a windbreak or landslide defense for spice crops.

Gulati et al., (2018) researched crop insurance in India: key issues and way forward and this paper analyses the agricultural insurance schemes that existed in the country prior to the introduction of the PMFBY in *Kharif* 2016, how the transition to the PMFBY took place and highlights the major challenges of the implementation of the PMFBY. Gulati et al., (2018) make some recommendations based on this evaluation and a review of how the United States, China, and Kenya are implementing crop insurance schemes. They propose that a comprehensive crop insurance system be developed in a country that is straightforward, only in terms of insured amounts, and easy to settle farmers' claims using high-end technology. Highlighting the role of technology and expertise from some of the best foreign crop insurance practices is a particular focus of this paper. Because of vagaries of nature, farmers in India are exposed to considerable agricultural risks. Indian agriculture still has rain fed just over half (53 percent) of its territory. This makes it particularly weather-sensitive, causing agricultural production to be unpredictable. Floods, droughts, heat waves, cyclones, and hailstorms are all examples of severe weather conditions that cause serious damage to crops. Subtle weather variations during critical crop production phases will greatly affect yields. Climate change increases agricultural risk by increasing rainfall variability, causing water stress, increasing plant disease vulnerability and pest attack, and, most importantly, increasing the frequency, severity and duration of extreme weather events including droughts, floods, cyclones, and storm surges. A comprehensive insurance scheme is one of the most important tools for reducing the agricultural risks. While crop insurance has been in the country since 1972, it has been plagued with many issues such as lack of transparency, high premium, delay in conducting crop cutting experiments and unpaid / delayed payment of claims to farmers. A new crop insurance scheme was introduced on Baisakhi day, Pradhan Mantri Fasal Bima Yojana (PMFBY), from *Kharif* 2016, recognizing the shortcomings of the current crop insurance program.

The Pande (2018) claimed that crop insurance policies in India need to be improved for better adaptation and called on the Indian government to recognize crop insurance schemes as climate adaptation schemes immediately and provide government guarantee coverage for all farmers in these schemes, as well as improved crop loss monitoring systems and appropriate payments that cover the entire loss for farmers.

Adhikari et al., (2018) researched and worked on the crop intensification method for more efficient, resource-conserving, climate-resilient and sustainable agriculture with experience of various crops in different agro-ecologies. Many other crops are now being adapted to the ideas and methods of the system of rice intensification (SRI), which increases the yield of irrigated rice. These crops include wheat, maize, finger millet, sugarcane, tef, mustard, legumes, vegetables, and even spices. The study's aim is to encourage better root growth and soil fertility with organic materials, which have been found to be efficient ways to increase crop yields with less water, fertilizer, seeds, and agrochemicals while also improving climate resilience. In this article, they review what is becoming known about various agroecological crop management technologies focused on farmers that may contribute to agricultural sustainability.

According to Melvani et al., (2020) multiple livelihood strategies and high floristic diversity, are increasing the adaptive capacity and resilience of Sri Lankan farming companies. Traditional farming undertakings show resilience though. Eighty-five farmer companies were sampled using mixed methods across nine locations in the Intermediate Agroecological Region. Components of subsistence on-and off-farm (graphical abstract) are introduced by agricultural companies. On -farm refers to tree-dominant forest gardens, paddy, cash crops, swidden plots (chenas), plantations, and livestock. Off-farm includes jobs, trade and grants. They investigated how farmer businesses remained resilient, and which land use had the greatest adaptive potential and household needs best fulfilled? Farming enterprises were evaluated in terms of water availability, the climate variability perspectives of farmers, their socioeconomic characteristics, and land uses in land holdings. Land uses have been defined and contrasted by floristic variety, crop: utility benefits, food functions, and use and sale benefits. Community was largely rainfed. Farmers' views of climate variability are confirmed by meteorological data showing that interannual and seasonal fluctuations in rainfall prevailed in the reference and preceding years. Forest gardens, the oldest and most dominant land use of all land uses, with the largest area, the highest abundance of plant and crop species, and the greatest diversity of crops, presented these challenges to farmers. The availability of a greater variety of primary and secondary forest garden crops and products offered several advantages for the home. High floristic diversity, tree dominance and multifunctionality provided good capacity for adaptation to forest gardens. Nevertheless, with diverse landscape designs and off-farm subsistence strategies, farmers simultaneously embraced multiple land uses because this provided greater opportunities, buffered risk, and improved resilience in farming businesses. A strong implication of this study is that when preparing for a sustainable agriculture in a variable climate scenario, policy makers should communicate with farmers.

3. MATERIALS AND METHODS

The choice of the appropriate methodology is extremely important to draw meaningful conclusions from the research. The proper methodology for data analysis was selected based on the literature review. In summary, the description of the study area, sampling procedure, method of data collection and the analytical framework are presented in this chapter.

3.1. Description of the study area

3.2. Sampling design

3.3. Analysis of data

3.1 DESCRIPTION OF THE STUDY AREA

The study was conducted in Thrissur and Ernakulam districts, as these districts were having the largest area under nutmeg cultivation in Kerala. In the present study, crop weather relationship of nutmeg farming, socio-economic characteristics, behavioural pattern and the strategies of nutmeg farmers for mitigating weather extreme conditions in Thrissur and Ernakulam districts were studied.

3.1.1 Kerala

Kerala is located on the south western tip of the Indian subcontinent, located between the Arabian sea to the West and the Western Ghats in the East with an area of 38,863 square kilometres. Kerala comprises of 1.18 percent geographical area of India and lies between East longitudes 74° 52’ and 72° 22’ and North latitudes 8° 18’ and 12° 48’. Kerala is divided in East-West direction in to three parts- highland, central plains and coastal areas. Highland comprises of the area in and around the Western Ghats or Sahyadri which are mostly wet evergreen forests, the main rivers of Kerala originate from these plateaus. The coastal strip is parallel to the Western Ghats and in between the highlands and the coastal plains are the middle lands, it is usually a combination of hills and valleys. The important spices and condiments crops being cultivated in our state are pepper, ginger, turmeric, cardamom, arecanut, tamarind, cloves, nutmeg *etc*. There are three seasons in Kerala: South West monsoon from June to September (*Edavappathy*), North East monsoon from October to December (*Thula Varsham*) and summer season (March-May). Kerala receives an average annual rainfall of 3,107 millimetres, which is higher than the average in India of 1,197 mm.

3.1.2 Thrissur district

Thrissur known as 'cultural capital of Kerala' came into existence on July 1st 1949. According to the 2011 census, Thrissur district had 9.34 percent of the total population in the state. Thrissur is the third most urbanised district in Kerala, with an urban population of about 67 percent of the total population in the district. Majority of the population is dependent directly or indirectly on agriculture for their livelihood. The total geographical area of the district is approximately 3029.19 km^2, equal to 7.81 percent of the state area. Out of the total district area, approximately 1036.19 km^2 of land are covered by forests. The major crops grown in the district are paddy, coconut, nutmeg, arecanut, banana, tapioca, etc.

3.1.2.1 Location

Thrissur district is located in the central part of Kerala. It lies between 10° 10' and 10° 46' North latitude and 75° 57' and 76° 54' East longitude. Thrissur districts borders with Malappuram district in the north, Ernakulam district in the south, Palakkad district in the east and Arabian sea on the west.

3.1.2.2 Topography and climate

Thrissur district extending from the Western Ghats in the east to the land slopes in the west, forms three distinct natural divisions (i) the thickly forest highlands, (ii) the fertile plains and (iii) the sea-board.

The district has a tropical humid climate with a hot season, and assured seasonal precipitation. The hot season starts in March and ends in May, followed by the South-West monsoon season from June to September. The October and November months accounts for the post monsoon season. The monsoon stops by the end of December and the following period is generally dry. The maximum average temperature in summer season is 35°C, While the minimum temperature is 22.5°C. The winter season experiences a maximum average temperature of 32.3°C and a minimum average of 20°C. The air is highly humid throughout the year and relative humidity is generally over 70 percent. The mean annual rainfall of the district is 3198 mm.

3.1.2.3 Demographic features

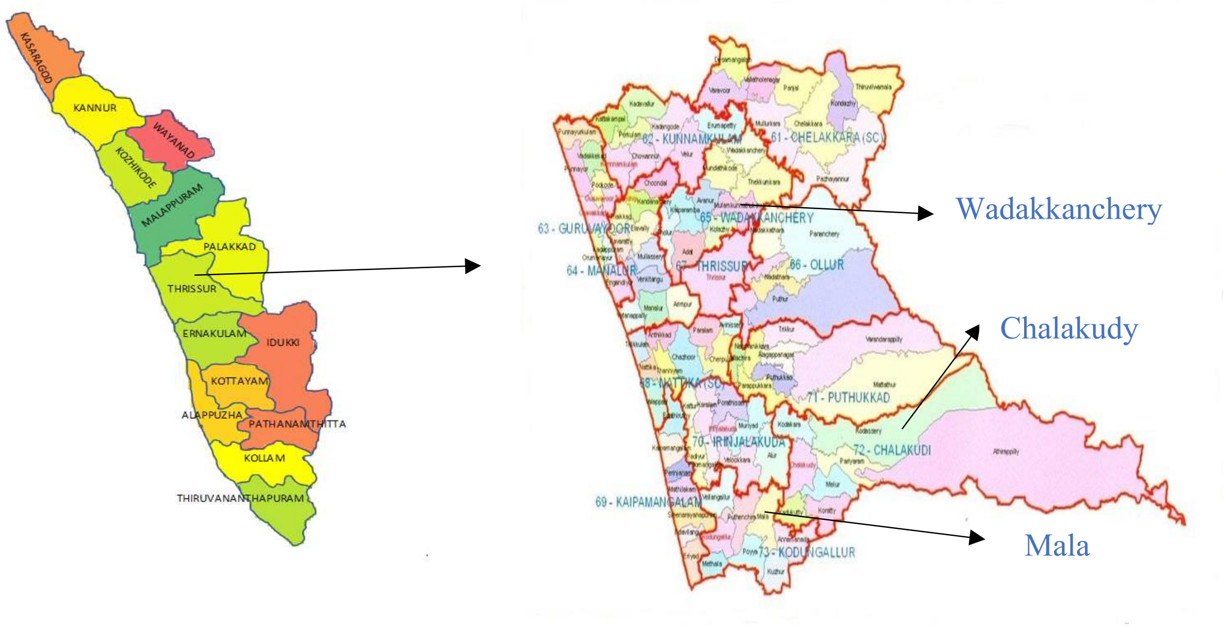
According to the 2011 census, the total population in Thrissur district was 31,21,200. The density of population was 1,031 per square km and the sex ratio in the district was 1108 females per 1000 males. The literacy rate in the district has increased from 92.27 percent in 2001 to 95.08 percent in 2011. The total number of workers in the district was 10,95,727 comprising of 9,29.506 main workers and 1,66,221 marginal workers.

3.1.2.4 Description of the selected blocks

The three blocks which are evenly affected by weather extremes in Thrissur district viz., Chalakudy, Mala and Wadakkanchery were chosen for the study. From each of block five Krishibhavans and from each krishibhavan six farmers were surveyed. Those Krishibhavans surveyed are Kadukkutty, Kodassery, Pariyaram, Meloor and Chalakudy Krishibhavans from Chalakudy block, Aloor, Mala, Annamanada, Kuzhur, and Poyya Krishibhavans from Mala block and Thekkumkara, Mundathikkode, Varavoor, Wadakkanchery and Erumapetty Krishibhavans from Wadakkanchery block.

3.1.3 Ernakulam District

Ernakulam district located in the central part of Kerala and it came into existence on April 1st 1958. The district headquarters is at Kochi, known as the Queen of the Arabian sea. According to 2011 census, the district has 9.82 percent of the total population of the state. Ernakulam is the first most urbanised district in



- Mala Block
  - Aloor
  - Mala
  - Annamanada
  - Kuzhur
  - Poyya

- Wadakkanchery
  - Thekkumkara
  - Mundathikkode
  - Varavoor
  - Wadakkanchery
  - Erumapetty

- Chalakudy
  - Kadukkutty
  - Kodassery
  - Pariyaram
  - Meloor
  - Chalakudy

Figure 3. 1 Map of the study area - Thrissur

Kerala, with an urban population of about 68 percent of the total population in the district. The total geographical area of the district is approximately 3068 km^2, equal to 7.9 percent of the state area. Out of the total district area, approximately 706.17 km^2 of land are covered by forests. Main crops grown in the district are paddy, coconut, arecanut, tapioca, cashew, cocoa, black pepper and banana.

3.1.3.1 Location

Ernakulam stands fourth in total geographical area among the districts of Kerala. It lies between 9° 42’ 30” and 10° 46’ 00” North latitude and 76° 12’ and 76° 36’ East longitude. The district shares its boundaries with Thrissur district in the north, Idukki district in the east, Arabian sea in the west, Kottayam and Alappuzha districts in the south.

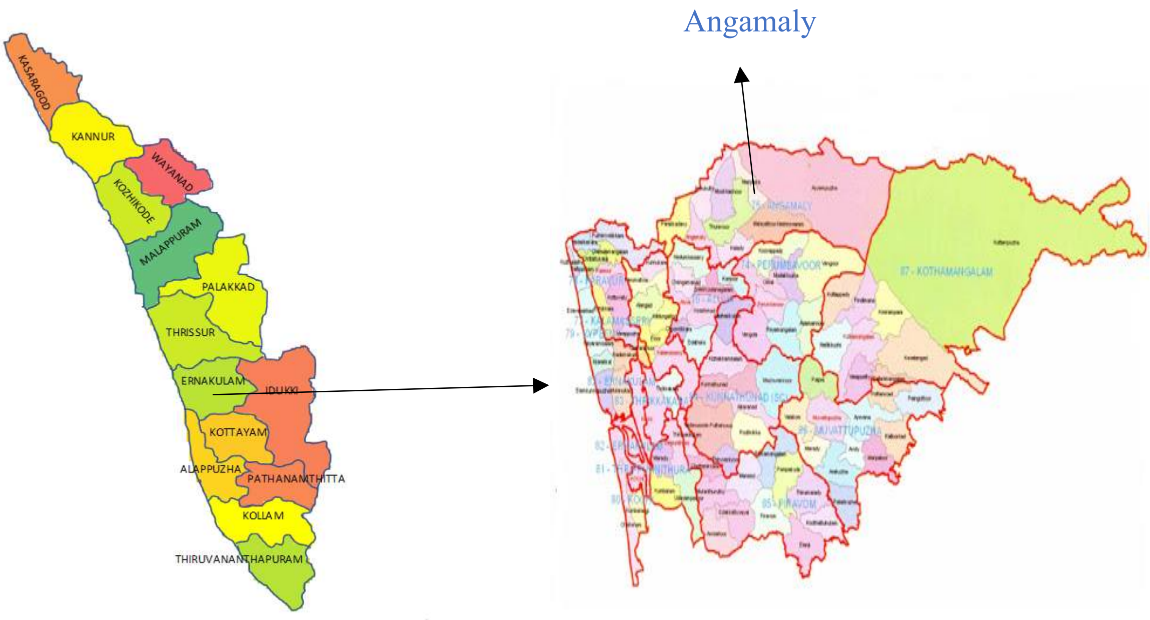
3.1.3.2 Topography and climate

Based on the geographical features, the district can be divided into three parts (i) the low land which constitutes 20 percent of the total area, (ii) the midland consisting mainly of the plain land and group of islands and (iii) the highland with seaboard, hills and forests. The hilly or eastern portion of the district is formed by a section of Western Ghats.

October and November months are the post monsoon or retreating monsoon period. Winter season is from December to February, which is slightly cool and windy, due to winds from the Ghats. The average annual rainfall of the district is 3,099 mm, with 132 average annual rainy days. The maximum average temperature during the summer season is 33°C, while the minimum temperature recorded is 22.5°C. The winter season records a maximum average temperature of 29°C and a minimum average temperature of 20°C.

3.1.3.3 Demographic features

According to the 2011 census, the total population in the Ernakulam district was 32,82,388. The density of population was 1072 per square km and the sex ratio in the district was 1027 females per 1000 males. The literacy rate in the district has



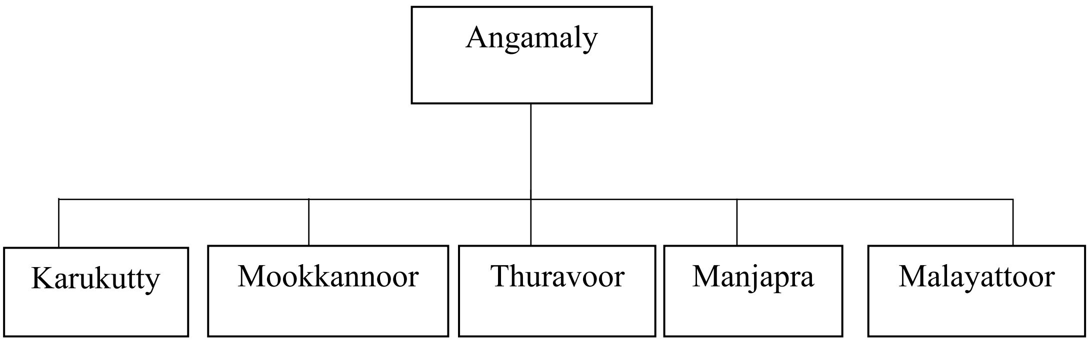


Fig 3. 2 Map of the study area – Ernakulam

increased from 93.20 percent in 2001 to 95.89 pr cent in 2011. The total number of workers in the district was 12,49,343, comprising of 10,61,388 main workers and 1,87,955 marginal workers.

3.1.3.4 Description of selected block

The one block which are evenly affected by weather extremes in Ernakulam district viz., Angamaly were chosen for the study. From the block five Krishibhavans and from each krishibhavan six farmers were surveyed. Those Krishibhavans surveyed are Karukutty, Mookkannoor, Thuravoor, Manjapra and Malayattoor Krishibhavans from Angamaly block.

3.2 SAMPLING DESIGN

The present study was based on both primary and secondary data. The micro-level study was conducted in Thrissur and Ernakulam districts, which accounted for about 30 percent and 29 percent of the area respectively and 28 percent and 37 percent of the production respectively of nutmeg in Kerala in 2018-19. The three blocks from Thrissur district and one block from Ernakulam district with evenly affected by weather extremes namely, Chalakudy, Mala and Wadakkanchery in Thrissur district and Angamaly in Ernakulam district were purposively selected. From each of the selected block, five Krishibhavans and from each krishibhavan six farmers were surveyed and hence making a total sample size of 120.

3.2.1 Collection of data

Data on weather extreme preparedness of nutmeg farmers was collected from these farm households using a structured and pre-tested interview schedule. Details on socio-economic characteristics of the farmers i.e., age, gender, educational status, annual income, occupation, land holding pattern, number of nutmeg trees, experience in farming, experience in nutmeg farming, cropping system, sources of irrigation, types of irrigation, mode of communication and behavioural characteristics of farmers such as components of climate change, impacts perceived due to climate change, climate change effects on nutmeg trees, constraints in nutmeg farming, support for farmers adaptation practices and type of adaptation practices followed by nutmeg farmers were collected. Secondary data such as yield data of nutmeg from the year of 2005-06 to 2018-19 was collected from Agricultural Statistics, Directorate of Economics and Statistics and weather data of Thrissur and Ernakulam was collected from College of Agriculture (COA) Vellanikkara (10.31° N, 76.13° E) and NASA Power data access viewer (9.98° N, 76.29° E) respectively. Secondary data on area, production, productivity was collected for both districts from the Directorate of Economics and Statistics, Government of Kerala, Thiruvananthapuram for the period of 2005 to 2018.

3.2.1.1 Weather Data

The daily data on maximum temperature, minimum temperature, rainfall, relative humidity, wind speed and solar radiation were taken and converted to monthly data and used for the study. The different weather parameters used in the study are described in Table 3.1.

Table 3. 1 Weather parameters used in the study

Sl.No.	Weather parameter	Unit
1	Maximum temperature (Tmax)	°C
2	Minimum temperature (Tmin)	°C
3	Rainfall (RF)	mm
4	Relative humidity (RH)	%
5	Wind speed (WS)	km hr^{-1}
6	Solar radiation (SRAD)	MJ m^{-2} day^{-1}

3.3 ANALYSIS OF DATA

The primary and secondary data were analysed using different analytical tools.

3.3.1. Weather extreme preparedness assessment of nutmeg farmers

The weather extreme preparedness of the farmers' were assessed scientifically using scoring procedure used for psychological variables. In this study, responses of five questions from the questionnaire were taken which is base for calculating weather extreme preparedness score. Responses were collected in a five-point continuum viz., strongly agree, agree, undecided, disagree, strongly disagree and the scores of 5,4,3,2 and 1 were given for these responses respectively. The cumulative score was taken as weather extreme preparedness score of a respondent. Thus, the maximum weather extreme preparedness score that could be obtained by a respondent was 25 and the minimum 5.

The respondents were categorized into three groups viz. low, medium and high on the basis of mean and standard deviation of the total score as follows.

Table 3. 2 Distribution of respondents based on the weather extreme preparedness scores

Category	Score
Low	< Mean – Standard Deviation
Medium	Mean ± Standard Deviation
High	> Mean + Standard Deviation

3.3.2. Statistical Analysis

The statistical analysis of the yield data which was collected from Agricultural Statistics, Directorate of Economics and Statistics for the years of 2005-18 were taken to study the weather relationship on the yield of Nutmeg.

3.3.2.1. Percentage analysis

The percentage analysis was done to make simple comparison wherever necessary.

3.3.2.2. Correlation Analysis

Correlation coefficient is a measure of the association between two variables. The correlation coefficient was worked out to measure the relationship between the dependent variable weather extreme preparedness and the independent variables.

The correlation analysis was done to detect the influence of major weather parameters namely maximum temperature (Tmax), minimum temperature (Tmin), mean temperature (Tmean), temperature range (Trange), rainfall (RF), mean relative humidity (RHmean), wind speed (WS) and solar radiation (SRAD) on the yield of nutmeg. The association of various weather parameters, yield and major phenological phases were studied by the correlation analysis. Average of monthly weather variables were taken for the correlation between the phenological phases and yield.

The pooled data of yield as well as the weather factors for the different years were used to run correlation analysis. The correlation analysis was done to find the influence of weather parameters on the yield data of nutmeg at the five strategic stages of growth. The major phenological phases considered were,

1. Flower bud development
2. Flowering
3. Fruit set
4. Fruit development
5. Harvesting

4. RESULTS AND DISCUSSION

In the last chapters we discussed the review of the previous works, description of the study area and the methodology adopted for the study. The data collected from the survey were tabulated and analysed using different statistical tools to reach meaningful conclusions. The results obtained from the analysis were described and discussed in this chapter.

4.1. AREA, PRODUCTION AND PRODUCTIVITY OF NUTMEG IN KERALA

The area, production and productivity of nutmeg crop in Kerala for the years from 2005-06 to 2018-19 is showed from Figure 4.1 to Figure 4.4. Kerala is the largest producer of nutmeg in India, with an area of 22,770.67 hectares during 2018-19 and a production of 14,598 tonnes. The productivity of nutmeg in Kerala during 2018-19 was 528.1 kg per hectare.

The area under nutmeg in Kerala has increased from 10,984 hectares during 2005-06 to 22,770.67 hectares during 2018-19. The production during the above period also increased from 2746 tonnes to 14,598 tonnes. The productivity of the crop increased from 260.97 kg per hectare in 2005-06 to 528.1 kg per hectare in 2018-19 and between these periods the productivity has showed a varying pattern.

The districts of Thrissur and Ernakulam are the state's main nutmeg-producing areas, together contributing about 60 percent of the area and 65 percent of the state's production during 2018-19.

4.2. INFLUENCE OF WEATHER PARAMETERS ON THE YIELD OF NUTMEG

The yields of nutmeg in Thrissur and Ernakulam districts were significantly influenced by the different weather variables in different phenophases of nutmeg. The five major phenophases of nutmeg and its respective months were showed in Table 4.1.

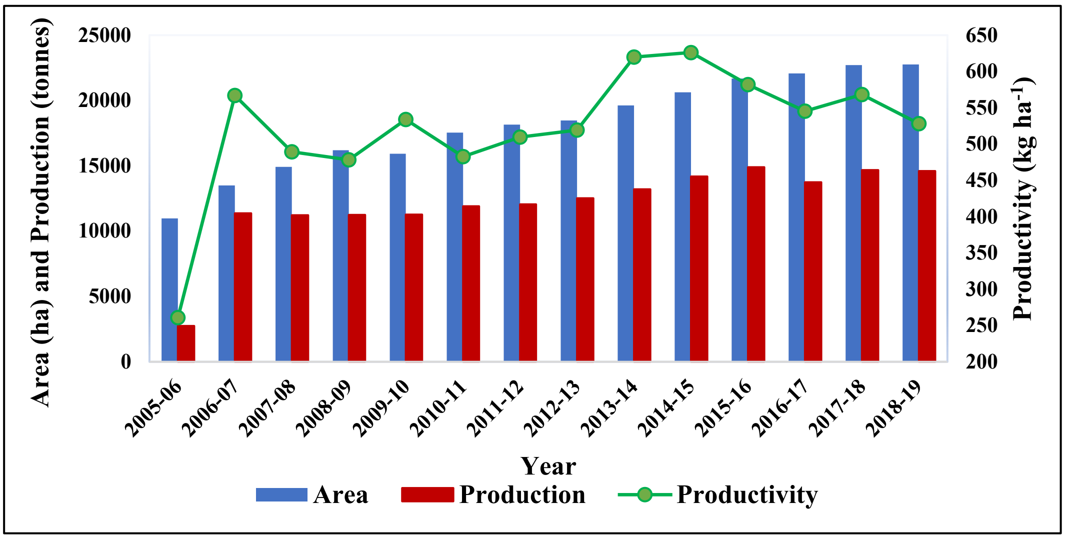


Fig. 4. 1 Area, production and productivity of nutmeg in Kerala

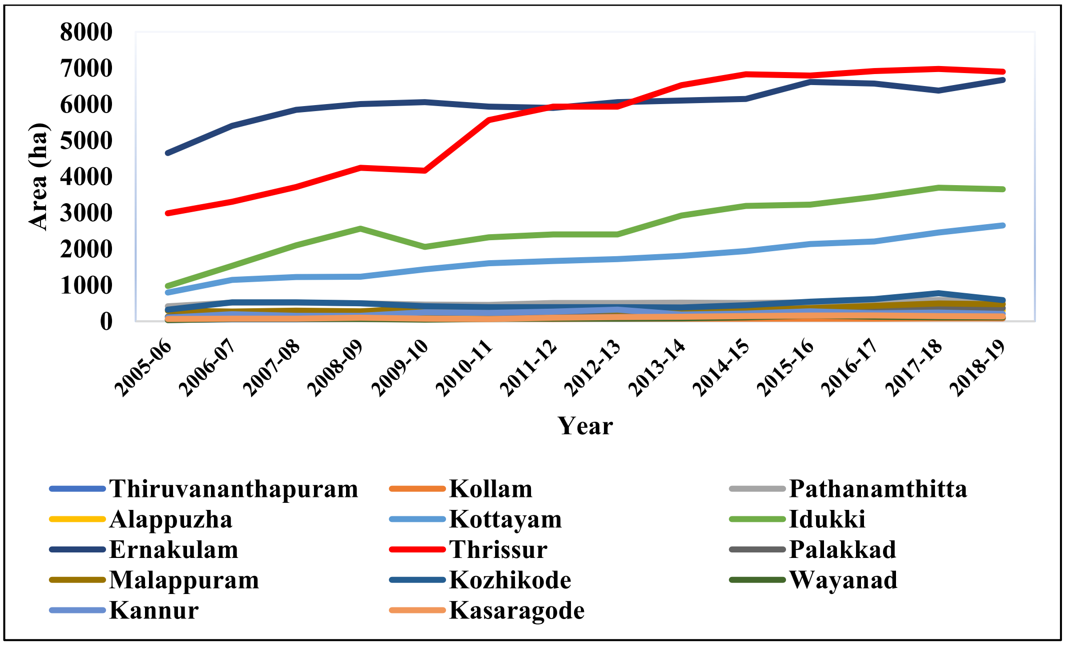


Fig. 4. 2 Area of nutmeg in Kerala

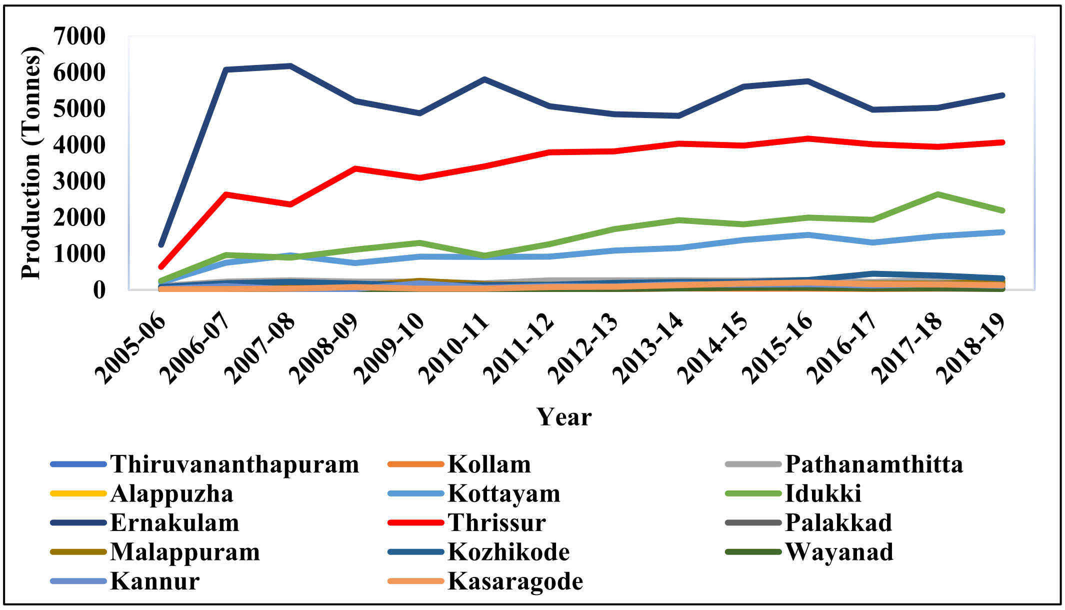


Fig. 4. 3 Production of nutmeg in Kerala

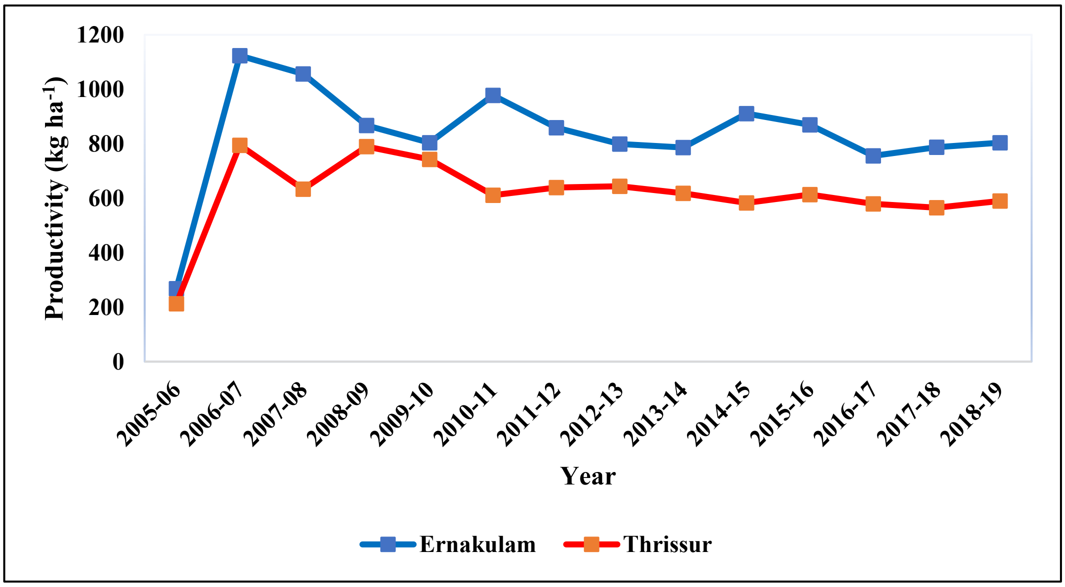


Fig. 4. 4 Productivity of nutmeg in Kerala

Table 4. 1 Major phenophases of nutmeg

Phenophases	Respective months
P1 – Flower bud development stage	April – May – June
P2 – Flowering stage	August – September – October
P3 – Fruit setting stage	September – October – November
P4 – Fruit development stage	November – December – January – February – March
P5 – Harvesting stage	June – July – August

Nazeem (1979) studied on growth, flowering, fruit set and fruit development in nutmeg and it was resembled with the phenophases given in Table 4.1. This study showed that during September, followed by May and June, maximum shoot growth and during July, followed by October, maximum flowering occurs. The total number of days between the bud emergence and the flower opening was 154. By the time the flower opened, new flushes had initiated on the same shoot. A month after flowering, the fruiting begins. Fruit development was found to steadily increase from the second week after the set. The fruits begin to split in 206 to 237 days after fruit set. The harvesting season is from June to August with peak harvesting in July.

4.2.1. Correlation analysis between weather variables and yield

Nutmeg yield data in tonnes from Thrissur and Ernakulam districts were taken along with the year wise weather data. The correlation analysis of the yield was carried separately for Thrissur and Ernakulam districts. The correlation was done for five major phenological phases in each district. The five major phenological phases of nutmeg are flower bud development, flowering, fruit set, fruit development and harvesting stage.

4.2.1.1. Correlation between weather variables and yield of Thrissur

The weather variables in different phenophases of nutmeg along with the yield data of Thrissur from 2005 to 2018 was used to found out the correlation.

The results were given in Table 4.2.

Table 4. 2 Correlation between weather variables and yield of Thrissur district

Stages	Tmax	Tmin	Tmean	Trange	RF	Mean RH	WS	SRAD
Flower bud development	0.339	-0.044	0.235	0.322	-0.082	0.403	-0.702**	-0.637*
Flowering	0.584*	0.007	0.434	0.618*	-0.205	0.047	-0.707**	0.181
Fruit set	0.711**	0.084	0.604*	0.626*	-0.255	-0.106	-0.664**	0.451
Fruit development	0.282	0.306	0.346	0.115	0.332	0.010	-0.564*	-0.524
Harvesting	0.314	-0.148	0.131	0.420	-0.125	0.368	-0.805**	-0.335

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

4.2.1.1.1. Effect of maximum temperature on yield during different phenophases

The result of correlation analysis (Table 4.2.) revealed that the maximum temperature had a significant positive correlation on flowering and fruit setting stage. There was a positive effect on flower bud development, fruit development and harvesting stages, but insignificant.

The above results were in agreement with the findings of Lonergan (1998) that temperature during flowering and fruit setting stage had a dominant influence on the yield of mango.

It was clear from the Figure 4.5 that during flowering phase, maximum temperature within 30.2 – 31.8°C was suitable for getting higher nutmeg yield.

It was observed from the Figure 4.6 that during fruit setting stage, maximum temperature within 31.1 – 32.5°C was suitable for getting higher nutmeg yield.

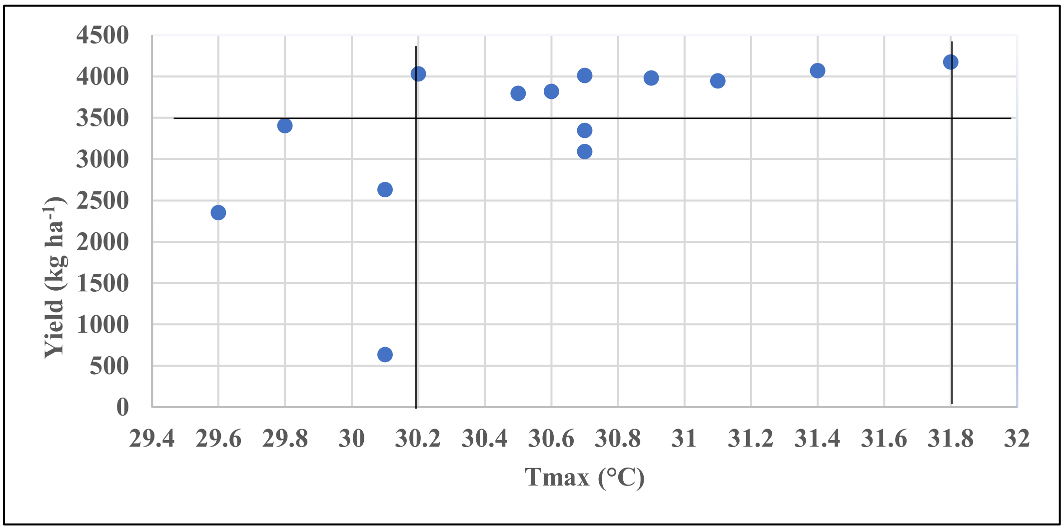


Fig 4. 5 Optimum maximum temperature for getting higher nutmeg yield during flowering phase of Thrissur district

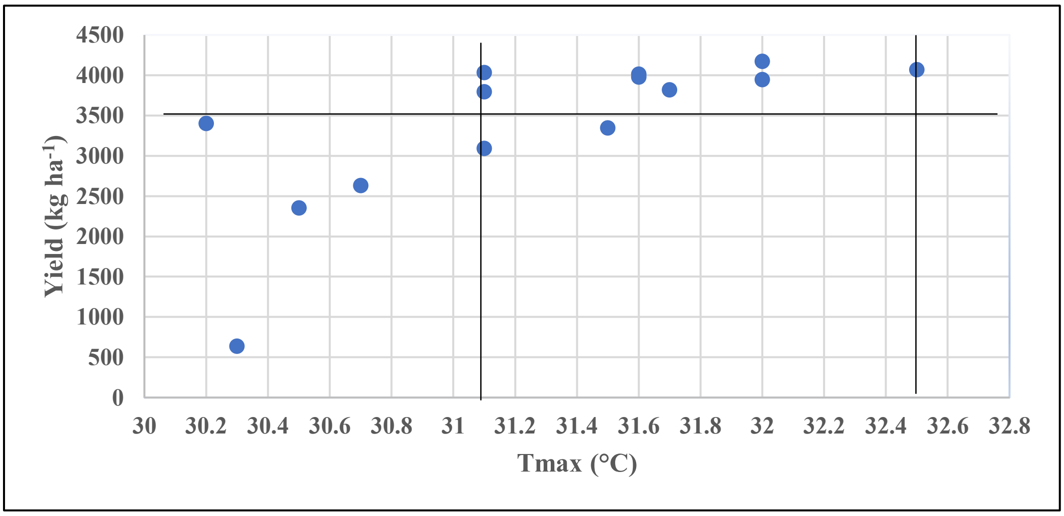


Fig 4. 6 Optimum maximum temperature for getting higher nutmeg yield during fruit setting phase of Thrissur district

4.2.1.1.2. Effect of minimum temperature on yield during different phenophases

From the correlation analysis (Table 4.2.) it was found that minimum temperature had showed a negative correlation effect on flower bud development and harvesting stage. A positive correlation with the minimum temperature was obtained in flowering, fruit setting and fruit development phase. But these are not significant.

4.2.1.1.3. Effect of mean temperature on yield during different phenophases

The mean temperature had showed a significant positive effect on fruit set and non-significant positive effect on flower bud development, flowering, fruit development and harvesting stage (Table 4.2.).

It was observed from the Figure 4.7 that during fruit setting stage, mean temperature within 27.0 – 27.9°C was suitable for getting higher nutmeg yield.

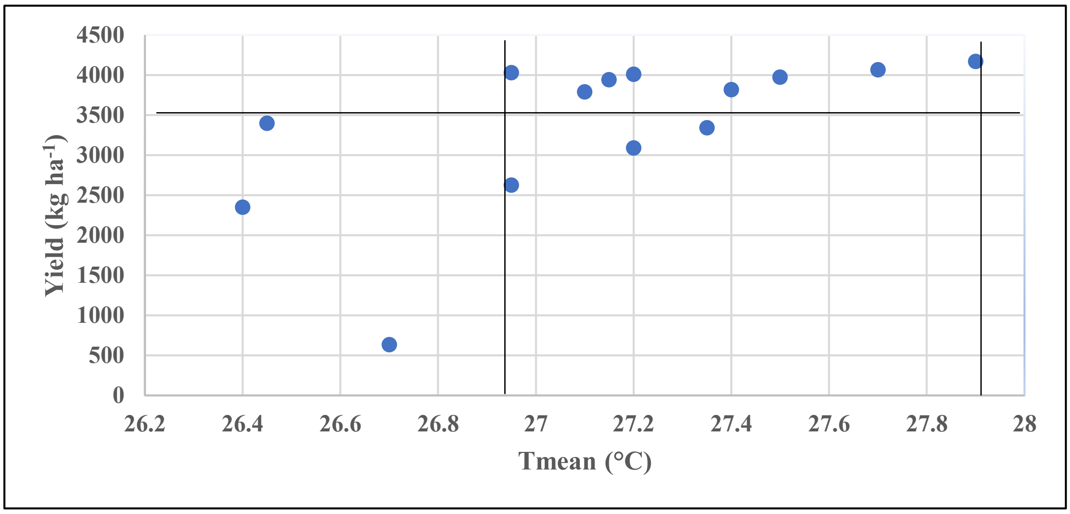


Fig 4. 7 Optimum mean temperature for getting higher nutmeg yield during fruit setting phase of Thrissur district

4.2.1.1.4. Effect of temperature range on yield during different phenophases

The temperature range had showed a significant positive effect on flowering and fruit setting stage and that of non-significant positive effect on flower bud development, fruit development and harvesting stage (Table 4.2.).

from the Figure 4.8 it was found that during flowering stage, temperature range within 7.4 – 8.9°C was suitable for getting higher nutmeg yield.

from the Figure 4.9 it was found that during fruit setting stage, temperature range within 8.0 – 9.7°C was suitable for getting higher nutmeg yield.

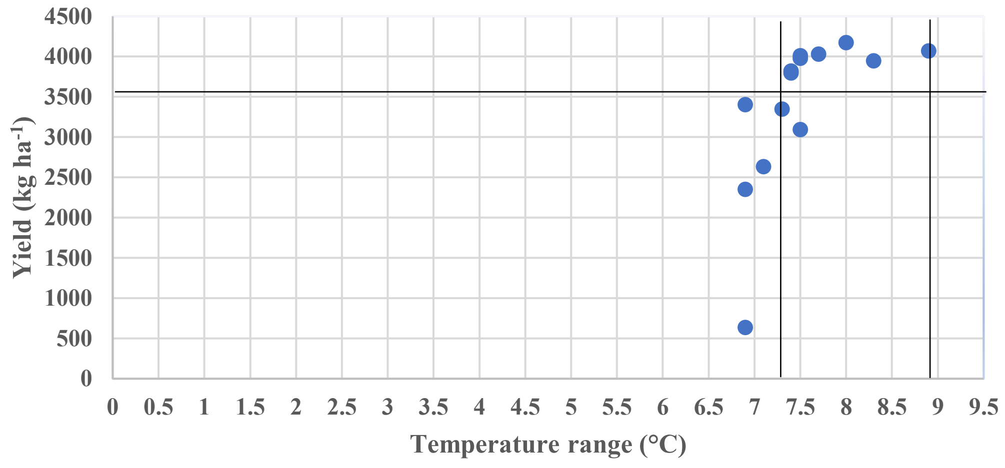


Fig 4. 8 Optimum temperature range for getting higher nutmeg yield during flowering stage of Thrissur district

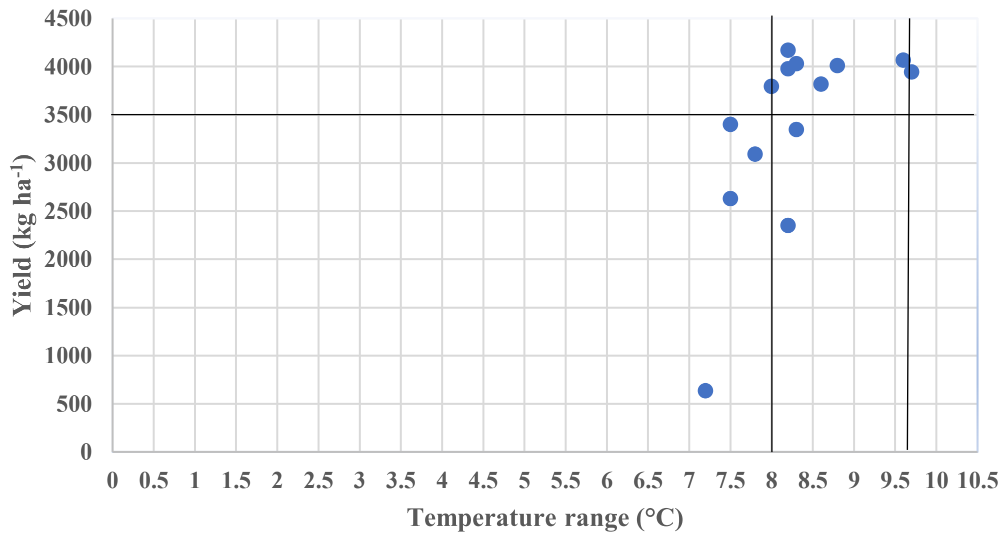


Fig 4. 9 Optimum temperature range for getting higher nutmeg yield during fruit setting stage of Thrissur district

4.2.1.1.5 Effect of rainfall on yield during different phenophases

The results of correlation analysis (Table 4.2.) showed that rainfall during the fruit development stage had showed a non-significant positive correlation between the yield and negative relationship in phenophases such as flower bud development, flowering, fruit set and harvesting stage.

The above results were in agreement with the findings of Ploetz (2003) that unpredictable rains during pre-flowering and flowering periods may cause poor fruit set and unseasonal rains encourage pests, which also lower fruit yield. Makhmale et al (2016) was in conformity with the results, they opined that rainfall during fruit development and maturity was critical.

4.2.1.1.6. Effect of mean relative humidity on yield during different phenophases

The mean relative humidity had positive effect on flower bud development, flowering, fruit development and harvesting stage. A negative effect with the mean relative humidity was obtained only in fruit setting phase (Table 4.2.).

The above results were in agreement with the findings of Das and Sharangi (2018), they opined that mean relative humidity had a positive association with the yield of nutmeg in all stages except the fruit setting stage.

4.2.1.1.7. Effect of wind speed on yield during different phenophases

The wind speed had showed a highly significant negative correlation on flower bud development, flowering, fruit set and harvesting stage. There was significant negative effect on fruit development stage (Table 4.2.).

The results were in conformity with the findings of Das and Sharangi (2018), they opined that wind speed had a negative association with the yield of nutmeg in all stages and it is great problem to trees with shallow roots like the nutmeg tree since it can uproot easily.

4.2.1.1.8. Effect of solar radiation on yield during different phenophases

From the correlation analysis (Table 4.2.) it can be observed that solar radiation had a significant negative correlation on flower bud development whereas a negative effect on fruit development and harvesting stage. Positive relationship with solar radiation was showed in flowering and fruit setting stage of nutmeg.

4.2.1 .2. Correlation between weather variables and yield of Ernakulam

The weather variables in different phenophases of nutmeg along with the yield data of Ernakulam from 2005 to 2018 was used to found out the correlation.

The results were given in Table 4.3.

Table 4. 3 Correlation between weather variables and yield of Ernakulam district

Stages	Tmax	Tmin	Tmean	Trange	RF	RHmean	WS	SRAD
Flower bud development	0.209	0.022	0.127	0.423	-0.259	-0.334	-0.009	-0.235
Flowering	0.041	-0.050	0.005	0.107	0.213	-0.092	-0.380	-.567*
Fruit set	0.273	0.221	0.278	0.194	-0.033	-0.247	-0.531	-0.279
Fruit development	0.247	0.048	0.151	0.260	-0.459	-0.530	-0.046	-0.257
Harvesting	0.078	-0.132	-0.021	0.394	0.058	-0.270	-0.424	-0.324

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

4.2.1.2.1. Effect of maximum temperature on yield during different phenophases

The correlation analysis between weather variables and yield data of Ernakulam (Table 4.3.) showed that the maximum temperature has a non-significant positive correlation in all the five major phenophases such as flower bud development, flowering, fruit set, fruit development, and harvesting stage.

These results were in agreement with Lonergan (1998) that maximum temperature was positively affected the yield of mango.

4.2.1.2.2. Effect of minimum temperature on yield during different phenophases

The results of correlation analysis (Table 4.3.) showed that minimum temperature had a negative correlation in flowering and harvesting stage. There was positive effect of minimum temperature on flower bud development, fruit setting and fruit development stage.

4.2.1.2.3. Effect of mean temperature on yield during different phenophases

The mean temperature had showed a non-significant positive effect on flower bud development, flowering, fruit set and fruit development stage. There was negative effect of mean temperature on harvesting stage (Table 4.3.).

4.2.1.2.4. Effect of temperature range on yield during different phenophases

The temperature range had showed a non-significant positive effect on flower bud development, flowering, fruit set, fruit development and harvesting stage (Table 4.3.).

4.2.1.2.5. Effect of rainfall on yield during different phenophases

From the correlation analysis (Table 4.3.) it can be observed that rainfall during the flowering and harvesting stage had showed a non-significant positive correlation between the yield and negative relationship in phenophases such as flower bud development, fruit set, and fruit development stage.

The results were in conformity with the findings of Das and Sharangi (2018), they opined that high rainfall result in lowering of fruit set and rainfall had negative influence on the yield of nutmeg.

4.2.1.2.6. Effect of mean relative humidity on yield during different phenophases

The mean relative humidity had negative effect on flower bud development, flowering, fruit set, fruit development and harvesting stage, but these are not significant (Table 4.3.).

4.2.1.2.7. Effect of wind speed on yield during different phenophases

The wind speed had showed a non-significant negative effect on flower bud development, flowering, fruit set, fruit development and harvesting stage (Table 4.3.).

The results were in conformity with the findings of Das and Sharangi (2018), they opined that wind speed had a negative association with the yield of nutmeg in all stages and it is great problem to trees with shallow roots like the nutmeg tree since it can uproot easily.

4.2.1.2.8. Effect of solar radiation on yield during different phenophases

From the correlation analysis (Table 4.3.) it was found that solar radiation had a significant negative correlation on flowering stage and that of a non-significant negative effect on flower bud development, fruit set, fruit development and harvesting stage.

4.2.1.3. Correlation of yield and weather parameters on monthly basis

The weather variables such as maximum temperature, minimum temperature, rainfall, mean relative humidity and wind speed were taken and the monthly average for the 2005 to 2018 years was calculated for each district. The correlation analysis between the yield of respective districts and monthly weather variables were taken for correlation analysis.

4.2.1.3.1. Correlation between monthly maximum temperature and yield

The results of correlation analysis between monthly maximum temperature and yield for Thrissur and Ernakulam districts were given in Table 4.4.

The correlation results from Table 4.4. showed that in Thrissur the monthly maximum temperature of September had highly significant positive correlation on yield and maximum temperature of November had significant positive correlation on yield.

Table 4. 4 Correlation between monthly maximum temperature and yield

Month	Thrissur	Ernakulam
January	0.202	0.020
February	0.123	0.103
March	0.155	0.095
April	0.409	0.405
May	0.184	-0.207
June	0.055	0.099
July	0.503	0.330
August	0.139	-0.335
September	0.669**	0.315
October	0.448	0.076
November	0.563*	0.337
December	0.524	0.233

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The results of Thrissur were in agreement with Das and Sharangi (2018), they opined that increasing temperature led to carbon dioxide enrichment which would boost productivity of nutmeg trees.

from the Figure 4.10 it was found that during September month, maximum temperature within 30.0 – 32.2°C was suitable for getting higher nutmeg yield.

from the Figure 4.11 it was found that during November month, maximum temperature within 31.4 – 33.0°C was suitable for getting higher nutmeg yield.

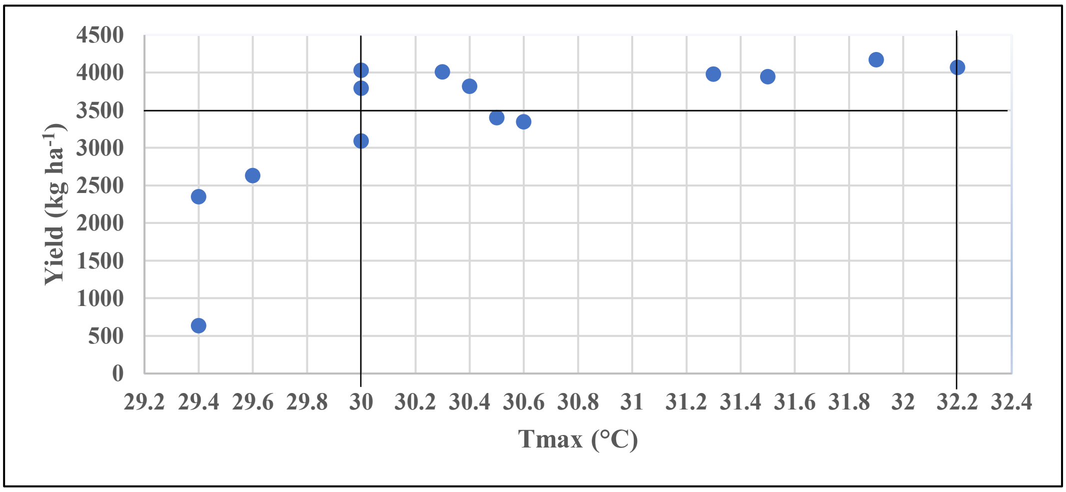


Fig 4. 10 Optimum maximum temperature for getting higher nutmeg yield during September month of Thrissur district

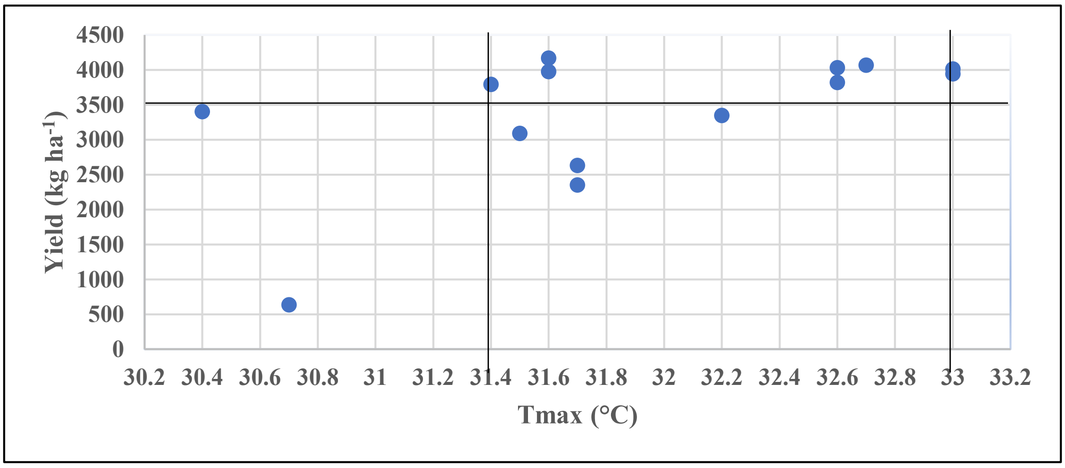


Fig 4. 11 Optimum maximum temperature for getting higher nutmeg yield during November month of Thrissur district

In Ernakulam there was no significant relationship between maximum temperature and yield.

4.2.1.3.2. Correlation between monthly minimum temperature and yield

The results of correlation analysis between monthly minimum temperature and yield for Thrissur and Ernakulam districts were given in Table 4.5.

Table 4. 5 Correlation between monthly minimum temperature and yield

Month	Thrissur	Ernakulam
January	-0.125	-0.203
February	0.410	0.155
March	0.084	-0.019
April	0.270	0.185
May	-0.140	-0.035
June	-0.105	-0.164
July	-0.138	0.090
August	-0.072	-0.290
September	-0.066	0.163
October	0.112	-0.101
November	0.112	0.477
December	-0.001	-0.076

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The correlation results from Table 4.5. showed that in Thrissur and Ernakulam districts there were no significant relationship with minimum temperature on yield.

4.2.1.3.3. Correlation between monthly rainfall and yield

The results of correlation analysis between monthly rainfall and yield for Thrissur and Ernakulam districts were given in Table 4.6.

Table 4. 6 Correlation between monthly rainfall and yield

Month	Thrissur	Ernakulam
January	-0.070	-0.856**
February	0.265	-0.013
March	0.025	0.094
April	-0.319	-0.567*
May	0.069	0.310
June	-0.058	-0.224
July	-0.298	0.042
August	0.141	0.325
September	-0.548*	0.102
October	0.010	0.026
November	0.236	-0.383
December	0.298	-0.121

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The correlation results from Table 4.6. showed that in Thrissur the monthly rainfall of September had significant negative correlation on yield.

In Ernakulam the rainfall during January had a highly significant negative correlation and rainfall during April had a significant negative effect on yield.

The above results were in agreement with the findings of Ploetz (2003) that unpredictable and unseasonal rains during pre-flowering and flowering periods may cause poor fruit set which also lower fruit yield. Das and Sharangi (2018) was in conformity with the results, they opined that rotting and uprooting of roots is predominant due to intense rainfall.

4.2.1.3.4. Correlation between monthly mean relative humidity and yield

The results of correlation analysis between monthly mean relative humidity and yield for Thrissur and Ernakulam districts were given in Table 4.7.

Table 4. 7 Correlation between monthly mean relative humidity and yield

Month	Thrissur	Ernakulam
January	-0.079	-0.192
February	0.079	-0.400
March	-0.062	-0.084
April	-0.097	-0.409
May	0.389	0.243
June	0.444	-0.395
July	-0.113	-0.418
August	0.477	0.226
September	-0.326	-0.327
October	0.043	-0.060
November	0.001	-0.262
December	0.093	-0.333

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The correlation results from Table 4.7. showed that in Thrissur and Ernakulam districts there were no significant relationship with mean relative humidity on yield.

4.2.1.3.5. Correlation between monthly wind speed and yield

The results of correlation analysis between monthly wind speed and yield for Thrissur and Ernakulam districts were given in Table 4.8.

The correlation results from Table 4.8. showed that, in Thrissur the monthly wind speed of March, April, May, October, and November had significant negative correlation on yield and wind speed of June, July, August, and September had highly significant negative correlation on yield. In Ernakulam there was no significant correlation between wind speed and yield.

Table 4. 8 Correlation between monthly wind speed and yield

Month	Thrissur	Ernakulam
January	-0.432	-0.181
February	-0.315	0.171
March	-0.605*	-0.062
April	-0.549*	0.197
May	-0.644*	0.070
June	-0.749**	-0.321
July	-0.791**	-0.482
August	-0.763**	-0.202
September	-0.772**	-0.376
October	-0.532*	-0.249
November	-0.597*	-0.298
December	-0.392	-0.279

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The results were in conformity with the findings of Das and Sharangi (2018), they opined that wind speed had a negative association with the yield of nutmeg in all stages and it is great problem to trees with shallow roots like the nutmeg tree since it can uproot easily.

4.3. SOCIO-ECONOMIC STATUS OF THE NUTMEG FARMERS

Using the collected primary data, the socio-economic status of the farmers was analysed in order to understand the sociological and economic condition of the respondents. In this study, the components of socio-economic status included age of the respondents, gender, educational status, annual income, occupation, land holding pattern, experience in farming, experience in nutmeg farming and number of nutmeg trees. The results of the analysis were discussed in detail in the following sub headings.

4.3.1. Age of respondents

The sample farmers were stratified into four groups based on their age and the age-wise distribution of the respondents were presented in Table 4.9. It could be observed that majority of sample farmers were in the age group of above 60 years and 45-60 years. Out of 120 respondent's 45.8 percent belong to above 60 years and 45 percent belong to 45 to 60 years age group. There were only 9.2 percent of the farmers in the age group of 30 to 45 years. In both of the selected districts, no farmers under the age of 30 were found, indicating a lack of interest among young people in farming as a profession, which is one of Kerala's major challenges for agricultural development.

Table 4. 9 Age-wise distribution of the sample respondents

Age profile (years)	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total sample
30 – 45	2 (6.7)	3 (10)	3 (10)	3 (10)	11 (9.2)
45 – 60	13 (43.3)	11 (36.7)	18 (60)	12 (40)	54 (45)
> 60	15 (50)	16 (53.3)	9 (30)	15 (50)	55 (45.8)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

4.3.2. Gender of respondents

Gender-wise distribution of the sample farmers were presented in Table 4.10. it could be noted from the table that majority of the respondents from the four blocks were male farmers i.e., 94.2 percent of farmers were male and 5.8 percent of the respondents were female farmers.

Plate 1: Survey of the farmers

Table 4. 10 Gender-wise distribution of sample respondents

Gender	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total sample
Male	30 (100)	27 (90)	28 (93.3)	28 (93.3)	113 (94.2)
Female	0 (0.0)	3 (10)	2 (6.7)	2 (6.7)	7 (5.8)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

The above results were in agreement with the findings of Reshama Sara (2019) that the majority of nutmeg farmers were males and only 12 percent of the respondents were female farmers.

4.3.3. Educational status

The details on the literacy level of the sample farmers were presented in Table 4.11. All the farmers surveyed were literate, among which 47.5 percent have attained education up to SSLC and about 32.5 percent were having education up to graduation. Nearly 10.8 percent and 7.5 percent of the sample farmers were below SSLC and HSE respectively.

Table 4. 11 Educational status of sample respondents

Education	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total Sample
Below SSLC	5 (16.7)	3 (10)	0 (0.0)	5 (16.7)	13 (10.8)
SSLC	10 (33.3)	16 (53.3)	16 (53.3)	15 (50)	57 (47.5)
HSE	4 (13.3)	4 (13.3)	0 (0.0)	1 (3.3)	9 (7.5)
Graduation	10 (33.3)	6 (20)	14 (46.7)	9 (30)	39 (32.5)
Post Graduation	1 (3.4)	1 (3.4)	0 (0.0)	0 (0.0)	2 (1.7)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

From the table of results, most of the farmers (89.2 percent) were educated SSLC or above SSLC. Only 10.8 percent of farmers was educated below SSLC were involved in nutmeg cultivation. It showed that educated farmers were more interested to do nutmeg cultivation and they make a good yield from it.

4.3.4. Annual income

The distribution of sample respondents on the basis of their annual income is depicted in Table 4.12. It was found that about 19.2 percent of the sample farmers earned a high income of above two lakh per annum. Out of the total sample farmers, 53.3 percent had income below ₹ 1,00,000 and 27.5 percent belonged to the income group ranging from ₹ 1,00,000 and ₹ 2,00,000.

From the result, out of the total 120 respondent's half of the farmers (53.3 percent) comes under the annual income of less than one lakh rupees.

Table 4. 12 Distribution of sample respondents based on their annual income

Annual income (Rupees)	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total sample
< 1,00,000	10 (33.3)	14 (46.6)	21 (70)	19 (63.3)	64 (53.3)
1,00,000 – 2,00,000	9 (30)	11 (36.7)	7 (23.3)	6 (20)	33 (27.5)
> 2,00,000	11 (36.7)	5 (16.7)	2 (6.7)	5 (16.7)	23 (19.2)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

4.3.5. Occupation

Main and subsidiary occupation of the respondents were described in the Table 4.13. Agriculture was a primary and main occupation for 90.8 percent of sample respondents. Among the respondents who took agriculture as a subsidiary occupation, 5 percent had government jobs and 4.2 percent respondents depended on self-employed as a main occupation.

It could be clearly seen that nearly 91 percent of respondents had agriculture as main occupation and they seriously approach to nutmeg cultivation.

Table 4. 13 Distribution of respondents based on major occupation

Occupation		Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total sample
Agriculture as main occupation		24 (80)	28 (93.3)	29 (96.7)	28 (93.3)	109 (90.8)
Agriculture as Subsidiary occupation	Govt. Job	1 (3.3)	2 (6.7)	1 (3.3)	2 (6.7)	6 (5)
	Self Employed	5 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	5 (4.2)
Total		30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

4.3.6. Land holding pattern

The classification of sample farmers based on the size of their land holdings is presented in Table 4.14.

Table 4. 14 Distribution of sample respondents according to size of land holding

Area in hectares	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total sample
< 1	20 (66.6)	24 (80)	23 (76.6)	23 (76.6)	90 (75)
1 – 2	8 (26.7)	6 (20)	5 (16.7)	5 (16.7)	24 (20)
> 2	2 (6.7)	0 (0.0)	2 (6.7)	2 (6.7)	6 (5)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

It could be observed from the table that 75 percent of the farmers had a land area of less than 1 hectare and 20 percent of farmers hold 1 to 2 hectares of land. About 5 percent of farmers possessed more than 2 hectares of land.

4.3.7. Experience in farming

The information on the experience of sample farmers is presented in Table 4.15. Generally, age decides the experience of the farmers in cultivation of crops and sample respondents were classified into two categories based on the number of years of experience in farming, as having 10 to 30 years and greater than 30 years. It could be observed from the table that 65.8 percent of the farmers had experience between 10 and 30 years. While about 34.2 percent had more than 30 years of experience in farming.

Table 4. 15 Distribution of sample farmers according to farming experience

Year of experience	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total sample
10 – 30	18 (60)	16 (53.3)	26 (86.7)	19 (63.3)	79 (65.8)
> 30	12 (40)	14 (46.7)	4 (13.3)	11 (36.7)	41 (34.2)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

4.3.8. Experience in nutmeg farming

The classification of sample respondents based on their experience in nutmeg cultivation is described in Table 4.16. It could be noted from the table that 40 percent of the farmers had experience in nutmeg farming between 20 to 30 years. While 24.2 percent farmers had above 30 years of experience in nutmeg farming. About 21.7 percent respondents started their nutmeg farming between 10 to 20 years and 14.1 percent respondents have recently started nutmeg cultivation, of less than 10 years.

Table 4. 16 Distribution of respondents based on experience in nutmeg farming

Years of experience	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total Sample
< 10	2 (6.7)	0 (0.0)	10 (33.3)	5 (16.7)	17 (14.1)
10 - 20	5 (16.7)	3 (10)	13 (43.4)	5 (16.7)	26 (21.7)
20 - 30	14 (46.6)	16 (53.3)	7 (23.3)	11 (36.6)	48 (40)
> 30	9 (30)	11 (36.7)	0 (0.0)	9 (30)	29 (24.2)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

4.3.9. Number of nutmeg trees

Table 4. 17 Distribution of sample respondents based on number of nutmeg trees

Number of Nutmeg trees	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total Sample
< 50	6 (20)	7 (23.3)	12 (40)	9 (30)	34 (28.3)
50 – 100	10 (33.3)	16 (53.3)	13 (43.4)	16 (53.3)	55 (45.8)
100 – 150	9 (30)	5 (16.7)	4 (13.3)	2 (6.7)	20 (16.7)
> 150	5 (16.7)	2 (6.7)	1 (3.3)	3 (10)	11 (9.2)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

The distribution of sample farmers based on the number of nutmeg trees showed in Table 4.17. 45.8 percent of farmers had 50 to 100 nutmeg trees out of 120 farmers, and 28.3 percent of respondents had less than 50 nutmeg trees. Although 16.7 percent of respondents in the survey had 100 to 150 trees, 9.2 percent of respondents had more than 150 nutmeg trees.

4.3.10. Trend analysis for prices of nutmeg

The general tendency of data to increase or decrease over time is called a trend. To better understand the long-term price behavior of nutmeg, trend analysis was conducted separately for each product using the least squares method. Different functional forms were used to try to explain the underlying trend in price behavior, with the model with the highest R^2 value being chosen as the best fit.

The trend in prices of nutmeg with shell, nutmeg without shell and mace were presented from Figure 4.12 to 4.14. The results showed that the power function gave the best fit for the trend in the prices of nutmeg without shell, nutmeg with shell and mace. The prices of nutmeg showed a decreasing trend in the long run, in spite of regular ups and downs in the short run. During the period from 2010-11 to 2013-14, the increase in prices of nutmeg with shell and without shell could again be attributed to the 112 percent increase in exports and a decrease in imports by 55 percent. In the later years, nutmeg price has fallen because the export growth was not so pronounced, together with considerable rise in imports. In the case of mace, a similar export growth as that of nutmeg was observed and imports also decreased by 30 percent from 2010-11 to 2012-13, which in turn was reflected as higher prices. The price of mace showed a decreasing pattern from 2013-14 to 2015-16 mainly because of the increase in imports by 50.71 percent. There was a discernible increase in the prices of all the three products in 2018-19 because the production was almost lower by 40 percent over the previous year. There is decrease in the prices of nutmeg without shell and with shell and increase in the price of mace during 2019-20.

Plate 2: Mace and nutmeg

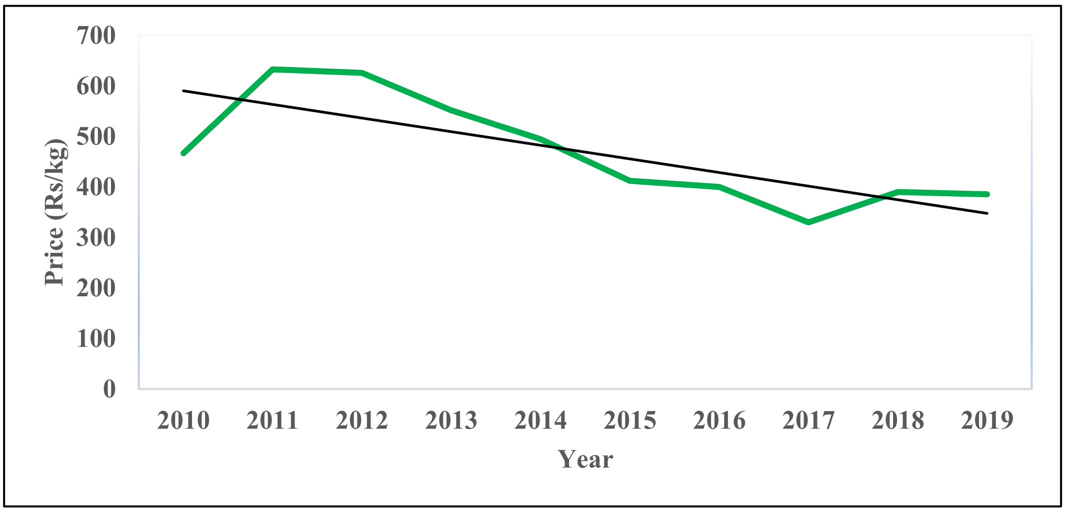


Fig. 4. 12 Trend in prices of nutmeg without shell

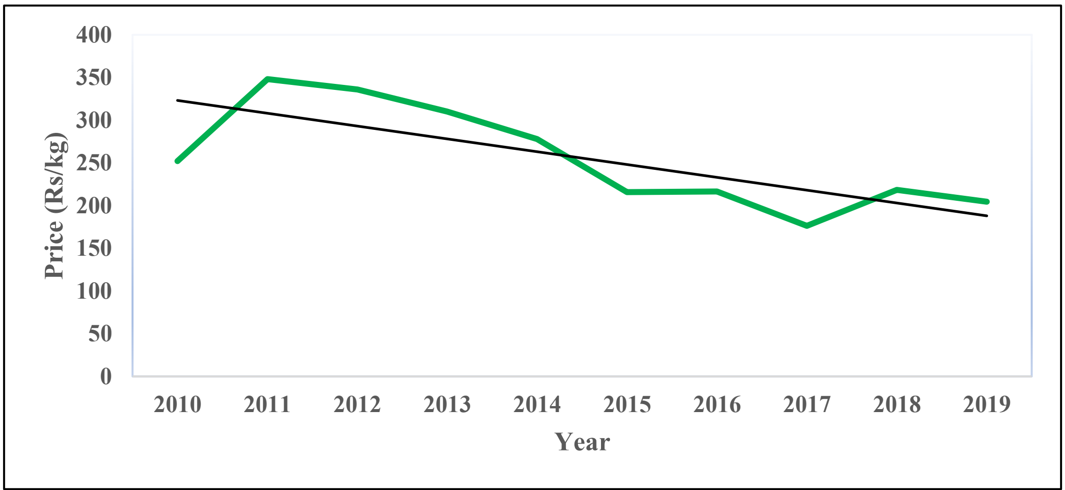


Fig. 4. 13 Trend in prices of nutmeg with shell

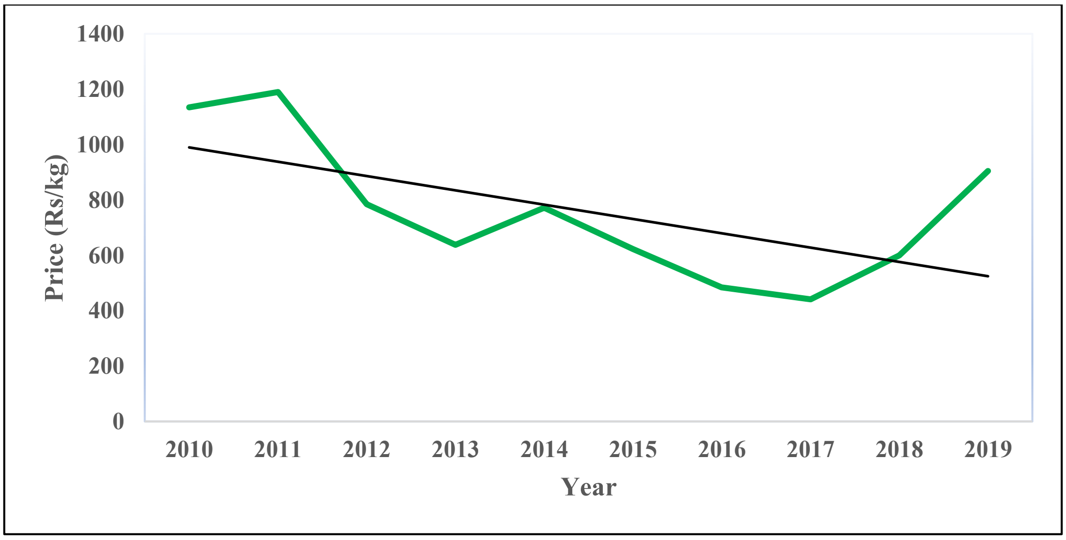


Fig. 4. 14 Trend in prices of mace

4.3.10.1. Relationship between nutmeg price and annual rainfall

The relationship between nutmeg price and annual rainfall from 2011 to 2019 showed in the Figure 4.15.

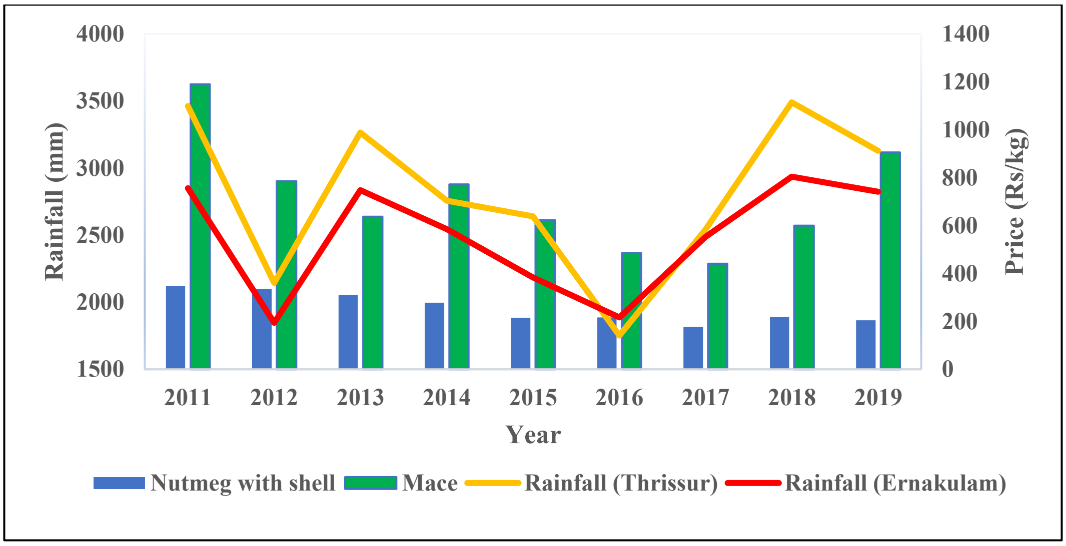


Fig. 4. 15 Relationship between nutmeg price and annual rainfall

The correlation of nutmeg price with annual rainfall from 2011 to 2019 was showed in the Table 4.18.

Table 4. 18 Correlation of nutmeg price with annual rainfall

Price	Rainfall (Thrissur)	Rainfall (Ernakulam)
Nutmeg with shell	0.193	0.019
Mace	0.489	0.361

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

It could be seen from the graph that the annual rainfall of Thrissur and Ernakulam districts having a similar decreasing and increasing trend from 2011 to 2019. With the help of table of correlation result that the price of nutmeg with shell and mace increases with increase of annual rainfall in both of Thrissur and Ernakulam districts.

4.3.11. Cropping system

The distribution of sample respondents based on the cropping systems depicted in Table 4.19. The common cropping systems followed was nutmeg, coconut, arecanut, and banana or vegetables (28.3%) and the same percent of respondents also followed nutmeg, coconut, arecanut, banana, pepper/rambutan/cocoa/mangosteen/vegetables/tuber/root vegetable crops combination (28.3%). Nutmeg, coconut and banana/root vegetable crops combination (27.6%) was followed by nutmeg and coconut combination (10%). While very less i.e., 5.8 percent of farmers followed monocropping pattern such as there was nutmeg alone in field.

Table 4. 19 Distribution of sample respondents based on the cropping systems

Cropping system	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total
Nutmeg	3 (10)	2 (6.7)	1 (3.3)	1 (3.3)	7 (5.8)
Nutmeg + coconut	2 (6.6)	2 (6.7)	4 (13.3)	4 (13.3)	12 (10)
Nutmeg+coconut+ arecanut+ banana/vegetables	11 (36.7)	9 (30)	8 (26.7)	6 (20)	34 (28.3)
Nutmeg+coconut+ arecanut+banana+ pepper/rambutan/ cocoa/mangosteen/ vegetables/tuber/root vegetable crops	11 (36.7)	13 (43.3)	4 (13.3)	6 (20)	34 (28.3)
Nutmeg+coconut+ banana/ root vegetable crops	3 (10)	4 (13.3)	13 (43.4)	13 (43.4)	33 (27.6)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

It could be seen that most of the farmers used shade loving nature of nutmeg and it makes suitable for grow as an intercrop with shade giving trees like coconut trees.

4.3.12. Sources of irrigation

The distribution of sample respondents based on the sources of irrigation showed in Table 4.20.

Table 4. 20 Distribution of sample respondents based on the sources of irrigation

Irrigation sources	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total
Own well	10 (33.3)	17 (56.6)	14 (46.7)	10 (33.3)	51 (42.5)
Canal	15 (50)	5 (16.7)	0 (0.0)	12 (40)	32 (26.7)
Pond	5 (16.7)	3 (10)	9 (30)	5 (16.7)	22 (18.3)
Bore well	0 (0.0)	5 (16.7)	7 (23.3)	3 (10)	15 (12.5)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

It could be observed from the table that 42.5 percent of the farmers had own well, a major source of irrigation followed by canal irrigation (26.7 percent). Nearly 18.3 percent and 12.5 percent of sample respondents having pond and bore well was a major source of irrigation respectively.

Nutmeg requires irrigation frequently to avoid the water stress conditions. So, most of the nutmeg farmers preferred own well as the major source of irrigation.

4.3.13. Types of irrigation

The distribution of sample respondents based on the types of irrigation showed in Table 4.21. It could be observed from the table that 88.4 percent of sample respondents had surface irrigation. The 5.8 percent of farmers had both of sprinkler and drip irrigation.

Table 4. 21 Distribution of sample respondents based on the types of irrigation

Irrigation types	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total sample
Surface irrigation	28 (93.3)	26 (86.7)	25 (83.4)	27 (90)	106 (88.4)
Sprinkler irrigation	0 (0.0)	1 (3.3)	4 (13.3)	2 (6.7)	7 (5.8)
Drip irrigation	2 (6.7)	3 (10)	1 (3.3)	1 (3.3)	7 (5.8)
Total	30 (100)	30 (100)	30 (100)	30 (100)	120 (100)

Note: Figure in parentheses indicate percent to column total

Thangaselvabai et al (2011) was in conformity with the results, they were of the view that farmers have not adopted new production technologies. These advanced production technologies will improve the profitable cultivation of nutmeg and tackle the challenges of global competition.

There was a smaller number of farmers aware about the importance of drip and sprinkler irrigation. This type of irrigations enhances the water use efficiency and also reduces the surface loss of water. So, educate farmers and make aware about the importance of these water conservation measures will improve the nutmeg yield and overcome the climate change challenges.

The nutmeg yield will increase when the farmers adopt the water conservation measures like sprinkler and drip irrigation. More farmers will adopt sprinkler and drip irrigation if government subsidy is brought for it. More adoption of sprinkler and drip irrigation will be possible only through the financial support of the government.

4.3.14. Sources of information for farmers regarding nutmeg cultivation

The distribution of sample farmers based on sources of information for farmers regarding nutmeg cultivation showed in Table 4.22.

Table 4. 22 Distribution of sample respondents based on sources of information for farmers regarding nutmeg cultivation

Sources of information for farmers	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total
Television	30 (100)	27 (90)	27 (90)	24 (80)	108 (90)
Newspaper	28 (93.3)	29 (96.7)	30 (100)	30 (100)	117 (97.5)
Social media	10 (33.3)	8 (26.7)	13 (43.3)	12 (40)	43 (35.8)
Neighbouring farmer	17 (56.7)	22 (73.3)	17 (56.7)	18 (60)	74 (61.7)

Note: Figure in parentheses indicate percent to the total number of respondents in respective group

It could be observed from the table that 96.7 percent of sample respondents in Mala block had newspaper, major source of information for farmers regarding nutmeg cultivation while it was television in Chalakudy block. Newspaper was the major source of information in Wadakkanchery and Angamaly blocks. Neighbouring farmer and social media were the sources of information for farmers regarding nutmeg cultivation for the 61.7 percent and 35.8 percent sample respondents respectively.

4.4. COMPONENTS OF CLIMATE CHANGE

From the analysis of collected primary data, it can be seen that increase in rainfall intensity and erratic rainfall were the major components of climate change affecting nutmeg production as revealed by 99.2 percent and 95.9 percent respectively. It could be seen that 93.3 percent of sample respondents reported that increase in rainfall duration is the component of climate change. Increase in temperature was reported as the component by 36.7 percent. The results were showed in Table 4.23.

Table 4. 23 Distribution of respondents based on components of climate change experienced by them

Climate change components	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total
Increase in Rainfall duration	28 (93.3)	24 (80)	30 (100)	30 (100)	112 (93.3)
Increase in Rainfall intensity	29 (96.7)	30 (100)	30 (100)	30 (100)	119 (99.2)
Erratic rainfall	26 (86.7)	29 (96.7)	30 (100)	30 (100)	115 (95.9)
Increase in temperature	11 (36.7)	10 (33.3)	8 (26.7)	15 (50)	44 (36.7)

Note: Figure in parentheses indicate percent to the total number of respondents in respective group

4.5. IMPACTS PERCEIVED DUE TO CLIMATE CHANGE

From the survey, farmers have reported different type of impacts they have perceived due to change in climate. Results were presented in Table 4.24.

As a result of climate change, the major impact perceived was changed timing and quantity of rains which was reported by 88.3 percent of the sample respondents. The second major impact showed by 85 percent of sample farmers was the flood. Although 15 percent of sample farmers had droughts, the impacts of climate change were perceived. Soil erosion was the least impact perceived which was reported by 5.8 percent of sample respondents.

A lot of people gave up farming after frequent cause of flood. They also complained that no compensation was provided for nutmeg loss.

Table 4. 24 Distribution of respondents based on impacts perceived due to climate change

Impacts	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total
Changed timing and quantity of rains	26 (86.7)	27 (90)	25 (83.3)	28 (93.3)	106 (88.3)
Flood	27 (90)	27 (90)	26 (86.7)	22 (73.3)	102 (85)
Drought	4 (13.3)	5 (16.7)	3 (10)	6 (20)	18 (15)
Soil erosion	1 (3.3)	1 (3.3)	5 (16.7)	0 (0.0)	7 (5.8)

Note: Figure in parentheses indicate percent to the total number of respondents in respective group

4.6. CLIMATE CHANGE EFFECTS ON NUTMEG TREES

The distribution of sample farmers based on climate change effects on nutmeg trees were showed in Table 4.25.

As a result of climate change, the major climate change effect on nutmeg tree was decreased yield which was reported by 91.7 percent of the sample respondents. Pest and disease occurrence was the second major climate change effect which was expressed by 50.8 percent of sample farmers. Changes in flowering season was the least climate change effect which was reported by 16.7 percent of sample respondents.

The study conducted by the Shankar et al (2013) on farmers' perception about climate change in eastern dry zone of Karnataka during 2012 also reported that decrease in yield was the major climate change effect perceived by farmers.

Table 4. 25 Distribution of sample respondents based on climate change effects on nutmeg trees

Climate change effects	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total
Decreased yield	28 (93.3)	30 (100)	24 (80)	28 (93.3)	110 (91.7)
Changes in flowering season	8 (26.7)	6 (20)	2 (6.7)	4 (13.3)	20 (16.7)
Pest and disease occurrence	13 (43.3)	20 (66.7)	15 (50)	13 (43.3)	61 (50.8)

Note: Figure in parentheses indicate percent to the total number of respondents in respective group

4.7. TYPE OF ADAPTATION PRACTICES FOLLOWED BY NUTMEG FARMERS

The analysis revealed that agronomic conservation measures such as mulching, mixed cropping, cover cropping and tillage practices was the major adaptation practice practiced by 86.7 percent of the total respondents. Pruning and organic farming was practiced by 57.5 percent and 45.8 percent of the total respondents respectively. The lime application practiced by 29.2 percent of respondents and water conservation measures such as sprinkler and drip irrigation practiced by 11.7 percent of sample respondents.

The other adaptation practices such as crop insurance and budded wild nutmeg trees practiced by 6.7 percent and 2.5 percent of sample farmers respectively. Results were represented in Table 4.26.

Akinola and Owombo (2012) have worked out the economics of mulching adaptation technology in yam production in Nigeria during 2011. It was reported that, mulching was the major adaptation practice to protect roots from increased temperature, moisture changes, improving soil fertility and control of weed growth.

Table 4. 26 Distribution of respondents based on type of adaptation practices

Weather extreme preparedness	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total
Agronomic measures	23 (76.7)	28 (93.3)	29 (96.7)	24 (80)	104 (86.7)
Pruning	17 (56.7)	19 (63.3)	10 (33.3)	23 (76.7)	69 (57.5)
Lime application	11 (36.7)	13 (43.3)	4 (13.3)	7 (23.3)	35 (29.2)
Organic farming	13 (43.3)	21 (70)	13 (43.3)	8 (26.7)	55 (45.8)
Water conservation measures	2 (6.7)	4 (13.3)	5 (16.7)	3 (10)	14 (11.7)
Crop insurance	4 (13.3)	3 (10)	0 (0.0)	1 (3.3)	8 (6.7)
Budded wild nutmeg trees	0 (0.0)	0 (0.0)	2 (6.7)	1 (3.3)	3 (2.5)

Note: Figure in parentheses indicate percent to the total number of respondents in respective group

4.7. CONSTRAINTS IN NUTMEG FARMING

The nutmeg farmers of Kerala were facing several constraints in production and marketing of the commodity. The important constraints were identified and listed based on the responses of the sample farmers.

4.7.1. Constraints faced by nutmeg farmers in production and marketing

The major constraints confronted by nutmeg farmers of four different blocks in the production and marketing of nutmeg were identified and were listed in Table 4.27.

Climate change was the most serious constraint faced by the nutmeg farmers, followed by occurrence of diseases. High wage rate was the third most important constraint faced by the nutmeg farmers. The non-availability of storage and drying facilities, wild boar and crab attack, labour shortage and decreased export of nutmeg were the other constraints faced by the nutmeg farmers. The wild boar attack at night and resulted damages to nutmeg trees. Crab found nutmeg from ground and most of them love eating fleshy part of nutmeg.

Table 4. 27 Distribution of respondents based on constraints in nutmeg farming

Constraints	Chalakudy Block	Mala Block	Wadakkanchery Block	Angamaly Block	Total
Climate change	18 (60)	16 (53.3)	13 (43.3)	14 (46.7)	61 (50.8)
Occurrence of diseases	11 (36.7)	17 (56.7)	15 (50)	14 (46.7)	57 (47.5)
High wage rate	2 (6.7)	8 (26.7)	3 (10)	3 (10)	16 (13.3)
Non availability of Storage and drying facilities	6 (20)	4 (13.3)	2 (6.7)	1 (3.3)	13 (10.8)
Wild boar and crab attack	0 (0.0)	1 (3.3)	5 (16.7)	1 (3.3)	7 (5.8)
Low nutmeg export due to Covid pandemic	1 (3.3)	2 (6.7)	0 (0.0)	2 (6.7)	5 (4.2)
Labour shortage	0 (0.0)	1 (3.3)	2 (6.7)	4 (13.3)	7 (5.8)

Note: Figure in parentheses indicate percent to the total number of respondents in respective group

The study conducted by Kalra et al (2007) on impacts of climate change on agriculture during 2007 also reported that climate change was the major constraint faced by farmers.

4.8. SUPPORT FOR FARMERS' ADAPTATION MEASURES

The distribution of respondents based on support for farmers' adaptation measures were showed in Table 4.28.

Table 4. 28 Distribution of respondents based on support for farmers' adaptation measures

Support	Farmers responded (%)
Government subsidies	99 (82.5)
Training	88 (73.3)
Extension services	47 (39.2)
Irrigation development	11 (9.2)
Credit facilities	19 (15.8)
Subsidy for crop Insurance payment	4 (3.3)

Note: Figure in parentheses indicate percent to total

It could be found from the table that government subsidies were the major support to 82.5 percent of the total sample respondents followed by training support (73.3%). The extension services such as technical advice on agriculture and weather warning to farmers supported 39.2 percent of sample respondents. About 15.8 percent of respondents were supported by credit facilities. Irrigation development and subsidy for crop insurance payment were extended to 9.2 percent and 3.3 percent respectively.

4.9. CORRELATION ANALYSIS

4.9.1. Weather extreme preparedness categorisation of nutmeg farmers

Distribution of respondents based on the scores of weather extreme preparedness is given in Table 4.29.

Table 4. 29 Distribution of respondents based on the scores of weather extreme preparedness

Category	Respondents
Low	15 (12.5)
Medium	89 (74.2)
High	16 (13.3)
Total	120 (100)

Low category is the score less than 13.5, medium category is in between 13.5 to 18.7 and high category included greater than 18.7.

Analysis of the preparedness of nutmeg farmers on extreme weather conditions showed that 74.2 percent of nutmeg farmers had medium scores, while low score for 12.5 percent nutmeg farmers and 13.3 percent farmers had high scores. It can be inferred from the table that about 87.5 per cent of the interviewed farmers had medium to high level of weather extreme preparedness, i.e., they are ready to face unfavourable conditions and carry out nutmeg farming for their sustenance.

4.9.2. Correlation of weather preparedness with independent variables

The independent variables such as age, experience in farming, experience in nutmeg farming, annual income, land area, number of nutmeg trees, nutmeg yield and mace yield was taken. The correlation analysis between the weather extreme preparedness and independent variables were taken for correlation analysis.

The correlation results from Table 4.30. revealed that annual income and land holding pattern had significant positive correlation on weather extreme preparedness score. The correlation between annual income and land holding pattern on weather extreme preparedness was significant at 1% level of significance. This result pointed out that farmers having high income are less prone to the uncertainties like yield losses resulting from climate change.

Table 4. 30 Correlation of weather preparedness with independent variables

SL. No	Dependent variable	Independent variables	Correlation coefficient
1.	Weather extreme preparedness score	Age	-0.022
		Experience in farming	0.043
		Experience in nutmeg farming	0.138
		Annual income	0.242**
		Land holding pattern	0.282**
		Number of nutmeg trees	0.175
		Nutmeg yield	0.067
		Mace yield	0.155

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Farmers possessing more land area are also less sensitive to climate changes as they will be getting income from different crops in their land. The results of the study suggest to have crop diversification to overcome or reduce losses incurred during climate change.

Age had non-significant negative effect and experience in farming, experience in nutmeg farming, number of nutmeg trees, nutmeg yield and mace yield had non-significant positive effect on weather extreme preparedness score.

5. SUMMARY

Nutmeg is a tree spice belonging to the family *Myristicaceae*. It produces two separate and distinct spices, the nutmeg and mace. The cultivation of nutmeg in India is limited primarily to Kerala, Karnataka and Tamil Nadu. The districts of Thrissur and Ernakulam were the state's main nutmeg-producing areas. There has been a varying pattern of productivity in nutmeg production in Kerala. Nutmeg needs a wet, humid climate with no extreme dry season. The soil should be well drained and rich in organic matter. The extreme weather events such as drought, flood effects the nutmeg production badly and creates economic loss to the nutmeg farmers. The 2016 drought condition and 2018 flood condition effects the nutmeg yield. In this context, a study on "Weather extremes preparedness of nutmeg (*Myristica fragrans*) farmers in Kerala" was undertaken. The objective of the study is to analyse the crop weather relationship of nutmeg farming in Kerala and to study the socio-economic characteristics of nutmeg farmers as well as to study the behavioural pattern and strategies of nutmeg farmers for mitigating weather extreme conditions.

The study was conducted in Thrissur and Ernakulam districts. The study will be undertaken in 4 blocks (Wadakkanchery, Mala, Chalakudy and Angamaly) of Thrissur and Ernakulam districts respectively. The selection of site was done purposively which are evenly affected by weather extremes. From each block 5 krishibhavans and from each krishibhavan 6 farmers will be surveyed hence making the total sample size of 120. The present study was based on both primary and secondary data. Weather data of Thrissur and Ernakulam was collected by College of Agriculture (COA) Vellanikkara and NASA power data access viewer respectively. Secondary data on area, production and productivity was collected for both districts from the Directorate of Economics and Statistics, Government of Kerala, Thiruvananthapuram for the period of 2005 to 2018.

The area and production of nutmeg in Kerala had an increasing trend, but the productivity exhibited a varying pattern during the period from 2005-06 to 2018-

19. The area under nutmeg in Kerala has increased from 10,984 hectares during 2005-06 to 22,770.67 hectares during 2018-19. The production during the above period also increased from 2746 tonnes to 14,598 tonnes. The productivity of the crop increased from 260.97 kg per hectare in 2005-06 to 528.1 kg per hectare in 2018-19.

The correlation analysis of the yield was carried separately for Thrissur and Ernakulam districts. The correlation was done for five major phenological phases of nutmeg are flower bud development, flowering, fruit set, fruit development and harvesting stage. The correlation analysis between the yield of respective districts and monthly weather variables were also taken for correlation analysis. The flower bud development stage occurs during April to June months. Flowering season is from August to October. A month after flowering, the fruiting begins. The months of fruit setting stage is from September to November. Fruit development was found to steadily increase from the second week after the set. The duration of fruit development stage of nutmeg is from November to March. The fruits begin to split in 206 to 237 days after fruit set. The harvesting season is from June to August with peak harvesting in July.

Maximum temperature and temperature range of Thrissur during flowering and fruit setting stages were positively influenced the yield. During flowering phase, maximum temperature within 30.2 – 31.8°C and temperature range within 7.4 – 8.9°C were suitable for getting higher nutmeg yield. During fruit setting stage, maximum temperature within 31.1 – 32.5°C and temperature range within 8.0 – 9.7°C were suitable for getting higher nutmeg yield. Mean temperature of Thrissur during fruit setting stage positively affected the yield. During fruit setting stage, mean temperature within 27.0 – 27.9°C was suitable for getting higher nutmeg yield. Maximum temperature of Thrissur during September and November months positively affected the yield. During September and November month, maximum temperature within 30.0 – 32.2°C and 31.4 – 33.0°C were suitable for getting higher nutmeg yield respectively. Wind speed of Thrissur during flower bud development, flowering, fruit set and harvesting stages had negative influence on yield. Solar radiation of Thrissur during flower bud development stage negatively affected the yield. Rainfall of Thrissur during September negatively influenced the yield. Wind speed of Thrissur from March to November had negative influence on yield.

Solar radiation of Ernakulam during flowering stage negatively affected the yield. Wind speed of Ernakulam during fruit development stage negatively influence on yield. Rainfall of Ernakulam during January and April negatively affected the yield.

The socio-economic status components included in the study were age of the respondents, gender, educational status, annual income, occupation, land holding pattern, experience in farming, experience in nutmeg farming and number of nutmeg trees. Out of 120 respondent's 45.8 percent belong to above 60 years and 45 percent belong to 45 to 60 years age group. In both of the selected districts, no farmers under the age of 30 were found, indicating a lack of interest among young people in farming as a profession, which is one of Kerala's major challenges for agricultural development. The majority of nutmeg farmers were males and only 6 percent of the respondents were female farmers. Most of the farmers (89.2 percent) were SSLC or above SSLC. Only 10.8 percent of farmers was educated below SSLC were involved in nutmeg cultivation. It showed that educated farmers were more interested to do nutmeg cultivation and they make a good yield out of it. The half of the farmers (53.3 percent) comes under the annual income of less than one lakh rupees. Nearly 91 percent of respondents had agriculture as main occupation and they seriously approach to nutmeg cultivation. Most of the farmers (75 percent) had a land area of less than 1 hectare. Age decides the experience of the farmers in cultivation of crops and most of the farmers (66 percent) had experience between 10 and 30 years. 40 percent of the farmers had experience in nutmeg farming between 20 to 30 years. 46 percent of farmers had 50 to 100 nutmeg trees out of 120 farmers.

The price behaviour of nutmeg with shell, nutmeg without shell and mace were analysed. There was a discernible increase in the prices of all the three products in 2018-19 because the production was almost lower by 40 percent over the previous year. There is decrease in the prices of nutmeg without shell and with shell and increase in the price of mace during 2019-20. The annual rainfall of Thrissur and Ernakulam districts having a similar decreasing and increasing trend from 2011 to 2019. The price of nutmeg with shell and mace increases with increase of annual rainfall in both of Thrissur and Ernakulam districts.

Most of the farmers use shade loving nature of nutmeg and makes it suitable for grow as an intercrop with shade giving trees like coconut trees. Nutmeg requires irrigation frequently to avoid the water stress conditions. So, most of the nutmeg farmers (42.5 percent) preferred own well as the major source of irrigation. 88.4 percent of sample respondents had surface irrigation. There was a smaller number of farmers aware about the importance of drip and sprinkler irrigation. This type of irrigations enhances the water use efficiency and also reduces the surface loss of water. So, educate farmers and make aware about the importance of these water conservation measures will improve the nutmeg yield and overcome the climate change challenges. The nutmeg yield will increase when the farmers adopt the water conservation measures like sprinkler and drip irrigation. More farmers will adopt sprinkler and drip irrigation if government subsidy is brought for it. More adoption of sprinkler and drip irrigation will be possible only through the financial support of the government. 96.7 percent of sample respondents in Mala block had newspaper, major source of information for farmers regarding nutmeg cultivation while it was television in Chalakudy block. Newspaper was the major source of information in Wadakkanchery and Angamaly blocks. Increase in rainfall intensity and erratic rainfall were the major components of climate change affecting nutmeg production as revealed by 99.2 percent and 95.9 percent respectively. The major impact perceived was changed timing and quantity of rains which was reported by 88.3 percent of the sample respondents. The major climate change effect on nutmeg tree was decreased yield which was reported by 91.7 percent of the sample respondents. Agronomic conservation measures such as mulching, mixed cropping, cover cropping and tillage practices was the major adaptation practice practiced by 86.7 percent of the total respondents. Climate change was the most serious constraint faced by the nutmeg farmers, followed by occurrence of diseases.

Government subsidies was the major support to 82.5 percent of the total sample respondents followed by training support (73.3%).

The weather extreme preparedness of the farmers' were assessed scientifically using scoring procedure used for psychological variables. In this study, responses of five questions from the questionnaire were taken which is base for calculating weather extreme preparedness score. Responses were collected in a five-point continuum viz., strongly agree, agree, undecided, disagree, strongly disagree and the scores of 5,4,3,2 and 1 were given for these responses respectively. The cumulative score was taken as weather extreme preparedness score of a respondent. Thus, the maximum weather extreme preparedness score that could be obtained by a respondent was 25 and the minimum 5. The respondents were categorized into three groups viz. low, medium and high on the basis of mean and standard deviation of the total score.

Analysis of the preparedness of nutmeg farmers on extreme weather conditions showed that 74.2 percent of nutmeg farmers had medium scores, while low score for 12.5 percent nutmeg farmers and 13.3 percent farmers had high scores. About 87 per cent of the interviewed farmers had medium to high level of weather extreme preparedness, i.e., they are ready to face unfavourable conditions and carry out nutmeg farming for their sustenance. Annual income and land holding pattern had significant positive correlation on weather extreme preparedness score. The correlation between annual income and land holding pattern on weather extreme preparedness was significant at 1% level of significance. This result pointed out that farmers having high income are less prone to the uncertainties like yield losses resulting from climate change. Farmers possessing more land area are also less sensitive to climate changes as they will be getting income from different crops in their land. The results of the study suggest to have crop diversification to overcome or reduce losses incurred during climate change. Age had non-significant negative effect and experience in farming, experience in nutmeg farming, number of nutmeg trees, nutmeg yield and mace yield had non-significant positive effect on weather extreme preparedness score.

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APPENDICES

Appendix I

Kerala Agricultural University

Analysis of weather extreme preparedness of farmers

Questionnaire for Nutmeg Farmers

No: Block: Krishi bhavan: Date:

1. **Socio-economic details of the farmer:**

A. Name of the respondent:

B. Age:

C. Gender: Male/Female/Transgender

D. Religion: Hindu/Muslim/Christian/Others

E. Caste: General/SC/ST/OBC/OEC/Others

F. Address:

G. Contact number:

H. Marital status: Married/Single/Widow/Widower/Divorce

I. Educational qualification:

a) Below SSLC ☐ b) SSLC ☐ c) Plus Two ☐ d) Degree ☐
e) Post graduation ☐ f) Diploma ☐ Specify (If any other) ....

b) The most impacted weather extremes in your locality:

c) Experience in farming(years):

d) Number of years farming in current location:

e) Number of labourers engaged in farming:

f) Year in which you started nutmeg farming:

g) Which type of agriculture do you practice? 1. Rainfed only 2. Irrigation only 3. Rainfed and Irrigation 4. Other (specify): ______________________

h) Number of nutmeg trees:

2. **<u>Income details:</u>**

A. Annual income

<50,000 ☐ 50,000-1 lakh ☐ 1 lakh- 1.5 lakh ☐ 1.5 lakh- 2 lakh ☐ >2 lakh ☐

B. Source of income:

a) Farming alone ☐ b) Farming+ Business ☐ c) Farming+ Government job ☐ d) Farming+ Self-employed ☐ Specify, if any other: ______

____

3. **<u>Land details:</u>**

Own land area: Rental land area:

Total land area (acres):

Rental value of own land (leased out):

Rental value of leased-in land:

4. **<u>Crop details:</u>**

SL. No.	Variety	Area (acres)	Quantity produced (Kg)	Price realized Rs /Kg	
				Current year	Previous year
1					
2					
3					

Other crops:

Nutmeg as: a) Main crop ☐ b) Intercrop ☐

Intercrop: if any, ____

5. **Method of Nutmeg cultivation:**

a) Organic ☐ b) By using chemicals ☐ c) Organic + Chemical ☐
d) Others ☐

6. **Input requirement details:**

6a. Sources of irrigation:

I. Own well ☐ b) Canal ☐ c) Rain water ☐ d) Bore well ☐
e) Others (specify)___________

II. Type of irrigation: a) Sprinkler ☐ b) Drip ☐ c) Surface irrigation ☐

6b. Whether you are getting any technical support? Yes ☐ / No ☐

If yes, details of support:

Sl.No.	**Name of the institution**	**Kind of support**
1	Farmers association	
2	Spices board	
3	VFPCK	
4	Krishi Bhavan	
5	KAU	
6	NGO	

6c. Did you experience any kind of loss due to: a) Pest and diseases ☐

b) Climate ☐ c). Government policy on pricing ☐ d) Labour shortage ☐

6d. In case of climate, specify the kind and cause of loss:

____

7. **PERCEPTION OF FARMERS ON CLIMATE CHANGE**

7a. Do you believe in the phenomenon of climate change? Yes ☐ No ☐

7b. Have you observed any long-term changes in the mean of climate variables (particularly temperature and rainfall) over the last 30 years? 1: yes ☐

2: No ☐

If yes, indicate (✓) what have been the changes.

S/N	7b. Long-term changes in mean climate variables	Selected factors (✓)
7.1b	Increased temperature	
7.2b	Decreased temperature	
7.3b	Increased in rainfall duration	
7.4b	Decreased in rainfall duration	
7.5b	Increased in rainfall intensity	
7.6b	Decreased in rainfall intensity	
7.7b	Increased in number of rainfall events	
7.8b	Decreased in number of rainfall events	

7c. To what extent are these changes? 1. Extreme changes ☐

2. Moderate changes ☐ 3. Limited changes ☐ 4. I don't know ☐

7d. What have you observed to be the main effects/impacts (negative) of these long-term changes in the mean of climate variables over the last 30 years? [indicate (✓)]

RANK: On a scale of 1-7, where 1=Extremely severe (Disastrous), 2=Very severe (Critical), 3=Severe, 4=Significant, 5= Somewhat significant, 6=Irrevalent, 7=I don't know

7d. Effect (Negative impact)	Selected factors (✓)	RANK (order of severity)
7.1d Changed timing and quantity of rains		
7.2d Increased intensity of rainfall		
7.3d Increased frequency of drought		
7.4d Increased frequency of floods		
7.5d Post harvest losses		
7.6d Pests invasion		
7.7d Erosion		
7.8d Changes in growing season		

7e. Reduction in nutmeg yield in comparison to the previous year: ……………….

7f. What do you think is the major cause of yield reduction, is that the weather extremes alone or any other factors in combination with this?

____

I. Does it affect the crop quality? 1: Yes ☐ / 2: No ☐

II. How much percentage reduction in market value? ____________________

III. Does any hike in price occurred due to shortage of crops? 1: Yes ☐/ 2: No ☐

IV. How do you market nutmeg? ____________________________________

V. What are the difficulties faced by you while marketing? ______________

____

8. **<u>Vulnerability assessment</u>**

8a. During the recent disaster events, were you affected by?

Floods ☐ Landslides ☐ Drought ☐ Not effected ☐ Others (specify)____

____

9. Farmers adaptation options

9a. Have you made any changes/adjustments in your farming ways in response to climate change and variability (shifts in climate variables) over the last 10 years?

1: Yes ☐ 2: No ☐

9b. What adjustments in your farming ways have you made to these long-term shifts in temperature?

1: Mulching, 2: Mixed cropping, 3: Cover cropping, 4: Other (specify) ______

9c. What adjustments in your farming practices have you made to these long-term shifts in temperature?

Questions	If yes, how and/or which?	If no, why?
1.Does the weather extreme experience help you to stay prepared in a better manner in future?		
2.Would some external supports (like training, information, agricultural extension etc.) help you to improve your future adaptation?		
3.Does farmer's association help you to increase climate resilience in some way?		
4.Did you adopt any alternative farming technology in the past five years?		
5. Have you noticed the early warnings and alerts given by the government? Do you know what different colours signify? Which mode of communication is most accessible for you?		

10. Support for farmers adaptation measures

10a. Do you receive any external support for your adaptation measures? 1: Yes ☐ / 2: No ☐

10b. If yes, in what form does the support come? 1: Financial support ☐

2: Material support☐ 3: Extension services☐ 4: Subsidized farm inputs ☐

5: Other (specify)____

10c. Is this support free? 1: Yes☐ / 2: No☐

10d. If no what are the conditions attached? 1: Loan to be paid back ☐

2: to buy farm machinery on credit☐ 3: to buy improved farm inputs (fertilisers, pesticides etc.) on subsidized prices ☐ 4: Other (specify)______

____

10e. How often do you receive this support? 1: once a year☐ 2: twice a year☐ 3: once every two years ☐ 4: once every three years ☐ 5: other (specify) ______

10f. Which organization offers this support? 1: Krishi Bhavan ☐ 2: KAU ☐ 3: NGO ☐ 4: Other (specify)____

10g. Do extension officers provide information on expected rainfall and temperature? 1.Yes ☐/ 2.No☐

10h. Apart from official extension workers where else do you receive the necessary information and technical assistance? 1: Television ☐2: Radio☐ 3: Neighbouring farmer ☐ Social media 5: Newspaper☐ 6: Other (specify)_____________

10i. Which of these sectors such as Krishi Bhavan, KAU, or NGO is responsible for giving the services, investments, or developments for adopt the issues generated from weather extremes? Please rank these issues in the order of importance?

[1st is most important, 6th is least important]

Issue	Rank	Who

Issues: - Irrigation development, Climatic information services, provision of credit facilities, review of land tenure system, agriculture mechanization, other (pls specify…………………………………………………………….)

Who : - Krishi Bhavan, KAU, NGO, other (pls specify………...............................)

Appendix II

Abbreviations and units used

AVRDC - Asian Vegetable Research and Development Centre

GHGs - Greenhouse gases

GIS - Geographic Information System

IPCC - Intergovernmental Panel on Climate Change

MPCI - Multi-Peril Crop Insurance

MSL – Mean sea level

MVP - Multivariate Probit

NASA – National Aeronautics and Space Administration

OECS - Organization of Eastern Caribbean States

PMFBY- Pradhan Mantri Fasal Bima Yojana

SCI- System of Crop Intensification

SIDS - Small Island Developing States

SRI- System of Rice Intensification

Weather parameters

RF – Rainfall

RHmean – Mean Relative Humidity

SRAD – Solar Radiation

Tmax – Maximum Temperature

Tmean – Mean Temperature

Tmin – Minimum Temperature

Trange – Range Temperature

WS – Wind Speed

Phenophases

P1: Flower bud development

P2: Flowering

P3: Fruit set

P4: Fruit development

P5: Harvesting

Units

°C : degree Celsius

mm : millimeter

km hr^{-1} : kilometer per hour

% : percent

Kg : kilogram

MJ : megajoules

Appendix III

Nutmeg yield in Thrissur from 2005 to 2018

Year	Yield (tonnes)
2005	635
2006	2630
2007	2352
2008	3346
2009	3092
2010	3402
2011	3794
2012	3819
2013	4031
2014	3978
2015	4171
2016	4011
2017	3944
2018	4068
Average	3376.6

Nutmeg yield in Ernakulam from 2005-06 to 2018-19

Year	Yield (tonnes)
2005	1244
2006	6070
2007	6173
2008	5209
2009	4873
2010	5807
2011	5067
2012	4842
2013	4799
2014	5599
2015	5751
2016	4967
2017	5020
2018	5362
Average	5055.9

Appendix IV

Weather variables in different phenophases of nutmeg in Thrissur from 2005 to 2018

Phenophases	Year	Tmax	Tmin	Tmean	Trange	RF	RHmean	WS	SRAD
Flower bud development	2005	32.4	24.4	28.4	8	972	77.95	3.6	15.5
	2006	31.7	24.2	27.95	7.5	1370.3	78.95	3.5	15.2
	2007	32.8	24.4	28.6	8.4	1127.9	75.8	3.9	15.8
	2008	32.0	24.4	28.2	7.6	709.4	77.35	3.4	14.3
	2009	32.3	24.6	28.45	7.7	781.0	77.8	2.3	14.6
	2010	32.8	24.8	28.8	8.0	927.8	79.8	3.1	14.9
	2011	32.2	24.3	28.25	7.9	1205.2	79.6	3.0	15
	2012	32.4	24.6	28.5	7.8	770.7	78.3	3.0	14.8
	2013	32.3	24.3	28.3	8	1130.9	79.3	1.2	13
	2014	33.1	25.0	29.05	8.1	854.4	78.45	2.3	14.8
	2015	32.6	24.4	28.5	8.2	1051	80.6	1.9	14
	2016	33.2	24	28.6	9.2	949.9	79.3	1.7	14.9
	2017	33.6	24.8	29.2	8.8	816.8	76.65	1.6	14.2
	2018	33	23.5	28.25	9.5	1242.6	79.1	1.7	14.2
Flowering	2005	30.1	23.2	26.65	6.9	941.0	81.6	3.4	14.4
	2006	30.1	23	26.55	7.1	1396.5	81.8	3.3	13.6
	2007	29.6	22.7	26.15	6.9	1669.4	83.15	3.1	12.2
	2008	30.7	23.4	27.05	7.3	1016.9	79.1	2.9	14.3
	2009	30.7	23.2	26.95	7.5	863.2	81.45	3	14.4
	2010	29.8	22.9	26.35	6.9	1204.9	84.5	2.5	12.7
	2011	30.5	23.1	26.8	7.4	1339	83.1	2.5	13.5
	2012	30.6	23.2	26.9	7.4	953.9	81.75	2.7	14
	2013	30.2	22.5	26.35	7.7	1019.8	83.95	1.8	13.8

	2014	30.9	23.4	27.15	7.5	1039.5	83.0	2.1	13.6
	2015	31.8	23.8	27.8	8	766.8	80.8	0.6	15.1
	2016	30.7	23.2	26.95	7.5	306.8	81.8	1.5	14.7
	2017	31.1	22.8	26.95	8.3	1257.5	84.15	0.6	13.4
	2018	31.4	22.5	26.95	8.9	1350	79.45	1.8	14.8
Fruit set	2005	30.3	23.1	26.7	7.2	606.1	78.3	3.8	14.4
	2006	30.7	23.2	26.95	7.5	925.2	77.95	4.1	14.5
	2007	30.5	22.3	26.4	8.2	1144.5	77.5	3.5	12.2
	2008	31.5	23.2	27.35	8.3	716.7	75.1	3.2	15.4
	2009	31.1	23.3	27.2	7.8	623.4	78.3	3.6	15.3
	2010	30.2	22.7	26.45	7.5	1277.1	82.8	2.7	13.4
	2011	31.1	23.1	27.1	8.0	865.2	76.8	3.4	15.4
	2012	31.7	23.1	27.4	8.6	356.1	76.1	2.8	16.1
	2013	31.1	22.8	26.95	8.3	795.9	80.45	2.1	14.7
	2014	31.6	23.4	27.5	8.2	525	78.1	2.7	14.7
	2015	32	23.8	27.9	8.2	597.2	78.1	1.2	15.0
	2016	31.6	22.8	27.2	8.8	137.1	76.95	1.5	15.1
	2017	32.0	22.3	27.15	9.7	837.2	79.3	0.9	14.9
	2018	32.5	22.9	27.7	9.6	488.6	73.1	2.6	17.0
Fruit development	2005	34.2	23.1	28.65	11.1	22.4	59.8	5.6	19.4
	2006	33.7	23.1	28.4	10.6	174.5	60.1	6.5	19.0
	2007	34	22.9	28.45	11.1	33.5	59.2	5.5	19.4
	2008	32.9	22.9	27.9	10	259.3	62.4	5.1	18.1
	2009	34.1	23.2	28.65	10.9	252.3	63.5	5.2	19.2
	2010	34.1	23.6	28.85	10.5	320.2	65.4	5	18.7
	2011	33.5	22.8	28.15	10.7	329.9	61.1	5.1	19.0
	2012	34.4	22.9	28.65	11.5	43.2	61	4.7	19.3

	2013	34.3	23.5	28.9	10.8	181.5	60.9	1.7	18.5
	2014	34.5	23.4	28.95	11.1	94.9	57.9	4.5	18.6
	2015	34.1	23.6	28.85	10.5	311.5	61.5	4.7	18.5
	2016	34.8	23.9	29.35	10.9	101.9	62.6	3.5	18.4
	2017	35.1	23.3	29.2	11.8	82.4	60	3.8	18.5
	2018	35.1	22.9	29	12.2	105	55.5	4.6	19.3
Harvesting	2005	29.5	23.3	26.4	6.2	1785.4	85.2	3.7	12.2
	2006	29.7	23.3	26.5	6.4	1678.2	84.2	3.2	12.3
	2007	29.2	23.1	26.15	6.1	2507.7	85.3	3.4	11.1
	2008	29.7	23.4	26.55	6.3	1370.5	83.7	3	11.4
	2009	29.6	23.3	26.45	6.3	1941.2	85.4	3.3	12.1
	2010	29.6	23.3	26.45	6.3	1463	86.9	2.6	11
	2011	29.3	23.1	26.2	6.2	2101.6	88	2.4	10.7
	2012	29.8	23.5	26.65	6.3	1543.8	85.5	2.7	11.9
	2013	28.9	22.8	25.85	6.1	2270	88.2	1.8	10.5
	2014	29.9	23.6	26.75	6.3	1837.6	86.5	2.1	11.1
	2015	30.8	23.7	27.25	7.1	1460.7	84.2	1.3	12.6
	2016	30.0	22.2	26.1	7.8	1231.2	85.8	1.5	11.8
	2017	30.5	23.3	26.9	7.2	1493.7	86.0	1.1	11.6
	2018	29.5	22.7	26.1	6.8	2451.3	88.2	1.7	10.5

Weather variables in different phenophases of nutmeg in Ernakulam from 2005 to 2018

Phenophases	Year	Tmax	Tmin	Tmean	Trange	RF	RHmean	WS	SRAD
Flower bud development	2005	29.62	27.0	28.3	2.62	1126.16	82.7	3.16	19.82
	2006	29.86	26.67	28.3	3.19	1172.2	80.4	3.33	19.38
	2007	29.95	26.94	28.5	3.01	958.2	80.77	3.24	19.4
	2008	29.1	26.43	27.8	2.67	660.9	83.02	3.2	19.09
	2009	29.64	26.81	28.3	2.83	1013.67	81.67	3.39	17.06
	2010	30.07	27.36	28.7	2.71	957.21	81.9	3.4	18.43
	2011	29.81	26.74	28.3	3.07	810.03	80.26	3.49	18.84
	2012	29.4	26.6	28.0	2.8	680.71	82	3.36	18.61
	2013	30.13	27.1	28.6	3.03	1149.08	78.65	3.93	16.45
	2014	30.25	27.37	28.8	2.88	690.45	80.9	3.31	18.49
	2015	29.92	27.1	28.5	2.82	819.23	80.43	2.77	14.68
	2016	30.68	27.58	29.1	3.1	815.48	79.5	3.46	16.66
	2017	30.3	27.32	28.8	2.98	835.81	80.47	3.43	17.35
	2018	29.81	27.1	28.5	2.71	970.06	81.64	3.23	16.67
Flowering	2005	27.73	25.4	26.7	2.33	1049.27	87.08	3.51	20
	2006	27.65	25.28	26.5	2.37	1547.57	86.94	3.12	18.05
	2007	27.43	25.16	27.0	2.27	1308.42	87.13	3.32	16.95
	2008	28.08	25.36	26.7	2.72	1001.43	84.39	3.0	18.65
	2009	28.18	25.47	26.8	2.71	628.35	84.76	3.23	18.36
	2010	27.63	25.24	26.4	2.39	1131.08	87.38	3.47	16.47
	2011	27.98	25.26	26.6	2.72	808.38	84.45	3.07	17.07
	2012	28.2	25.51	26.9	2.69	724.89	84.3	3.11	17.61
	2013	27.64	25.2	26.4	2.44	694.2	86.25	3.48	15.53
	2014	27.91	25.4	26.7	2.51	1203.06	86.04	3.22	16.46
	2015	28.59	25.9	27.2	2.69	747.41	84.78	2.66	17.74

	2016	28.13	25.2	26.7	2.93	387.34	84.82	3.57	18.53
	2017	28.02	25.73	26.9	2.29	991.15	86.92	3.16	16.3
	2018	28.2	25.35	26.8	2.85	992.02	84.88	3.17	17.72
Fruit set	2005	27.78	25.25	26.515	2.53	1173.44	85.34	2.97	18.03
	2006	28.09	25.41	26.75	2.68	1395	84.89	2.57	16.96
	2007	28	25.2	26.6	2.8	1118.74	82.74	2.72	17.55
	2008	28.82	25.58	27.2	3.24	790.72	80.28	2.5	17.93
	2009	28.59	25.51	27.05	3.08	747.49	82	2.66	16.56
	2010	27.84	25.29	26.565	2.55	1151.57	85.19	2.87	16.41
	2011	28.81	25.4	27.105	3.41	634.6	80	2.66	17.75
	2012	28.74	25.68	27.21	3.06	520.1	80.81	2.52	18.65
	2013	28.16	25.44	26.8	2.72	641.26	82.97	2.8	16
	2014	28.55	25.56	27.055	2.99	683.03	82.23	2.57	16.61
	2015	28.87	26	27.435	2.87	818.55	82.34	2.38	16.85
	2016	28.8	25.29	27.045	3.51	336.93	81	2.83	18.21
	2017	28.54	25.85	27.195	2.69	823.65	83.3	2.69	15.48
	2018	29.07	25.7	27.385	3.37	648.46	80.6	2.44	17.34
Fruit development	2005	31.2	25.7	28.45	5.5	498.3	69.2	2.2	22.8
	2006	31.3	25.3	28.3	6	388.4	66.7	2.1	22.2
	2007	31.7	25.6	28.65	6.1	170.3	64.4	2.3	22.6
	2008	30.8	25.4	28.1	5.4	423.3	69	2.1	19
	2009	31.7	25.8	28.75	5.9	374.4	66.5	2.1	21.3
	2010	31.6	26.3	28.95	5.3	423.1	68.1	2.2	20.7
	2011	30.8	25.3	28.05	5.5	458.6	69.2	2.1	21.5
	2012	31.6	25.8	28.7	5.8	217.6	66.3	2.2	20
	2013	31.5	26.2	28.85	5.3	412.9	67.9	2.1	20.8
	2014	31.7	26.1	28.9	5.6	209.1	65.4	2.1	20.8

	2015	31.6	26	28.8	5.6	391.4	66.2	2.2	21.1
	2016	31.9	26.4	29.15	5.5	281	68.6	2	19.9
	2017	31.5	25.9	28.7	5.6	373.1	67.3	2.2	20.1
	2018	31.8	26.4	29.1	5.4	296.3	66.4	2	19.3
Harvesting	2005	27.8	25.8	26.8	2	1307	88.4	4.1	17.9
	2006	27.8	25.5	26.65	2.3	1377.3	87.8	3.6	18.6
	2007	27.6	25.6	26.6	2	1652.3	88.1	3.9	15.9
	2008	27.5	25.3	26.4	2.2	1029.5	87.7	3.7	16.5
	2009	27.7	25.5	26.6	2.2	1264.7	87.2	3.8	16.6
	2010	27.8	25.6	26.7	2.2	1289	87.2	4	15.2
	2011	27.7	25.3	26.5	2.4	1154.8	86.9	3.7	14.9
	2012	27.9	25.6	26.75	2.3	846.9	86.4	3.8	16.3
	2013	27.4	25.3	26.35	2.1	1764	88.6	4.1	13.5
	2014	28	25.8	26.9	2.2	1390.4	87.7	3.9	14.8
	2015	28.4	26	27.2	2.4	827.3	86.4	3.4	12.5
	2016	27.9	25.7	26.8	2.2	1064.4	87.6	3.9	15
	2017	28.1	25.9	27	2.2	1104.8	87.7	3.6	15
	2018	27.7	25.6	26.65	2.1	1771.2	88.6	4	13.1

Appendix V

Monthly weather variables of nutmeg in Thrissur from 2005 to 2018

Months	Year	Tmax	Tmin	Tmean	Trange	RF	RHmean	WS	SS_hrs
January	2005	33.2	22.6	27.9	10.6	7.6	55.5	6.1	8.2
	2006	32.5	22.6	27.6	9.9	0	57.5	8.5	8.7
	2007	32.5	22.0	27.3	10.5	0	53.5	9.2	8.7
	2008	32.3	21.7	27.0	10.6	0	59.0	6.9	9.4
	2009	32.8	21.9	27.4	10.9	0	54.0	8.0	9.3
	2010	32.5	22.7	27.6	9.8	0	61.0	7.6	9.0
	2011	32.7	22.2	27.5	10.5	0	58.5	6.3	8.5
	2012	32.8	21.3	27.1	11.5	0	57.5	6.3	9.5
	2013	34.1	22.3	28.2	11.8	0	52.0	5.2	8.8
	2014	32.8	23.0	27.9	9.8	0	51.0	6.7	8.7
	2015	32.5	22.1	27.3	10.4	0	58.0	5.4	8.8
	2016	33.2	23.0	28.1	10.2	23.8	56.0	6.5	8.6
	2017	34.1	22.9	28.5	11.2	0	53.0	5.3	7.6
	2018	33.5	20.9	27.2	12.6	0	52.5	5.4	8.2
February	2005	35.1	22.3	28.7	12.8	0	52.5	5.8	10.0
	2006	34.3	22.3	28.3	12.0	0	51.0	7.2	9.6
	2007	34.0	22.2	28.1	11.8	0	55.0	4.9	9.8
	2008	33.6	22.9	28.3	10.7	29.7	60.6	4.5	8.2
	2009	35.1	22.1	28.6	13.0	0	56.5	5.1	9.6
	2010	34.9	23.7	29.3	11.2	0	59.0	6.0	9.1
	2011	33.7	22.0	27.9	11.7	77.5	56.5	5.3	8.5
	2012	35.1	22.1	28.6	13.0	0	54.0	5.4	9.2
	2013	34.7	23.3	29.0	11.4	84.4	56.5	0.6	8.6

	2014	34.7	22.9	28.8	11.8	0	56.0	4.5	8.6
	2015	34.3	23.0	28.7	11.3	0	55.0	6.0	8.8
	2016	35.3	23.6	29.5	11.7	11.4	56.5	4.0	8.2
	2017	36.0	23.2	29.6	12.8	0	50.5	5.0	8.7
	2018	35.7	22.5	29.1	13.2	5.2	46.5	5.7	9.5
March	2005	35.7	24.6	30.2	11.1	0	62.5	5.5	8.8
	2006	34.8	23.8	29.3	11.0	95.2	67.5	4.0	7.6
	2007	36.0	24.4	30.2	11.6	0	62.5	4.2	8.2
	2008	33.2	23.4	28.3	9.8	205.3	63.7	4.9	6.9
	2009	35.1	24.4	29.8	10.7	29.0	70.0	3.4	7.9
	2010	36.2	24.8	30.5	11.4	12.9	66.5	3.7	8.4
	2011	34.8	23.9	29.4	10.9	10.0	64.0	4.1	8.7
	2012	35.2	24.2	29.7	11.0	4.5	67.5	3.5	7.6
	2013	35.4	24.4	29.9	11.0	14.6	64.0	0	7.1
	2014	36.7	24.2	30.5	12.5	0	55.0	3.8	8.5
	2015	35.8	24.9	30.4	10.9	72	63.5	3.4	8.0
	2016	36.3	25.6	31.0	10.7	0	67.0	2.8	8.0
	2017	36.1	24.7	30.4	11.4	13.2	66.5	2.2	7.4
	2018	36.7	24	30.4	12.7	33.2	59.0	3.3	8.0
April	2005	33.7	24.8	29.3	8.9	171.4	74.0	3.7	7.1
	2006	33.4	24.7	29.1	8.7	86.2	74.5	3.6	7.1
	2007	35.7	25.0	30.4	10.7	61.0	68.5	4.3	7.7
	2008	33.2	25.0	29.1	8.2	65.6	74.6	3.2	6.3
	2009	34.5	25.3	29.9	9.2	16.5	73.5	1.8	5.8
	2010	35.1	25.2	30.2	9.9	103.6	74.0	3.7	7.4
	2011	34.3	24.5	29.4	9.8	207.1	73.0	3.3	6.6
	2012	34.7	24.8	29.8	9.9	101.9	73.0	3.4	6.6

	2013	34.9	25.1	30.0	9.8	0	71.5	0	6.5
	2014	35.3	25.7	30.5	9.6	61.0	73.0	2.3	6.4
	2015	34.0	24.6	29.3	9.4	162.2	76.5	2.4	6.8
	2016	35.8	26.3	31.1	9.5	25.8	71.0	2.1	7.9
	2017	35.7	26.0	30.9	9.7	19.1	70.0	2.1	6.5
	2018	36.2	24.8	30.5	11.4	28.9	70.0	2.0	7.3
	2005	33.6	25.0	29.3	8.6	89.2	74.0	3.7	7.0
	2006	31.8	24.3	28.1	7.5	675.5	78.5	3.7	5.8
	2007	32.8	24.7	28.8	8.1	240.5	75.0	3.7	6.6
	2008	33.0	24.7	28.9	8.3	11.5	72.5	4.1	6.1
	2009	32.6	24.8	28.7	7.8	199.5	76.5	1.9	5.5
	2010	33.1	25.6	29.4	7.5	123.8	79.0	3.0	5.4
May	2011	33.0	24.9	29.0	8.1	198.5	77.0	3.1	6.8
	2012	32.6	25.3	29.0	7.3	117.3	76.0	3.0	6.0
	2013	33.7	25.2	29.5	8.5	99.1	76.5	2.1	4.0
	2014	33.2	25.0	29.1	8.2	323.6	77.0	2.5	5.9
	2015	32.9	24.8	28.9	8.1	259.0	80.0	1.7	5.0
	2016	34.0	24.2	29.1	9.8	269.4	78.0	1.9	5.9
	2017	34.6	24.9	29.8	9.7	167.5	73.5	1.8	5.5
	2018	33.2	22.6	27.9	10.6	483.6	78.5	1.8	4.8
	2005	29.9	23.5	26.7	6.4	711.4	86.0	3.5	3.1
	2006	29.9	23.6	26.8	6.3	608.6	84.0	3.2	3.8
	2007	30.1	23.5	26.8	6.6	826.4	84.0	3.8	3.5
June	2008	29.9	23.5	26.7	6.4	632.3	85.0	3.0	2.0
	2009	30.0	23.7	26.9	6.3	565.0	83.5	3.4	3.9
	2010	30.4	23.8	27.1	6.6	700.4	86.5	2.8	3.0
	2011	29.3	23.6	26.5	5.7	799.6	89.0	2.6	2.5

	2012	30.1	23.9	27	6.2	551.5	86.0	2.7	2.8
	2013	28.5	22.7	25.6	5.8	1031.8	90.0	1.5	1.0
	2014	30.9	24.4	27.7	6.5	469.8	85.5	2.2	3.0
	2015	31.0	23.9	27.5	7.1	629.8	85.5	1.6	1.8
	2016	29.8	21.6	25.7	8.2	654.7	89.0	1.3	1.6
	2017	30.6	23.7	27.2	6.9	630.2	86.5	1.1	2.0
	2018	29.8	23.2	26.5	6.6	730.1	89.0	1.5	1.7
July	2005	28.7	23.0	25.9	5.7	727.5	87.5	3.9	1.7
	2006	29.5	23.3	26.4	6.2	519.0	85.5	3.4	2.1
	2007	28.4	22.9	25.7	5.5	1131.6	88.0	3.2	0.7
	2008	29.3	23.2	26.3	6.1	416.3	84.0	3.1	2.7
	2009	28.6	22.9	25.8	5.7	955.8	87.7	3.6	1.7
	2010	29.2	22.9	26.1	6.3	552.0	88.0	2.0	1.8
	2011	29.1	22.9	26.0	6.2	588.2	88.0	2.2	1.6
	2012	30.0	23.7	26.9	6.3	375.8	84.5	2.9	3.2
	2013	28.4	22.7	25.6	5.7	932.3	90.5	1.9	0.7
	2014	29.4	23.1	26.3	6.3	768.0	87.5	2.1	1.6
	2015	30.3	23.5	26.9	6.8	510.1	84.5	1.4	3.8
	2016	29.9	21.6	25.8	8.3	393.0	85.5	1.4	2.3
	2017	30.8	22.8	26.8	8.0	385.5	84.5	1.1	2.9
	2018	29.6	22.6	26.1	7.0	793.2	88.5	1.7	1.9
August	2005	29.9	23.3	26.6	6.6	346.5	82.0	3.6	5.2
	2006	29.8	23.1	26.5	6.7	550.6	83.0	3.1	4.3
	2007	29.0	22.8	25.9	6.2	549.7	84.0	3.3	3.2
	2008	29.8	23.6	26.7	6.2	321.9	82.0	3.0	3.4
	2009	30.2	23.2	26.7	7.0	420.4	85.0	2.9	4.1
	2010	29.3	23.2	26.3	6.1	210.6	86.1	3.0	2.5

	2011	29.4	22.9	26.2	6.5	713.8	87.0	2.4	2.2
	2012	29.2	23.0	26.1	6.2	616.5	86.0	2.6	2.9
	2013	29.9	22.9	26.4	7.0	305.9	84.0	2.1	4.3
	2014	29.5	23.2	26.4	6.3	599.8	86.5	1.9	2.6
	2015	31.0	23.7	27.4	7.3	320.8	82.5	0.8	4.9
	2016	30.4	23.3	26.9	7.1	183.5	83.0	1.9	4.9
	2017	30.1	23.3	26.7	6.8	478.0	87.0	1.0	3.1
	2018	29.2	22.3	25.8	6.9	928.0	87.0	1.8	2.2
September	2005	29.4	23.3	26.4	6.1	416.1	83.5	3.6	4.4
	2006	29.6	23.0	26.3	6.6	522.2	84.0	3.4	3.9
	2007	29.4	22.9	26.2	6.5	735.9	85.5	3.0	2.5
	2008	30.6	23.2	26.9	7.4	314.2	80.0	2.4	5.3
	2009	30.0	23.2	26.6	6.8	276.0	83.0	3.0	4.1
	2010	30.5	23.1	26.8	7.4	326.7	82.5	2.6	4.2
	2011	30.0	23.1	26.6	6.9	435.2	84.5	2.2	4.4
	2012	30.4	23.3	26.9	7.1	191.8	82.4	2.3	4.6
	2013	30.0	22.2	26.1	7.8	344.1	85.0	1.6	3.7
	2014	31.3	23.3	27.3	8.0	215.1	82.0	2.2	5.7
	2015	31.9	23.8	27.9	8.1	242.2	81.0	0.4	5.6
	2016	30.3	23.6	27.0	6.7	86.0	82.0	1.8	4.8
	2017	31.5	22.9	27.2	8.6	413.9	84.0	0.7	4.2
	2018	32.2	22.5	27.4	9.7	29.0	75.5	1.7	7.2
October	2005	31.0	23.2	27.1	7.8	178.4	79.5	3.0	5.2
	2006	31.0	23.0	27.0	8.0	323.7	78.5	3.6	4.8
	2007	30.5	22.5	26.5	8.0	383.8	80.0	3.2	4.4
	2008	31.7	23.4	27.6	8.3	380.8	75.5	3.3	5.7
	2009	32.0	23.2	27.6	8.8	166.8	76.5	3.3	6.7

	2010	29.7	22.4	26.1	7.3	667.6	85.0	2.1	4.2
	2011	32.1	23.5	27.8	8.6	190.0	78.0	3.1	6.1
	2012	32.2	23.5	27.9	8.7	145.6	77.0	3.2	6.2
	2013	30.8	22.6	26.7	8.2	369.8	83.0	1.7	5.3
	2014	32.0	23.7	27.9	8.3	224.6	80.5	2.2	4.4
	2015	32.5	24.1	28.3	8.4	203.8	79.0	0.8	5.6
	2016	31.5	22.7	27.1	8.8	37.3	80.5	1.0	5.5
	2017	31.7	22.4	27.1	9.3	365.6	81.5	0.2	4.9
	2018	32.8	22.9	27.9	9.9	393.0	76.0	2.0	5.7
November	2005	30.7	22.9	26.8	7.8	11.6	72.0	4.9	5.2
	2006	31.7	23.7	27.7	8.0	79.3	71.5	5.5	6.5
	2007	31.7	21.7	26.7	10.0	24.8	67.0	4.5	8.0
	2008	32.2	23.1	27.7	9.1	21.7	70.0	4.0	6.0
	2009	31.5	23.7	27.6	7.8	180.6	75.5	4.6	5.7
	2010	30.4	22.6	26.5	7.8	282.8	81.0	3.5	4.1
	2011	31.4	22.9	27.2	8.5	240.0	68.0	5.0	6.3
	2012	32.6	22.7	27.7	9.9	18.7	69.0	3.0	7.5
	2013	32.6	23.8	28.2	8.8	82.0	73.5	3.0	6.2
	2014	31.6	23.2	27.4	8.4	85.3	72.0	3.7	5.1
	2015	31.6	23.7	27.7	7.9	151.2	74.5	2.5	4.6
	2016	33.0	22.2	27.6	10.8	13.8	68.5	1.9	5.8
	2017	33.0	21.8	27.4	11.2	57.7	72.5	1.9	6.4
	2018	32.7	23.4	28.1	9.3	66.6	68.0	4.3	6.9
December	2005	31.5	22.1	26.8	9.4	3.2	65.6	5.7	7.3
	2006	31.5	23.6	27.6	7.9	0	56.3	10.8	7.8
	2007	31.6	22.7	27.2	8.9	8.7	59.6	8.6	6.7
	2008	31.6	22.5	27.1	9.1	2.6	60.0	7.1	7.7

	2009	31.8	24.0	27.9	7.8	42.7	63	8.9	7.8
	2010	30.9	22.0	26.5	8.9	24.5	70	5.0	6.67
	2011	31.9	22.6	27.3	9.3	2.4	61.75	6.3	7.3
	2012	33.0	23.2	28.1	9.8	20.0	58.0	6.7	8.1
	2013	31.9	22.3	27.1	9.6	0.5	61.0	5.5	8.2
	2014	31.9	23.2	27.6	8.7	9.6	65.5	5.4	6.1
	2015	32.3	23.3	27.8	9.0	88.3	65.5	6.0	6.9
	2016	32.4	22.3	27.4	10.1	52.9	68.5	2.9	6.5
	2017	32.4	21.1	26.8	11.3	11.5	63.5	5.2	7.3
	2018	33.0	22.5	27.8	10.5	0	62.5	4.7	7.0

Monthly weather variables of nutmeg in Ernakulam from 2005 to 2018

Months	Year	Tmax	Tmin	Tmean	Trange	RF	RHmean	WS	SRAD
January	2005	30.7	24.8	27.8	6.0	91.5	66.7	1.8	20.5
	2006	30.6	24.4	27.5	6.2	12.8	66.2	1.6	20.0
	2007	31.2	23.8	27.5	7.4	1.9	60.6	1.7	21.3
	2008	30.9	23.7	27.3	7.2	0.1	63.7	2.0	17.1
	2009	31.0	24.0	27.5	7.0	12.1	60.3	1.8	21.0
	2010	30.9	24.9	27.9	6.0	24.2	66.8	1.8	16.4
	2011	30.0	24.2	27.1	5.8	16.5	68.9	1.6	19.9
	2012	30.5	24.2	27.3	6.3	2.1	66.5	1.8	20.7
	2013	31.8	25.5	28.7	6.3	3.4	63.0	2.0	20.7
	2014	30.9	24.6	27.7	6.3	6.0	64.5	1.7	20.2
	2015	30.5	24.6	27.6	5.9	4.7	65.8	1.9	20.7

	2016	30.7	24.9	27.8	5.8	1.5	67.1	1.6	20.4
	2017	31.2	25.1	28.2	6.0	23.7	63.4	1.9	19.5
	2018	30.5	24.9	27.7	5.6	3.2	66.6	1.6	19.9
February	2005	32.0	25.3	28.6	6.7	0.56	65.0	2.0	24.4
	2006	32.5	24.9	28.7	7.6	0	56.1	2.0	24.0
	2007	31.8	25.3	28.6	6.5	1.8	60.3	2.3	23.5
	2008	31.9	25.8	28.9	6.1	25.1	65.4	2.2	21.3
	2009	32.6	25.6	29.1	7.0	0	60.3	2.2	23.2
	2010	32.7	26.4	29.5	6.3	1.3	62.8	2.0	22.2
	2011	30.5	24.8	27.7	5.7	116.6	67.2	2.0	22.1
	2012	32.4	25.4	28.9	6.9	22.7	60.4	2.0	18.0
	2013	31.8	26.1	29.0	5.7	80.6	65.1	2.3	21.7
	2014	31.7	26.0	28.9	5.8	25.2	64.1	2.3	22.4
	2015	32.4	25.7	29.0	6.7	2.6	58.2	2.2	22.6
	2016	32.3	26.3	29.3	6.0	73.1	65.7	1.9	18.2
	2017	32.6	25.6	29.1	7.0	1.6	59.3	2.3	22.9
	2018	32.5	26.1	29.3	6.4	10.1	60.0	1.8	18.6
March	2005	32.5	27.1	29.8	5.4	28.2	67.6	2.6	25.6
	2006	31.7	26.5	29.1	5.2	106.8	72.2	2.5	24.1
	2007	33.3	27.2	30.2	6.2	2.1	64.7	2.7	24.8
	2008	30.2	25.8	28.0	4.5	305.7	72.5	2.2	19.4
	2009	32.6	26.9	29.7	5.8	57.8	68.5	2.3	23.5
	2010	33.4	27.7	30.6	5.7	50.3	65.9	2.8	23.9
	2011	32.0	26.3	29.2	5.7	28.9	69.4	2.3	24.1
	2012	32.2	26.7	29.5	5.5	47.6	68.4	2.9	22.7
	2013	32.6	27.3	29.9	5.4	57.2	67.8	2.2	21.8
	2014	33.4	27.3	30.3	6.1	19.1	61.0	2.2	22.8

	2015	32.7	27.1	29.9	5.6	53.4	66.8	2.4	22.9
	2016	33.0	27.7	30.4	5.3	52.7	68.4	2.3	23.1
	2017	31.8	26.8	29.3	5.1	107.3	71.1	2.4	21.8
	2018	32.9	27.5	30.2	5.5	53.5	67.0	2.5	22.2
April	2005	30.0	27.0	28.5	2.9	312.7	81.4	2.2	22.9
	2006	31.6	27.1	29.3	4.5	57.8	74.2	3.1	22.7
	2007	31.6	27.5	29.5	4.2	157.4	75.0	2.5	22.9
	2008	29.8	26.6	28.2	3.3	155.2	81.3	2.6	21.5
	2009	31.3	27.5	29.4	3.9	145.8	76.2	3.0	20.6
	2010	31.2	27.8	29.5	3.4	161.7	79.1	2.5	22.1
	2011	30.7	26.9	28.8	3.8	125.2	76.4	2.7	21.3
	2012	30.7	27.1	28.9	3.6	258.2	77.6	2.8	20.8
	2013	32.4	28.0	30.2	4.3	22.1	69.5	3.4	21.2
	2014	31.6	27.8	29.7	3.8	130.9	76.0	2.7	21.2
	2015	30.9	27.4	29.1	3.5	163.8	75.3	2.1	20.3
	2016	32.6	28.3	30.5	4.3	64.8	73.9	2.9	21.0
	2017	31.9	27.7	29.8	4.2	56.2	75.1	3.2	21.4
	2018	31.5	27.9	29.7	3.6	114.1	76.0	2.3	21.4
May	2005	30.4	27.4	28.9	3.1	191.3	79.8	3.1	21.0
	2006	29.8	27.1	28.4	2.8	594.7	80.7	3.6	17.6
	2007	30.0	27.1	28.6	2.8	216.3	80.6	3.3	19.9
	2008	29.3	26.7	28.0	2.6	170.3	82.1	3.2	20.1
	2009	29.5	27.1	28.3	2.4	356.6	82.9	3.3	14.3
	2010	30.4	27.9	29.1	2.5	236.6	81.4	3.5	17.5
	2011	30.2	27.1	28.6	3.0	219.4	79.0	3.6	19.8
	2012	29.2	26.9	28.0	2.3	134.5	83.2	3.6	19.1
	2013	30.2	27.4	28.8	2.8	220.6	78.9	4.0	17.1

	2014	30.2	27.6	28.9	2.6	262.9	81.3	3.0	18.9
	2015	30.0	27.3	28.6	2.7	234.6	81.5	2.7	16.4
	2016	30.9	28.0	29.4	2.9	268.2	79.0	3.4	16.9
	2017	30.4	27.65	29.0	2.7	325.7	80.5	3.3	17.4
	2018	29.6	27.08	28.3	2.5	307.0	82.3	3.4	16.8
June	2005	28.5	26.6	27.5	1.9	622.1	87.0	4.2	15.4
	2006	28.2	25.9	27.0	2.3	519.7	86.3	3.3	17.9
	2007	28.3	26.2	27.3	2.1	584.6	86.7	4.0	15.4
	2008	28.2	26.0	27.1	2.2	335.5	85.7	3.8	15.7
	2009	28.2	25.9	27.0	2.2	511.4	85.9	3.9	16.3
	2010	28.7	26.4	27.5	2.2	558.9	85.2	4.2	15.7
	2011	28.6	26.2	27.4	2.4	465.5	85.4	4.2	15.4
	2012	28.3	25.8	27.1	2.4	288.0	85.3	3.7	16.0
	2013	27.8	25.9	26.9	1.9	906.3	87.5	4.5	11.0
	2014	29.0	26.7	27.9	2.3	296.7	85.5	4.3	15.4
	2015	28.9	26.7	27.8	2.3	420.9	84.6	3.5	7.4
	2016	28.6	26.4	27.5	2.2	482.5	85.8	4.1	12.1
	2017	28.7	26.6	27.6	2.1	453.9	85.9	3.8	13.3
	2018	28.4	26.4	27.4	2.0	549.0	86.6	4.0	11.8
July	2005	27.2	25.5	26.3	1.7	485.3	90.4	4.4	15.5
	2006	27.6	25.4	26.5	2.2	436.8	89.3	4.0	18.2
	2007	27.4	25.6	26.5	1.7	738.7	89.0	4.1	15.2
	2008	27.2	25.2	26.2	2.0	415.5	88.9	3.9	15.3
	2009	27.3	25.2	26.3	2.1	585.1	88.9	3.8	15.6
	2010	27.6	25.4	26.5	2.3	480.7	86.3	3.8	14.6
	2011	27.4	24.9	26.2	2.4	335.3	87.3	3.4	14.3
	2012	27.8	25.6	26.7	2.2	223.4	87.6	4.0	17.3

	2013	27.0	25.1	26.0	2.0	578.7	88.9	4.0	13.1
	2014	27.7	25.5	26.6	2.2	441.7	89.9	3.6	14.4
	2015	28.2	25.8	27.0	2.4	226.2	86.8	3.6	11.9
	2016	27.5	25.3	26.4	2.1	402.4	89.0	3.7	14.7
	2017	28.1	25.7	26.9	2.4	287.6	87.7	3.5	16.4
	2018	27.5	25.5	26.5	2.0	677.8	89.3	4.0	13.1
August	2005	27.8	25.4	26.6	2.4	199.6	87.7	3.8	22.6
	2006	27.5	25.1	26.3	2.4	420.9	87.9	3.4	19.8
	2007	27.3	25.1	26.2	2.2	329.0	88.7	3.5	17.1
	2008	27.2	24.8	26.0	2.4	278.6	88.4	3.3	18.7
	2009	27.8	25.4	26.6	2.3	168.3	86.9	3.8	17.9
	2010	27.1	25.1	26.1	2.1	249.4	90.2	4.0	15.3
	2011	27.2	24.9	26.0	2.3	354.0	87.9	3.6	15.1
	2012	27.6	25.2	26.4	2.4	335.5	86.3	3.7	15.7
	2013	27.3	24.9	26.1	2.4	278.9	89.4	3.7	16.3
	2014	27.3	25.2	26.2	2.1	652.0	87.8	3.7	14.7
	2015	28.1	25.6	26.8	2.5	180.2	87.7	3.0	18.2
	2016	27.8	25.3	26.5	2.5	179.5	88.0	4.0	18.1
	2017	27.6	25.4	26.5	2.2	363.3	89.5	3.4	15.2
	2018	27.2	24.9	26.1	2.3	544.3	90.0	4.1	14.5
September	2005	27.4	25.2	26.3	2.2	377.6	88.6	3.7	18.9
	2006	27.4	25.3	26.4	2.2	516.0	87.5	3.6	16.9
	2007	27.4	25.3	26.4	2.1	595.0	87.6	3.6	16.4
	2008	28.1	25.4	26.7	2.6	374.3	84.1	3.2	19.1
	2009	27.8	25.4	26.6	2.4	326.3	87.0	3.5	17.5
	2010	27.9	25.1	26.5	2.7	337.7	86.9	2.9	17.3
	2011	27.8	25.3	26.5	2.5	307.6	85.9	3.4	17.1

	2012	28.0	25.5	26.8	2.5	183.1	85.1	3.3	19.0
	2013	27.7	25.2	26.4	2.5	209.6	86.0	3.6	16.4
	2014	28.0	25.6	26.8	2.5	230.4	86.7	3.6	18.0
	2015	28.5	26.0	27.3	2.5	265.2	84.8	2.9	18.6
	2016	27.8	24.9	26.4	2.9	59.4	86.3	3.8	18.7
	2017	28.0	25.7	26.8	2.3	380.0	87.1	3.5	17.2
	2018	28.4	25.3	26.8	3.1	101.2	83.6	3.3	20.9
October	2005	28.0	25.7	26.8	2.3	472.1	85.0	3.0	18.5
	2006	28.0	25.5	26.7	2.6	610.7	85.4	2.4	17.5
	2007	27.6	25.2	26.4	2.5	384.4	85.1	2.8	17.4
	2008	29.0	25.8	27.4	3.2	348.6	80.7	2.5	17.4
	2009	29.0	25.6	27.3	3.4	133.8	80.4	2.4	19.7
	2010	27.9	25.6	26.8	2.4	544.0	85.0	3.5	16.9
	2011	29.0	25.6	27.3	3.4	146.8	79.6	2.3	19.0
	2012	29.0	25.8	27.4	3.2	206.3	81.6	2.4	18.2
	2013	28.0	25.5	26.8	2.5	205.7	83.4	3.1	13.9
	2014	28.5	25.6	27.0	2.9	320.7	83.7	2.4	16.7
	2015	29.2	26.2	27.7	3.0	302.0	81.9	2.1	16.5
	2016	28.9	25.4	27.1	3.5	148.4	80.1	2.9	18.8
	2017	28.5	26.1	27.3	2.4	247.9	84.2	2.7	16.5
	2018	29.1	25.9	27.5	3.2	346.5	81.1	2.1	17.7
November	2005	28.0	24.9	26.4	3.1	323.7	82.5	2.2	16.7
	2006	28.9	25.5	27.2	3.3	268.3	81.7	1.7	16.5
	2007	29.0	25.2	27.1	3.8	139.3	75.5	1.7	18.9
	2008	29.4	25.5	27.4	3.9	67.9	76.1	1.8	17.3
	2009	29.0	25.6	27.3	3.5	287.4	78.6	2.1	12.5
	2010	27.7	25.2	26.5	2.6	269.9	83.7	2.2	15.1

	2011	29.7	25.3	27.5	4.4	180.2	74.6	2.3	17.1
	2012	29.2	25.7	27.5	3.5	130.7	75.7	1.9	18.9
	2013	28.8	25.6	27.2	3.2	226.0	79.5	1.7	17.8
	2014	29.2	25.6	27.4	3.7	132.0	76.4	1.8	15.2
	2015	29.0	25.8	27.4	3.1	251.3	80.4	2.2	15.5
	2016	29.8	25.6	27.7	4.2	129.1	76.6	1.8	17.1
	2017	29.2	25.8	27.5	3.4	195.8	78.7	2.0	12.8
	2018	29.7	26.0	27.8	3.8	200.8	77.2	1.9	13.4
December	2005	28.8	24.7	26.8	4.1	54.3	75.5	2.0	18.4
	2006	30.0	23.7	26.8	6.3	0.6	67.1	2	19.0
	2007	29.9	24.3	27.1	5.6	25.2	69.0	2.0	18.1
	2008	30.1	24.5	27.3	5.6	24.6	67.5	1.5	14.6
	2009	30.0	25.3	27.6	4.6	17.2	73.0	1.8	18.1
	2010	27.9	24.7	26.3	3.2	77.4	76.5	1.7	16.5
	2011	30.0	24.7	27.3	5.4	116.4	69.5	1.9	17.7
	2012	31.0	25.3	28.1	5.6	14.6	68.4	1.8	18.0
	2013	29.5	24.5	27.0	5.0	45.7	69.8	1.9	18.3
	2014	29.8	25.4	27.6	4.4	26.8	72.7	1.7	15.9
	2015	29.9	25.4	27.6	4.5	79.4	74.7	1.6	17.1
	2016	30.6	25.3	28.0	5.2	24.5	71.3	2.3	17.4
	2017	29.6	24.7	27.1	4.9	44.7	72.4	2.1	14.4
	2018	30.1	25.8	28.0	4.4	28.8	72.8	1.6	18.0

Appendix VI

Prices of nutmeg without shell, nutmeg with shell and mace from 2010 to 2019

Year	Price of nutmeg with shell	Price of nutmeg without shell	Price of mace
2010-11	252.3	466.5	1135.1
2011-12	348.2	632.5	1190.1
2012-13	335.9	625.7	785.1
2013-14	310.0	551.3	637.8
2014-15	278.1	494.5	771.9
2015-16	216.0	412.1	622.5
2016-17	216.5	400.0	484.5
2017-18	176.3	329.6	441.1
2018-19	218.5	389.6	599.5
2019-20	204.6	385.5	905.4

WEATHER EXTREMES PREPAREDNESS OF NUTMEG (*Myristica fragrans)* FARMERS IN KERALA

by

ADHARSH C J

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THESIS

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ABSTRACT

Nutmeg is a tree spice from the Myristicaceae family. Nutmeg and mace are two distinct spices produced by it. Nutmeg cultivation in India is primarily limited to Kerala, Karnataka, and Tamil Nadu. The districts of Thrissur and Ernakulam produced the majority of the state's nutmeg. Nutmeg requires a humid, wet climate with no long periods of drought. The soil should be well-drained and organically rich. The nutmeg yield has been harmed by the drought in 2016 and the flood in 2018. In this context, a study on "Weather extremes preparedness of nutmeg (*Myristica fragrans*) farmers in Kerala" was undertaken. The objective of the study is to analyse the crop weather relationship of nutmeg farming in Kerala and to study the socio-economic characteristics of nutmeg farmers as well as to study the behavioural pattern and strategies of nutmeg farmers for mitigating weather extreme conditions.

The study was conducted out in the districts of Thrissur and Ernakulam. The survey will be done in four blocks in the Thrissur and Ernakulam districts (Wadakkanchery, Mala, Chalakudy, and Angamaly). The site was purposefully chosen to be equally affected by weather extremes. A total of 120 farmers will be surveyed, with 5 krishibhavans from each block and 6 farmers from each krishibhavan. Primary and secondary data were used in this study. Weather data of Thrissur and Ernakulam was collected by College of Agriculture (COA) Vellanikkara and NASA power data access viewer respectively. Secondary data on area, production and productivity was collected for both districts from the Directorate of Economics and Statistics, Government of Kerala, Thiruvananthapuram for the period of 2005 to 2018.

The correlation analysis of the yield was carried separately for Thrissur and Ernakulam districts. The correlation was done for five major phenological phases in each district. The five major phenological phases of nutmeg are flower bud development, flowering, fruit set, fruit development and harvesting stage. The

correlation analysis between the yield of respective districts and monthly weather variables were taken for correlation analysis.

Maximum temperature and temperature range of Thrissur during flowering and fruit setting stages were positively influenced the yield. Mean temperature of Thrissur during fruit setting stage positively affected the yield. Maximum temperature of Thrissur during September and November months positively affected the yield. Wind speed of Thrissur during flower bud development, flowering, fruit set and harvesting stages had negative influence on yield. Solar radiation of Thrissur during flower bud development stage negatively affected the yield. Rainfall of Thrissur during September negatively influenced the yield. Wind speed of Thrissur from March to November had negative influence on yield. Solar radiation of Ernakulam during flowering stage negatively affected the yield. Wind speed of Ernakulam during fruit development stage negatively influence on yield. Rainfall of Ernakulam during January and April negatively affected the yield.

The socio-economic status components included in the study were age of the respondents, gender, educational status, annual income, occupation, land holding pattern, experience in farming, experience in nutmeg farming and number of nutmeg trees. Out of 120 respondent's 45.8 percent belong to above 60 years and 45 percent belong to 45 to 60 years age group. The majority of nutmeg farmers were males and only 6 percent of the respondents were female farmers. Most of the farmers (89.2 percent) were SSLC or above SSLC. It showed that educated farmers were more interested to do nutmeg cultivation and they make a good yield out of it. The half of the farmers (53.3 percent) comes under the annual income of less than one lakh rupees. Nearly 91 percent of respondents had agriculture as main occupation. Most of the farmers (75 percent) had a land area of less than 1 hectare. Age decides the experience of the farmers in cultivation of crops and 40 percent of the farmers had experience in nutmeg farming between 20 to 30 years. 46 percent of farmers had 50 to 100 nutmeg trees out of 120 farmers.

Most farmers used nutmeg because of its shade-loving nature, which makes it ideal for growing as an intercrop with shade-giving trees like coconut trees. To avoid water stress, nutmeg needs to be irrigated on a regular basis. So, most of the nutmeg farmers (42.5 percent) preferred own well as the major source of irrigation. 88.4 percent of sample respondents had surface irrigation as the major type of irrigation. There was a smaller number of farmers aware about the importance of drip and sprinkler irrigation. This type of irrigation improves water efficiency while also reducing surface loss of water. If a government subsidy is provided, more farmers will use sprinkler and drip irrigation. Newspaper was the major source of information for farmers in Mala, Wadakkanchery and Angamaly block, while it was television in Chalakudy block. Increase in rainfall intensity and erratic rainfall were the major components of climate change affecting nutmeg production as revealed by 99.2 percent and 95.9 percent respectively. The major impact perceived was changed timing and quantity of rains which was reported by 88.3 percent of the sample respondents. The major climate change effect on nutmeg tree was decreased yield which was reported by 91.7 percent of the sample respondents. Agronomic conservation measures such as mulching, mixed cropping, cover cropping and tillage practices was the major adaptation practice practiced by 86.7 percent of the total respondents. Climate change was the most serious constraint faced by the nutmeg farmers, followed by occurrence of diseases. Government subsidies was the major support to 82.5 percent of the total sample respondents followed by training support (73.3%).

The weather extreme preparedness of the farmers' were assessed scientifically using scoring procedure used for psychological variables. In this study, responses of five questions from the questionnaire were taken which is base for calculating weather extreme preparedness score. Responses were collected in a five-point continuum viz., strongly agree, agree, undecided, disagree, strongly disagree and the scores of 5,4,3,2 and 1 were given for these responses respectively. The cumulative score was taken as weather extreme preparedness score of a respondent. Thus, the maximum weather extreme preparedness score that could be obtained by a respondent was 25 and the minimum 5. The respondents were categorized into three groups viz. low, medium and high on the basis of mean and standard deviation of the total score.

Analysis of the preparedness of nutmeg farmers on extreme weather conditions showed that 74.2 percent of nutmeg farmers had medium scores, while low score for 12.5 percent nutmeg farmers and 13.3 percent farmers had high scores. About 87 percent of the interviewed farmers had medium to high level of weather extreme preparedness, i.e., they are ready to face unfavourable conditions and carry out nutmeg farming for their sustenance. Annual income and land holding pattern had significant positive correlation on weather extreme preparedness score. The correlation between annual income and land holding pattern on weather extreme preparedness was significant at 1% level of significance. These findings indicated that farmers with a high income are less vulnerable to risks such as yield losses due to climate change. Farmers with more land are also less vulnerable to climate change because they can make profit from a variety of crops grown on their land. The study's findings suggest that crop diversification can help to mitigate or minimize losses caused by climate change. Age had a non-significant negative effect on weather extreme preparedness, while farming experience, nutmeg farming experience, number of nutmeg trees, nutmeg yield, and mace yield had a non-significant positive effect.