Journal of Agriculture and Environmental Sciences
June 2014, Vol. 3, No. 2, pp. 157-174
ISSN: 2334-2404 (Print), 2334-2412 (Online)

Published by American Research Institute for Policy Development

A Study on the Scope and Importance of Tuber Crops with Special Reference to Cassava as Resilient Crop towards Climate change-Kerala

Anju Lal[1], Gopikrishna V.G[2]., Ambily P.G[2]., Amalraj M.[3]

Abstract

Climate has been recognized as a principal factor that control crop distribution and growth. Agricultural productivity has been found to be exaggerated by climate change, resulting in food insecurity and poverty. To find out an alternative food source is very much necessary for the existence of life during such catastrophic events. This study examines selected meteorological conditions of Kottayam district, especially inter-annual and inter-seasonal trends from a climate change perspective and also reviewed the farmer's perception, tubers as a better resilient crop under extreme weather events on regional basis and their promotion need to be emphasized in a better manner. Simple random sampling procedure was used to select 130 tuber cultivating farmers especially cassava, using extensive field visit and structural questionnaire data were collecting. The collected data were analyzed using descriptive statistics such as frequency table, percentage, mean and chi-square test. The results of the study revealed the occurrence of climate change on regional basis. The result also highlights the sensitive nature of our staple food crop towards the climate change and hence causes food insecurity related problems. A shift in cultivation trends were also noticed i.e. most of the farmers engaged in rice production now opt tuber, vegetable and other cash crops for cultivation on an extensive basis. Emergence of more tuber cultivation incidence was reported. Cassava and other tubers showed more resilience under climate change events and was found to be sustainable on production and economy basis. The study concluded that the viable and cheap alternatives are the ever resilient tubers.

Keywords: Climate Change, Agriculture, Tuber crops, Cassava

[1] School of Environmental Sciences ,Mahatma Gandhi University, Kottayam, Kerala, India. kollamparambil, Pachalam P.O., Kochi-682012, Phone: +919961394159 Email: lalanju81@gmail.com
[2] School of Environmental Sciences ,Mahatma Gandhi University, Kottayam, Kerala, India.
[3] Institute of Land and Disaster Management, PTP Nagar, Trivandrum, Kerala, India.

Introduction

Climate change and climate variability have become a reality today, with a significant threat to ecosystem, food security, water resource and economic stability, which are the foundation of life. Numerous studies have been carried out on the impacts of climate variability on crops yield in different parts of the world by Intergovernmental Panel on Climate Change (IPCC) and other scholars. Some of these studies reveal that climate variability has significant impacts on agricultural sector especially during the last 40 years. According to IPCC (2001), climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity and to the Article 1 of United Nations Framework Convention on Climate; climate change is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural variability observed over comparable time periods (UNFCC, 1992). The physics and chemistry of the Earth's atmosphere largely determines our climate (Lockwood, 1979). The earth's climate depends on the functioning of natural "greenhouse effect", which effect is the result of heat trapping gases known as Greenhouse gases like water vapour, carbon dioxide, ozone, methane and nitrous oxide. However, human activities are causing GHGs levels in the atmosphere to increase and thus rising the Global temperature, resulting in so called Global Warming. The continued upsurge of greenhouse gases warm up the earth's surface and lead to increase in air temperature; ultimately changes the pattern of precipitation. The observed changes and future projections shows that the GHGs such as atmospheric carbon dioxide (CO_2) present concentration 360ppm doubling up to 700ppm by the 21st century and other gases like methane(CH_4) from 700to 1720 ppm, nitrous oxide (N_2O) from 275 to 310 ppm and chlorofluorocarbon (CFCs) respectively (IPCC, 2007; Vellinga *et al,* 2001).

Due to summer monsoonal circulation, the weather and climate are subjugated by largest seasonal mode of precipitation around the world; give rise to extreme seasonal anomalies, paving way to large scale drought, floods, heavy rain, hailstorms, heat stress and high wind extremes (Krishnamurthy, 2011). It is predicted that the mean global surface temperature will increases by 3 to 5^0 C from present levels and in the rice producing zones air temperature predicted increase up to 7^{0}C. Extreme weather events are expected to increase in future. India is a developing country and an agricultural nation, providing livelihood to more than 65-70% of the population. Heat stress is another vital factor affecting crop yield (Wringely *et al*., 1994).

Reports show that Asia-Pacific regions are likely to face the nastiest impacts on cereals crops. The cereals yield loss wheat, rice and maize is expected to be in vicinity of 50%, 17%, and 6% respectively by 2050; for every 1^0 C increase in temperature, yield of wheat, soya bean, mustard, groundnut, potato are expected to decline by 3-7%, whereas in case of rice, yield may decline by 6%. Indian Network for Climate Change Assessment (INCCA,2010), in their 1^{st} report pointed out that reduced rainfall, increased atmospheric temperature and flooding due to sea level rising is going to affect the climate change scenario of Western Ghats and Kerala in next 20 years.

Kerala is an agricultural state, and owes the third highest population density in India. Acute food insecurity, import of grains and heavy unemployment are the problems faced by the state. It is estimated that minimum air surface temperature in Western Ghats regions may rise by 2 to 4.5^0C and the average temperature in the regions bordering Kerala is likely to rise by 1 to 3^0C, in the coming years. Apart from the present problems, frequent occurrence of weather abnormalities is also a part of climate change and will adversely damage agricultural sector resulting in food price increase. The state experience unusual summer rain and other climate anomalies like drought, floods, high winds, and all are upshot of climate change. The scientist reported that the present weather related hazards will continue in future. The staple food of keralites is rice which is highly vulnerable to climate change. From several studies, it is evident that the rice cultivation and subsequent yield is under threat of climate change also leads to the reduction in yield. Here the present study is an endeavor to track the scope of promoting the cultivation of tuber crops as an additional substitute for staple food, during climate change associated emergency cases such as extreme weather events and related disasters especially among marginalized people on a regional basis.

One plus point of tropical root and tuber crop is that the economically important part, that is tuber and shoots grows simultaneously during normal or unfavourable conditions. These crops cease tuber development as well as vegetative growth and become dormant during unfavourable conditions such as drought, flood, and heat stress condition and growth resumed during favorable conditions. This shows less instance of crop failure. But in the case of cereals, the flowering and grain filling stages are critical period of growth and are highly sensitive to environmental stress conditions.

Therefore if cereals face these stress condition during their critical growth period, the entire crop will lost. The regular cultivation of cassava in most regions of the world does not involve use of chemical input (Asher *et al*., 1980). From this point of views, Cassava is considered as the future food security crop due to its biological efficiency coupled with ability to sustain under changing climate especially during drought (by shedding leaves) and to grow well in marginal soils. Sweet potato too can tolerate and yield considerably under saline conditions whereas elephant foot yam, tannia and arrow root are tolerant to shade conditions. Cassava was found to maintain nearly 50% of its photosynthetic rate under drought conditions (Ravi *et al*., 2001) offering a better alternative of crop in future warm climate conditions. Cassava act as global warming mitigating crop (Susan John *et al*., 2011) and is also a source of starch and is therefore an industrially important crop and is also used in animal husbandry. Cassava shows significant growth under high temperature and CO_2 (Ravi *et al., 2011*). The tuber crops needs less maintenance and high yield and forms the important component of food and nutritional security especially among poor and marginal farmers.

The specific objectives of the study are the following:

- Assessment of selected meterological conditions of the study area especially inter-annual and intra seasonal trends from a climate change perspective.
- To assess the status of rice cultivation and production during 1993-2013 in the study area.
- To assess the trends in cultivation patterns of tuber crops in the study area.
- To find out the impacts of common natural hazards such as floods, drought, high precipitation, winds on tuber crops.
- To understand and evaluate farmers perception on the resilience of tuber crops under these hazards and adaptation strategies to cope with the impacts.

Study Area

The selected study area for the research is Kottayam district in the Indian state of Kerala. The district is boarded by lofty and mighty Western Ghats on east and Vemband lakes and paddy field of Kuttanad on the west. The district has Meenachil River and a network of canals running across with considerable number of settlements and agricultural lands set up on the bank of the river. The climate of Kottayam is basically shrewd blend of tropical and equatorial climate. Weather of the locality is characterized as hot and humid.

Summer season in Kottayam start from March and last till June, where temperature is extremely high during March to May. The district also receives plenty of rainfall during Monsoon season from July to September and north east monsoon brings winter rain during October to November, together add an annual rainfall of 2701 millimeter to the region. The Kottayam district is a multi-hazard prone area where flood, lightening, landslides, drought etc are the natural disasters faced by the vicinity. The important food crop cultivated in the district is the rice, staple food for the people, whereas the other major food crops widely cultivated area cassava, coconut, banana, tuber crops and vegetables.

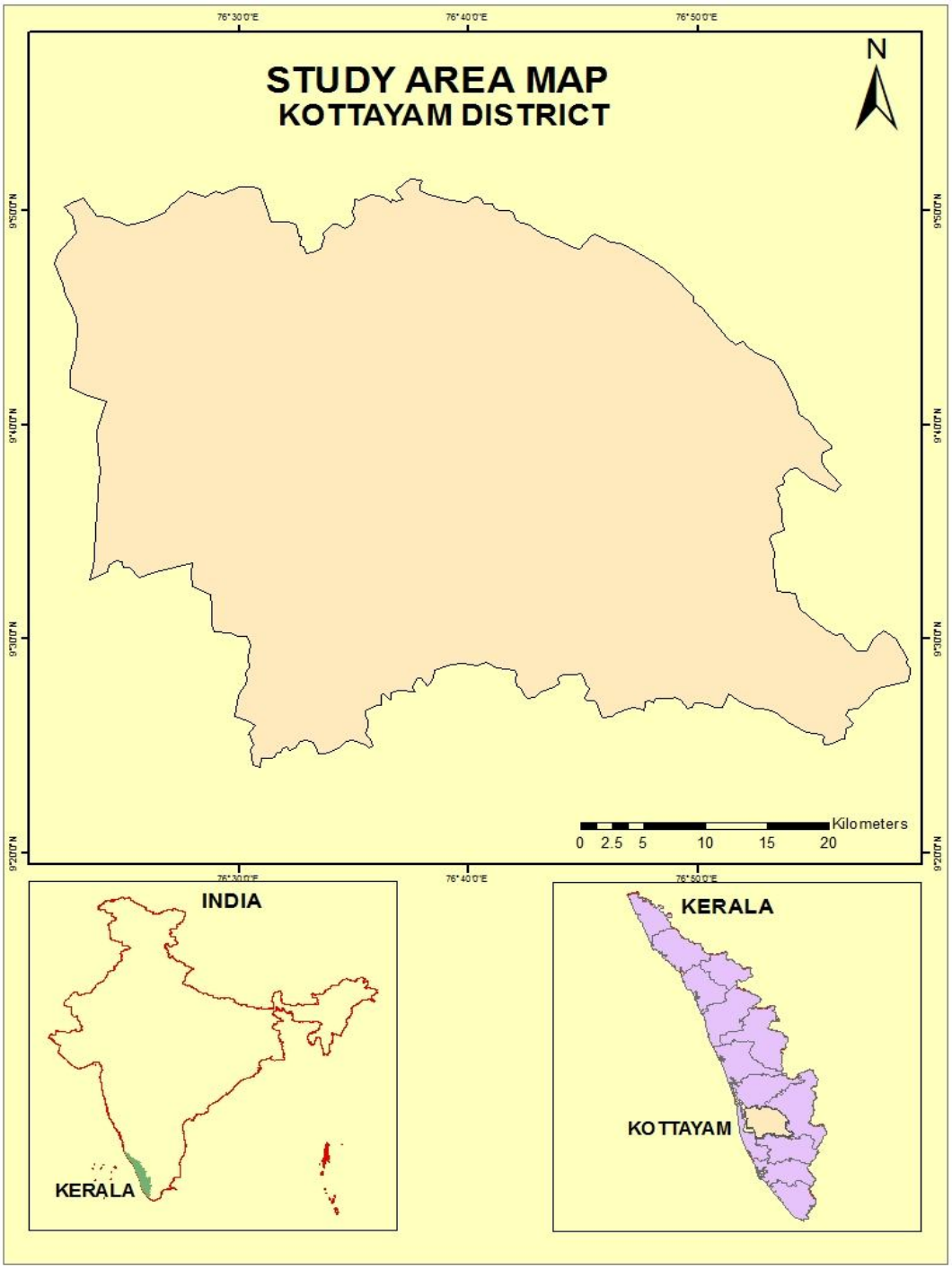

Plate no: 1 Study area Map

Materials and Methods

This work consists of a list of farmers growing root crops especially cassava collected from selected villages of 5 taluks of Kottayam district, and 130 farmers were collected at random. Extensive field visit using personal interview schedule, collecting the data relating landholding status of tuber crops, status of fertilizers application and irrigation, cost of production, production and productivity of tuber crop, major constraints in production of tuber crops, farmers perceptions towards the resilience of tuber crops and crop insurance status, was done during April 2013. Meteorological data was collected from Rubber Board, Kerala for a period from 1993-2013. Other secondary data were collected from the government revenue department offices, Agriculture department Kottayam, reports, articles published in journals and from newspapers. The collected data were analyzed using suitable statistical techniques. Descriptive statistics such as frequency table, mean, and percentage analysis, Test of significance –Chi-square test etc were used in this study.

Result and Discussion

Result of Meterological data Analysis

The collected data from the time period of 1993-2013 were categorized and analyzed for further conclusion. From two decades rainfall shows a deceasing trend in the study area (Fig: 1). Maximum rainfall is received in the year 1995 (6293.7 mm) and the minimum rainfall received in the year 2012 (3260.2 mm). If current trend continues rainfall may further decrease with each year and the decrease in the amount can be projected with the help of depended variables of the equation given in the time series. The projected values obtained (Fig: 2) also shows the decreasing trend of annual rainfall. Along with the changes in the amount of rainfall availability, Climate change has brought changes in the total number of rainy days also. Future projection also shows a slight increase in rainy days (Figure: 3, 4). From seasonal variations data (Figure: 5, 6), monsoon rainfall shows a sharp declining trend where as pre-monsoon and post monsoon rainfall shows a slight increasing trend. The agriculture pattern of the study area solely depends upon the extent and magnitude of monsoon. Hence it is a matter of concern regarding agriculture productivity, especially that of rice from a climate changes perspective.

Two decadal data of maximum and minimum temperature shows slight increase and decreasing trend. If the current trend continues, maximum temperature will be increasing each year, whereas minimum temperature will be decreasing (Figure: 7, 9). Wind speed shows a decreasing trend (Figure 8, 10).

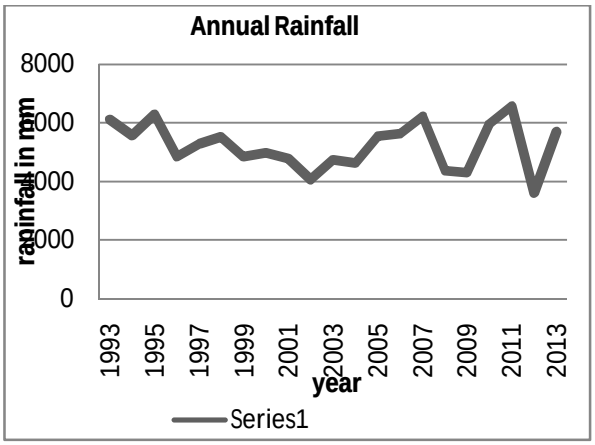

Fig : 1 Annual Rainfall

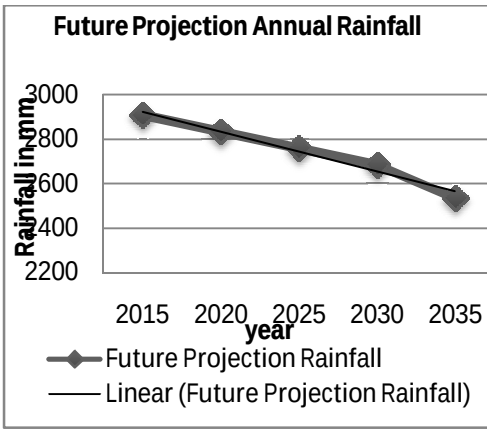

Fig : 2 Future Projection of Annual Rainfall

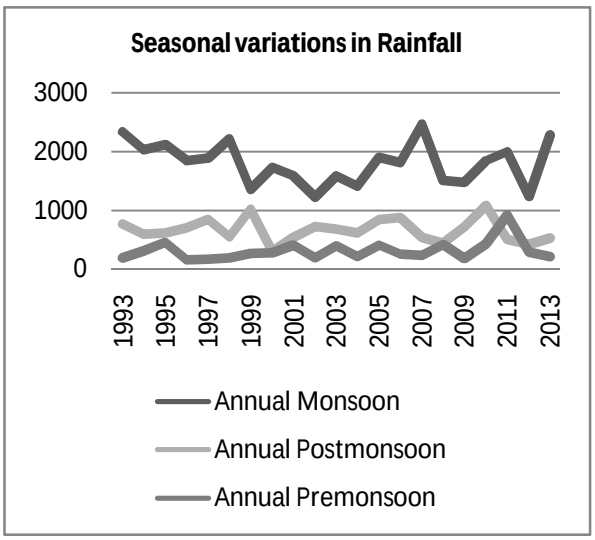

Fig : 3 Seasonal variations in Rainfall

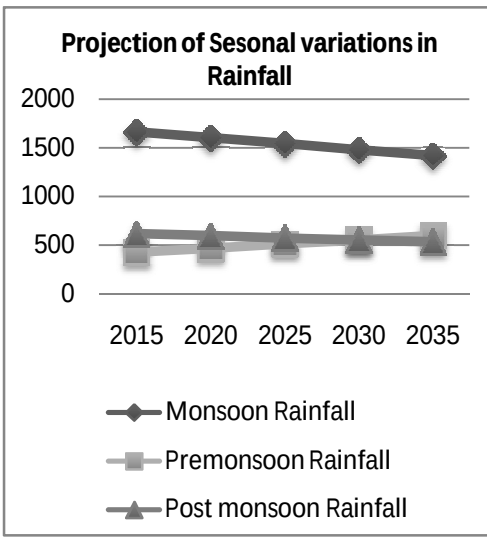

Fig: 4 Future Projection in Rainfall

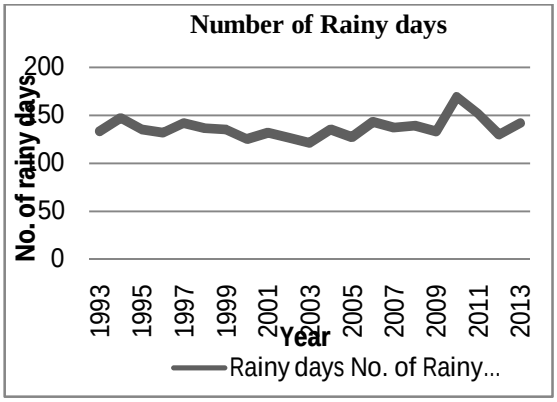

Fig : 5 Number of Rainy days

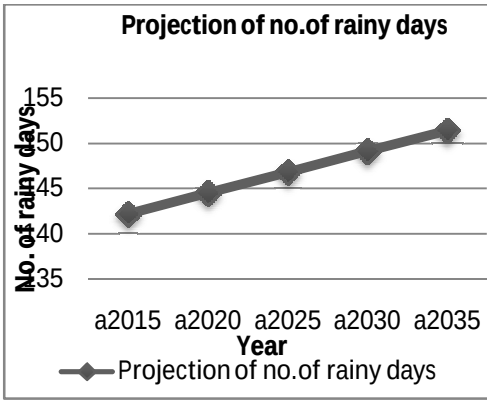

Fig : 6 Future Projection of Rainy days

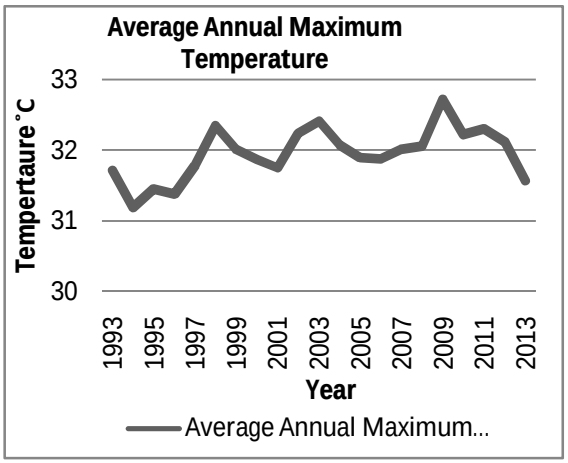

Fig : 7 Average Maximum Temperature

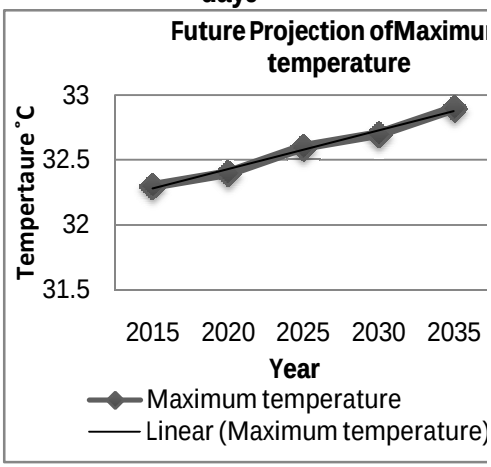

Fig : 8 Future Projection

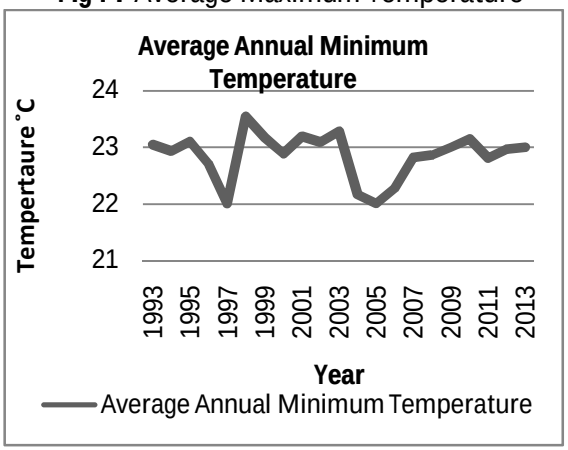

Fig : 9 Average Minimum Temperature

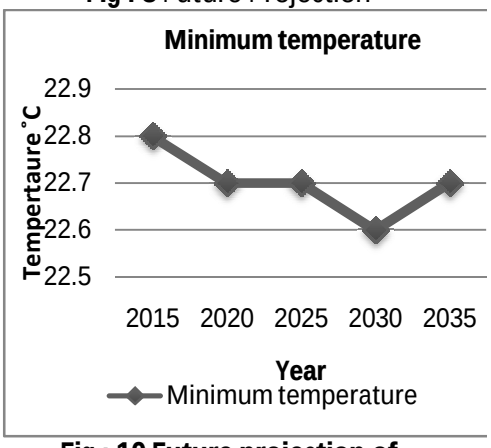

Fig : 10 Future projection of Minimum Temperature

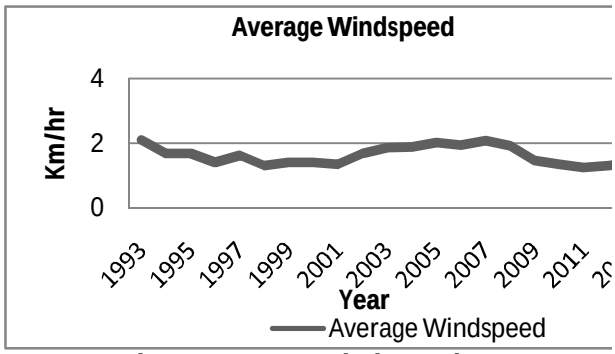

Fig: 11 Average Wind speed

Result of Rice Cultivation and Production Status

Rice is the most important cereal and staple food produced and consumed by the Keralites. In Kottayam district also rice is cultivated in vast areas. Apart from rice, cassava, coconut, pepper, rubber, banana and other vegetables are cultivated. The study also encloses a part of Kuttanad rice bowl and other rice cultivating tracts in Kottayam district. The government records shows that, in Kottayam district during 1993-94 nearly 29723 hectares of land were under paddy cultivation with a production rate of 61002 tones while during 2012-13 it was only 17511 hectare with production rate of 29589 tones. From the situation prevailing and from the farmer's report, it can be stated that paddy cultivation and paddy production is declining considerably on annual basis. The Figure: 12 show the trend of rice cultivating area and production in Kottayam district.

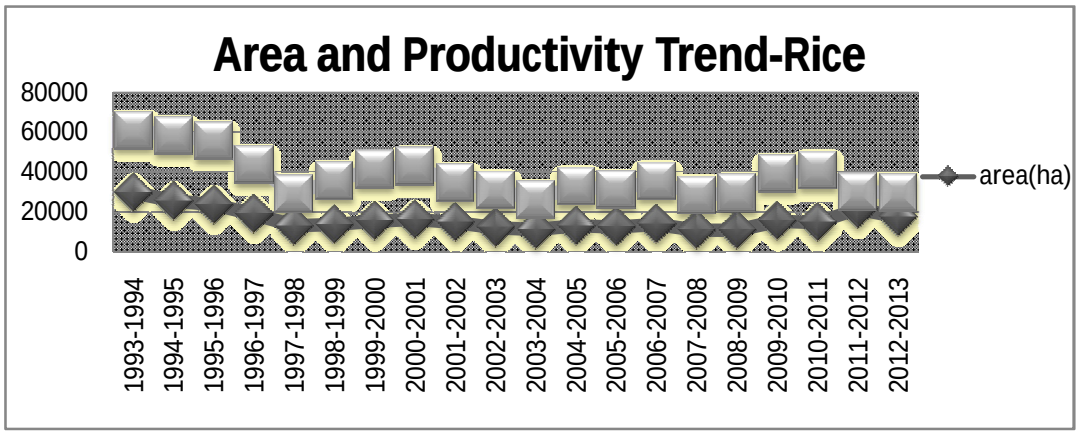

Fig: 12 Area and Production Trend- Rice in Study area

The farmers also reported that the variation in climate plays an important role in the growth and development of paddy. The low profitability in paddy cultivation appears to have contributed to the shifting of paddy land to other crops and other construction activities. Most of the farmers prefer tuber crops especially cassava and elephant foot yam, colocasia and other cash crops like rubber, pepper and coconut. A clear cut reduction in the production of rice in the locations like Vaikom (46%), Kaduthuruthy(38%), Kuruvalangad(45%) and Marungattupally (56%) were reported. This can be evidently related to the climate variability especially alteration in temperature and rainfall. Farmers points to reasons for reduction in production of paddy in the study areas as regular flood submergence during monsoon and saline water intrusion during summer, heavy rainfall and flash floods and resultant bund breaching which affects the second round of rice cultivation, prevalence of dampness and high moisture during harvesting time, unexpected wind fall prior to harvest of rice and dry spell along with high temperature stress condition.

Result of Socio Economic Characteristics

The result of socio-economic analysis (Table: 1) shows the age, sex, marital status, farming experience, household size, farm size and aim of production. The results shows that greater part (40.7%) of the tuber cultivating farmers especially cassava, was of 43 years with oldest being 74 years and youngest being 27 years. This could probably imply that the farmers who are actively participated for the study were old enough to have been able to experience the changes in climate and as such able to give liable response to the questions in the research. It also shows that 90.7% of the farmers were male while the rest percentages (9.2%) were female. This means that men are more involved in tuber farming than their female counterpart. A large percentage of (84.6%) tuber cultivating farmers are married, this may help to reduce the hired labor if the farmers family also engage in farming activities. Most (50.7%) of the respondents have family size ranges between 6 and below.

The table (Table: 1) also shows the result of the farming experience of the farmers. 33% of the farmers had more than 10 year of experience. It further shows that 36.1% of the respondent had access to land below 0.4 hectare to 1 hectare while 13.8% had 1 hectare of land and above.

It also shows that approximately 27.6% of farmers producing the tuber crop had sale of product as their major aim of production. 20.7% had consumption as their major aim of production while 51.5% had both sale and consumption purposes.

Table: 1: Distribution by Socio-Economic Characteristics

Characteristic	Variables	Frequency	Percentage	Mean
Age	21-30	11	8.4%	43.6
	31-40	42	32.3	
	41-50	53	40.7	
	51-60	12	9.2	
	61-70	9	6.9	
	71-80	3	2.3	
Gender	Male	118	90.7	
	Female	12	9.2	
Marital Status	Single	16	12.3	
	Married	110	34.6	
	Divorced	1	0.7	
	Widowed	3	2.3	
Farming Experience	10 & below	11	8.4	25.4
	11-20	43	33	
	21-30	32	24.6	
	31-40	27	20.7	
	41-50	14	10.7	
	Above 51	3	2.3	
House Hold Size	5 & below	61	46.9	6 Persons
	6-10	66	50.7	
	11-15	3	2.3	
	16 & above	0	0	
Farm Size	0.02 hect& belov	33	25.3	
	Above 0.02 hect	39	30	
	Above 0.4 hect-l			
	1 hect& above	41	31.5	
		18	13.8	

Source: Field survey 2013

Result of Production and Productivity of Cassava

Table 2 indicates the features of cost of production and productivity of tuber crops especially tapioca in Kottayam district. 83% of the farmers depend on rainwater as the major source of tuber growth whereas only 16.9% farmers depend on other irrigation mediums like well and other water sources. 68.4% farmers adopt organic farming which is eco-friendly and devoid of any health issues while 31.5% farmers use chemical fertilizers mainly urea, potash and rock dust (mineral fertilizer). The table also shows that 40.7% of the farmers produce less than 1000kg/ha of cassava, 22.3% of farmers produce between 1000-2000 kg/ha and 17.6% of farmers produce greater than 4000kg/ha of cassava tuber. The result also reveals that 33% of the farmers earn more than 75000 Indian rupees per period, which means 1/4 of the cassava producers in the study area gain high profit. In the case of crop insurance status, only 16.1% farmers insured their tuber, especially cassava, whereas 91.5% of farmers have not insured their crop because of the resilience of the crops towards weather related catastrophes. At the same time it is noticed that the crops like rice, rubber, banana and other crops are insured because of the vulnerable nature of these crops.

Table: 2 Distribution by Production and productivity of Cassava

Characteristics	Frequency	Percentage
Farm accessibility		
Near	65	50
Far	65	50
Source of water		
Irrigation	22	16.9
Rain water	108	83
Fertilizer application		
Organic farming	89	68.4
Inorganic farming	41	31.5
Plant protection		
Fencing	11	8.4
No protection	119	91.5
Quantity of cassava		
<1000 kg	53	40.7
1000-2000	29	22.3
2000-3000	14	10.7
3000-4000	11	8.4
>4000	23	17.6
Earnings		
10,000 & below	15	11.5
10,000-25,000	27	20.7
25,000-50,000	26	20
50,000-75,000	19	14.6
75,000 & above	43	33
Crop insurance		
Yes	21	16.1
No	119	91.5

Source: Field survey 2013

Result of Cropping Pattern

Crop rotation and intercropping are the two extensively practicing methods used by the farmers in the study area. Majority of the farmers (80%) report that intercropping pattern for tuber crops such as green gram, black gram, vegetables like brinjal, chilly, amaranths and fruit crop like banana. This is highly profitable and is being successfully adapted by the farmers. 20% of the farmers are growing cassava alone, implementing crop rotation pattern.

It is noted that the crop rotation and intercropping methods will improve the soil productivity and lushness. Cultivation of cassava and yam under coconut plantation, cassava based agro-forestry systems especially cassava and mango/guava are other cropping systems followed by the farmers in the study area. Farmer's highlights that by practicing these methods they have increased profit and at the same time they can produce more than three crops simultaneously and protect soil naturally.

Result of Farmers Perception

The meteorological data clearly indicates the climate change happening at regional level and its relation to the natural anomalies occurring in the study area. The common natural hazards occurring in Kottayam district are floods, droughts, landslides and cyclones. These hazards produced notable changes in the rice production. But the farmers engaged in tuber production are of the opinion that cassava is highly heat tolerant and tide over the unfavorable condition by shedding their leaves and reducing transpiration rate. The plant also grows in the normal land, under paddy polders and water logging condition. Out of the total respondent (130), nearly 68% reported that events of temperature hike do not affect the tapioca plants where under polder situation 58% recorded the resilience (Table: 3).This point to the resilience of cassava towards drought. In the case of other tubers, 66% of the respondents marked the category, temperature resilient or tolerant. The anomalies in rainfall (erratic rainfall) events reported minimal damages to tapioca and other tubers in the study area. The extreme rainfall events are hence found to produce minimal disturbance to this crop category. Nearly 60% of respondent recorded the resilience of cassava towards increased rainfall whereas 63% towards decreased rainfall. Climate induced diseases and pest outbreaks are comparatively lower in the study area since tubers are found to be resistant to such incidence. Owing to its potential to tide over stress conditions cassava is found to be cultivated in arable land and in field conditions along with paddy i.e., on bunds and reclaimed paddy polders. The respondent reported their satisfaction in cultivating tuber especially cassava under climate change scenarios owing to its innate capacity to cope with events related to changing weather and climate.

Table: 3 Distribution by Farmers Perception Regarding the Resilience of Tuber Crops Towards Climate Change

	Tapioca (on land)			Tapioca (under paddy polder)			Other tubers(yam, elephant foot yam, sweet potato, clolcasia, lesser yam)		
	Not affected (%)	Slightly affected (%)	Highly affected (%)	Not affected (%)	Slightly affected (%)	Highly affected (%)	Slightly affected (%)	Not Affected (%)	Highly affected (%)
Increase Temperature	68	35	6	58	20	20	66	20	6
Decrease Temperature	73	32	2	63	17	18	61	23	14
Increase Rainfall	60	33	8	54	27	17	69	19	11
Decrease Rainfall	63	28	10	60	23	15	73	16	10
Climate change related disease	62	28	12	55	35	9	66	17	15
Uncertainty of weathers	58	27	18	53	29	17	63	22	6

Source: Field survey 2013

In order to verify the farmers perception towards resilience of tuber crop especially cassava Chi-Square test has been applied.

H_0: The research is unbiased, the climate change related catastrophes affects tuber crops especially cassava production (null hypothesis)

H_1: The research is biased, the climate change related catastrophes not affects tuber crops especially cassava production (Alternative hypothesis)

Table 4: Distribution by Farmers Perception Resilience of Tuber Crops Especially Cassava Towards Climate Change Related Catastrophes

		Affect Cassava growth	**Not affects cassava growth**
Climate change	Yes	45	85
	No	35	95

Table 5: The Summery of Chi-Square Result of Farmer's Perception

Category	N	Test of significance	Calculated Value	Table Value	Level of significance	Comment
2	130	X^2	1.8	3.145	5%	NS

Since the calculated value of X^2(1.8) is much below the table value (3.145) which infers it is not statistically significant. Hence the null hypothesis is accepted and it can be concluded that the research is unbiased i.e. climate change related catastrophes will not affect the tuber crops especially cassava production.

Conclusion and Recommendation

The study is basically focused on the effects of climate change on tuber crops especially cassava and how it is resilient towards the impact of climate change related catastrophes in Kottayam district of Kerala state, India. The study revealed the occurrence of climate change on regional basis. The annual rainfall, seasonal changes and temperature shows changing trends and these changes produce notable variation on crop production especially rice, the staple food which is sensitive in nature towards variations in climate and hence causes food insecurity issues and largely affects the marginalized community. Tubers especially cassava is likely to outperform other crops amid rising temperature and could even become more productive, offering farmers a way to cope with changing climate. The study also shows a shift in cultivation trends i.e. most of the farmers engaged in rice production now opt tuber crops, vegetables and cash crops like rubber and pepper. The farmer's perception towards the resilience of tuber crops especially cassava under climate change related catastrophes showed satisfaction of farmers with tubers production and consumption for better income generation and profitable ever sustaining field other than rice.

The farmers reported that cassava is drought tolerant, rich in carbohydrate content and can sustain communities throughout the year as the main source of calories. The chi square test also shows, test is not statistically significant i.e., climate change related catastrophes will not affect cassava production. Therefore it is established that the climate change related issues do not affect the tuber production in the study area. Hunger and malnutrition are the future threats for the world, view against the rapid population growth. Here is the place of interest of the study, the study area encloses a part of Kuttanad rice cultivating tract which is under risk of climate change related hazards and fast receding but the number of mouth to feed rapidly increasing day by day. The price peak of staple food and its vulnerability towards the climate related catastrophes such as flood, drought make situation more complicated, generally affecting marginalized poor people.

The people in the study area especially marginalized peoples includes the tuber crops especially tapioca in their daily diet in means of cheaply available food stuff. And majority of the people in the study area consider the tuber's in their Kitchen garden while the farmers who are actively participating in the tuber cultivation are highly satisfied by means of resilience in growth under extreme climate related incidence and also by means of income generation. The study concluded that the viable and cheap alternatives are the ever resilient tuber crops especially tapioca. Further studies needed to understand if there is any relationship between the increasing concentration of greenhouse gases and the yield of tubers.

Reference

Asher. C.J., Edawards . D.C., Howler .R.H., (1980) Nutritional disorders of Cassava. St.Lucia, Queensland.

Indian Network for Climate Change Assessment (2011)."Climate Change and India: A 4X4 Assesment - A sectoral and regional analysis for 2030s". Ministry of Environment and Forests, Govt of India.

IPCC (2001). Intergovernmental Panel on Climate Change, Climate change 2001: Synthesis report. Cambridge University Press. Cambridge.

IPCC (2007). Climate change impacts, Adaptation and Vulnerability. Cambridge, UK: Cambridge University.

Krishnamurthy. V., (2011). Extreme Events and Trends in the Indian Summer Monsoon. COLA Technical Report 314.

Lockwood. J.G., (1999). Is potential evapotranspiration and its relationship with actual evapotranspiration sensitive to elevated atmospheric CO2 levels. Climate change. 41: 193-212.

Ravi. V, Saravan .R., (2001). Photosynthesis and productivity of cassava under water deficit stress and stress free conditions. Journal of Root crops. 27:214-218

Ravi.V, Ravindran.C.S., Ramesh (2011) .V. The impacts of climate change on photosynthesis and productivity of cassava and sweet potato: Effect of rise in temperature, CO2 and UV-B radiation: an overview. Journal of Root Crops. 34(2).95-107.

Scott. G., Rosegrant. M., Ringler. C.,(2000). Global Projection for root and tuber crop to the year 2020. Food Policy. 25(5):561-597

UNFCC, 1992. United Nations Framework Convention on Climate Change Secretariat, Bonn

Wrigley, C.W., Blumental.,C.Gras., P.W. Barlow., 1994. Temperature variation during grain filling and changes in wheat grain quality. Australian Journal Plant physiology. 21: 875-885.