CHAPTER I

INTRODUCTION

Climate change refers to the long-term shifts in temperature and weather patterns. These shifts may be natural, but since the 1800^{s}, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels (like coal, oil, and gas), which produces heat-trapping gases (Intergovernmental Panel on Climate Change IPCC, 2013). Climate changes include changes which occur due to internal and natural processes as well as the ones caused by external factors especially human activity induced pollution and its impact on natural resources, biodiversity, land use, etc. Climate change could be one of the affecting parameter all over the world. It is predicted by IPCC that many of the observed changes due to climate change are unprecedented (IPCC, 2011). Global sea level rise is projected to be between 0.17 to 0.41 m in the year 2050 (Brown et al., 2015). It is observed that the rate of rising sea level has been larger than the mean rate during the previous two millennium years, till the mid-19th century (Kemp et.al., 2011). The changes in precipitation will be non-uniform and its extreme events over most of the mid-latitude and wet tropical regions will become more intense and frequent (Kitoh et.al., 2016).

Heat wave frequency has increased since the middle of the 20th century in large part of Asia (IPCC, 2014). Moreover concentration of CO_2 and other greenhouse gases leads to increase the temperature. The United Nations Framework Convention on Climate Change (UNFCCC, 2016) defined "Climate Change" as a variation in the composition of the entire atmosphere that is related directly or indirectly to human activity. El Nino is related with the Pacific Ocean, which inhabits nearby one-third of the Earth's surface. El Nino is a climate occurrence in the equatorial Pacific when sea surface temperatures exceed a threshold of +0.5 degrees Celsius (and cools by the same margin during alter La Nina). These observed changes are responsible for varying the climate at different parts of the Earth and sometimes it may result into extreme weather events. Climate change may increase or decrease the crop yield depending on the latitude of the area and irrigation application. Increasing temperature and varying precipitation may decrease the crop productivity in future (Kang et al., 2009). Temperature could be an impactful parameter which affects crop yield all over the world.

Climate Change and India

India has also started experiencing extreme weather events which lead to change the climate. Global warming is one of the major affecting parameter to change the climate. In India, it is observed that the annual mean temperature has increased at the rate of 0.42°C (Arora et al., 2005). Indian agriculture system is based upon south-west and north-east monsoon. Almost 80 per cent of the total precipitation comes from south-west monsoon in India. Any fluctuations and uncertainties in long range rainfall pattern may affect the agriculture sector and also lead to increase the frequency of droughts and floods at regional scale (Jain and Kumar, 2012). India gets affected by western disturbances at small scale as such disturbances have impact only on rabi production (Chand et al., 2015) not only monsoon, but temperature has also shown its effect on agriculture. Extreme maximum and minimum temperature showed an increasing trend in India. The increase in temperature, would leads to crop productivity is likely to decrease in future (Kumar, 2015). Hence, there is dependency of temperature on crop productivity, stability, yield and quality to uplift the country's economy.

Climate Change and Agriculture

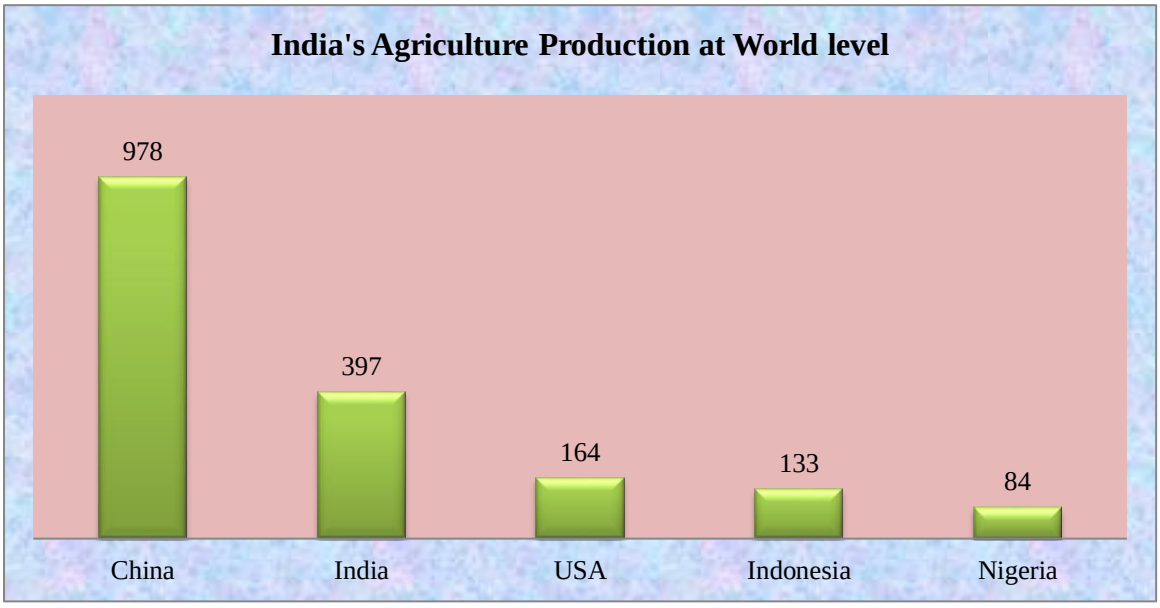
Agriculture sector in India is vulnerable to climate change. Higher temperatures tend to reduce crop yields, favour weed and pest proliferation. Climate change can have negative effects on irrigated crop yields across agro-ecological regions both due to rise in temperature and changes in water availability. Agriculture is one of the most vulnerable sectors owing to its high dependence on climate and weather conditions. India is one of the largest food producers in the world, with about 68 per cent of its 1.3 billion populations directly or indirectly engaged in agriculture. Though agricultural contribution to GDP has gone down from 51 per cent in the 1950^{s} to around 16 per cent, the number of household's dependent on agriculture have increased from 70 million in 1951 to 120 million in 2020. This massive dependence on agriculture makes India more vulnerable to climate change (Economic Survey, 2020). India incurs losses to the tune of USD 9-10 billion annually due to extreme weather conditions. It is a key challenge for food security and rural livelihoods in the country. India's position at world level is given in the table- (1).

Table-1

India's Position in World Agriculture

Sector	Agriculture	Industry	Service
World	3,358	23,518	58,883
India	**397**	**727**	**1,596**
Share	12	3	3
World Rank	2	5	9

Source: World Bank Database (2019).



Source: World Bank data, (2019).
Figure: 1

India ranks second in the world in agricultural production, alone occupying around 12 per cent of world share, after China (29 per cent). The top three in the world in agricultural production are; China, India, USA. Agricultural production now exceeds the USA that once supplied food grains to India to tide over food shortage and starvation in 1960^{s}. Contrary to the public perception, it is in agricultural sector, India holds a higher global rank, whereas in industry and service sector, it ranks lower, fifth and ninth respectively. The agricultural sector creates wealth from land, water and light using skilled family labour and agriculture inputs.

Impact of Climate Change on Agriculture

India is highly vulnerable to climate change due to its considerable and growing population and growing economy, both closely tied to a limited natural resource base. More than half of the 1.3 billion populations directly depend on climate sensitive sectors (agriculture, forestry, fisheries) and natural resources (water, biodiversity and coastlands) for

subsistence and livelihood. As India strives to develop its economy, rising industrialization, urbanization, agricultural commercialization, and expansion of power generation capacity based predominately on non-renewable fuels will rapidly increase green-house gas (GHG) emissions. Indian agriculture is particularly vulnerable due to:

- Predominantly un-irrigated (rain-fed) agriculture largely contingent on monsoon rains,
- Himalayan glacier-fed, river based irrigation in the north and east,
- Massive livestock population, specifically cattle and water buffalo,
- Densely populated, low lying 7,500 kilometer coastline, and;
- Large number of resource poor farmers and
- Other producers with limited ability to adopt the sustainable resource technologies.

"According to the Government of India, Ministry of Earth Sciences (2020) stated that since the middle of the twentieth century, India has experienced a rise in average temperatures, a decrease in monsoon precipitation, a rise in extreme temperature, rainfall and drought events, an increase in intensity of severe cyclones and other changes in the monsoon system. Scientific evidence suggests that these climate change distresses are expected to continue during the twenty-first century. Factors including excessive temperatures, acute monsoon system transformations, fragile glacial fed river systems, extreme weather events, and inundation of coastlines due to rising sea levels all will impact India's existing water-based ecosystems. Agriculture is the most vulnerable sector to climate change, owing to its sensitivity to precise weather parameters and likely economic impacts. The changes in climatic events such as temperature, rainfall and atmospheric carbon dioxide (CO_2) can significantly affect crop yields. These factors affect the livestock, fisheries, plantation, and forestry sectors. Consequently, the livelihoods of a vast population, where more than half of the country relies on agriculture, forestry, wet lands and fisheries as a primary source of income will be affected by the looming climate change scenario".

Trends of Climate Change in India

According to the World Metrological Organization (WMO) estimates the five year period, 2011 to 2015, has been the warmest five year period on record. The world experienced several extreme weather events such as heat waves primarily a result of the ongoing climate change (WMO, 2015). India has a reason to be concerned about climate change, as a vast population depends on climate-sensitive sectors like agriculture, forestry and fishery for their livelihood. The adverse impact of climate change in the form of decline in rainfall and rise in temperature has resulted in increased severity of livelihood issues in the country. Climate change would represent additional stress on the ecological and socio-economic systems that are already under tremendous pressure due to rapid industrialization, urbanization and economic development (Balasubramanian and Birundha, 2018). Climate and agriculture are intensely interconnected with global processes. Even a small change in climate affects agriculture adversely decreasing the production rate.

Trends of Climate Change in India

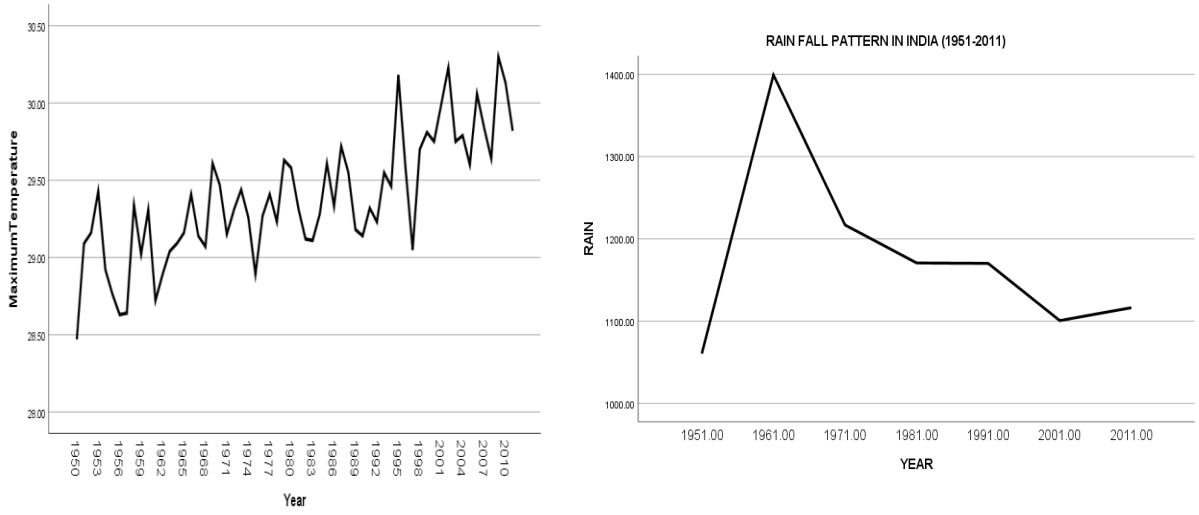


Figure: 2

Challenges of Climate Change and Agriculture Sector

Even though the dependence on agriculture has increased, the arable land has been decreasing in size as well as quality, reducing the average size of land holdings to 1.08 hectares. Division of cultivable land into smaller pieces coupled with negligent soil management is increasing the rate of degradation of land. In 2019, Intergovernmental Panel on Climate Change (IPCC) reported that "land degradation is a driver of climate change

through emission of greenhouse gases and reduced rates of carbon uptake". It's a vicious cycle as the socio-economic effects of climate change accelerate land degradation. Climate changes have also led to unpredictable weather and natural crises be it drought, pandemic, cyclones, heavy rain and flood. Increased unpredictability in humidity, temperature and precipitation disrupt the traditional agricultural calendar with intense bursts of extreme weather. Increased water use in irrigation has resulted in a continued decline in India's per capita water availability by 60 per cent over the last 50 years, accelerating land degradation. Furthermore, being one of the world's leading exporters of water intensive crops such as rice and sugarcane, thus end up exporting water (virtual water) along with the agricultural exports. This depletion not only accelerates climate change, but also leads to lower productivity over consequent growth cycles.

Climate Change and Cropping Pattern

Climate change on food production has examined the influence on crop yields. However, climate influences all components of crop production, includes cropping area (area planted or harvested) and cropping intensity (number of crops grown within a year). Increased temperature, changed precipitation conditions and increased CO_2 content in the atmosphere are the major climatic factors affecting crop production. Rise in atmospheric temperature will lead to loss of soil moisture and will increase the crop demand for water. The results also show that the irrigation potential of the watershed will be at least halved by mid-century in all scenario combinations. While major cereal crop sensitivities to temperature changes, moisture, and CO_2 concentration under various climatic scenarios in the Indian subcontinent, there are no conclusive reports on the overall impact these factors. India's two leading food grains, suggest that wheat is sensitive to rising maximum temperature and augmented heat waves, and rice is vulnerable to increased minimum temperatures in the region (Duku et.al., 2018). However, productivity declines due to increased temperatures may be partially offset by elevated CO_2 levels, but projected water shortages and extreme thermal stresses could adversely impact yield. Historically, India's rice yields experience larger declines during extreme weather conditions, including drought. Climate change impacts on horticultural and other field crops vary based on rising temperatures or regional CO_2 concentration, but India's cropping pattern may be more vulnerable to the expected higher incidences of extreme weather (e.g. rainfall duration and intensity, drought/flood), pests, and disease. Some of the shorter duration water stress tolerant crops like coarse grains and pulses

may perform better than the other higher yielding input intensive crops under varying climate change conditions.

Land Use Pattern in India

Amoung all the resources land is a limited and most important basic natural resource. The layout or arrangement of the uses of the land is known as "land use pattern". Land use is multi displinary area and is a perquisite resources base for all activities of society (Rani , 2020). It describes the various ways in which human beings make use and manage the land and its resources. The land may be used for agriculture, forest, pasture etc. The following table- (2) shows the land use pattern in India.

Table-2

Details of Land Use Pattern in India

(area in million hectares)

Particulars	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11
Geographical area	328.73	328.73	328.73	328.73	328.73	328.73	328.73
Reporting area	284.32	298.46	303.75	304.16	304.86	305.19	305.61
Forest area	40.48	54.05	63.83	67.46	67.81	69.84	70.04
Land not available for cultivation	47.52	50.7	44.61	39.55	40.48	41.23	42.95
Area under non agri. Use	9.36	14.84	16.48	19.60	21.09	23.75	26.17
Barren and Uncultivable land	38.15	16.48	28.13	19.96	19.39	17.48	16.78
Other Uncultivated land	49.45	37.64	35.13	32.31	30.22	27.74	26.36
Fallow land	28.12	22.82	19.33	24.55	23.37	25.04	26.24
Net sown area	118.75	133.20	140.86	140.29	143.00	140.70	140.02
Area sown more than once	13.15	19.57	24.93	34.63	42.74	47.59	52.18
Gross cropped area	131.89	152.77	165.79	172.63	185.74	188.29	192.20

Source: Indian Agriculture at a Glance, (2012).

The land use pattern in India, the total geographical area was 328726 thousand hectares reveals that marginal increase in forest land from 9.30 to 16.45 per cent from 1950-51 to 2010-11 has been noticed the rise that forest land in previous decades could be due to the forestation of land on large scale to preserve the ecological balance. Other categories of lands such as barren land, cultivable waste land and permanent pastures and grazing land had revealed declining trend. There was a declining trend in other fallow lands and net sown area has also been noticed. Current fallows declined since 1950-51 to 2010-11. The reasons after these changes in land categories could be the impossibility of monsoon, limited irrigation facilities and sub division and fragmentation of lands these all were making cultivation

costlier. Now it was very difficult task for policy makers to maximize the income of farming community through continuous declining net sown area.

Agriculture Land Holdings in India

All land which is used wholly or partly for Agricultural production is operated as one technical unit by one person alone or with others without regard to the title, legal form, size or location. Operated area includes both cultivated and uncultivated area, provided part of it is put to agricultural production. Table- (3) revealed the agriculture land holders and area operated for agriculture purposes in India.

Table-3

Details of Agriculture Land Holdings in India

(in per cent)

Farmers Category	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11
Land Holdings						
Marginal	39.1	45.8	56.6	62.8	69.8	66.4
Small	22.6	22.4	19.3	17.8	16.1	18.0
Small Medium	19.8	17.7	14.2	12.0	9.0	10.3
Medium	14.0	11.1	8.6	6.1	4.3	4.4
Large	4.5	3.1	1.9	1.3	0.8	0.7
Operated area						
Marginal	6.9	9.2	11.5	15.6	22.2	22.1
Small	12.3	14.8	16.6	18.7	20.6	21.8
Small Medium	20.7	22.6	23.1	24.1	22.4	23.8
Medium	31.3	30.5	30.1	26.4	22.7	21.8
Large	29.0	23.0	18.2	15.2	12.1	10.3

Source: Agriculture Census Report, (2000 and 2011).

Agricultural Census presented data that the number of operational holdings has been consistently increasing since the first Agriculture Census in 1960-61. The number of holdings, which was increase of marginal land holdings, in which decline the category of other famer's category from 1960-61 to 2010-11. The operated area which was 162.3 million hectares in 1970-71, initially increased to 165.5 million hectares in 1990-91 and thereafter declined to 158.3 million hectares in 2005-06 which rose to 159.59 million hectares in 2010-11, indicating a marginal increase of 0.80 per cent. The average size of holdings had shown a consistent decline over all the census periods.

Sources of Water Resources in India

Water is a critical resource for farmers. Securing water access is crucial to poverty alleviation in rural areas because it strengthens food security for all. “Farmers and water go together. Without water there is no agriculture and therefore no food security” (Singh, 2013). The details of different water resources was given in the below table- (4).

Table-4

Different Sources of Irrigation in India

Year	Canals	Tanks	Wells	Other Sources	Total
1950-51	8295	3613	5978	2967	20853
1960-61	10370	4561	7290	2440	24661
1970-71	12838	4112	11887	2266	31103
1980-81	15292	3182	17695	2551	38720
1990-91	17453	2944	24694	2932	48023
2000-01	15965	2455	33828	2885	55133
2010-11	17006	2249	30258	4289	64625

Source: Directorate of Economics and Statistics, Ministry of Agriculture, (2012).

Government of India had given considerable importance to the development of command area under canals. Earlier during 1950-1951, the canal irrigated area was 8.3 million ha which now 17 million hectares despite that, the relative importance of canals had come down from 40 per cent in 1951 to 26 per cent in 2010-11. Wells and tube wells accounted for 29 per cent total irrigated area in 1951 and they had a share of 64 per cent of the total irrigated area in 2010-11.

Agriculture Production in India

The growth pattern of agriculture witnessed in the country since 1951 showed that broadening the base of agriculture growth and modernization through the development of infrastructural services and procurement policies for crops, essential for accelerating the pace of agricultural output. An important aspect of India's agriculture strategy under the plan has been overcoming the institutional constraints to agriculture development (Naiyer and Haque, 2015).

Table-5

All India Area, Production and Yield Along with Coverage under Irrigation in India

Area in Million hectares
Production in Million tonnes
Yield in '00kg per hectares
Area under irrigation in per cent

Year	Area	Production	Yield	Area Under Irrigation
1951	97.32	50.82	522	18.1
1961	115.58	82.02	710	19.1
1971	124.32	108.42	872	24.1
1981	126.67	129.59	1023	29.7
1991	127.84	176.39	1380	35.1
2001	121.05	196.81	1626	43.4
2011	126.67	244.49	1930	47.8

Source: Agriculture Statistical at glance, (2015).

As its clear from the above table- (5) that there is increase in production during 1951 it is 50.82 million tonnes which rose to 244.29 million tonnes in 2011. The area under irrigation in 1951 was 18.1 per cent and it has increased to 47.8 in 2011. The total production has increased from 51 million tonnes in 1951 to 244 million tonnes in 2011. The country's requirement for food grain production in order to provide for its population is projected to be 300 million tonnes by 2025 (Second Advanced Estimates of production of Food Grains, 2016-17).

Agriculture Input Usage in India

The agricultural growth experience of India since independence was essentially an outcome of the massive efforts aimed at ensuring availability and use of quality seeds, chemical fertilizers, irrigation, pesticides, farm machinery and equipment, agricultural credit, etc. Quality seeds are crucial for enhancing agricultural production. Integrated Nutrient Management (INM) is crucial for maintaining the soil's carrying capacity even while obtaining the maximum productivity of the land to meet the increasing food demand (State of Indian Agriculture, 2015). Soil productivity enhancement depends on the optimal usage of primary, secondary as well as micro nutrients through timely application.

Table- 6

Details of Agriculture Input Usage in India

(in thousand tonnes)

Year	N	P	K	Total
1950-51	58.7	6.9	-	65.6
1960-61	210.0	53.1	29.0	292.1
1970-71	1487.0	462.0	228.0	2777.0
1980-81	3678.1	1213.6	623.9	5515.6
1990-91	7997.2	3221.0	1328.0	12546.2
2000-01	10920.2	4214.6	1567.5	16702.3
2010-11	16558.2	8049.7	3514.3	28122.2

Source: Agriculture Situation in India, (2015).

The above table- (6) examined the consumption of fertilizers in India in terms of NPK Nitrogen (N), Phosphatic (P), and Potassic (K) has increased substantially from a mere 1.2 million tonnes in 1966-67 in the pre-green revolution period to more than 25 million tonnes in 2010-11. As per the International Fertilizer Association, India ranked second in total world fertilizer consumption in 2012. At all-India average consumption of fertilizers has increased from 1950-51 to 2010-11 respectively.

Agriculture and Five Year Plans in India

India is considered as one of the fastest growing economies in the world. Agriculture is the mother of any economy, whether it is rich or poor (Kumar, 2014). Much of its influence is on the other sectors of economy - industry and service. India is the second largest in farm output. Hence, India's economic security continues to be predicated upon the agriculture sector, and the situation is not likely to change in the near future. The plan wise agriculture and allied sector is given in the table- (7).

The growth performance of agriculture has always been lower than that of the total economy, since the early independence period in pre-green revolution era (1951-52 to1967-68). The difference was highest during the Tenth Plan Period where the total economy was growing at 7.77 per cent, the agriculture and allied sector was witnessing a growth of 2.47 per cent during the tenth Plan Period. The agriculture sector has shown a remarkable average growth rate, i.e., 4.1 per cent during the eleventh plan period, may be due to a better monsoon in some of the years. In the 12^{th} Plan, GDP of the total economy is growing at 7.9 per cent, but that of agriculture is only 1.6 per cent which is less than the expected target of 4 per cent per annum.

Table - 7

Plan Wise Economic and Agriculture Growth Rate in India

(in per cent)

Plan	Economy	Agriculture sector Including Livestock
First Plan (1951-56)	3.6	3.2
Second Plan (1956-61)	4.3	3.6
Third Plan (1961-66)	2.8	-0.7
Fourth plan (1969-74)	3.4	3.0
Fifth Plan (1974-78)	4.9.	4.0
Sixth Plan (1980-85)	5.5	6.3
Seventh Plan (1985-90)	5.7	3.1
Eighth Plan (1992-97)	6.5	4.9
Ninth Plan (1997-2002)	5.7	2.5
Tenth Plan (2002-2007)	7.6	2.5
Eleventh Plan (2007-12)	8.0	3.8
Twelveth Plan (2012-17)	7.9	1.6

Source: Economic Survey, (2015).

Agriculture and Share of GDP in India

Agriculture plays an essential role in the process of economic development of less developed countries like India (Tripathi and Prasad 2009.) Agriculture and allied activities contributed nearly 50 per cent to India's national income and it is found to be declining from 1950-51 to 2010-11. In spite of this, it is also an important feature of agriculture that is to be noted that growth of other sectors and overall economy depends on the performance of agriculture to a considerable extent. Because of these reasons agriculture continues to be the dominant sector in Indian Economy.

Table- 8

Gross Domestic Product and Share of Agricultural Sector in India

(Numbers in crores rupees)

Year	Current prices		2004-05 Prices	
	GDPFc	Share of Agriculture and Allied Activities	GDPFc	Share of Agriculture and Allied Activities
1950-51	10036	5274	279618	150191 (53.68)
1960-61	17049	7434	410279	204340 (49.80)
1970-71	44382	19086	589787	258665 (43.85)
1980-81	136838	50760	798506	305906 (38.30)
1990-91	531814	168166	1347889	444880 (33.00)
2000-01	1991982	506476	2342774	592227 (25.27)
2010-11	7157412	1461095	4885954	818524 (16.75)

Source: Economic Survey, (2011-12).

Climate Change in Tamil Nadu

The climate of Tamil Nadu is strikingly different from the general climate of the country. Due to its topographical features and geographical area the climate of Tamil Nadu is referred to semiarid and tropical monsoon. The long coastal stretch in the east, hill orography of the western rim, and plain inlands play a significant role and influence the climate. The Climate of Tamil Nadu is tropical with little variation in summer, winter temperatures and features hot temperatures over the year except during the monsoon season. Due to proximity to the sea, the temperatures and humidity remain relatively high all the year round. The summer is hot with the temperature rising to 43 degree Centigrade and extends from April to June. November to February is the coolest winter period with temperatures around 18 degrees Centigrade (Climate Profile of Tamil Nadu, 2020). The State receives maximum rainfall during the months of October, November, and December (post monsoon), whereas in the rest of the country, the maximum rainfall is received in the months of June, July, August, and September months (monsoon). The State is frequently subjected to extreme weather conditions such as flooding in the coastal districts and severe droughts in some areas due to monsoon failure, which consequently affect the production and productivity of the food grains.

Population in Tamil Nadu

Population is a distinct group of individuals, whether that group comprises a nation or a group of people with a common characteristic. Tamil Nadu has been in the forefront of introducing social reforms and implementing a slew of welfare schemes to empower the marginalized sections of the society. The provisional population of India (Census, 2011) is 121.1 crore comprising of population of Tamil Nadu stood at 72,147,030. It ranks 6th among the States/Uts. The population, which was 30,119,047 in 1951, has gone up by 72,147,030 over the last sixty years.

Table-9
Details of Population in Tamil Nadu

S.No	Year	Population of Tamil Nadu	Rural Population
1	1950-51	30,119,047	22,785,522
2	1960-61	33,688,953	24,696,425
3	1970-71	41,199,188	26,734,334
4	1980-81	48,408,077	32,456,202
5	1990-91	55,858,946	36,781,354
6	2000-01	62,405,679	34,921,681
7	2010-11	72,147,030	37,229,590

Source: Census of India, (1991,2001, 2011).

Land Use Pattern in Tamil Nadu

Tamil Nadu has 130.33 lakh hectare of area and 58 per cent of it (75.50 lakhs hectare) is cultivable area. According to sixth Economic census Tamil Nadu has 50,29,402 establishments of which 35 per cent (17,47,205) are agricultural and allied establishments and these establishments provides around 26 per cent of total employment of all establishments (Report on Sixth Economic Census-Tamil Nadu, 2016).

Table- 10

Details of Land Use Pattern in Tamil Nadu

S.No	Particulars	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11
1	Forest	14.0	14.70	15.40	16.00	16.48	16.17	16.55
2	Current Fallow	8.60	7.40	9.20	12.40	7.95	7.77	7.06
3	Other Fallow	5.10	4.70	4.10	5.40	8.45	11.50	14.62
4	Total Fallow	13.70	12.10	13.30	17.80	16.40	19.27	31.68
5	Barren and uncultivable land	7.50	6.80	5.40	4.30	3.80	4.93	3.51
6	Land put to non-agricultural uses	9.80	10.40	12.40	13.80	14.73	20.46	16.90
7	Cultivable wastes	6.70	5.10	3.20	2.40	7.95	2.56	2.48
8	Permanent pastures and other grazing lands	2.90	2.60	1.50	1.10	0.95	0.84	0.83
9	Land under miscellaneous tree crops and groves	1.90	2.00	1.70	1.40	1.78	1.99	1.70
10	Net area sown	43.50	46.30	47.20	43.20	43.34	38.71	36.35
	Total geographical area	100	100	100	100	100	100	100

Source: Season and Crop Report of Tamil Nadu (2015). State of Agriculture Profile of Tamil Nadu (1999-2011)

The table- (10), explains the land use pattern of Tamil Nadu from 1950-51 to 2010-11. There has been a marginal increase in area under forests from 14.0 lakh ha to 16.55 lakh ha while there was a decline in area under barren and uncultivable lands from 7.50 lakh ha to 3.51 lakh ha between 1951 and 2011. Due to the increasing demand for land for industrial, housing and infrastructure development, the land put to nonagricultural uses has shown a increased between the periods. The area under cultivable wastes has decreased from 6.70 lakh ha to 2.48 lakh ha. Though the area under current fallows increased to 12.40 lakh ha during 1980, it decreased to 7.06 lakh ha during 2011. One of the most disturbing trends is the sharp increase in other fallows from 5.10 lakh ha in 1951 to 14.62 lakh ha in 2011. But for the moderate increase in net sown area during the sixties and seventies, there has been stagnation in the net sown area, which has further decreased to about 36.35 lakh ha during the 2010-2011. Thus, the dynamics of land use pattern in the Tamil Nadu over the last fifty years

reveals that there was a significant decline in the net sown area, gross cropped area, and the area under cultivable wastes and barren and uncultivable wastes while there was a sharp increase in the land put to nonagricultural uses and other fallow lands.

Rural Population and Workforce

Tamil Nadu accounted for 22,799,066 of total main workers in 1991 where it is increased as 4,942,500 in 2011. Table - (11) examined the rural population between 1991 and 2011 Censuses the number of cultivators has slightly decreased as 5,664,090 to 4,248,457and agricultural labourers has increased as 7,896,295 to 9,606,547 respectively.

Table- 11

Details of Rural Population and Workforce in Tamil Nadu

(Population in Crores)
(Cultivators in Millions)
(Agriculture labourers in million)

Year	1991	2001	2011
Total Main Workers	22,799,066	23,684,611	4,942,500
Cultivators	5,664,090	5,114,384	4,248,457
Agricultural Labourers	7,896,295	8,665,040	9,606,547
Total Population	55,858,946	62,110,839	72,147,030

Source: Indian Agriculture at a Glance, (2020).

Average Size of Holdings in Tamil Nadu

As per the Agricultural Census 2010-11, marginal and small holdings of less than 2 hectares accounted for 92.0 per cent of the total holdings and 61.0 per cent of the total operated area was given in the table- (12). They in turn are unsuitable for conventional technology and machinery use to boost agricultural production. This led to a process of marginalization of small and marginal farmers and casualization of agricultural labourers. To empower marginal and small farmers, they may be motivated to farmers' groups so as to get all the technical inputs in time and to ensure judicious use of various scarce resources.

Table- 12

Details of Average Size of Holdings in Tamil Nadu

(in hectares)

S.No	Classification	1970-71	1980-81	1990-91	2000-01	2010-11
1	Marginal (<1ha)	0.42	0.38	0.36	0.37	0.37
2	Small (1-2 ha)	1.42	1.41	1.41	1.39	1.39
3	Semi medium (2-4 ha)	2.75	2.77	2.73	2.72	2.70
4	Medium (4-10 ha)	5.83	5.78	5.72	5.68	5.63
5	Large (>10 ha)	16.94	17.97	18.44	19.48	20.13

Source: Agriculture Census Report of Tamil Nadu, (1990, 2011).

Water Resources and Irrigated Area

The ground water availability is found to be in safe condition only with 429 firkas (38 per cent) of Tamil Nadu is given in the below table – (13). The details of net area irrigated using various sources of irrigation across the State (1971-2011) are as follows, the area irrigated by wells and bore wells accounted for 62 per cent followed by Canals (25 per cent) and Tanks (13 per cent).

Table-13

Details of Water Resources and Irrigated area in Tamil Nadu

Source	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11
Canals	7.88	8.82	8.84	8.89	7.69	8.33	7.5
Tanks	5.65	9.36	8.98	5.90	5.31	5.88	5.3
Wells	4.26	5.98	7.75	10.67	10.59	14.49	16.2
Other Sources	0.76	0.46	0.35	0.24	0.14	0.16	0.1
Total	18.55	24.62	25.92	25.90	23.73	28.87	29.1

Source: State of Agriculture Profile of Tamil Nadu (1999-2011)

Area Production and Yield in Tamil Nadu

Achieving food security by increasing agricultural production forms the core of agricultural development strategy in the State. The favorable temporal and spatial spread of rainfall and adequate availability of water both in surface and sub-surface flow for irrigation, the production of principal crops in the State witnessed increase in 2010-11 as compared to 1950-51. The increase in production was mainly adduced to the increase in yield rate of crops rather than that of area. The area, production and yield of crops in the State were given in the following table- (14).

Table-14

Details of Area Production and Yield in Tamil Nadu

Area in Million hectares
Production in Million tonnes
Yield in '00kg per hectares

Year	Area	Production	Yield
1950-51	1.723	1.712	9.94
1960-61	2.518	3.559	14.13
1970-71	2.686	5.303	19.74
1980-81	2.230	4.159	18.65
1990-91	1.856	5.782	31.16
2000-01	2.080	7.366	35.41
2010-11	1.906	5.792	30.40

Source: Ministry of Agriculture, (2015).

During 1950 there is slightly increase in production 1970 and its again increased and decreased from 2001, there was an all-time high production of food grains at 101.52 lakh tonnes. However, a wide spread drought during 2011 triggered a steep decline in food grains production. The fall in the production of all constituents of food grains viz., rice, pulses and millets caused the overall decline in food grains production during 2011 respectively.

Opportunity Areas: Technology, Sustainability and Policy Support

Climate change is a critical issue especially in the Indian context. The country with its diverse geography comprising of mountains, coasts, forests, deltas and deserts divers is highly vulnerable to climate change due to threats like glacial melts, rising sea levels, extreme heat waves, droughts, desertification, floods, storms and loss of farm lands, grass lands, biodiversity and marine ecosystems. These extreme weather events also amplify the occurrence of heat strokes, vector and water borne diseases adversely affecting human health and productivity. Further, the presence of a high absolute number, as well as, a large proportion of the world's poor population also augment the country's vulnerability with the poorest people in the poorest countries expected to be the worst affected due to climate change (Stern 2006 and Parry et.al., 2007). Climate change affects the large poor and food insecure population through a number of ways including their livelihoods, food availability and affordability. Rising temperature and changes in rainfall patterns affect agricultural yields of both rain- fed and irrigated crops, directly affecting the availability of crop production. The unchecked rise of sea levels leads to loss of land, land scape and infrastructure affecting availability and access dimensions of the agriculture production (Wheeler and Von Braun, 2013).

Climate Change and Crop Diversification

"Crop Diversification provides better conditions for food security and enables farmers to grow surplus products for sale at market and thus help to obtain increased income to meet other needs related to household well-being". Crop diversification makes farms more environmental friendly. This is because planting a variety of crops makes the soil healthier, which in turn reduces the need to use excessive amounts of fertilizer.

Advantages of Crop diversification

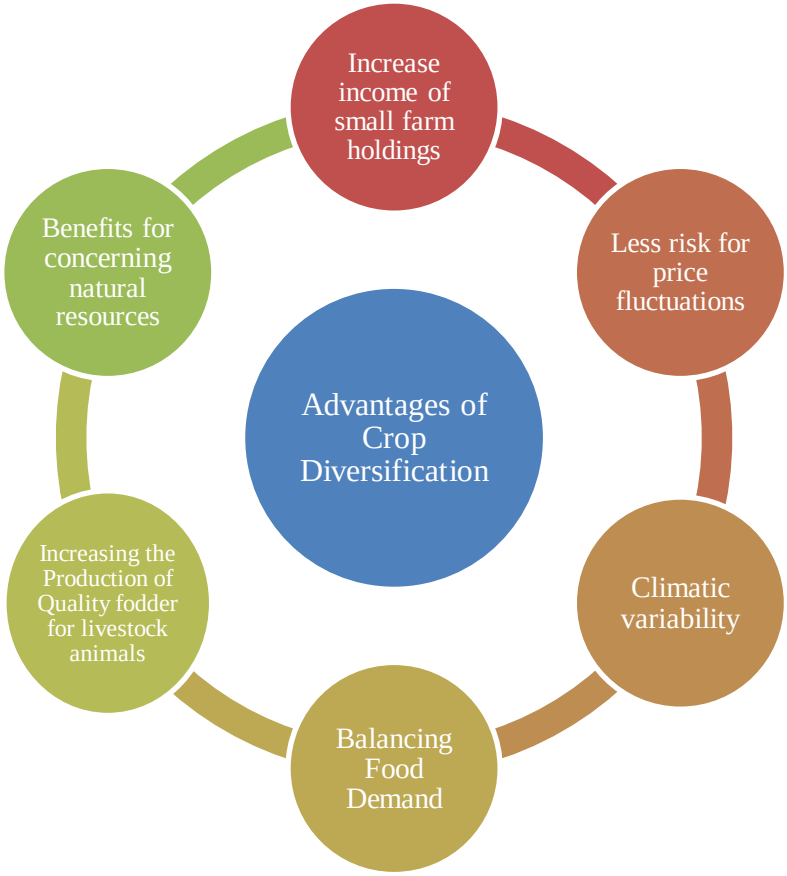


Figure: 3

Crop Diversification can improve resilience in a variety of ways by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by suffering crop production from the effects of greater climate variability and extreme weather events' The most important reason for the emergence of agrarian distress in the country during 1990^{s} is the low level of absolute income as well as large and deteriorating disparity between income of a farmers and non-agricultural worker, which turned even more serious in latest years. To double farmers' income by 2019-

20 can play crucial role to promote farmers welfare, reduce agrarian distress and bring parity between income of farmers and those working in non-agricultural professions. Therefore, strong measures are actually needed to harness all possible sources of growth in farmers' income within as well as outside agriculture sector (Nayak and Kumar, 2019). The major sources of growth operating within agriculture sector may be improvement in productivity, resource use efficiency or saving in cost of production, increase in cropping intensity, diversification towards high value crops etc. The useful strategies were proposed like Irrigation ('Per Drop More Crop'); Quality seeds (Improving seed replacement rate); Soil-test based nutrient management (Distribution of soil-health cards); Post-harvest crop losses (Large investments in warehousing and cold chains); Value addition; Creation of a national agricultural market, removing distortions and e-platform etc.;. Crudely, increase in area and productivity can be two major options to increase the agricultural output. Three prolonged strategies focused on

(i) Development initiatives,
(ii) Technology and
(iii) Policy reforms in agriculture are needed to double farmers' income.

High demand of lands for non-agricultural sectors limits the possibility for further expansion of the land for cultivation. Besides, the productivity of the most of the crops is low in the country, and there is a huge scope to raise the productivity to enable doubling the farmers' income. Even within the country, there is huge yield variation of different crops among the states. Variation in productivity with the same level of irrigation, and low income level of the farmers is due to the less adaptation of developed technologies and lack of modernization of farms. Farmers, at least medium and large farmers associated with small- and marginal-farmers, to adopt the alternative in agriculture alternatively, the diversification of crops and integrated farming system, which may turn more remunerative, better input use efficient, and less risk involved (Sen, 2017). Promotion of integrated farming system approach requires synergistic blending of crops, horticulture, dairy, fisheries, poultry, etc. Micro irrigation along with the nutrient application can be highly efficient and priority should be given to empower farmers with micro irrigation.

Among the different strategies and technologies, crop diversification and inclusion of new varieties is of the prioritized technology to increase the farm income and profitability. Agricultural crop diversification is an important stress relieving option for economic growth

of the farming community. Diversification of agriculture in the first Green Revolution areas such as Punjab, Haryana and Western Uttar Pradesh seems need of the hour. Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value added crops with complementary marketing opportunities. Crop diversification and inclusion of the new varieties can be one of the important technologies in increasing the farmers' income to a certain extent, if not double (Khan, 2017). Crop diversification is to increase crop portfolio so that farmers are not dependent on a single crop to generate their income. When farmers go for single crop type they are exposed to high risks in the event of unforeseen climate events that could severely impact agricultural production, such as emergence of pests and the sudden onset of frost or drought. Introducing a greater range of varieties in a particular agro ecosystem leads to diversification of agricultural production which can also increase natural biodiversity, strengthening the ability of the agro ecosystem to respond to these stresses. The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. It reduces the risk of total crop failure and also provides alternative means of generating income, as different crops will respond to climate scenarios in different ways. While the cold may affect one crop negatively, production in an alternative crop may increase.

Crop diversification in India is generally viewed as a shifting from traditionally grown less remunerative crops to more remunerative crops. Crop diversification and growing of large number of crops are practiced in dry land areas to reduce the risk factor of crop failures due to recurring droughts. Crop substitution and crop shift are also taking place in the areas suffering with some specific soil related problems, like salinity, sodicity, acidity etc. Conclusively, major advantages of crop diversification include income increases of small farm holdings; less risk for price fluctuation, climatic variability etc., balancing food demand; increasing the production of quality fodder for livestock animals; beneficial for conserving natural resources; minimize environmental pollution; reduce dependence on off farm inputs; and community food security can be increased (Chinnadurai, et.al., 2016). Technological breakthroughs of shifting production frontiers and raising efficiency in use of inputs, precision farming to raise production and income of farmers substantially etc. Farm mechanization with modern machineries such as, precision seeder, laser land leveler and planter, and practices like SRI (System of Rice Intensification), direct seeded rice, zero

tillage, raised bed plantation and ridge plantation, drip and sprinkler irrigations allow technically high efficient farming and sustainable income enhancement.

Information and Communication Technology (ICTs) in Agriculture

Information and Communication Technology (ICTs) denote a wide range of services, applications and technologies, using various types of hardware and software, often running over telecom networks (Pradhan and Mohapatra ,2015). ICTs facilitate improvement in information management and dialogue between individuals, groups, communities etc. It consists of mainly three technologies. They are, Computer Technology, Communication Technology and Information Management Technology. These technologies are applied for processing, exchanging and managing data, information and knowledge. The tools provided by ICTs include computer hardware, operating systems, application software, as well as networks and intranets, telephone and electricity lines, radio and satellite systems by which they operate. The information technologies that can be used in agriculture are Satellite Communication, Geographic Information System (GIS), computer network, video, radio and reprography. Teleconferencing, e-mail, fax and mobile phones are some other potential technologies that could be used in effective transfer and dissemination of agricultural information to the farmers.

E-Agriculture in India

ICT in agriculture is also known as e- agriculture. E-Agriculture Community is made up of individual stakeholders such as information and communication specialists, researchers, farmers, students, policy makers, business people, development practitioners, and others. More specifically, e-agriculture involves the conceptualization, design, development, evaluation and application of innovative ways to use information and communication technologies (ICTs) in the rural domain, with a primary focus on agriculture. E-agriculture is the Internet platform of this global initiative aimed at promoting sustainable agricultural development and food security by improving the use of information, communication, and associated technologies in the sector. E-agriculture is a rising field for enhancing existing agriculture and food security through enhanced processes for knowledge access and switch using information and communication technologies. The World Summit on the Information Society (WSIS) Plan of Action comprises e-agriculture as a region of function of information and communication

technologies (ICTs). E-agriculture is a relatively recent term in the field of agriculture and rural development practices (Raj, 2013). An emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes. To enable Community members to exchange opinions, experiences, good practices and resources related to e-agriculture, and to ensure that the knowledge created is effectively shared and used worldwide. Applications of e-agriculture in intensive agricultural systems in developed countries are gearing towards using sophisticated technologies to improve the quantity and quality of production, in order to maximize profits. This is the case in precision agriculture in which farmers are harnessing computer and satellite technologies to cut costs, improve yields and protect the environment.

Role of ICTs in Agriculture

ICTs is an term that includes any communication device or application, encompassing: radio, television, mobile and fixed phones, computer and network hardware and software, satellite systems and so on, (as well as the various services and applications associated with them, such as videoconferencing, distance learning, etc) necessary for the delivery of information in the form of audio, data, video, image, etc. ICTs consist of all technical means used to handle information and aid communication. Several reports underscore just how significant and extraordinary ICTs productivity gains are not only for individuals and businesses, but for a nation (Ghogare and Monga 2015).

Role of ICTs in Tamil Nadu

ICTs has been an integral part of our society since it plays an important role to our day to day life. The rise of population of India has been a major issue in India, i.e. around 121 crore, out of which Tamil Nadu's population is around 7.21crores in 2011 census. ICTs can deliver useful information to farmers about agriculture like crop care and animal husbandry, fertilizer and feedstock inputs, pest control, seed sourcing and market prices (Singh 2016). There are many possibilities of integration of ICTs in agricultural, for the overall agricultural and rural development.

- The ICTs tools provide networking of Agriculture Sector globally, the Centre and State Government Departments will have reservoir of databases" and also "bring farmers, researchers, scientists and administrators together".

- ICTs plays an important role in enhancing the impact and performance of agriculture production and in direct poverty alleviation by enhancing activities of poor and increasing their productivity by way of new credit and financial services.
- Up-to-date information, supplied to farmers as early as possible, about subjects such as packages of practices, market information, weather forecasting, input supplies, credit availability, etc.
- Tele-education for farmers.

In the last few decades, information and communication technologies (ICTs) have provided immense opportunities for the social and economic development of rural people, and some technologies have surpassed others. Mobile telephony is one such technology that has developed significantly in the past few years, and the subscription rate in developing countries has gone up from 22 per 100 inhabitants in 2005 to 91.8 per 100 inhabitants in 2015. Mobile technology goes beyond geographic, socio-economic, and cultural barriers and this large increase in mobile subscriptions, along with the recent roll out of 3G and 4G technology, can play a big role in the development of rural people. Mobile phones are devices that can create, store, access, and share information anytime, anywhere (Saravanan and Suchiradipta, 2015). But they are more than that. When teamed with extension and advisory services, they can help improve the livelihoods of rural people by getting much needed timely information to their fingertips at potentially low cost. So called mobile based extension and advisory enable value-added services, such as mobile agro-services and machine to machine services, which help farmers monitor their crops and farm machinery through mobile phones. While value added services are generally fairly accessible to all the farmers in rural areas, machine to machine services are more cost intensive and require infrastructure that is often not present in developing countries.

Research Gap

There have been many studies (Chand et.al.,1968, Culas and Raja 2005, Brithal et.al., 2006, Acharya et.al., 2011, Chinnadurai et.al., 2016, Nayak and Kumar, 2019) on the working of "Climate Change and Crop Diversification in Selected Study Blocks of Coimbatore District" in different parts of India. These studies mostly covered the climate change working in the states of Andhra Pradesh, Madhya Pradesh, Orissa, Karnataka, and Tamil Nadu. Several studies (Dev, 2006, Denis J. Murphy, 2007, Deressa et.al., 2005, Mall,

R.K., 2006, Raymond Guiteras, 2007, Yinhong Kang, 2009) discussed mainly various socio-economic parameters of farm households related to the situation during pre-climate change and post climate change periods. Other studies (Shreekant Gupta, 2012, Valizadeh et.al., 2013, Birthal, B.S 2014, Harpreet Kaur and Simrit Kaur 2016, Subodh Dhakal 2016) assessed more specific type of issues such as role of climate change on Agriculture. A specific study on climate change and agriculture (Battese and Coelli 1995, Datta and Joshi 1992, Jayaram et.al., 1992, and Rama Rao et.al., 1994, Bhende and Kalirajan, 2007) found that a high proportion of farm households reported significant development their crop diversification and technical efficiency. The study also reported that most of the cropping pattern pressure, challenges and stress due to monsoon failure and high temperature.

The present study is different from the earlier studies in two aspects. First, not many studies have done on the climate change on agriculture in Coimbatore district focusing on a wide range of socio economic issues, including the environmental and role of information communication technology and crop diversification aspects of farm households. Second, the analysis of the study was based on a large sample size and covers a wide cross section from almost all areas of Thondamuthur and Annur blocks. Besides, the present study attempts to assess the social, economic and environment impact of crop diversification in Coimbatore district, which has not been covered in the literature.

Need for the Study

India needs to rejuvenate at least 30 million hectares of barren land to reverse land degradation by 2030. There is an immediate need for the agricultural sector to adopt leading edge technological interventions couple with sustainability and enabling policy support, to mitigate the impact of climate change and improve farm productivity. Agriculture is one of the most vulnerable sectors owing to its high dependence on climate and weather conditions. India is one of the largest food producers in the world, with about 68 per cent of its 1.3 billion populations directly or indirectly engaged in agriculture. Though agricultural contribution to GDP has gone down from 51 per cent in the 1950s to around 16 per cent, the number of household's dependent on agriculture have increased from 70 million in 1951 to 120 million in 2020. This massive dependence on agriculture makes India more vulnerable to climate change. According to the Economic Survey of 2017 the country incurs losses to the tune of USD 9-10 billion annually due to extreme weather conditions. It is a key challenge for food security and rural livelihoods in the country.

There are many studies suggesting the success of climate change in agriculture production. But some of the important questions that here are: Are our (traditional cropping methods) farmers capable of handling so many ICTs tools? Are the weather forecasting given to the farmers sufficient to start a cultivating activity in their farm? What are the likely crop diversification problems which are the likely to arise when farm households start cropping method?. This study attempts to examine these questions and arrive at a conclusion regarding whether the farmers are heading towards right direction of agriculture production.

Statement of the Problem

. For the long-term changes, agriculture can tolerate moderate variations in the climatic mean. Changes beyond the bands of tolerance may require shifts in cultivars and crops, new technologies and infrastructure, or ultimately conversion to different land uses. Agriculture is inherently sensitive to climate conditions and is the most vulnerable sector to the risks and impacts of climate change (Sagun, 2009). Climate change is the long-term conspicuous deviation from the usual prevailing climate bringing variations in temperature, rainfall, and atmospheric circulation. Thereby the problem is not with the weather in essential the variability factor gets become unpredictable with the uncertain turn out of events, the seriousness of the difficulty arises with it. Nearby it is essentially to know the effects of climate change on the farming region both the global and regional levels, particularly from the fact of view the food vulnerability section of the population. Hence the present study was undertaken to study the impact of " Climate Change and Crop Diversification in Selected Study Blocks of Coimbatore District". Further an attempt is also made to evaluate the crop diversification benefits accruing to among the farm households. The present study endeavors to examine the technical efficiency of input and output relationship between their selected crops in among the selected farm households. The specific objectives of the study are

Objectives

1. To study the general profile of the selected farm households
2. To identify the important climatic problems faced by the farm households
3. To analyze the crop diversification in the selected study blocks
4. To estimate the technical efficiency of crops diversified in the selected study blocks
5. To study the soil and water conservation measures and ICTs usage in the selected study blocks

Hypothesis

1. There is a shift from cereals to pulses and spices
2. There are no important climatic problems faced by the selected farm households
3. There is no significant relationship between climatic and farm input factors on technical efficiency
4. There is no relationship between ICTs tools usage and socio-economic problems.

The findings of the study are expected to be of immense help to policymakers and the government to bring the importance of the farm households especially small farmers.