Climate Change
and
GIS based Agriculture Mapping in Kerala

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Kripa Drishti Publications, Pune.

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PREFACE

When population growth expands at geometric proportion on a Global scale, results in enhanced pressure on land and its scarce natural resources. International agencies like the Food and Agricultural Organization of the United Nations (FAO) forecasts that global food production will need to increase by 70% if the population reaches 9.1bn by 2050. Moreover, many developing countries like Brazil and China are now categorised as rich nations whose population started increasing its consumption especially meat and dairy products. As per rough estimates, it takes five times as much grain to produce one kilo of meat which could have been sold in the market. This increase in consumption is stimulated by globalisation induced economic growth which also altered the prevailing food supply chain. The present food supply chain now involves more countries as each entity specialises on one operation – production, processing, and packing.

But the present climate change scenario is putting undue pressure on agriculture which depended on fixed proportions of vital elements and nutrients along with the sufficient availability of other attributes like temperature, precipitation etc. Moreover, one can witness a tilt in the two relationships between climate and agriculture sector which is adversely affecting even the livelihoods of the population who depend on it. Hence urgent measures are needed to devise strategies to strengthen the sector that ensures 'Life on Earth'.

This book looks at the use Geographical Information System in devising resource-based strategies and to enhance productivity in this sector. This study is restricted to the region that is regarded as the 'Rice Bowl of Kerala' – Kuttanad.

Dr. Syamlal G. S.

Summary

Agriculture can be defined as a process that requires fixed proportions of vital elements and nutrients along with the sufficient availability of other attributes like temperature, precipitation etc. One can witness a two-way relationship between climate change and agriculture sector which is more prevalent in the developing countries as majority of the population depends on the agriculture sector for their livelihood. Moreover, climate variations like effects in the form of wide and varied temperature changes, paucity or extremity of rainfall can result in the occurrence of floods or drought which adversely affects the livelihood of these populations.

Climate change can be defined as the result of uncontrolled human activities that resulted in altering the prevailing climate comprising of temperature, precipitation, wind etc on a global scale. Agricultural practices are directly correlated to the variation in atmospheric temperature levels that determines the life and maturity of crops. Modified precipitation patterns will enhance water scarcity and associated drought stress for crops and alter irrigation water supplies. In short vagaries in climate either a reduction or excess will adversely affect the agriculture growth in a country.

Various research studies (European Union, 2015) viewed agriculture as an important sector contributing to climate change after energy, transport, industry, residential and commercial sectors. This sector play an important role both as emitters of Green House Gases (directly and indirectly) and the removal of it from the atmospheres through carbon sequestration. Vegetation and soils had acted as a carbon sink and when it is disturbed through land use changes for agriculture, GHGs like carbon dioxide (CO_2) also known as dry ice in solid form, methane (CH_4) popularly known as marsh gas and nitrous oxide (N_2O) are emitted back to the atmosphere resulting in the heating of the atmosphere. Each of the above gases mentioned above had varying levels of Global Warming Potential (GWP). If we consider the case of CO_2, the GWP value is 1, while that of marsh gas (CH_4), the GWP is estimated to be 28–36 and that of N_2O is 265–298 times that of CO_2 for a 100-year timescale. Moreover, the farmer's attitude of liberal use of essential plant nutrient nitrogen in the form of fertilizers will result in the conversion of nitrogen (N) into nitrous oxide (N_2O) at a faster rate. Hence the need of the hour is to regulate the usage of fertilizer and to adopt new agricultural practices for the long-term benefit of the World and to achieve a transition from a carbon centric to a Low carbon/carbon Neutral economy. Policy Makers have paid little attention to agriculture sector as a strategy for Climate Change Policy as there exist a false dichotomy between food security and environmental health. Hence a low-emission strategy in agriculture is not accepted seriously as it is given to the question of food security and livelihoods. But for a good Climate Change Policy, strategies should be adopted to reduce the depletion of soil fertility, reclamation of lands that are degraded along with synergizing agricultural activities and environment. Planers and Policy makers ought to develop long term policies that will ensure synergy with minimal trade-offs.

Insight from Research Studies:

Climate and climate change issues are generally trans-disciplinary in nature, as they cannot be confined within the four walls of any discipline. The intrusion or rather the engagement of various disciplines had resulted in the enrichment of research studies undertaken under the domain of climate change.

Yet even after years of sustained engagement of disciplines, what we observe today is that there exists a void between the communications that the scientific or research community desires to convey and the receptive nature of the stakeholders and the public at large. Hence to highlight the growing environmental concerns this research study had undertaken a systematic review of available research studies. Through a careful perusal of the literature, it can be observed that Researchers are of the view satellite-based biophysical indicators at high temporal resolution provide key information about vegetation status in near real-time and over large areas which will provide timely information about possible crop production anomalies. Thus, there is a need to encourage systematic research on developing more cost-effective and accurate tools like Geo-informatics in deriving viable solution for agricultural sector.

Conventional farming supplemented by chemically induced 'Green Revolution' according to Researchers is the present malady of the agriculture sector. One can observe that the trend is 'mono-cropping' where a single crop is cultivated again and again which culminated in the depletion of soil nutrients. Through the timely introduction of biotechnology tried to minimize these negative impacts, yet to sustain these high productive levels, farmers still need to depend on chemical fertilizers. Based on historical research studies, we observed that all the great civilization once flourished on the banks of rivers which ensured abundant supply of water along with fertile soil. Archaeological research studies with the extensive use of scientific technologies like geo-science techniques, was able to conclude that the decline of Indus Valley civilization can be attributed to 'climate change' phenomena at a global level. These occlusions are even applicable to other civilization that disappeared from earth like the Egyptian, Mesopotamian etc.

Rational Choices Theories are of the view that collective action for the protection of common pool resources is a challenging task. As the problem of common pool resources the dangers posed by global warming are not considered as the matters for urgent measures, hence it's prudent to undertake a dialogue process supported by political influences to derive lasting solution. Moreover, research studies undertaken in biotechnology, science had conveyed that nature and natural forces are immaterial and it has the potential to dominate everything. But the excessive scientific research had finally culminated in the destruction of man and his material world.

Researchers are of the view that ecological issues can be addressed effectively, if they are brought in the forefront of the development process. Climate change is going to impede all the development initiatives undertaken particularly in third world countries. Hence researchers are of the view that environmental issues, participatory forest management and environmental practices when clubbed with development practices can ensure sustained economic growth.

Scope Study Area and Methodology:

Strong consensus is emerging among the Ecological Economists and Environmentalists that the Climate Change phenomenon will adversely affect the rural poor in South Asia due to unfavourable geography, limited asset holdings, and excessive dependence on means of income that are sensitive to climate change phenomenon (World Bank.2009). As per the estimates of International Monetary Fund (IMF), Global Warming by the year 2080 will result in reduction in per hectare productivity due to lack of carbon fertilization and if carbon fertilization persists, then the reduction will be of the tune of 3 percent.

This when compared with population or country wise analysis provides us with a grim picture (Cline, 2008). Since agriculture contributes around 16% of GDP, climate change impacts on Indian agriculture could cost 0.7% to 1.5% in GDP growth in the medium term, and 4.6% to 6.1% in the long run (Swain, 2012).

Indian Agriculture accounts for 17.6% of total emissions in the country (MoEF, 2010-11). If we combine the emission caused by subsidised electricity provided to the agriculture sector along with emission from fertilizers units and amount of diesel used in transportation, this sector can be regarded as largest contributor of GHGs in India. But like any other part of the World, India's climate change mitigation strategies are restricted only to industry and transport sector. Moreover, in Global Climate Change discussion forums, India usually adopts the position that agriculture must be discussed under the realm of adaptation and not as mitigation. But as there is a growing demand at the global level for the inclusion of agriculture in the development of mitigation strategies, India should also start exploring these options at least in the national or regional levels. Hence this sector merits prioritization in the transition towards of a Low-carbon Economy.

Kerala has suffered a massive humanitarian crisis in the form of what are being described as the worst floods to have hit the state in 100 years. The significant losses of property and disruption caused by this natural disaster have tremendous ramifications from a financial and societal perspective. When a crisis such as these hits, it does not spare anyone, and therefore several businesses, whether individual shopkeepers, SMEs or large corporates, and their operations have suffered badly. But one of the most severely affected is the agriculture on which the livelihood of many thousands of the population depended upon. Moreover, Kerala faces another issue popularly known as the '***Flooded–Soil Syndrome***'. Researchers (Bijl et.al, 2015) was of the view that agriculture producers face a number of legal, economic, and physical challenges when developing their recovery strategy after floods. The direct impacts of floods will be deposition of sand and debris on productive lands; erosion of agricultural soils; and finally, the Flooded soil syndrome - loss of beneficial fungi which mobilize soil-based plant nutrients. The need of the hour is for the Agricultural consultants and University Extension Staff to undertake scientific analysis with the help of cutting-edge technologies to ensure a flow of information about the methods and assistance in implementing the strategies for recovery.

This study is mainly focused on the Champakulam and Veliyanad block of Kuttanad. This area is consisting of 8 panchayats comprising of Kainakary, Nedumudi, Champaulam, Edathua, Kavalam, Pulincunnoo, Ramankary, and Veliyanad. All these panchayts exhibits different characteristics as those lying near to the Vembanad Lake, faces a slow rise in water level during the flood while the others are quickly inundated by flash floods. Based on the analysis of the satellite imagery and substantiated by the findings of the American Weather Centre is that in the distant future (After 2050) the whole of Kuttanad will be submerged under sea. Agricultural decisions typically involve multiple criteria and some of which are even subjective in nature.

The important attributes that influence agriculture decision making are business, environmental, food-habits and lifestyle. These criteria can be difficult to trade-off using traditional methods. Multiple Criteria Decision Analysis (MCDA) provides a formal, quantitative means of evaluating agricultural decisions taking all these factors into account.

For an effective analysis of the effects of climate change on livelihoods, we had undertaken a Qualitative Analysis of the selected blocks – Chempakulam and Veliyanad. Since the questions are open-ended, we can elicit detailed information about the effects of climate change on life and livelihoods and the proposed action that ought to be instated by the farming community, public and government officials as well.

Scientific methodologies like Geographical Information System (GIS) were used to analysis the extent of the impact of flood, deposition of sand debris through 'Flooded-Soil Syndrome', analyse the trend in the land use pattern and its effect on carbon emission in the study area. Digitization of maps will be undertaken for the Base Year Period which will be compared with the Current period to determine the change in land use pattern and its effects on carbon emission. Certain critical components like pH value of the study area will be selected from research studies undertaken by scientific institutions. Parameters regarding emission norms and energy utilization will also be collected to suggest the future course of action.

Situation Analysis of Kuttanad:

Kuttanad is popularly known as the 'Holland of Kerala', is a deltaic formation from the four major rivers – Pampa, Manimala, Meenachil and Achencoil. Rice is the important crop cultivated in this area as this land can boast of all the attributes for rice cultivation. It is due to the share determination of people, who even modified the prevailing ecology, braced the hostilities, and finally transformed the swamps into arable and habitable land. As a result of this sheer determination of this 'Collective Group', now any farmer can use this land for agriculture, aquaculture, etc.

Kuttanad can be regarded as the only region in India which practices 'Below Sea Level Farming', under which hectares of land are reclaimed from delta swamps. Locally these peculiar ecosystems are known as '*Puncha Vayals*' and with this mastery of harvesting, the farmers of Kuttanad were able to play an effective role in the conservation of the unique ecosystem of Kuttanad. Though 'Doubling of Farmers Income' is a new concept in India, yet the farmers had already mastered this art through integrated rice and fish cultivation. It is during the monsoons, these paddy fields acts as a buffer zone against floods in this part of the world. The peculiar feature is recognized by Food and Agriculture Organisation (FAO) as the Globally Important Agriculture Heritage System (GIAHS) based on the project proposal submitted by the Government of Kerala with the support from M.S. Swaminathan Research Foundation (MSSR).

When we analysed the demographic profile of Kuttanad, it can be observed that majority of its area falls inside the district of Alapuzha with a small percentage spill over to the adjoining districts of Kottayam and Pathanamthitta. On a closer look at the population trends between 2001 to 2011, it can be observed that initially the population was 2,109,160 of which males were 1,014,529 and remaining 1,094,631 were females. It increased to 2,127,789 of which males are 1,013,142 and females were 1,114,547 respectively.

Based on the input provided by the official records, it can be opined that the change of the population was of the tune of 0.88 percent compared to the earlier census of 2001. Joint study undertaken by three important health departments of Kerala (Department of Community Medicine of the Alappuzha Medical College, the Regional Prevention of Epidemic and Infectious Diseases (PEID) Cell and the State Disease Control and

Monitoring Cell (SDCMC), opined that there is excessive use of fertilizers within the fragile environment of Kuttanad. As a result, the existence of cancer and the incidence is going to be at higher levels as these toxic chemicals had also entered the food chain of population.

Key Informant Survey was undertaken with open ended questionnaire was used to undertaken to analyse the effect of climate change on life and livelihoods in the study area. From the Champakkulam and Velianad Block 20 farmers, 10 members from the fishing community and 10 casual labourers were randomly selected for the study. Later other stakeholders like elected representatives of the panchayat, members from prominent Self-Help Groups (SHGs) was also included in the research process as they are able to assist in the policy formulation of the area.

We had included a dominant representation from the farming community along with other popular forms of livelihood - fishing community, lime shell producers and casual labourers in this research study. Both the blocks – Champakkulam and Velinadu is effectively represented with a sample size of 40 evenly distributed among them. As the active participation in any development activity in a rural area is dominated by male members, this study is also dominated by male respondents.

In-land Fishing can be considered as another popular profession in Kuttanad which is practiced for many centuries. The traditional fishing community dominated by Dheevara depends on indigenous tools for fishing which can be regarded as strictly adhering to sustainable protocols of nature. As the population pressures increased in this area, large scale reclamation of *Kayal* lands was undertaken without any regard to any norms or sensitivity of nature. Hence one can witness a decline both in agriculture productivity and area under agriculture operations. So, the only alternate employment available in this part of the world is in-land fishing that prompted non-fishing communities like Ezhava to shift to this occupation to sustain their life and livelihood. We also observed that to sustain their life and livelihood, they had started using large nets and other advanced accessories which is adversely affecting the sustainability of rivers and lagoons in Kuttanad.

Under the traditional land revenue system, the labourers (*Kudiyanmar*) are considered as an important part of the traditional agriculture productive system and are literally tiled to the land with certain rights and privilages (*Kudikidappu Avakasham*). But after the independence and through the implementation of the Kerala Land Reforms Bill, we witnessed the casualization of agriculture labourers who is included into the system as and when need arises.

This casualization of agriculture labourers can not only be attributed to the change in the Land Revenue System but also can be attributed to population pressures on land. Moreover, the illiterate or less educated casual labourers are now exposed to the market forces due to which they are expected to compete for their fulfilment of needs.

Kuttanad can also boast of 13 cooperative societies that is engaged in the procurement and marketing of white lime shells which are fossils of black clams. This limestone is locally known as '*neetukakka*', is of great demand in local markets as it is regarded as a soil neutralizer in the acidic fields of Kuttanad. As per a rough estimate, the average annual production of lime shells is of the tune of 32,000 tonnes. The calm collectors are now facing a difficult scenario in Kuttanad.

Daily they risk their life by going deep down to the riverbed to gain their livelihood. But the subsidized distribution of dolomite is replacing the demand for these lime-shells and its adversely affecting the Lime-shell Collector.

Climate Change phenomenon had adversely affected their life and livelihood of the farmers. These untimely rains had resulted in heavy erosion which affected the livelihoods of the fishing community in this area. Crop failures as per the survey can be attributed to irregular, insufficient or heavy rainfall and erratic temperature variations. Based on the survey, it can also be opined that due to climate changes in the study area, there is decline in water table because of this water shortage has become a norm both for drinking and for agricultural practices. Recent flooding of Kuttanad had resulted in loss of cattle wealth which had eroded the sustenance of agricultural practices in Kuttanad. Hence the farmers slowly started realizing that the agriculture practices cannot be regarded as profitable venture. Moreover, the lax in the implementation of 'Kuttanad Package' had also alienated them from this traditional profession.

Heavy growth of Water Hyacinth along with various invasive weeds like Cabomba (Cabomba Caroliniana) popularly known as Fanworth is creating many problems in this riverine ecology. The construction of the Thanneermukkom Salt water regulated the flow of salt water into these water bodies which literally had made these into freshwater bodies conducive for the growth of these alien species. Uncontrolled sand mining all along the banks of Pampa River and Vembanad Lake had reduced the heavy flow that further enabled the speedy growth of these weeds. The rapid growth of this plant species will promote sand silting which will finally result in river becoming shallow or even to dry. This thick growth of invasive weeds will not only direct sunlight into water but also will cut the oxygen levels, such a phenomenon will adversely affect the diversity of fish species which will in turn affect the livelihood of the fishing community.

Majority of them believed that the frequent floods and heavy rains are the result of vagaries of climate change. Based on their experience they prefer a people centric strategy where the essence is on self-reliance. When faced with climate change issues like floods, the first strategy adopted by the respondents is to reduce expenditure basically on food items. If such a strategy is adopted, it will adversely affect the most-vulnerable groups – women and child which will have adverse long run defects like malnutrition etc. Through the survey, it can be observed that Cash Transfer is the most preferred mitigation strategy that people prefer along with the usual free rations when faced with heavy floods. Though the public is apprehensive about the lack of active participation from the government in climate mitigation and support system, yet the general public still believes that Government can be considered as the only institution that can be trusted for the above assigned activities. Respondents are also of the view that technology is yet to reach its potentiality in agriculture sector as its access is restricted to scientific community.

The general view is that the friendly neighbourhood Panchayat Member along with Local Self-Governments (LSGs) as the true representative who will be able and efficient in guiding the government officials in development of new strategies. When enquired about the expected assistance, the respondents had voiced for both financial and input assistance irrespective of the region under consideration. They are of the view that all the departments like Agriculture, Irrigation Department, Public Works Department, Meteorological Department, Pollution Control Board all should chip in to make Kuttanad a better place.

Moreover, the farmers observed that the excessive dependence on agriculture is not beneficial for Kuttanad in the long run. Based on the analysis undertaken on the ownership of land, it can be observed that majority of the farmers surveyed is undertaking agriculture traditionally in their own land dominated by small farmers with landholdings of 1 – 2 hectares. To overcome the seasonality of paddy cultivation, they even depended on leased plots of plantain and mixed crops of vegetable to sustain their livelihood. As reported by the respondents, the average cost of cultivation per acre is about Rs. 34,132 and the expected returns from these fields are around Rs 49,545. The general view of the farmers in Kuttanad is that paddy cultivation or rather agriculture in total cannot be considered as a dependable occupation.

Padasekharam Committees are entrusted with construction and maintenance of boundaries that need support from other farmers. The expenditure is based on the area owned by each farmer. Majority of these occupations are entrusted to daily waged labourers whose wages ranges from Rs 700-1000. Women are also employed in lighter jobs based on a deferred payment or at a rate less than that offered to men. On an average the wage for women ranges from Rs 600 – 800. When we analysed the amount of manpower used, it can be observed that except the laborious task of land preparation, women are given preference than males. One way it can be regarded as a way of cost cutting while in another way the farmers are of the opinion that women workers are more efficient than men along sizeable amount of savings as well as.

Agriculture Mapping of "Kuttanad":

With the help of Geographical Information System (GIS) agriculture Mapping was undertaken in the study area. It was observed that majority of the land is used for cultivation of agriculture crops like paddy and the buffer zone is maintained through a sizeable land area categorized as fallow land. The innumerable number of streams and canals along with other water bodies ensure that sufficient water is provided to this agriculture land for undertaking effective cultivation practices. We also observed that there was a shift of population from agriculture to aquaculture due to various climatic related changes which had eroded the profitability of agriculture. Through a scientific analysis with Digital Elevation Model (DEM), it was observed that the area exhibits feature of a smooth slope devoid of any deformities except in the periphery areas to restrict water flow. Hence the area ought to be regarded as non-flooding region and hence it will be able to withstand the usual rains observed in this part of the world. It can also be observed from the slope map derived from Arc GIS conveys that Kuttanad and the adjoining areas are evenly sloped with minimal possibility of flooding.

Secondary data sources (Kerala Soil Health Information System) conveys that the soils in Kuttanad are strongly acid to moderately acid where the pH value ranges between 4.5 to 6.0. When the soil becomes too acidic, certain vital nutrients like phosphorous becomes less active those are essential for plant growth and productivity along with neutralizing bacterial growth. From secondary data sources, it can be observed that the soils in the study region had high carbon levels along with high phosphorous levels. The presence of high carbon levels in the agricultural lands of the Kuttanad region is a positive sign that even after periodic mono-cropping in these areas, the carbon levels or the organic carbon matter had not depleted. Hence it can be opined that the agriculture fields in the Kuttanad region had not adversely affected the greenhouse gas emission of this part of the world.

Transition to a Low Carbon Economy:

Climate change is expected to intensify and will create innumerable number of problems in all productive sectors. This is more critical in agriculture and allied occupations due to its peculiar nature like excessive dependence on forces of nature like rains and other climatic factors, inequality in distribution of land and other resources, limited access to credit and other financial support systems by the farmers, lack of integration of research and development into real time agriculture activities etc. As majority of the population is linked to primary and other allied occupations, such scenarios will jeopardise the growth and development of these regions. The only solution is to shift from a carbon centric production process to a carbon neutral production strategy.

The proportion of NPK, the most popular fertilizer in Kuttanad is 7:5:6. This proportion conveys that there is excessive dependence on nitrogen which when compared to Indian Standards is very high. Moreover, the prevailing ecology in Kuttanad comprises of many water bodies which will result in excess fertilizer (nitrogen) seeping into the water bodies. Erratic occurrence of rains also further causes various ecological disturbances. The study is of the view that proper farm management practices should be adopted under the guidance of Agriculture Scientist to limit the excessive dependence on poisonous N_2O.

As a result of this surplus deposition of nitrogen in the atmosphere will create ammonium ions that will finally result in soil acidification. Soil acidity is measured based on pH scale that measures from 1 to 14. Study observed that majority Kuttanad Soil can be categorised as strongly acidic to very strongly acidic and even to extremely acidic. So, the general trend in Kuttanad to adopt excessive fertilizer and water should be discouraged and effective Management Practices should be quickly adopted to limit erosion in Kuttand and to restore the confidence of agriculturist.

Another important issue faced by Kuttanad is the contamination of water bodies including ground water table through fertilizer run-off. Such a process is known scientifically as eutrophication that results in the accumulation of algae on the water surface. These dead or decomposed algae consume the dissolved oxygen which is very indispensable for the existence of marine life. To sustain livelihood of the fishing community that had integrated into the ecosystem of Kuttand, efforts should be initiated to discourage excess use of chemical fertilizers and to achieve a transition to organic fertilizers which are not only ecologically friendly, but carbon neutral as well. Moreover, Marginal Farmers need support to enhance access to input markets, assistance, and guidance in achieving diversification and value addition along with final marketing support. Climate change strategies can be adopted in each stage of these value chain components.

Development of Policy Formulation:

Through the initiation of Local Level Analysis of Nitrogen Footprint, farmers can be given a clear insight regarding the amount of nitrogen pollution resulting from his activates. As these traditional farmers who prefer to undertake agriculture operation respecting the rules and regulations of mother earth, they all will be whole heartedly cooperating in this endeavour. Through these activities, we will not only able to pass on the information regarding the reduction in the use of nitrogen but will also be able to involve them in climate protection initiatives at the local level. These initiatives will not only open new avenues for financial savings but will also make his produce eco-friendlier in nature.

Strategies like biogas plants should be devised or adopted by farmers to regulate the emission of poisonous methane gas in the atmosphere. Government and non-governmental agencies through the incorporation of subsidies scheme should encourage farmers to incorporate biogas plants in their respective fields and to be part of green development programme.

As per the recent report, Government of India had developed 41 varieties of rice and 22 varieties of wheat that require less water for irrigation. Such climate-smart varieties not only save input cost but also provide more yield as well. Government should incorporate various types of extension and demonstration projects through which the local farmers in Kuttanad will also shift towards this climate smart technologies.

Pradhan Mantri Fasal Bima Yojana (PMFBY), though had taken into consideration various components of climate change yet farmers are apprehensive because of issues related to claims assessment, settlement, and quantum of support. The Insurance programme ought to be made effective during these adversities through the effective incorporation of information technology and smart phones in coverage and assessment, quick and easy settlement of claims, strengthening the distribution network of the insurers and intermediaries etc.

For an effective participation of all the stakeholders in addressing the climate change phenomena, the study suggests the incorporation of Eco/Green Labelling. Through this method, policy makers can empower the consumers to make their purchase decisions based on the environmental performance and ecological sensitiveness of the product under consideration. They also can assist in developing the Government Procurement policies giving due importance to climate change. This can be regarded as the best and prudent policy without any undue pressure on the financial exchequer or on political hurdles.

It can be suggested that India must focus on carbon-taxing as an instrument for its carbon mitigation strategy and meeting the targets envisaged under the Millennium Development Goals (MDGs). It is estimated that there are 26 carbon tax system prevailing among developed and developing countries. Government of India should first identify the sectors that can be covered under the carbons tax and should adopt a Progressive Carbon Taxing System which will encourage market participation in an effective manner.

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Chapter 1

Introductory Framework

1.1 Introduction:

In the neo-classical dictum, 'Market Failure' is the norm as it fails to determine the actual price of the product. This can be attributed to externality which is an action by either a consumer or producer which has its adverse effects on either of the parties. Externalities can be positive or negative. The former will be realized quickly, but the negative externalities can be felt only over a period of time. The negative externality that should be given due consideration is the excessive emission of CO_2 which had resulted in accumulation of Green House Gases (GHGs) and heating of the environment. A. C. Pigou the 20th century British Economist advocated for making the manufacturer and the customer to foot the bill for these unacknowledged causes which popularly came to be known as '*Internalizing the Externalities'* (Beeks and Ziko, 2018). Though this idea was resented by the public initially, in later stages we saw the evolution of new emission limiting methodologies like 'cap-and-trade' (Kaufman, 2016).

Agriculture can be defined as a process that requires fixed proportions of vital elements and nutrients along with the sufficient availability of other attributes like temperature, precipitation etc (Varun et.al, 2009). A two-way relationship exists between climate change and agriculture sector. This is more prevalent in the developing countries as majority of the population directly or indirectly depends on the agriculture sector for their livelihood. Agricultural activities are affected by climate change due to their direct dependence on climatic factors for its growth. It can be opined that climate change effects in the form of wide and varied temperature changes, paucity or extremity of rainfall can result in the occurrence of floods or drought. This adverse variation can influence life in soil and quality in the form of changes in pests, occurrence of various types of diseases, wide variation in atmospheric carbon dioxide can alter the growing season of crops [World Bank, 2008]. Agricultural practices are directly correlated to variation in atmospheric temperature levels that determines the life and maturity of crops [Hoffman, 2013]. Modified precipitation patterns will enhance water scarcity and associated drought stress for crops and alter irrigation water supplies. In short vagaries in climate either a reduction or excess will adversely affect the agriculture growth in the country.

According to the report of the European Union (2015) agriculture can be regarded as an important sector contributing to climate change after energy, transport, industry, residential and commercial sectors. Agriculture sector in today's world ought to play an important role both as emitters of Green House Gases (directly and indirectly) and the removal of it from the atmospheres through carbon sequestration. Vegetation and soils had acted as a carbon sink and when it is disturbed through land use changes for agriculture, GHGs like carbon dioxide (CO_2) also known as dry ice in solid form, methane (CH_4) popularly known as marsh gas and nitrous oxide (N_2O) are emitted back to the atmosphere resulting in the heating of the atmosphere. Each of the above gases mentioned above had varying levels of Global Warming Potential (GWP).

If we consider the case of CO_2, the GWP value is 1, while that of marsh gas (CH_4), the GWP is estimated to be 28–36 and that of N_2O is 265–298 times that of CO_2 for a 100-year timescale. Moreover, the farmer's attitude of liberal use of essential plant nutrient nitrogen in the form of fertilizers will result in the conversion of nitrogen (N) into nitrous oxide (N_2O) at a faster rate. Hence the need of the hour is to regulate the usage of fertilizer and to adopt new agricultural practices for the long-term benefit of the World and to achieve a transition from a carbon centric to a Low-carbon/carbon Neutral economy. Policy Makers have paid little attention to agriculture sector as a strategy for Climate Change Policy as there exist a false dichotomy between food security and environmental health. Hence a low-emission strategy in agriculture is not accepted seriously as it is given to the question of food security and livelihoods. But for a good Climate Change Policy, strategies should be adopted to reduce the depletion of soil fertility, reclamation of lands that are degraded along with synergizing agricultural activities and environment. Planers and Policy makers ought to develop long term policies that will ensure synergy with minimal trade-offs.

1.2 Objectives:

The objectives framed for the study are as follows:

- Scientific analyses of flood sensitivity and water logging of agriculture land in the study area.
- Analyse the extent of 'Flooded-Soil Syndrome' in the study area.
- Identify the 'Recovery Strategies' that can be adopted based on socio-economic and scientific analysis.
- Gauge the extent of carbon emission and to suggest a course of action for achieving 'Carbon-Neutral Economy' and to make agriculture sustainable in the long run.

1.3. Review of Literature:

Climate and climate change issues are generally trans-disciplinary in nature, as they cannot be confined within the four walls of any discipline. The intrusion or rather the engagement of various disciplines had resulted in the enrichment of research studies undertaken under the domain of climate change. Yet even after years of sustained engagement of disciplines, what we observe today is that there exists a void between the communications that the scientific or research community desires to convey and the receptive nature of the stakeholders and the public at large. Hence to highlight the growing environmental concerns this research study had undertaken a systematic review of available literature which is synoptically given under the following heads.

- ***Scientific Analysis of Agriculture:*** Through a careful perusal of the literature, it can be observed that Researchers are of the view satellite-based biophysical indicators at high temporal resolution provide key information about vegetation status in near real-time and over large areas which will provide timely information about possible crop production anomalies.
  Thus, there is a need to encourage systematic research on developing more cost-effective and accurate tools like Geo-informatics in deriving viable solution for agricultural sector.

- ***Defective Agriculture Practices*:** Conventional farming supplemented by chemically induced 'Green Revolution' according to Researchers is the present malady of the agriculture sector. One can observe that the trend is 'mono-cropping' where a single crop is cultivated again and again which culminated in the depletion of soil nutrients. Through the timely introduction of biotechnology tried to minimize these negative impacts, yet to sustain these high productive levels, farmers still need to depend on chemical fertilizers.
- ***History of Climate Change*:** On the basis of historical research studies, we can be observed that all the great civilization once flourished on the banks of rivers which ensured abundant supply of water along with fertile soil. Archaeological research studies with the extensive use of scientific technologies like geo-science techniques, was able to conclude that the decline of Indus Valley civilization can be attributed to 'climate change' phenomena at a global level. These occlusions are even applicable to other civilization that disappeared from earth like the Egpytian, Mespotomian etc.
- ***Climate Change and Collective Action:*** Research studies on common pool resources are included in the domain of Rational Choices Theories. These theories are of the view that collective action for the protection of common pool resources is a challenging task. As the problem of common pool resources the dangers posed by global warming are not considered as the matters for urgent measures, hence its prudent to undertake a dialogue process supported by political influences to derive lasting solution.
- ***Climate Change and Arrogance of Science:*** Through research studies undertaken in bio-technology, science had conveyed that nature and natural forces are immaterial and it has the potential to dominate everything. But it is clear that the excessive scientific research had finally culminated in the destruction of man and his material world.
- ***Industrialised and the Developing World at Logger Heads*:** Research studies and reports had clearly conveyed that both North and South are at logger heads. Developing nations are opposing all the suggestions put forward by the Development on the pretext that these strict emission norms are going to be implemented without giving sufficient time and space for their urge for development.
- ***Adaptation Strategies and Economic Growth:*** Researchers are of the view that ecological issues can be addressed effectively, if they are brought in the forefront of the development process. Climate change is going to impede all the development initiatives undertaken particularly in third world countries. Hence researchers are of the view that environmental issues, participatory forest management and environmental practices when clubbed with development practices can ensure sustained economic growth.

An in-depth analysis of the research studies is undertaken in the subsequent chapter for preparing a grassroots level research based on scientific inputs.

1.4. Scope and Methodology:

Scope:

Strong consensus is emerging among the Ecological Economists and Environmentalists that the Climate Change phenomenon will adversely affect the rural poor in South Asia due to unfavourable geography, limited asset holdings, and excessive dependence on means of income that are sensitive to climate change phenomenon (World Bank.2009).

As per the estimates of International Monetary Fund (IMF), Global Warming by the year 2080 will result in reduction in per hectare productivity due to lack of carbon fertilization and if carbon fertilization persists, then the reduction will be of the tune of 3 percent. This when compared with population or country wise analysis provides us with a grim picture (Cline, 2008). Since agriculture contributes around 16% of GDP, climate change impacts on Indian agriculture could cost 0.7% to 1.5% in GDP growth in the medium term, and 4.6% to 6.1% in the long run (Swain, 2012).

Indian Agriculture accounts for 17.6% of total emissions in the country (MoEF, 2010-11). If we combine the emission caused by subsidised electricity provided to the agriculture sector along with emission from fertilizers units and amount of diesel used in transportation, this sector can be regarded as largest contributor of GHGs in India. But like any other part of the World, India's climate change mitigation strategies are restricted only to industry and transport sector. Moreover, in Global Climate Change discussion forums, India usually adopts the position that agriculture must be discussed under the realm of adaptation and not as mitigation. But as there is a growing demand at the global level for the inclusion of agriculture in the development of mitigation strategies, India should also start exploring these options at least in the national or regional levels. Hence this sector merits prioritization in the transition towards of a Low-carbon Economy.

Kerala has suffered a massive humanitarian crisis in the form of what are being described as the worst floods to have hit the state in 100 years. The significant losses of property and disruption caused by this natural disaster have tremendous ramifications from a financial and societal perspective. When a crisis such as these hits, it does not spare anyone, and therefore several businesses, whether individual shopkeepers, SMEs or large corporates, and their operations have suffered badly. But one of the most severely affected is the agriculture on which the livelihood of many thousands of the population depended upon. Moreover, Kerala faces another issue popularly known as the '***Flooded–Soil Syndrome***'.

Researchers (Bijl et.al, 2015) was of the view that agriculture producers face several legal, economic, and physical challenges when developing their recovery strategy after floods. The direct impacts of floods will be deposition of sand and debris on productive lands; erosion of agricultural soils; and finally, the flooded soil syndrome - loss of beneficial fungi which mobilize soil-based plant nutrients.

The need of the hour is for the Agricultural consultants and University Extension Staff to undertake scientific analysis with the help of cutting-edge technologies to ensure a flow of information about the methods and assistance in implementing the strategies for recovery.

1.4.1 Study Area and Methodology:

***A. Study Area*:**

The contribution of agriculture to Kerala's GSDP was declined from 52 % in 1960-61 to 11 % in 2014-15 and 10.58 % in 2016-2017. Kuttanad in Alapuzha District is known as 'The Rice Bowl of Kerala' which comprises of comprises of 143 villages. Representative villages will be selected based on the intensity of paddy cultivation.

This study is mainly focused on the Champakulam and Veliyanad block of Kuttanad. This area is consisting of 8 panchayats comprising of Kainakary, Nedumudi, Champaulam, Edathua, Kavalam, Pulincunnoo, Ramankary, and Veliyanad. All these panchayts exhibits different characteristics as those lying near to the Vembanad Lake, faces a slow rise in water level during the flood while the others are quickly inundated by flash floods. Based on the analysis of the satellite imagery and substantiated by the findings of the American Weather Centre is that in the distant future (After 2050) the whole are of Kuttanad will be submerged under sea.

B. Methodology Adopted:

Agricultural decisions typically involve multiple criteria and some of which are even subjective in nature. The important attributes that influence agriculture decision making are business, environmental, food-habits and lifestyle. These criteria can be difficult to trade-off using traditional methods. Multiple Criteria Decision Analysis (MCDA) provides a formal, quantitative means of evaluating agricultural decisions taking all these factors into account.

For an effective analysis of the effects of climate change on livelihoods, we had undertaken a Qualitative Analysis of the selected blocks – Chempakulam and Veliyanad. Since the questions are open-ended, we are able to elicit detailed information about the effects of climate change on life and livelihoods and the proposed action that ought to be instated by the farming community, public and government officials as well. Scientific methodologies like Geographical Information System (GIS) were used to undertake an analysis the extent of the impact of flood, deposition of sand debris through 'Flooded-Soil Syndrome', analyse the trend in the land use pattern and its effect on carbon emission in the study area.

Digitization of maps will be undertaken for the Base Year Period which will be compared with the Current period to determine the change in land use pattern and its effects on carbon emission. Certain critical components like pH value of the study area will be selected from research studies undertaken by scientific institutions. Parameters regarding emission norms and energy utilization will also be collected to suggest the future course of action.

1.5. Relevance:

1.5.1 Relevance:

Concept of '*Inclusive Green Growth*' tries to satisfy the urge of Developing Countries' need for rapid growth and poverty alleviation with minimal environmental damage. Neo-classical economists had preached that a smoking chimney ought to be regarded as a sign of economic activity and growth. But this *Inclusive Green Growth* Model decouples / segregates emission form economic growth for fostering low-carbon, socially and environmentally inclusive growth. The outcome of this model will be eco-friendly products from the sectors along with a reduction in vulnerability of the agriculture-dependent population. To meet the growing demands of an ever-increasing population in developing countries, there is tendency towards liberal usage of fertilizers and pesticides will finally end in crisis.

Asia and Northeast Africa had already achieved high levels of per hectare fertilizer use which is clearly conveyed by a decline in productivity, agriculturalist are yet to adopt proper environmentally sustainable nutrient management techniques. Giving due consideration to the climate change, developing countries need to look beyond the prevailing management techniques and should incorporate the policy of '*Green Tax*' based on the levels of carbon emission to achieve transition to a Low-carbon Economy.

1.5.2 Anticipated Outcomes:

- ***Assessment of Emission from Primary Sector:*** Land use changes and the subsequent use of fertilizer for increasing productivity, together with energy used in processing and transportation of the products will result in agriculture becoming the dominant sector for carbon emission in developing countries like India. Periodic assessment of this sector will enable us to monitor and evolve strategies for mitigation to achieve transition towards a low-carbon economy. This will result in a '*win-win*' option as it not only reduces emission of GHGs but also reduces poverty through increase in efficiency.
- ***Strengthening the National Action Plan on Climate change:*** National Mission on Sustainable Agriculture (NMSA) strategies towards climate change mitigation was largely limited to technical aspects rather than encouraging adoption of best practices like nutrient and water management. This shift in priority will result in encompassing a greater number of small and marginal farmers into the adoption of mitigation strategies. This study will also assist in the development of a Regulatory Framework for achieving the targets in a time bound manner and to achieve a speedy transition towards a low-carbon economy.

1.5.3 Proposed Outputs:

S*trengthening Alternate Paradigms:* Research Papers and Book brought out from this project will chart a new course towards the initiation of an '*Inclusive Green Growth Model*' in the economy.

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Chapter 2

Review of Literature

Climate change has become a major concern as it has become difficult to sustain life on earth. As a result of unhindered human activities under the guise of development activities, we are now exposed to vagaries of climate change like heavy rain, floods, drought, forest fires etc. But many of the climate change research studies are just, limited to the study of the melting of poles (North and South Pole) and the impact on earth.

But recently we can observe a higher level of seriousness had been put into climate and climate change issues with the active participation of both government and non-governmental agencies. The special feature of these research studies are that it is devoid of any concrete boundaries envisaged by various disciplines. It is this intrusion of or engagement of disciplines to evolve viable alternatives that ensures the embellishment of various disciplines.

But in the real-world scenario, what we witness is that there exists a void between the communications that the scientific or research community desires to convey and the receptive nature of the stakeholders and the public at large. Hence this literature review will try to analyse and highlight the growing environmental issues that marred the path towards sustainable development.

2.1 Scientific Analysis of Agriculture:

Researchers (Rambold et.al, 2018) are of the view that satellite-based biophysical indicators at high temporal resolution provide key information about vegetation status in near real-time and over large areas which will provide timely information about possible crop production anomalies, while other researchers (Elbana et.al, 2017) opined that traditional trial-and-error technique in agricultural experiments to improve land and water productivity is time-consuming and economically unaffordable. Thus, there is a need to develop more cost-effective and accurate tools like Geo-informatics in deriving viable solution for agricultural sector.

2.2 Defective Agriculture Practices:

Conventional farming is popularly known as Monocropping where a single crop is grown year after year that impoverishes the earth surface from vital nutrients which was later restored through excessive use of fertilizers which got further augmented by green technologies (Conrad et.al, 2013).

But Green Revolution had fostered contradiction as it provided certain political privileges to some of them at the cost of others (Jacques and Jacques, 2012). Today, one can observe that there is an increase in use of high yielding varieties evolved from biotechnology, whose productivity is enhanced by excessive use of agro chemicals which will finally end in crisis.

2.3 History of Climate Change:

When we analyse great civilizations like Egypt and Mesopotamia, it can be observed that these civilizations flourished on the banks of rivers that provides a continuous supply of water for their nourishment. Moreover, river valley civilization also provides a congenial atmosphere for the effective development of these inhabitants. Researchers are of the view that those civilizations that flourished near the riverbanks provided them a sense of stability and security (Egyptian Civilization) while certain others (Mesopotomian) felt it as a threat to their very existence (Issar and Zohar, 2007). Later research studies funded by British Council observed that it is the weakening of summer monsoons in the Northwest India that resulted in the vanishing of this civilization (Sinha, 2016). They also opined that with the help of archaeology and geo-science techniques that many other civilizations (Egptian and Mesopotomian) also vanished from earth's surface because of this phenomena of climate change.

2.4 Climate Change and Collective Action:

Rational Choice Theories are of the view that collective action of common pool resources will not be that attractive to a rational individual based on the view that it is a public good and he get only a marginal benefit. Hence researchers are of the view that the economic benefits will be accrued to the Corporate Polluter for the pollution of a common pool resource, but it's unfair to entrust the cost of the pollution on certain individuals (Gupta, 1997). Likewise, Climate Change discussions and discourses are slowly alienating the developing countries from the process of policy making related to climate change as they felt that they are entrusted to clean the mess that was created by developed countries (Pearce, 2005). Antony Giddens is of the view that as the impact of climate change is not immediate or easily felt by the public and hence, they prefer to ignore it. This is popularly known as '*Giddens Paradox*' and a solution to such issues can only be derived through political discourse (Giddens, 2011).

2.5 Climate Change and Arrogance of Science:

In the post war era, what we witnessed is the enormous development of 'science' into a dominant and arrogant entity. Scientist had devised various tools under biotechnology to prove that the natural phenomena is irrelevant and laboratory induced experiments can derive lasting solutions. Researchers are of the view that the general public is intoxicated by this ominous dominance of science which had even prompted them to go beyond their limits that will have catastrophic effects. Technological advancements are also encouraging the mankind to stretch its limits to the maximum devoid of any responsibilities. Some research studies are of the view that the ultimate act of human hubris is the excessive use of toxic synthetic chemicals like DDT which is fuelled by greed and ignorance (Carson et.al, 2002).

Certain Researchers (Dinger. 2010) opined that even after employing terrestrial analysis substantiated with advancement satellite inputs, these scientific community can predict today's weather. With these inefficiencies they are not able to predict the climate change phenomena and the future of earth.

Audio-Visual aids like documentaries are also influencing the thought process of the public towards climate change. The notable one is 'An Inconvenient Truth' by Al Gore which was able to alter Americans though process towards climate phenomena and ushered in an era of proactiveness towards global environment philosophies (Weber and Jentleson, 2010).

2.6 Clash between Developed and Developing World:

Though there are innumerable and viable GHG Mitigation strategies are available, yet the impeding reasons for both the Developed is the barrier created by their affluent lifestyle while the Developing world is hampered by the liberal provision of energy subsidies, inertia created by institution setup and other vested interests. Hence researchers are of the view that at this juncture there is a need for realignment for shaping the economy (Ravindranath and Sathaye, 1972). Only under a climate change regime, it will be mandatory for manufacturing and energy sectors of the economy to avail emission licenses. But it is a politically tricky question to decide the basis under which these licenses can be sanctioned. It is when these issues are brought under the ambit of Climate Change phenomena; both the Developed and the Developing world will end in logger heads.

The main issue for contention is that the Developing nations are pressurised through climate change norms before providing sufficient space for development (Pearce, 2005). Researchers are of the view that any move to regulate economic activity in developing countries will generate negative feelings as they are not able to bear these economic sacrifices like the Developed world (James. 2012). Those countries that are lagging in the development process comprising of the mainly of the developing countries feel that non-tariff barriers in the form of environmental standards will be used as discriminatory trade practices (Weiss and Thakur. 2010).

"The Limits to Growth" report put forward by the Club of Rome advocated for limiting population growth to usher in an era of sustainable growth through the control of pollution. The First World Climate Conference (1979) even opined those uncontrolled human activities on Earth is going to result in an era of climate change both at the regional and even at global levels. The conference ended with a demand for strengthening international cooperation for ensuring a bright future for the global society. A sense of negativity also entered this as many of participating nationals were sceptical about formation of such a cooperation where the Developed Nations are dictating the terms (Alam et. al. 2015). Researchers are of the view that if the cleaning of the mess can be achieved only through a strong cooperation from developing countries and to achieve this cooperation, provisions should be made so that the developing along with poorer countries are assured of minimum subsistence (Gough and Stables, 2008). The Group of Seven (G-7) should not adopt aggressive postures whereby they are literally denying the perks and liberties that they enjoyed during their development phase.

Hence, these poorer countries stress on access to energy rather than what a developed countries demand for clean energy (Lesage et.al. 2010). A market based flexible approach was adopted through the Koyoto Protocol and Marrakesh through which carbon credits (buying the right to pollute) can be traded. Such a market-based approach will act as motivating factor for investing in emission reduction strategies (Woodcock. 2008).

To quicken the pace of international cooperation for emission reduction, a larger framework was constituted under the United Nations Framework Convention on Climate Change (1992) and the Kyoto Protocol (1997). As a result of this it has become mandatory for each nation to play a fairer and justifiable role in the process for greening the Earth.

2.7 Adaptation Strategies and Economic Growth:

Researchers are of the view that economic growth can be dampened if we did not heed to the incorporation of adaptation strategies. At times this lethargic attitude can even result in negative effects through the reversing of past gains achieved by the country. Hence it is prudent to bring ecological issues in the forefront of the development process. Under such a process, one can witness the application of appropriate adaptive measures which may involve financial obligation as well. According to Stern, climate change damage associated with moving from an existing to an altered climate represents a welfare loss, which is reduced by adaptation (Chambwera and Stage. 2010).

Developing countries should not consider Climate Change as a bane but rather they should consider it as a boon for incorporating shifting agriculture practices. As envisaged by the Green Korea Conferences (Schäfer. 2015). Studies had conveyed that climate change will have its impact on agriculture sector in India. A warming scenario of a rise in mean temperature by +2.00 C rise in mean temperature and a +7% increase in precipitation levels will create a 12% reduction in net revenues of the country (Dinar et. al 1998).

The study highlighted that region like Gujarat, Maharashtra and Karnataka will be the most affected regions while high value agricultural regions of Punjab, Haryana and Western Uttar Pradesh show a small loss. Innovative agricultural practices and technologies can go a long way in minimising the adverse effects of climate change. It can be opined that the suggested course of action that can be incorporated is the extensive use of early warning systems that will assist in effective forecasting to support the fight against climate change (Manas et al, 2013).

2.8 Climate Change and Agriculture Adaptation Strategies:

Agriculture can be regarded as first important component affected by Climate Change. Right from the olden days, agriculture was undertaken based on perfect observation of the movement of earth, sun, moon etc. But now due to the advancement of information and technology, agriculture operations are based on various scientific inputs like of soil, prevailing climate trends and other associated components. But with the occurrence of Climate Change Phenomena, the dependency on these scientific inputs will ensure the effectiveness of adaptation strategies in the long run. Researchers (Howden et.al, 2007) are of the view that these scientific tools will be effective under moderate climate change phenomena but for advance methodologies should be incorporated like diversification of production systems and livelihoods.

Researchers are of the view that it is a herculean task to limit the Earth's temperature to 1.5^0C (Carter, 2018). The expected solution for agriculture sector is transformative adaptation that ensures food security and reduces the risk of a crisis.

2.9 Transition to Low Carbon Economy:

United Nations Framework Convention on Climate Change (UNFCCC) Rio, 1992 adopted the concept of low carbon development. As many economies had achieved a transition from a less developing to developing countries, they need to adapt strategies to make optimum use of the ecosystem rather than depending on heavy carbon-based inputs. Researchers are of the view that reclaiming degraded lands, restoring soil fertility through natural methods along with integration or rather synergizing of the farm and forest will go a long way in achieving Climate Friendly Policies (De Pinto, 2016).[1]

2.10 Conclusion:

It can be concluded that various studies on Climate Change provided a grim picture regarding which will both directly and directly affect the development strategies envisaged by both Developed and Developing Countries. The general conclusion is that to achieve sustainability and to make the economy climate friendly in nature, there is an urgent need to achieve a transition to a low carbon economy irrespective of sectoral or regional differences. Moreover, majority of the researchers are unanimous is their view that agriculture sector should take the lead in these transition efforts.

[1] De Pinto Alessandro, Li Man, Haruna Akiko, Graham Hyman Glenn, Andrés Mario Martinez Londoño, Creamer Bernardo, Kwon Ho-Young, Garcia Jhon Brayan Valencia, Tapasco Jeimar, Martinez Jesus David (2016) Low Emission Development Strategies in Agriculture. An Agriculture, Forestry, and Other Land Uses (AFOLU) Perspective World Development, Volume 87, November 2016, Pages 180-203.

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Chapter 3

Situation Analysis of Kuttanad

3.1 Introduction:

Kuttanad is popularly known as the 'Holland of Kerala', as it resembles Holland where one can identify a low-lying area with backwaters and innumerable number of canals and stream networks. The average elevation of the lad here is 1 m above MSL with an extent of 340km^2. This deltaic formation popular known to the outside world as 'Kuttanad' is derived from the four major rivers – Pampa, Manimala, Meenachil and Achencoil.

Rice is the important crop cultivated in this area as this land can boast of all the attributes for rice cultivation which are as follows:

- ***Equatorial Temperate Regions*:** Rice is a tropical crop that is best suited for the regions where the temperature ranges between 16^{0}C to 270C. The potential growth for this crop can be achieved only it has abundant sunshine during its effective growth period of four months. Moreover, if the temperature declines to less than 15^{0}C, it can even affect germination of the seed. As per the District Survey Report (DSR) prepared by Geological Survey of India (2016), in Alapuzha district, March and April can be regarded as the hottest months where the temperature ranges between 28.8^{0}C to 32.7^{0}C while the minimum temperature are in the range of 22.6^{0}C to 25.5^{0}C, thus the maximum average temperature in the region comprising of Kuttanad region is 30.7^{0}C while the minimum temperature is 23.9^{0}C which is best suited for cultivation of paddy.
- ***Sufficient Monsoon Rainfall*:** Standing water is the essential condition for the survival of rice plants. Hence it is popularly grown in areas which had abundant rainfall as well. Though it is opined that a rain fall of 115 cm can be regarded as a minimum requirement, yet suggested rainfall is within the range of 175-300 cm. transplantation is another important component in the cultivation of rice for which it is advocated that the seedlings should be submerged in a standing water of 25 mm thickness. The duration for submersion is estimated to be an average of 10 weeks duration. Though the period from March to the end of May is the hot season, yet it is followed by the southwest monsoon season, which continues till the end of September. As per the DSR of Geographical Survey of India (GSI) - 2016, the June to September rains contribute about 60.3% of the annual rainfall From October to mid of November one can witness the retreat of southwest monsoon and the emergence of northeast monsoon which contributes 20.9% of the rainfall. As a result of this the region receives rainfall till the end of December. The balance rainfall of 18.8% is received during the months from January to May. Thus GSI (2016) is of the view that Alapuzha district comprising of Kuttanad receives an average annual rainfall of 2965.4 mm.
- ***Deltaic or Alluvial Soils*:** Another important component for effective cultivation of rice is Alluvial soils or soils found in river basins which of course is very fertile. Hence rice cultivation is spread over regions comprising India, China and Thailand. Clay loam and alluvial soils or saline areas of deltaic region is regarded as the best for cultivation of rice.

- ***River Basin and Level Plains*:** As a flooded land is an important criteria in the cultivation of the crop, hence the land should be level plains with minimal runoff. It is thus best suited in the Gangetic River basin, Godavari and Krishna delta along with other popular deltaic regions like Irrawaddy, Yangtzekiang etc.
- ***Abundant use of Fertilizers*:** The three essential plant nutrients needed for the cultivation of paddy area nitrogen, phosphorous and potassium. If found that the cultivable land is devoid of fertilizers, natural or chemical fertilizers needed to be added in sufficient quantities.

3.2 Historical Interpretations:

Kuttanad can be regarded as a different region as it was an inhospitable terrain during a whirlwind sea, backwaters and lagoons. It is opined by various researchers (Swaminathan; 1991).[1] It is due to the share determination of people, who even modified the prevailing ecology, braced the hostilities, and finally transformed the swamps into arable and habitable land. Now any farmer can use this land for agriculture, aquaculture, etc. A careful perusal of historical research studies undertaken in this area; it can be observed that there is sufficient mention of this region in various literary works especially belong in to Tamil Literature. The *Sangam* literary works – *Venpa* and *Tholkappiyam* had mentioned that Kuttanadu is one of the twelve principalities where people speak native Tamil. In the epic Mahabaratha the *Kahndha Vana* is situated somewhere near to this place. Legend also conveys that the *Karinilams* found in this area are the remains of charred wood of this forest and hence, it came to be known as *Chuttanad* which means burnt land that finally came to be known as Kuttanadu. According to the other view, this region got its name from the stone carved statue of *Karumadi Kuttan*, the stone carved statue of Lord Buddha.

3.3 Confluence of Rivers:

Kuttanad, is situated at the mount of the confluence of four major river systems in Kerala - Pampa, Achencoil, Manimala and Meenachil which finally debouch into Vembanad Lake. Hence this deltaic region is best suited for the cultivation of rice and got its nickname 'Rice Bowl of Kerala'. Moreover, this deltaic region is said to have reclaimed from the Vembanad Lake which extends from Alapuzha in the south to Kochi harbor and gentle opens its mouth into Arabian Sea. Another important finding put forward by M. S Swaminathan Foundation (2007)[2] that centuries ago these areas was covered by forest and even the Arabian Sea reached to the foothills of Western Ghats. Later under the influence of certain geological patterns, the sea receded enroute uprooting the trees. This process had resulted in the development of low-lying marshy saline lands. Fertility of these lands was also enhanced by liberal organic deposits, fossils of timber and shellfish.

[1] http://www.fao.org/3/a-bp793e.pdf

[2] Kuttanad Below Sea Level Farming System (The only system in India that has been practicing rice cultivation below sea level since the past 2 centuries) A Candidate System for Globally Important Agricultural Heritage Systems (GIAHS) Programme, FAO, Rome A proposal by M S Swaminathan Research Foundation, India and the Government of Kerala.

3.4 Thanneermukkom Saltwater Barrier:

The Thanneermukkom Saltwater Barrier (Thanneermukkom Bund) can be regarded as the 'Sethubandan' of the 20th Century. It is this barrier that connected Vechoor of Vaikom taluk of Kottayam district and Thanneermukkom of Cherthala taluk belonging to Alappuzha district this project was instated by a group of enthusiastic farmers during the beginning of 1975. The main object for this initiative is to restrict the saltwater intrusion into the life and livelihoods in the Kuttanad area. Construction of this barrier resulted in the division of Vembanad Lake into two parts – upstream fresh water and a downstream salt water. The barrier is open during the monsoon and closed for another six months to assist in the breeding of fish as it happens only in warm water zones. Periodic shutting and closing of barrier also encourage cleansing of the lake from water weeds and other ecological problems.

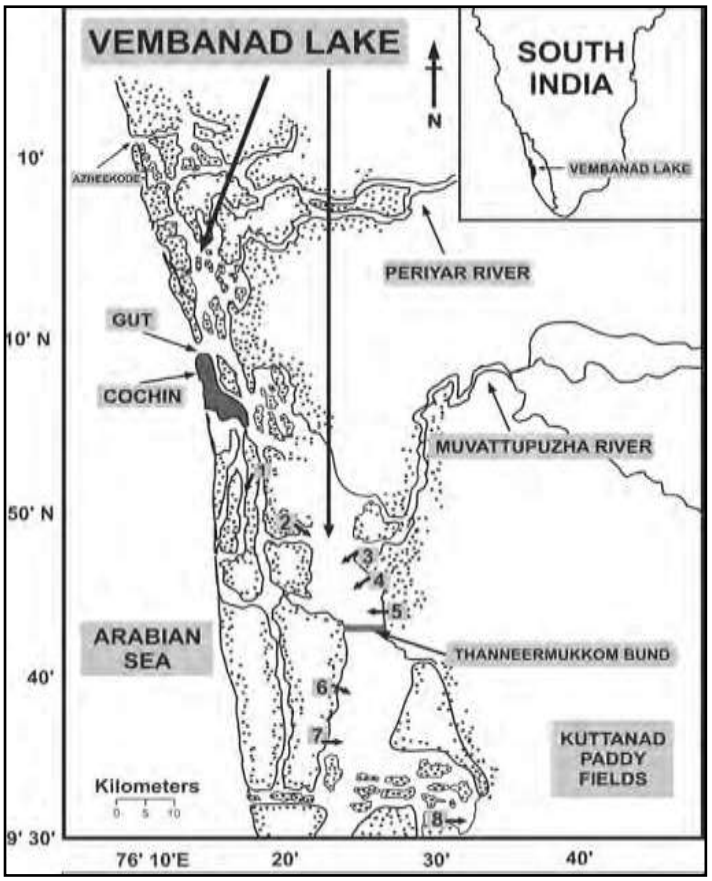

Figure 3.1: Paddy Fields of Kuttanad and Vembanad Lake

Source: The Black Clam, Villorita cyprinoides, Fishery in the State of Kerala, India November 2010Marine Fisheries Review 72(3) Project: 'Development of shallow water grow - out techniques for the Corbiculid clam Villorita cyprinoides (Gray) and for the Venerid clam Paphia malabarica (Chemnitz)' N. SujaN. SujaKolliyil Sunil Kumar Mohamed Kolliyil Sunil Kumar Mohamed

This artificial barrier resulted in the transition of Kuttanad from a just a rice cultivating region to the present 'Rice Bowl' of Kerala. This project epitomizes the determination and the will power of the farmers in Kuttanad as they initiated a spectacle when the educated and technically trained Engineers of Irrigation Department Government of Kerala was sceptical.

The First Phase and the Second Phase was initiated by the Irrigation Department and the most import Phase of the Project, the Third Phase, was abandoned by the Engineers citing various technical issues like depth of the river, heavy currents etc.

But under the leadership of Kunchappan, the farmers collected mud from the lake and to strengthen this mixture, they used a local reed 'Kathira' (Phragmites australis) collected from Lakshmithoppu near Thottapally that ensured tight binding of the mud resulted in the farmers achieving this grand spectacle.

After the construction of the mud bund, a road was constructed on it that linked Kottayam and Alapuzha district and finally became the lifeline of the people.

Figure 3.2: Thanneermukkom Bund

3.5 Agro-Ecological Zones of the Region:

The Kuttanadu region spread over 54 revenue villages is a unique tropical flooded paddy land with lots of global interest as it is in the Vembanadu Ramsar zone.

The artificial barrage, popularly known as the 'Thannirmukkam barrage', which was constructed during the 1970s to protect the vast paddy lands against saltwater incursion had resulted in it becoming an artificially maintained freshwater system.

It is reported that these paddy fields lie at an average depth of 2 to 2.5 m below sea level. Moreover, these paddy fields remain as a freshwater zone all through the twelve months of the year except the crop seasons.

The major crops that are cultivated in these areas are '*puncha'* which is the summer crop and extends from December to March, while the other popular variety is the *Virippu* which is the monsoon crop spread over from May to October. The climate is also best suited for adopting the two-system cropping patter.

Research studies Shari and Chitra 2005) undertaken by had shown that this region experiences warm climate with a uniform temperature that ranges between 21^0–36^0C with high humidity.

They also opined that this region also receives an average rainfall of 3000mm from the southwest monsoon months.

Kuttanad is popularly known as the "Rice Bowl of Kerala", as by estimates (Sudhikumar and Sebastian 2005) rice is cultivated in 53,639 hectares which is unevenly distributed among 1086 units where rice is cultivated.

It was opined by the farmers that during the non-cropping season, majority of the fields are inundated with water and to initiate cultivation process, water had to pumped to make it into an arable land.

The sensitive and fragile ecosystem of Kuttanad can be classified into 6 agro-ecological zones:

- Upper Kuttanad
- Lower Kuttanad
- North Kuttanad
- Kayal lands
- Purakkad
- Vaikom Kari lands

These regions are spread between three important districts in Kerala - Alapuzha (57%), Kottayam (36%) and Pathanamthitta (7%).

Kuttanad can boast of the fact that the entire paddy cultivation of these districts are undertaken only in this region (Thomas, 2002).

3.5.1 Upper Kuttanad:

This zone lies in the southeastern side of Kuttanad which includes comparatively high lands. The elevation ranges from 0.5 to 6 m above MSL. The zone experiences low risk from saline intrusion and flood. Three major rivers include Achenkovil, Pampa and Manimala enter Kuttanad in this zone.

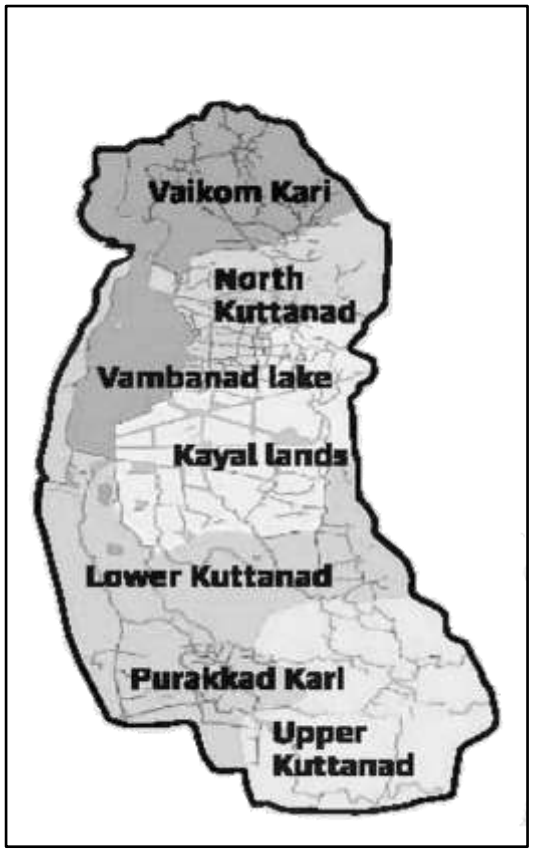

Figure 3.2: Agro-Ecological Zones of Kuttanad

3.5.2 Purakkad Kari:

It is situated at the western side of Upper Kuttanad zone, near to sea. The zone has high soil and water acidity owing to the presence of peaty soil (partially decomposed organic matter in high proportions). The risk of saline water intrusion is high compared to other zones, since it is near the sea coast.

3.5.3 Lower Kuttanad:

It is situated north of Upper Kuttanad. The area lies 1 - 2 m below MSL in some parts. The risk from flood and saline water intrusion is the highest here. The flood season is slightly of more duration compared to other zones. The presence of a number of small islands with human habitation is a special feature of this zone.

3.5.4 Kayal Lands:

This zone lies north of Lower Kuttanad. It includes Kayal rice fields, which were reclaimed by earthern bunding of the shallow portions of south eastern part of then Vembanad Lake. These fields lie 1 to 2m below MSL. The flood risk and saline water intrusion is high here.

3.5.5 North Kuttanad:

This zone lies north of Kayal lands. It was formed by the natural reclamation of Vembanad Lake due to the silt carried by Meenachil River and its distributaries. The western portions lie 0.5m below MSL and the eastern portion lie 1m above MSL. Even though the flood risk is high, saline water intrusion is the major problem here since it is very near to the Cochin estuary.

3.5.6 Vaikom Kari:

This zone lies at the northern most end of Kuttanad. It lies 0.5m below MSL in western portions and upto 6m above in eastern portions. The area lies at the northern side of Thanneermukkom barrage, so the risk of saline water intrusion is the highest here in summer. The name "Kari" is derived from the intense black colour of soil. High content of organic carbon in this soil imparts this characteristic black colour to the soil. The presence of partially decayed or petrified logs of wood (peat) is high in this zone. Other characteristic features of Vaikom Kari soils are heavy texture, poor aeration, bad drainage and low content of available nutrients. The soil and water are highly acidic.

There is accumulation of sulphur compound, which on microbial action, is converted to sulphuric acid. Due to acidity, toxic compound of iron, aluminum and manganese are released and they accumulate in toxic proportions in these soils. Because of its peat content, the soil become too hard on drying and when burned, it flames like coal. Odour of marsh gas and hydrogen sulphide persists in the soil. Yellow brown encrustations are very common. The area is fed by a major distributory of Muvattupuzha river called Kari Ar, entering at Thalayolaparambu, flowing through Ezhumamthuruthu and discharging into the Vembanad lake near Moothedathukavu Temple at TV Puram, where a temporary earthern bund called "Kari Ar muttu" is constructed to check the saline water if required. The size of the land holdings is large as in Kayal lands. The bunds around the fields are cultivated with coconut and banana.

3.6 Kuttanad and GIAHS:

The peculiar feature that one can observe in Kuttanad is that this region is recognized by Food and Agriculture Organisation (FAO) as the Globally Important Agriculture Heritage System (GIAHS) based on the project proposal submitted by the Government of Kerala with the support from M. S. Swaminathan Research Foundation (MSSR).[3][4] The total landscape of Kuttanad comprises around 1100 km^2 out of which304 km^2 lies below sea level. As Kuttanad is drained by a network of rivers and man-made channels, this inhabited land was reclaimed from waterlogged areas.

[3] R. Ramabhadran Pillai (2015) Global centre for below sea-level farming soon ALAPPUZHA:, DECEMBER 31, 2015 00:00 IST https://www.thehindu.com/news/national/kerala/global-centre-for-below

[4] http://www.fao.org/3/a-bp793e.pdf

The distinguishing feature of this area is the drainage system which was literally evolved from Vembanad Lake which was earlier a lagoon. The tidal flow in this area is regulated by Thaneermukkom regulator. It is because of this network of canals and bunds; it is regarded as the 'Holland' of Kerala.

Figure 3.3: Below Sea Level Farming

Kuttanad can be regarded as the only region in India which practices below sea level farming, under which hectares of land are reclaimed from delta swamps. Locally these peculiar ecosystems are known as 'Puncha Vayals' and with this mastery of harvesting, the farmers of Kuttanad was able to play an effective role in the conservation of the unique ecosystem of Kuttanad. Though 'Doubling of Farmers income' is a new concept in India, yet the farmers had already mastered this art through integrated rice and fish cultivation. It is during the monsoons, these paddy fields acts as a buffer zone against floods in this part of the world (Padma Kumar, 2013).

3.7 Variability of Climate in the Region:

Kuttanad exhibits a typical tropical climate due to which the temperature ranges between 21^0C to 36^0C. The average annual rainfall recorded in this art of the world is 3000mm from the two monsoons – south-west and north-east. Among them the north-east monsoon is spread between October to November while the south-west sheds during the fall of June to August. When we observe the trends in temperature it ranges between 30^0C to 34^0C at the highest while the lowest range is between 22^0C to 24^0C. Though the driest month is between the latter half of January to March, the tropical rains are felt in the severity during the months of April and May.

Like any other region, human interventions had resulted in land use changes and the flood water that emerges from the upstream basin brings it with large amounts of sediments and debris into these lowlands. As a result of this natural phenomenon, flood water overflow is a recurrent one both into the homesteads and farms. Though paddy farming can be regarded as one of the important occupations, yet one can observe other crops like pepper, banana and yams liberally cultivated in these homesteads. These lands in which cultivations are undertaken are reclaimed lands from the lake and canals without any effective hydrological management.

3.8 Demographic Profile of Kuttanad:

When we analysed the demographic profile of Kuttanad, it can be observed that majority of its area falls inside the district of Alapuzha with a small percentage spill over to the adjoining districts of Kottayam and Pathanamthitta. When we take a closer look at the population trends between 2001 to 2011, it can be observed that initially the population was 2,109,160 of which males were 1,014,529 and remaining 1,094,631 were females. It increased to 2,127,789 of which males are 1,013,142 and females were 1,114,547 respectively. Based on the input provided by the official records, it can be opined that the change of the population was of the tune of 0.88 percent compared to the earlier census of 2001, while when compared to 1991 census the increase is at the rate of 5.39 percent.

Table 3.1: Comparative Analysis of Demographic Parameters 2001-11

Description	**2011**	**2001**
Population	21.28 Lakhs	21.09 Lakhs
Actual Population	21,27,789	21,09,160
Male	10,13,142	10,14,529
Female	11,14,647	10,94,631
Population Growth	0.88%	5.39%
Area Sq. Km	1,415	1,415
Density/km2	1,504	1,492
Proportion to Kerala Population	6.37%	6.62%
Sex Ratio (Per 1000)	1100	1079
Child Sex Ratio (0-6 Age)	951	956
Average Literacy	95.72	93.43
Male Literacy	97.36	96.27
Female Literacy	94.24	90.82
Total Child Population (0-6 Age)	1,92,046	2,26,408
Male Population (0-6 Age)	98,444	1,15,752
Female Population (0-6 Age)	93,602	1,10,656
Literates	18,52,797	17,58,978
Male Literates	8,90,552	8,65,286

Description	2011	2001
Female Literates	9,62,245	8,93,692
Child Proportion (0-6 Age)	9.03%	10.73%
Boys Proportion (0-6 Age)	9.72%	11.41%
Girls Proportion (0-6 Age)	8.40%	10.11%

Source: https://www.census2011.co.in/census/district/281-alappuzha.html

On a careful perusal, one can infer from the official data that the density of the population increased from 1,492 people per sq.km in 2001 to 1,504 per sq.km in 2011. This density increased in an area of just 1,415 square kilometers which is a combination of settlements, kayal land and farmland as well.

As it is observed in Kerala, the average literacy of Alapuzha district increased from 93.43 in 2001 to 95.72 in 2011 and the proportion between male and female is exhibiting a similar trend (Males - 97.36 and Females - 94.24). Hence the total literacy among the population is to the tune of 1,852,797 of which male and female were 890,552 and 962,245 respectively.

3.9 Climate Change and Agriculture Practices in Kuttanad Region:

Right from the historical time, Kuttanad is regarded as the centre for various types of agricultural practices. The crops that are cultivated in Kuttanad area are paddy, coconut, arecanut, mango, jack, beetel, pepper etc. periodic manmade interventions can be regarded as the important reason for popularization of agriculture. As the land is surrounded by canals and backwaters, they are optimally utilized by the local population for irrigation and navigation purpose.

The lush green paddy fields are segregated with dikes that restrict the water flows into the farms. Due to the abundance of water in these areas, the agriculture strategy adopted in this area is entirely different from other parts of the world. Excess water has become a norm in the day-to-day life of the people in Kuttnanad.

The excess water from the fields is removed with the help of water wheels (Chakrams/Vallathoney) mainly made out of wood and reinforced with nails. Till now plough driven by buffaloes was used for ploughing the fields is another important feature of this area. Rather than cow which is popular in other parts of Kerala and India, buffaloes are popularly used for household and agriculture related practices. As it name conveys, Water buffaloes are best suited to wetlands of the Kuttanad Region.

Chavittumaram is another instrument used for levelling of the land which has an average length of 7 feet with sharp teeth in its bottom part and is dragged by s single bullock. Earlier the farmers depended on cowdung as the most important fertilizer, now to sustain the productivity levels and in their desire to ensure profitability, liberal dozes of fertilizers and pesticides are used in these fields. Though Kerala is popular for its lateraite soil, yet in Kuttnad region, one can find soil which is black in colour that can be attributed to the presence of large amount of decayed matter.

3.9.1 Climate Change and Adaptive Responses:

As a part of this research study, we had tried to analyse the knowledge of farmers with respect to climate change phenomena and the adaptive response that had implemented or planning to implement is taken into due consideration. As majority of the farmers are involved paddy cultivation in this part of Kerala, hence we tried analysing the adaptive response towards the cultivation of the staple crop – rice. Open ended questionnaire survey methodology was adopted to undertake the analysis of farmer's perception. Farmers were randomly selected for this study and the problem of climate change was discussed independently or in various other scenarios, group discussion was also encouraged to derive long term strategies for conservation of Kuttanad and even to device sustainable livelihood strategies.

3.9.2 Adverse effects of Pesticides and Chemical Fertilizers:

To sustain productivity levels and to ensure minimum profits, farmers are compelled to use high doses of fertilizers and pesticides. As the rain is erratic due to climate change, these untimely rains takes the chemicals from the fields into the nearby water bodies like canals and rivers. Joint study undertaken by three important health departments of Kerala (Department of Community Medicine of the Alappuzha Medical College, the Regional Prevention of Epidemic and Infectious Diseases (PEID) Cell and the State Disease Control and Monitoring Cell (SDCMC), opined that there is excessive use of fertilizers within the fragile environment of Kuttanad.

As a result of this long-term practice of excess use of highly toxic chemical inputs had started showing its impacts on the health of the population in this area. There is the existence of cancer and the incidence is going to be at higher levels as these toxic chemicals that had also entered into the food chain of population.[56]

3.9.3 Climate Change on Life and Livelihoods:

Key Informant Survey was undertaken with open ended questionnaire was used to undertaken to analyse the effect of climate change on life and livelihoods in the study area. From the Champakkulam and Velianad Block 20 farmer's, 10 members from the fishing community and 10 casual labourers were randomly selected for the study.

Later other stakeholders like elected representatives of the panchayat, members from prominent Self-Help Groups (SHGs) was also included in the research process as they are able to assist in the policy formulation of the area.

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[5] https://www.thehindu.com/news/national/kerala/Survey-confirms-high-prevalence-of-cancer-in-Kuttanad/article16837172.ece

[6] Devi P. Indira (2007) Pesticide Use in the Rice Bowl of Kerala: Health Costs and Policy Options Working Paper No. 20-07South Asian Network for Development and Environmental Economics (SANDEE) PO Box 8975, EPC 1056Kathmandu, Nepal. https://core.ac.uk/reader/29135162

Table 3.2: Profile of the Respondents

Block	Velianadu	Champakulam	Total
Farmers	20	20	40
Fishing Communities	10	10	20
Casual Labourers	8	8	16
Lime Shell Producers	2	2	4
Total	40	40	80

From the above table to analyse the core topic of climate change we need a sizeable representation of the dominant section of the society in the study area. As Kuttanad is known as the 'Rice Bowl' of Kerala, we had included a dominant representation from the farming community along with other popular forms of livelihood - fishing community, lime shell producers and casual labourers. Both the blocks – Champakkulam and Velinadu is effectively represented with a sample size of 40 evenly distributed among them. As the active participation in any development activity in a rural area is dominated by male members, this study is also dominated by male respondents.

In-land Fishing can be considered as another popular profession in Kuttanad which is practiced for many centuries. The traditional fishing community dominated by Dheevara depends on indigenous tools for fishing which can be regarded as strictly adhering to sustainable protocols of nature. As the population pressures increased in this area, large scale reclamation of *Kayal* lands was undertaken without any regard to any norms or sensitivity of nature. Hence one can witness a decline both in agriculture productivity and area under agriculture operations. So, the only alternate employment available in this part of the world is in-land fishing that prompted non-fishing communities like Ezhava to shift to this occupation to sustain their life and livelihood.

These fishing communities' lives in worse living conditions that depended on a low yield occupation that is subject to severe seasonal variations. On a closer observation, it can be observed that they live in deplorable living conditions devoid of basic necessities of life like good food, clothing, proper sanitation facilities etc. majority of their income is spent on food consumption and to meet the frequent medical needs. We also observed that to sustain their life and livelihood, they had started using large nets and other advanced accessories which is adversely affecting the sustainability of rivers and lagoons in Kuttanad.

Under the traditional land revenue system, the labourers (*Kudiyanmar*) are considered as an important part of the traditional agriculture productive system and are literally tiled to the land with certain rights and privilages (*Kudikidappu Avakasham*). But after the independence and through the implementation of the Kerala Land Reforms Bill, we witnessed the casualization of agriculture labourers who is included into the system as and when need arises. This casualization of agriculture labourers can not only be attributed to the change in the Land Revenue System but also can be attributed to population pressures on land. Moreover, the illiterate or less educated casual labourers are now exposed to the market forces due to which they are expected to compete for their fulfilment of needs.

Table 3.3: Respondents attitude towards Natural Calamities effect on Life and Livelihood

Impact of Natural Calamities	Salinity Levels		Floods		Flash Floods	
	Velianadu	Champakulam	Velianadu	Champakulam	Velianadu	Champakulam
Death of Family Member	0	0	0	0	3	5
Missing Household Member	0	0	0	0	0	0
House completely Destroyed	0	0	1	1	14	25
House partially Destroyed	0	0	2	3	13	29
Loss of Domestic Animals	0	0	1	0	25	32
Loss of Crops	3	5	1	1	17	21
Loss of Land	4	5	5	8	8	9
Adverse health effects to family	4	3	1	2	7	5
Affected educational initiatives of family members	4	2	2	4	5	12
Others	0	0	0	0	0	0

Kuttanad can also boast of 13 cooperative societies that is engaged in the procurement and marketing of white lime shells which are fossils of black clams.

Vembanad and the adjoining areas are rich in lime shells which are of in great demand both in the local market and in other parts of the country. The calcium-rich resource is used for construction works and among poultry farmers as a calcium supplement. This limestone is locally known as '*neetukakka*', is of great demand in local markets as it is regarded as a soil neutralizer in the acidic fields of Kuttanad. As per a rough estimate, the average annual production of lime shells is of the tune of 32,000 tonnes.[7] The calm collectors are now facing

[7] https://www.thehindu.com/news/national/kerala/lime-shell-business-stares-at-a-crisis/article31718053.ece

a difficult scenario in Kuttanad. On a daily basis they risk their life by going deep down to the riverbed to gain their livelihood. But the subsidized distribution of dolomite is replacing the demand for these lime-shells and its adversely affecting the Lime-shell Collector.

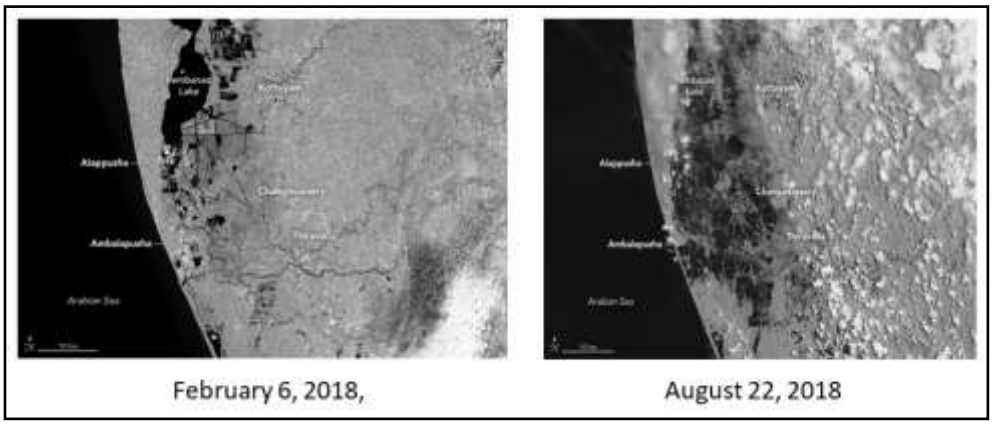

Figure 3.4: Landsat 8 Satellite Imagery Before and During Floods

Source: NASA Earth Observatory images by Lauren Dauphin, using modified Copernicus Sentinel data (2018) processed by the European Space Agency and Landsat data from the U.S. Geological Survey.

From the survey, it can be observed that water salinity and floods are the part and parcel of life of the people in Kuttanad. Yet from the study it can be observed that both the issues – salinity and floods are an accepted norm and majority of the respondents are not disturbed by it. But the recent floods which were caused by simultaneous opening of dam shutters of many dams in Kerala had dent a severe blow on this fragile environment. When we take a closer look at the two images, it can be observed that the left image, which was taken by Operation Land Imager (OLI) on the Landsat 8 Satellite conveys that there is a distinct difference between water bodies and agricultural land in Alapuzha District. But 'once-in-a-century' flood that happened on August 2018 had literally inundated whole of the Kuttanad area. In the image dark blue colour inundation of water while the green patches convey the vegetation in the area. This conveys that all the respondents or rather all of the population in Kuttanad had faced some type of natural disaster in their lifetime.

Table 3.4: Respondents observed Climate Change

Observed Change	Velianadu	Champakulam	Total
Rainfall (Irregular, Insufficient, Heavy)	19	20	39
Variation in Temperature	16	19	35
Increase in Frequency and Magnitude of Flood	13	18	31
High levels of Erosion by rivers	14	16	30
Rise in sea level	15	18	33
Increase in crop failures	17	18	35

Observed Change	Velianadu	Champakulam	Total
Adverse effects on health	10	12	22
Adverse effects on productivity levels	16	18	34
Others	4	2	6

When we tried to analyse the important Climate Change phenomenon experience by the respondents, it can be observed that the vagaries of climate change had adversely affected their life and livelihood.

Irregular rains and wide variation in temperature had adversely affected their agriculture practices which finally ruined both their income and health. These untimely rains had also resulted in heavy erosion which affected the livelihoods of the fishing community in this area. Crop failures as per the survey can be attributed to irregular, insufficient or heavy rainfall and erratic temperature variations.

Table 3.5: Effects of Climate Change on Household Level

Effects on Household Level	Velianadu	Champakulam	Total
Decline in Agriculture Production	19	20	39
Loss of Agriculture Land	12	12	24
Loss of Health	9	11	20
Loss of Domestic Animals	12	12	24
Decline in Potable Drinking Water	15	18	33
Migration of Family Members	10	9	19

Based on the survey, it can be opined that due to climate changes in the study area, there is decline in water table because of this water shortage has become a norm both for drinking and for agricultural practices. Recent flooding of Kuttanad had resulted in loss of cattle wealth which had eroded the sustenance of agricultural practices in Kuttanad. Hence the farmers slowly started realizing that finally agriculture practices cannot be regarded as profitable venture.

Table 3.6: Response of Government towards Climate Changes

Government Response	Proactive Participation		Passive Participation		No Response	
	Velianadu	Champakulam	Velianadu	Champakulam	Velianadu	Champakulam
Government Response	4	3	15	17	1	0
Flash Flooding	9	7	11	13	0	0
Salinity Issues	5	0	15	18	0	2

As the Kuttanad Agriculture Belt is exposed to vagaries of climate change, the agriculturist expected a proactive participation from the government and to redress their grievances in the shortest possible time. But from the study, it can be opined that the respondents view that government is passive towards developing strategies against climate change. The best example they had highlighted is the lag in the implementation of the 'Kuttanad Package'.

Kuttanad package intended to revive agriculture along with ensuring Kuttanad as a 'flood free zone' through ecological restoration. Kuttanad package was devised by the famous scientist M.S. Swaminathan who hails from this part of the world. But the lack of effective cooperation coupled with nepotism and redtapism. Hence the government was not able to play an effective role even after heavy flooding for two consecutive years that destroyed both life and livelihood. The opinions made in this report that flood in Kuttanad can be attributed to excess flow of water to various water bodies. Already prevailing natural flow to the Arabian Sea is restricted by the unscientific construction of roads, bridges, culverts and sand silting.

Heavy growth of Water Hyacinth along with various invasive weeds like Cabomba (Cabomba Caroliniana) popularly known as Fanworth is creating many problems in this riverine ecology. These invasive fast-growing weeds prefers stagnant or slow flowing water bodies and can reach up to the depth of 12 feet. The construction of the Thanneermukkom Salt water regulated the flow of salt water into these water bodies which literally had made these into freshwater bodies conducive for the growth of these alien species. Uncontrolled sand mining all along the banks of Pampa River and Vembanad Lake had reduced the heavy flow that further enabled the speedy growth of these weeds.

The rapid growth of this plant species will promote sand silting which will finally result in river becoming shallow or even to dry. This thick growth of invasive weeds will not only direct sunlight into water but also will cut the oxygen levels, such a phenomenon will adversely affect the diversity of fish species in turn affects the livelihood of the fishing community.

Table 3.7: Household level Strategies Initiated by Respondents

Strategies Initiated	Velianadu	Champakulam	Total
Raised the Plinth Area	19	20	39
Planning to Migrate	12	12	24
Planted more trees and other species	7	9	16
Constructed new house in an elevated area	12	12	24

When we analyse the history of Kuttanad, we can observe that it had a long history of people movement. The Thaneermukkom Bund was constructed in the year 173 is the typical example of people cooperation. When the engineers of Irrigation Department, Government of Kerala was sceptical about the construction of Thaneermukkom bund to prevent saltwater intrusion, the then Nedumudi Panchayat President Kunchappan Koshy formed a farmers committee and constructed the mud bank within just 21 days.

The same enthusiastic spirit can be observed during our field survey. After realizing that there is delay or apathy from the Government side, people are exhibiting their interest towards individual or group initiatives. Majority of them preferred to live in Kuttanad, and only the younger population realizing that the agriculture sector is not efficient enough to sustain a life, is interested in migrating. As flooding is very frequent in these areas, the farmers prefer to increase the plinth area so that flood water doesn't inundate their kitchens and verandhas. Those with sufficient financial backing had sold their old house and shifted to higher levels.

Table 3.8: Household Responses towards Climate Change Mitigation Strategies

Strategies Initiated	Velianadu	Champakulam	Total
Stress on self-resilience	18	20	38
Community Participatory Strategies	11	15	26
Strengthening Government Initiatives	8	9	17
Proactive participation from international agencies	8	9	17
Assistance from non-governmental agencies	10	12	22
Assistance from Corporate Sector	7	9	16
Strengthening training and capacity building strategies	14	20	34

Majority of them believed that the frequent floods and heavy rains are the result of vagaries of climate change. Based on their experience they prefer a people centric strategy where the essence is on self-reliance. Moreover, Kerala is popular all over the world for its 'People Plan Campaign' which witnessed the emergence of Self-Help Groups (SHGs) in the Local Level Development strategies. In Kuttanad also people prefer a proactive role of SHGs in climate change mitigation strategies which can be supplemented through capacity building.

When faced with climate change issues like floods, the first strategy adopted by the respondents is to reduce expenditure basically on food items. If such a strategy is adopted, it will adversely affect the most-vulnerable groups – women and child which will have adverse long run defects like malnutrition etc. Through the survey, it can be observed that Cash Transfer is the most preferred mitigation strategy that people prefer along with the usual free rations when faced with heavy floods. Cash transfers form can take any form like meeting basic needs, helping vulnerable communities to enhance adaptive capacity, from increased subsidies etc.

Table 3.9: Household Responses towards Climate Change Mitigation Strategies from Government

Strategies Initiated	Velianadu	Champakulam	Total
Cash Transfer	20	20	40
Research based Planning and Policy	13	15	28

Strategies Initiated	Velianadu	Champakulam	Total
Distribution of free rations, houses etc	14	17	31
Panchayat Level Development Strategies	13	14	27

Though the public is apprehensive about the lack of active participation from the government in climate mitigation and support system, yet the general public still believes that Government can be considered as the only institution that can be trusted for the above assigned activities.

Table 3.10: Household Response to Agencies that can be entrusted with Climate change Mitigation Strategies

Agencies	Velianadu	Champakulam	Total
Government and Allied Agencies	18	19	37
Non-governmental Agencies	13	15	28
SHGs and Community Groups	14	17	31
International Agencies	5	5	10
Private Agencies	9	11	20

But on a closer perusal, they are of the view that Local Self-Government (LSG) should be assigned to play a more proactive rule as they had already established an effective association with grass root level population like farmers, casual laborers, fishing communities and other downtrodden sections of the society.

Non-governmental agencies and other private agencies will be given the least preference by the respondents. The respondents are sceptical about the participation of International Agencies in these development activities as they fear that it will be backed by certain conditionalities that will hamper their prospects.

Table 3.11: Household Response to Strengthening Community Participation

Strategies	Velianadu	Champakulam	Total
Stress on Community Opinion making	18	19	37
Stress on SHG formation	15	15	30
Strengthening Information and Technology integration	16	17	33

When we enquired about how to strengthen the effectiveness of government initiatives, we received a unanimous opinion from the respondents that they expected more active participation from the community groups and their elected representatives. They are of the opinion that SHGs can be regarded as the most important means for strengthening community level activities against climate change.

As the farmers in this part of the world is educated they have ample knowledge regarding the potential of information technology in enhances productivity. A respondent is of the view that this technology is yet to reach its potentiality in agriculture sector as its access is restricted to scientific community. Technology will achieve its effectiveness only if it is aligned with the needs of the farmers and integrated into the grassroots level applications.

Table 3.12: Household Response to Source of Assistance for Climate Change Strategies

Agencies	Velianadu	Champakulam	Total
Government Institutions	18	19	37
Local Panchayats	13	15	28
Elected Panchayat Members	14	17	31
Elected Assembly Members	12	16	28
Elected Members of Parliament	13	18	31
Private Individuals and Corporate	7	9	16
Non-Governmental Organisation	7	9	16

When asked about the most trusted official for the conduct of the integration of climate change activities they expected the friendly neighbourhood Panchayat Member as the true representative who will be able and efficient in guiding the government officials in development of new strategies.

Rather than a centralized approach whereby the state government decides the regional programmes, they preferred a decentralized approach where the LSGs should play a proactive part. Hence it can be opined that they prefer a 'Bottom-up' Approach rather than a 'Top-Down' Model. For strengthening the strengthening Central Government allocation, they prefer the elected members of the Parliament to supplement the state initiatives. Hence it can be concluded that the respondents in Kuttand prefer an integrated approach to solve the climate change crisis.

Table 3.13: Household Response to Resources Provided for Climate Change Strategies

Agencies	Velianadu	Champakulam	Total
Monetary Assistance	19	19	38
Food and Other Provisions	10	9	19
Building and Other Accessories	10	10	20
Credit Assistance	15	17	32
Seeds and Fertilizer Assistance	15	17	32
Water and Sanitation Facilities	15	16	31
Training and Other Assistance	10	12	22

When enquired about the expected assistance, the respondents had voiced for both financial and input assistance irrespective of the region under consideration. The main objective of such a strategy is to channelize the external assistance for the effective development of Kuttanad region. For that they expect multilateral assistance through the integration of all allied agencies. They are of the view that all the departments like Agriculture, Irrigation Department, Public Works Department, Meteorological Department, Pollution Control Board all should chip in to make Kuttanad a better place. When enquired about the area that needs more attention the answer was on expected lines – agriculture. They are of the view that excessive dependence on agriculture is not beneficial for Kuttanad in the long run. The respondents are of the view that strategies like 'Doubling of Farmers' Income' should be adopted to restore profitability in primary occupation.

As agriculture practices like paddy cultivation is a seasonal occupation, to tide over the offseason lag and lethargy they prefer to have an alternate or supplementary occupation. They prefer livelihood support system rather than free cash transfers which conveys the real hardworking nature of the people in Kuttanad. The study observed that water bodies play an effective role in restoring the profitability of agriculture sector. Through the building of embankments and periodic dredging of the rivers will result in reducing the adversities caused by floods.

They also opine that effective disaster management practices if implanted through the optimal use of information technology can restore the confidence of the general public thus will become the 'Holland' of India.

Table 3.14: Household Response to Specific Assistance for Climate Change Strategies from Government

Agencies	Velianadu	Champakulam	Total
Agriculture Package	20	20	40
Infrastructure Strengthening	12	14	26
Direct Cash Transfer	10	10	20
Livelihood Support	15	17	32
Building Embankments	16	17	33
Resettlement of People	7	9	16
Livestock Support	10	12	22
Dredging of River	15	16	31
Early warning and Weather Centers	16	16	32

3.10 Land Reclamation and Willington Island:

Another important environmental threat faced by Kuttanad is land reclamation due to the increase of pressure and greed for land. Major changes to the landscape of the backwater and Kuttanad Ecosystem occurred after the construction of Cochin Port (1930-1940).

As per the Parliament Papers of Great Britain[8], the old Cochin Port was not that shallow which restricted the entry of large ships and hence they were docked in outer seas. British Engineers were assigned to undertake a study to develop and inner harbour concluded that the port is filled with heavy sand bars across the harbour mouth, and it is just impossible to increase the depth to eight to nine feet. But it was Lord Willingdon, the then Governor of Madras who assigned Mr. Robert Bristow, a qualified Harbour Engineer to develop the Port. Bristow prepared a detailed plan of reclaiming a large island and to build a complete harbour with jetties, bridges and railway lines at an expected cost of 2.5 Crores. A special dredger 'Lord Willington' was specially made for this assignment and effectively used for cutting the heavy sand bars of Cochin. During the cutting of the heavy sand bars, Bristow was of the view that the development of Cochin harbour will adversely affect the prevailing ecology of the region. Along with reducing the sand siltation from the Vembanad Lake, he also tried to protect Vypeen Island from the reactionary effect of the sea. A man-made island was developed from the soil dredged from the sea and is now known as the Willington Island. Research studies conducted in this area also substantiates this view that the development of Cochin Harbour had reduced the carrying capacity of the Vembanad Lake from 2.4 kms to 0.6kms. Along with these external environmental issues, another important issue is the scale of conversion in Kuttanad. The picture given below conveys the scale of conversion and the shrinking of the river that had occurred in and around the Vembanad Lake comprising of the Kuttanad region. When we closely observe the scenario, it can be observed that for the past four decades, land reclamation took the following forms.

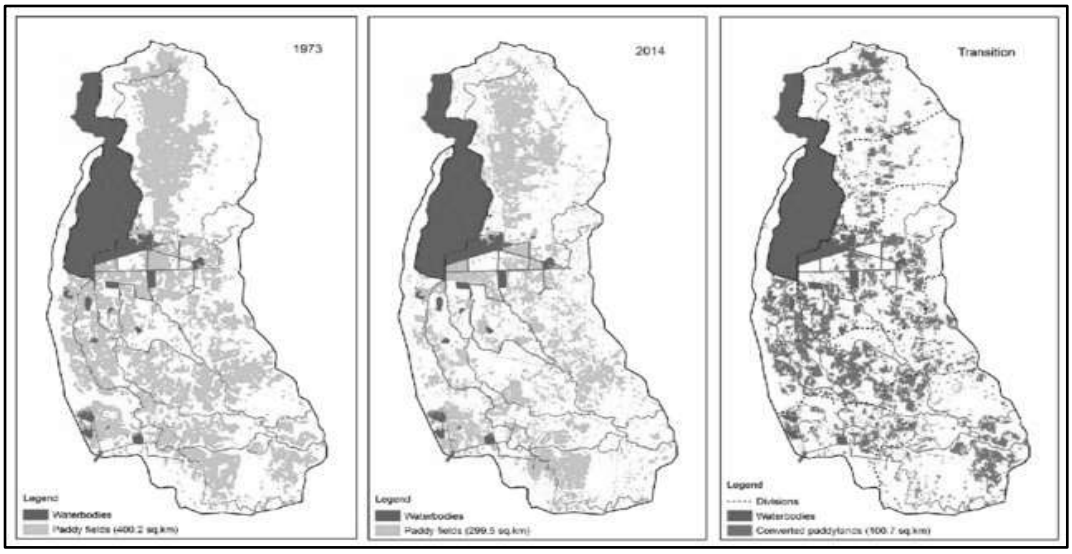

Figure - 3.5: Land Conversion in Kuttanad[9]

[8] Parliamentary Papers, Volume 49 by Great Britain. Parliament. House of Commons by Great Britain. Parliament. House of Commons Parliamentary Papers, Volume 49

[9] Published on Jan 25, 2018 NANDINI MENON1 AND GRINSON GEORGE (2018) Menon and George - UEI Day 2 - Kochi Jan18 https://www.slideshare.net/iukwc/menon-and-george-uei-day-2-kochi-jan18

Source: https://www.slideshare.net/iukwc/menon-and-george-uei-day-2-kochi-jan18

- First type of land reclamation that happened in this area is from the estuaries for cultivation of paddy. The low-lying regions were rich in soil fertility as it was created out of the silt deposition by Vembanad Lake which is very conducive for undertaking paddy cultivation in this area. The selected are first covered with bunds and water is drained out after leaving sufficient space for navigation, irrigation, and drainage. These reclamations were undertaken by private individuals influenced by market pulls who were later were conferred property rights by the State as a pretext for food security. Hence it can even be opined that these conservations are induced by State.
- Second or the most recent form of reclamation prevailing in this part of the world is conversion of paddy land into real estate properties. (Kuriakose, 2014; Padma Kumar, 2013; Sreejith, 2013). It was observed that the wetland paddy lands were first converted into coconut or plantain cultivation which was then finally converted into homestead with mixed crops. The only area that is still untouched is the Below Sea Level farming region.

Till the recent years land under paddy cultivation was protect under various laws that are enacted from time to time. First of the kind was initiated in the year 1958 which was known as the Kerala Land Utilization Order – 1958 that was later amended in the year 1967. On the eve of Independence, India was facing a series of famines and food crisis along with restriction on inter-state movement of food grain. As per the Act, the District Collector was assigned with the responsibility of overseeing the cultivation of crops by the landholder. He is entrusted with the issue of notices to the Holder to ensure that the cultivation is undertaken in the land. If the landholder doesn't respond to these notices, then the District Collector is empowered to either auction such land or the rights for cultivation to another for a said period. The order also states that if the land holder is cultivating the same crop for three years, the same crop should be cultivated for another few more years without changing the crop or pattern of cultivation. Aggrieved parties are also given provision for the Right to Appeal before the Board of Revenue. As the period suggested is too short and in collusion with the Land Revenue Officials, Kerala witnessed widespread filling up of paddy fields that had serious repercussions both at the economy level and environmental level as well. All the provision envisaged under the Kerala Land Utilization Order was later taken away through the promulgation of the Kerala Conversion of Paddy and Wet Land Act, 2008 that came to effect from August 12, 2008.

Though the Act of 2008 was promulgated with good intensions for restricting land conversion, yet this act has given the District Collector to regularize unauthorized conversion or reclamation of paddy land initiated before the act came into force. For regularization, the applicant needs to pay just specified fees of Rs. 500 which based on 25% of the fair value of the land per acre. The malady of this valuation is that it gives importance only to the market value rather than the ecological valuation of the said asset. Moreover, the government doesn't have a proper data bank regarding the land or land conversion; hence large scale conversion was undertaken within a short period of time. Gauging the adverse effect of these toothless Acts, a Public Interest Litigation was filed in the High Court of Kerala which slowly resulted in the enactment of the Kerala Conservation of Paddy land and Wetland (Amendment) Act – 2018.

Under this act entities were assigned individual role that enhanced effective scrutiny and protection of the environment. When a request for Conversion is submitted, the Revenue Divisional Officer (RDO) has to seek report from the Agriculture Officer of the particular area if the land under consideration is a paddy field.

While, if the land under consideration is a wetland, the RDO has to seek report from the Village Officer. Finally, this act was able to put an end to the practice of converting 5 cents of farm land for construction of houses.

Wetlands play an important role in sustaining life of earth and minimize the negative effects of climate change. Around the world one can observe large scale conversion of wetland into agriculture or through integrating it into urban landscapes. When such uncontrolled conversions happen, it will have adverse effects on the environment.

Conversion of wetlands will reduce Methane (CH_4) emissions and increases Carbon-dioxide emissions thus affecting the CHG in the area under consideration. When we take a closer look at the **Figure: 3.5,** it can be observed that large scale conversion is happening whereby waterfront and wetland are first converted to paddy fields and later due to the onslaught of development; it later got converted to homestead farms.

3.11: Fertilizer Consumption and GHG Emissions:

From the Table - 3.15, it can be observed that from the selected blocks – Velianadu and Champakulam twenty farmers each where selected for the study. Out of these 40 farmers, we also analysed the ownership of the paddy field in which they are engaged in production activities.

It can be observed that majority of the farmers surveyed is undertaking agriculture practices in their own land rather than on private land. This conveys that farmer is involved in agriculture practices for a longer duration of time and their family occupation is agriculture.

Table 3.15: Details of Ownership of Land under Cultivation

Nature of Ownership	**Number of Farmers**	
	Number	**Percentage**
Land Owned	20	50
Own and leased	11	27.5
Lease only	9	22.5

When we analysed the area under cultivation, we can observe that majority of them belonged to small and marginal farmers who had inherited both the land and occupation from their forefathers.

Hence it can be opined that these farmers are born and brought-up through agriculture and allied occupations.

Table 3.16: Details of Cultivated Land Holdings

Size of Land Holdings	**Cultivated Area**	
	Average Area	***Percentage***
Large Farmers (More than 2 Hectares)	9	22.5
Small Farmer (1 – 2 Hectare)	21	52.5
Marginal Farmers (Below 1 Hectare)	10	25

From the study, it can be observed that majority of the farmers belonged to the small group with a landholding of 1 – 2 hectares. Majority of these small farmers depend on their own farm for livelihood while some others, to overcome the seasonality of paddy cultivation had depended on leased plots of plantain and mixed crops of vegetable to sustain their livelihood.

As reported by the respondents, the average cost of cultivation per acre is about Rs 34,132 and the expected returns from these fields are around Rs 49,545. The farmers opined that the profitability is on a declining trend, hence the farmers are interested in keeping it barren or doing some other allied occupation. Coupled with the climate change the profitability per acre is expected to decline over time. So, the general view of the farmers in Kuttanad is that paddy cultivation or rather agriculture in total cannot be considered as a dependable occupation.

Paddy cultivation is undertaken in the same place again and again, it will result in loss of fertility and escalation in the cost of cultivation. More and more doses of chemical fertilizers are needed to ensure the minimum productivity over time. Moreover, along with fertility, liberal doses of pesticides also should be added to protect the crops from the menace of various plant diseases. For the cultivation, a farmer needs to undertake the following activities which are undertaken on a periodic basis. The important occupations related to the agriculture operation are as follows.

- Construction/Maintenance of outer boundaries.
- Dewatering of the land
- Clearing and levelling of land for sowing
- Sowing and transplanting of plant
- Manuring of the field
- Weeding of the field
- Spraying of pesticides
- Reaping, thrashing, and winnowing

In the above-mentioned activities, *Padasekharam* Committees are entrusted with construction and maintenance of boundaries that need support from other farmers. The expenditure is based on the area owned by each farmer. Majority of these occupations are entrusted to daily waged labourers whose wages ranges from Rs 700-1000. Women are also employed in lighter jobs based on a deferred payment or at a rate less than that offered to men. On an average the wage for women ranges from Rs 600 – 800.

When we analyzed the amount of manpower used, it can be observed that except the laborious task of land preparation, women are given preference than males.

One way it can be regarded as a way of cost cutting while in another way the farmers are of the opinion that women workers are more efficient than men along sizeable amount of savings as well **(Table: 3.17)**.

Table 3.17: Details of Labour Requirements for Paddy Cultivation

Type of Operation	**Labour Requirements** (Per acre)		
	Male	***Female***	***Total***
Preparation of Land	2	9	11
Sowing of Seeds	2	10	12
Transplanting	-	20	20
Manuring of Plants	2	-	2
Weeding related Activities	-	12	12
Harvesting	3	17	20
Others	1	4	5
Total	10	72	82

Kerala Agriculture University had started an independent Rice Research Station at Monkompu situated in the Champakulam Panchayat in Kuttanad Taluk. The main emphasis of this research center is to develop rice varieties that suites the deep-water ecosystem. Most of the varieties developed are tolerant towards various type of diseases like brown plant hopper, gall midge, blast and sheath blight. The center is popular among the farmers of this area as it developed new varieties of seeds that are not only high yielding but also disease resistant as well. These seeds are protected under the Plant Varieties and Farmer's Rights Act 2001 – MO 15, MO 16, MO 17, and MO 18 etc while Bhadra (Mo 4), Karthika (Mo 7), Makom (Mo9), Uma (Mo16), and Revathy (Mo17) are nationally acclaimed varieties. MO 16 (Uma) is the most popular rice variety of the State currently occupying more than 60 % of the rice area of the State and more than 80% area in Kuttanad[10], The farmers also purchased other High Yielding Varieties (HYV) of seeds like *'Jyothi', 'Pavizham', 'Triveni', 'Kanchana', 'Bhadra'* etc from the National Seed Corporation (NSC). The malady of Monocropping is that one crop is cultivated a greater number of time as a result of which there will be excessive depletion of soil fertility. As a part of restoring fertility and to ensure the productive levels, the farmers need to do periodic manureing. The 'Green Revolution' had ushered in the era of HYVP in India which high yielding programme that is presented as a package comprising of the following components.

- High Yielding Varieties of Seeds
- Excessive dependence on chemical fertilizers

[10] https://www.icar-iirr.org/AICRIP/Centers/19%20Moncompu.pdf

- Increased supply of water to neutralize the effect of Chemicals
- Pesticides and Weedicides based Plant Protection Strategies
- Use of Mechanised Sowing and Harvesting machines
- Support system in the form of warehousing and marketing

The popular fertilizer used by the farmers in this area is NPK (Nitrogen, Phosphorus and Potash) at the ratio of 7:5:6.

3.12 Conclusion:

The study observed that there is an increase in the use of fertilizer coupled with an increase in the cost of other inputs like labour, transportation, fuel; pesticides etc are eroding the profitability nature of productive actives in the 'Rice Bowl of Kerala'. Coupled with the frequent floods one can observe that there is a significant trend towards shifting from agriculture and allied occupations to other jobs. Based on the ecological importance of 'Below Sea Level Farming' Government should enact policies to protect, preserve and encourage sustainable agriculture practices in the area.

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Chapter 4

Agriculture Mapping and Emission Analysis

Right from the historical times, primary sector dominated by agriculture and cattle rearing is the main stay of the Indian economy. But on a closer look one can observe that agriculture still can be regarded as a 'gamble with the *monsoons'.* Though India had made rapid strides in many professions, yet we are yet to take a serious look into agriculture based primary sector. It is this sector that is the main stay of Indian economy that gives us a clear insight into the deprivations in the economic and the privileges enjoyed by the other half. Any plan, programme or reform will be effective if it is able to make an effective impact on the main stay of this Indian economy – agriculture. For sustaining any development programme, the agriculture sector should generate re-investable surplus which will be ploughed into the industrial sector which finally will enhance the prospects of the tertiary or service sector.

4.1 History of Scientific Farming:

India attained its independence on the backdrop of the famous Bengal Famine during 1942-43. It is during this period India was unable to meet the food needs of innumerable number of women and children, due to which we lost about 3-4 million of our population. It led to the then Prime Minister Pandit Jawaharlal Nehru to give a clarion call in 1947, '*Everything else can wait; but not agriculture*' that resulted in imparting new energy into the 'Fight against Hunger' in India. Several programmes were introduced into the agriculture sector like expansion of irrigation facilities, initiation of seed corporations, setting up off fertilizer and pesticide factories, strengthening the market infrastructure and to enhance scientific agriculture through the development of Universities related to Agriculture Research etc.

The year 1960s saw the initiation of 'package programme' under the label of Intensive Agriculture District Programme (IADP) to enhance agriculture operation in areas where irrigation water was sufficiently available. Though the programme was failure, yet it gave some insights to agriculture researchers like Dr. Swaminathan regarding how to chart the future course of action. As the population in India was growing at a rapid pace, India was not able to meet the growing food needs of the population. The emphasis till then was to expand the land area under cultivation which will increase productivity. Yet this strategy was not sufficient to meet the growing demands and India was literally in need of a 'miracle' or else famine and death with become a part and parcel of Indian life.

Realizing this inevitable nature in Indian agriculture sector, Dr. M. S. Swaminathan took an independent initiative. He wrote a letter to the then Director, Indian Agriculture Research Institute (IARI) requesting him to seek the assistance of the renowned scientist Dr. Norman Borlaug and to invite him to India. This initiative was based on his realization that India is lacking scientific input in its agriculture programmes in the forms of a genetically modified seed that can positively respond to soil fertility and sufficient water supply. Thus scientific and technical inputs had resulted in the transformation of Indian Agriculture.

'Green Revolution', the golden period of Indian agriculture facilitated increase in cropped area by manifold along with a subsequent increase in productivity. This improved agronomic technology assisted India in achieving high per crop productivity and per area productivity. This golden period in the agriculture sector, facilitated in increasing crop yields by manifolds. Improved agronomic technology allowed India to overcome poor agricultural productivity with the incorporation of new farming technologies like drip irrigation, efficient fertilizers, potent pesticides etc. Thus India transformed from a food deficient to a food surplus country, which was able to export its food grains to different part of the world. As a result of this famine and starvation had become a thing of the past and is now confined to the pages of history. It is in the agriculture sector in Kerala, India conducted its first remote sensing study. This project was initiated by Dr. M. S. Swaminathan in association with Dr. Vikram Sarabhai who joined hand with NASA for analysing root wilt disease in coconut plantations in Kerala.

4.2 Climate Change and Geographical Information System:

Geographical information system (GIS) can be regarded as a set of computer-based scientific tools that collects analysis and interprets spatial data on various scales to meet the needs of mankind. The best part of this technology is that it utilizes database functions and visualization to generate spatial images to highlight vulnerability or potentiality of geographical region.

GIS based spatial visualization is the outcome of various digital mapping approaches. The present-day GIS can be regarded as the outcome of the MIMO Model (map-in-map-out) model introduced in 1959. MIMO model adopted data capture and analysis through geo-coding. Later it is the US Census Bureau that extensively used geo-coding and analysis with the help of Dual Independent Map Encoding (DIME) to undertake demographic analysis of the region. Later various other institutions like the Harvard University (Graduate School of Design) have developed a grid based mapping which can be incorporated into mainframe computers.

Though all these tools were popular during this period, yet a systematic study on the climate change phenomena with GIS was undertaken by Canadian Land Inventory in the 1960s that finally resulted in the development of a country specific GIS system. With this system, Canada was able to undertake an in-depth analysis of its natural resources and was able to classify regions based on special features like agriculture land, forest, and wildlife regions. This large-scale mapping of land and its resources enabled them to achieve optimal use of resources and to achieve sustainability in the long run.

Real effect of climate change can be understood in the long run, as each life form had different levels of sensitivity. GIS assist in undertaking an in-depth analysis of each entity like plant species, animal, and human being or to incorporate a total analysis of the ecosystem as well. Such an analysis is important as the sensitive levels of them are wide and varied and the concentration of a micro unit to derive macro solutions is not an easy task and can result in various ir-reputable conclusions. Planners, Policy Makers and Scientist can adopt Data Induced Decision Making (DIDM) strategies effectively through the incorporation of GIS.

Recent advances in GIS technology had assisted in using sophisticated tools like remote sensors and satellite imagery for advanced analysis of the topic under consideration. With the support of opens source materials and institutional associations, researchers now can analyse the changes that happened in the planet or the environment so far and what the future is in store for mankind. High speed data processing and abundance in source material had assisted in deriving real time images through GIS. GIS was able to establish a clear link with the state of climate change with that of the real areas of concern. The prospective areas in which GIS is used by the researchers are as follows.

- Locating areas that can be classified as hotspots.
- Developing climate simulation models to give a clear insight regarding the expected outcome in future.
- To identify prospective regions for sustainable development strategies.

Based on the projections put forward by GIS, it can be concluded that the recent climatic extremities can be attributed to climate change phenomena which is engulfing the world. As a result of this, floods, droughts, hurricanes, and heat waves all had become a part and parcel of life of the mankind. Advanced Geospatial Intelligence (AGI) can predict the exact impact on a particular region and to channelize men and materials for their well-being

4.3 Relevance of Agricultural Mapping:

With the help of science and technology, farmers can adopt precision agriculture to feed the growing population and to ensure the nutritional levels through an increased productivity. Though the force of nature is difficult to be tamed, yet through this precession agriculture, farmers can get a clearer insight into the real world scenario and the effective steps that can be incorporated to achieve the desired results. GIS tools will provide though we can regard natural phenomena like rain, flood, and heat wave conditions as uncontrollable, yet the dynamism of agriculture can be better understood with GIS applications. GIS applications can be used for effective analysis of soil fertility, expected crop yields, identification of terrain issues like landslides can be understood and effective remedial measures can be incorporated. Both the developing and third world economies are directly and indirectly employed in agriculture related occupations. Effective use of GIS technologies in a way can supplement farmers traditional knowledge gained over centuries of experience with scientific inputs. These scientific tools provide visualizes the actual agricultural environment based on prevailing determinants and will assist these traditional farmers in determining which crops are to be planted/cultivated and to ensure effective growth through proper maintenance of soil nutrients. This interlinking of traditional and scientific knowledge of mankind will result in better crop management, increased productivity thus restoring farmer's confidence in agriculture through enhanced profits.

This marriage of tradition with scientific knowledge is a 'boon' for the small and marginalized farmers who comprises about 80 percent of the global population and is regarded as marginalized or vulnerable community. Application of Geomatics through the adoption of GIS techniques empowers the farming community to analyse and predicts future fluctuation based on precipitation, temperature crop output etc. periodic corrective steps can be initiated without any lag that can ensure sustained productivity levels.

4.4 Agriculture Mapping in Kuttanad:

Wetland ecosystem is the most sensitive and the productive ecosystem of the world as it sustains life to more than thousands of wide and varied species. Wetlands can be found at varies levels of topography like coral reefs, mangroves found nearby the seashore, swamps near the rivers etc. Wetlands that are nearer to the deltaic regions are regarded as the most vulnerable as it is not able to withstand the human pressure under the guise of development. Moreover, the development that is happening in the upstream area has also adversely affecting their existence (Barker and Maltby, 2009).[1] Wide and varied climate changes in the form of frequent droughts, storms, floods, and irregular precipitation are adversely affecting these sensitive[12] environments. Hence it had caught the attention of researchers, planners and policy makers to device strategies to protect these fragile regions. Like any other geographical region in the world, India can also boast of having a sizeable number of designated wetlands, amounting to 37, which are regarded as the Wetlands of International Importance under the Ramsar Convention. Ramasar Convention advocates for international cooperation for supplementing national action for the conservation of wetlands and advocating sustainability through the wise use of resources. Though these conventions put forward a bleak picture, yet the wetland count in India is to the tune of 37 sites with a total surface area of 1,067,939 hectares.

The Wetland Ecosystem of Kuttanad comprises of 64 panchayats spread over Alapuzha, Kottayam and Pathanamthitta is dominated by agriculture sector. Out of these 64, majority of the panchayats (32) is in Alapuzha district while Pathanamthitta has only 5 panchayats. As Kuttanad lies at the mouth of deltaic region of Vembanad Lake, it is regarded as the most fertile region for the cultivation of rice. But the only defect we observed is that the soil is regarded as acidic as the region was once regarded as a heavy forest area. Along with rice cultivation, other popular agriculture practices that is popular in this region area plantain cultivation, cattle rearing, fishing etc. toddy tapping, shell mining and clay mining are also popular in these regions.

But with the over eager to sustain the productivity levels, the agriculturalists are using heavy doses of fertilizers and pesticides. The pollution gets aggravated during the monsoon and other rainy seasons as this area is situated two to three meters below sea level and hence one can witness of inflow of water rather than outflow. The Thanneermukkom saltwater barrier along with other unscientific constructions like roads had also restricted the flow of water made this part of the region into a ‘cesspool’ of pesticides. Hence this study observed that the problem faced by Kuttanad region is as follows.

- Fertilizer and pesticide pollution due to the excessive dependence on high yielding varieties.
- Resultant excessive growth of alien species of waterweeds and plants in the water bodies that choke the supply of the oxygen and devoid the native from an alternate means of livelihood.

[1] Maltby Edward and Tom Barker (2007) The Wetlands Handbook published by John Wiley and Sons, United Kingdom

- Subsequent decline of shellfish and prawns which was also a means of livelihood.
- Excessive growth of alien species had restricted the natural flow of the river and resulted in the occurrence of various waterborne and microbial diseases.
- Unscientific construction of water ways and canals also adversely affected the natural flow of river in this part of the world.
- Increase in the development activities in these areas also resulted in the illegal sand mining on a large scale that also mar the natural flow of the river.
- Popularization of tourism as an alternate means of livelihood also aggravated the pollution levels in rivers, canals, and other water bodies.
- Lack of scientific sanitation facility also resulted in large scale dumping of human waste into the water bodies which also affected the drinking water source.

Hence the only source that can sustain life in this area is agriculture and allied activities which are affected by frequent floods due to the climate change phenomena. Hence this study will try to analyse the various aspects related agriculture as a means of livelihood.

Agriculture Mapping – Change in Land use Pattern: Nature of the economic activity of a particular region determines the land use pattern of the area. Hence for analysing the extent and direction of economic activity, we had undertaken an in-depth analysis of the land use pattern in the selected panchayats of the study area. The study area comprised of Kainakary, Kavalam, Nedumudi, Pulinkunnu, Champakulam, Veliyanad, Ramankary and Edathuva Panchayaths belonging to Champakkulam and Veliyanadu blocks.

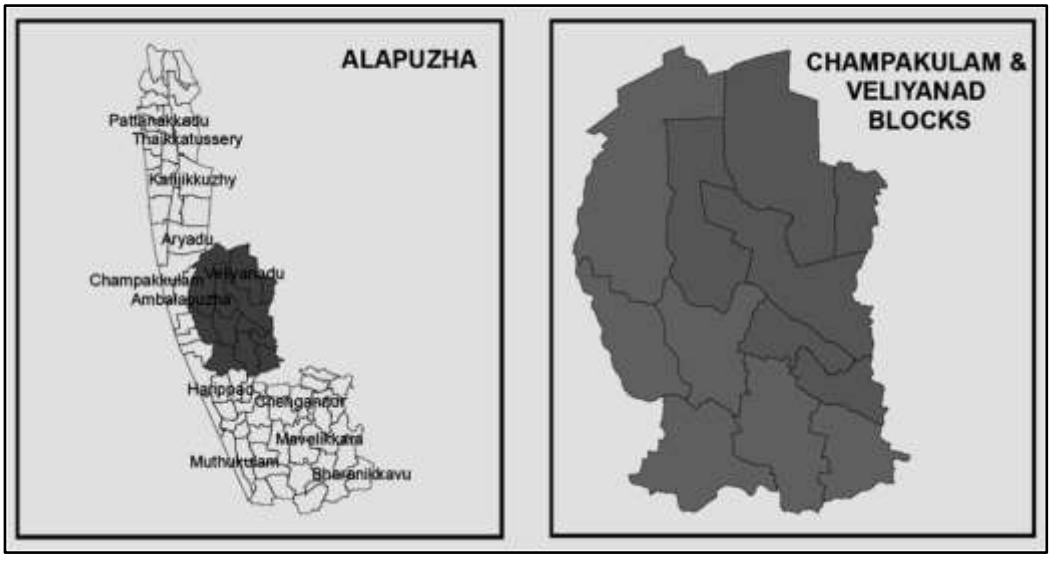


Figure 4.1: Graphical Representation of the Study Area

Source: Analysis undertaken by Syamlal G.S and Manu V, GIS Consultant

From the picture given above, it can be observed that the heart of Alapuzha comprising the important blocks of Champakkulam and Veliyanad are selected for this study.

It can be observed that majority of the land is used for cultivation of agriculture crops like paddy and the buffer zone is maintained through a sizeable land area categorized as fallow land. The innumerable number of streams and canals along with other water bodies ensure that sufficient water is provided to this agriculture land for undertaking effective cultivation practices.

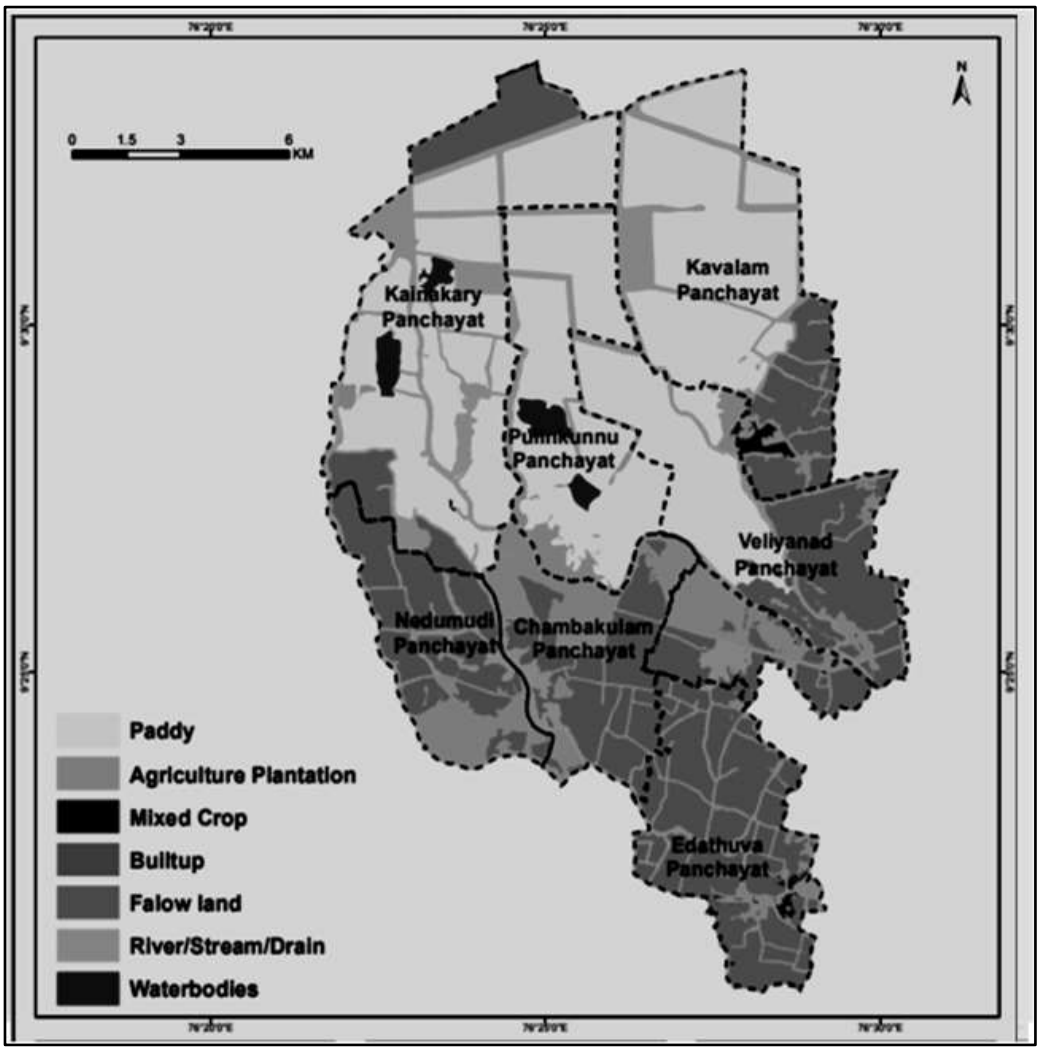


Figure 4.2: Landuse Pattern in the Study Area (Year 2003)

Source: Analysis undertaken by Syamlal G.S and Manu V, GIS Consultant

But by the year 2018, we can see a shift in the agriculture practices in this area. On a careful perusal of the area, it can be observed that there is a shift of population from agriculture to aquaculture due to various climatic related changes which had eroded the profitability of agriculture. This shift is clear from the picture given below. The shaded portion in blue colour conveys the amount of shift towards aquaculture, while the yellow portions that is shaded conveys the shrinking of agriculture occupation in the 'Rice Bowl' of Kerala.

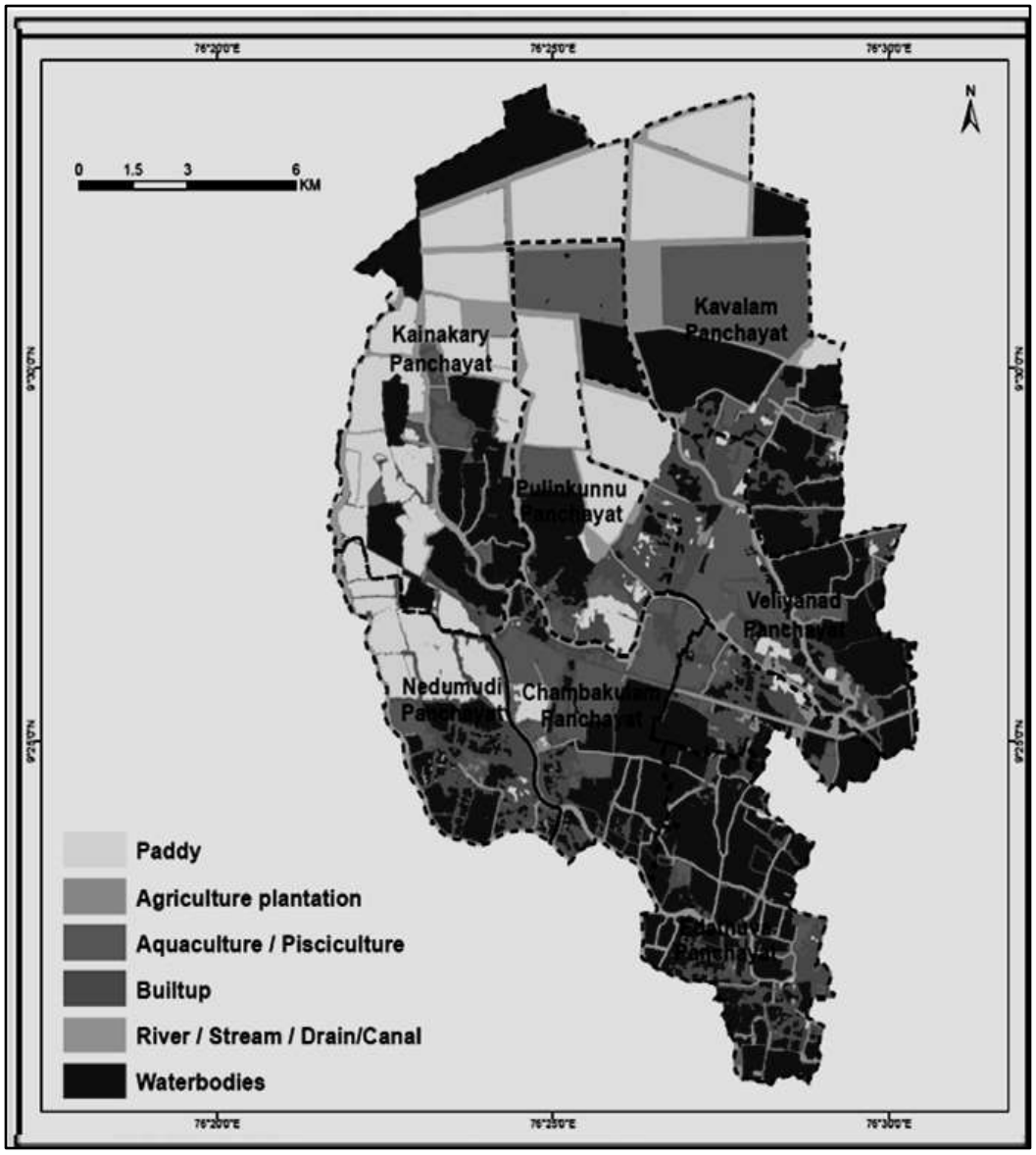


Figure 4.3: Landuse Pattern in the Study Area (Year 2018)

Source: Analysis undertaken by Syamlal G. S. and Manu V, GIS Consultant

Agriculture Mapping – Intensity of Rainfall:

Intensity in the rainfall determines the lives and livelihood pattern in a particular geographical area.

As the most popular occupation in the area is agriculture, it can be inferred that this area is prone to sufficient rainfall as the most important requirement for cultivation of rice is standing water.

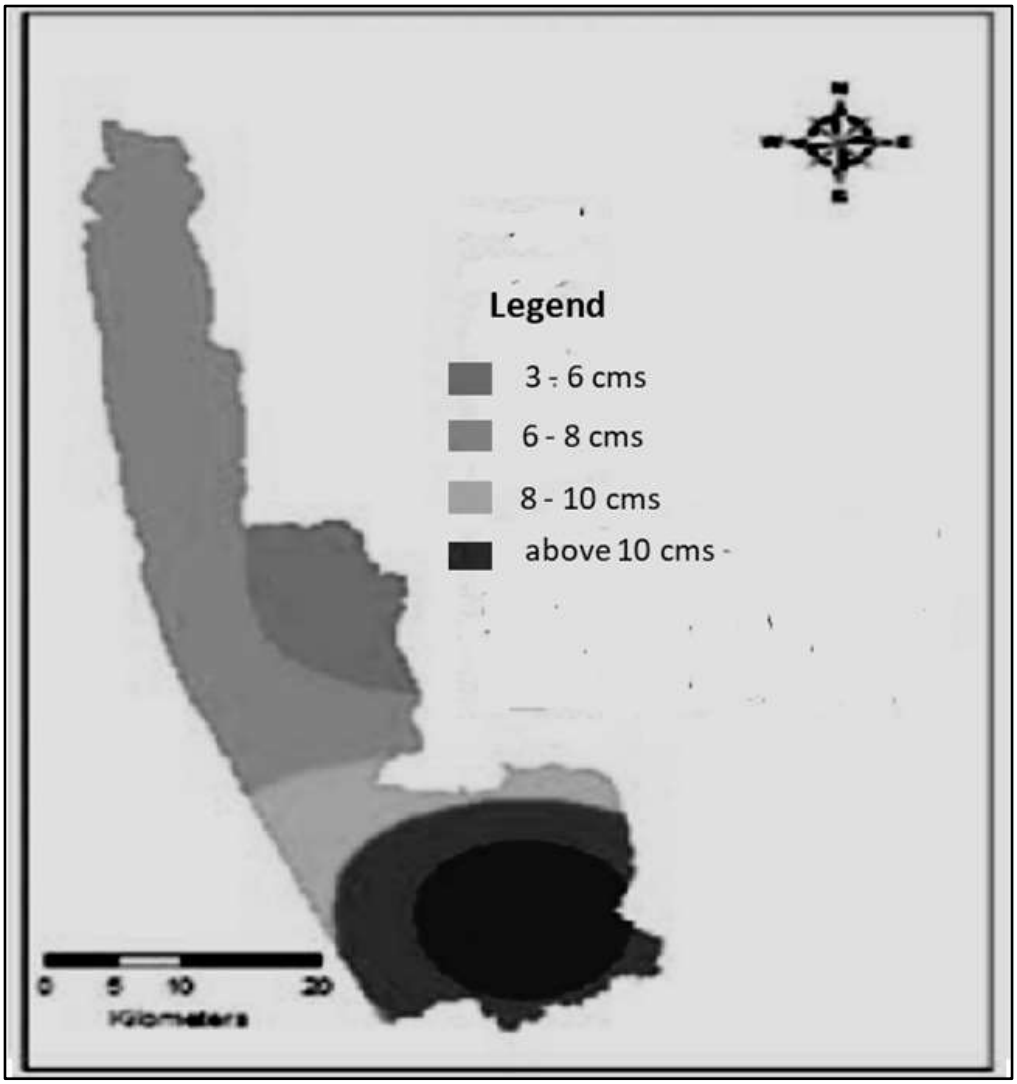


Figure 4.4: Rainfall Intensity in Kuttanad and Adjoining Panchayats

Source: *Analysis undertaken by Syamlal G.S and Manu V, GIS Consultant*

From the above picture Kuttanad and its adjoining panchayat can boast of having sufficient rainfall ranging from 3-10 cms that are sufficient to popularize agriculture as the most important occupation in the area.

Agriculture Mapping – Flow Accumulation: Flow accumulation can be regarded as the best tool for analyzing the frequent climatic changes in agriculture sector especially with regard to below sea level farming. Through a scientific analysis with Digital Elevation Model (DEM) using the Hydrology toolset from the Spatial Analyst toolbox of Arc GIS was used to derive the flow accumulation map in Kuttanad and adjoining areas. For deriving the exact picture of the study area, Alapuzha district is taken into consideration as majority of the region selected falls in this district.

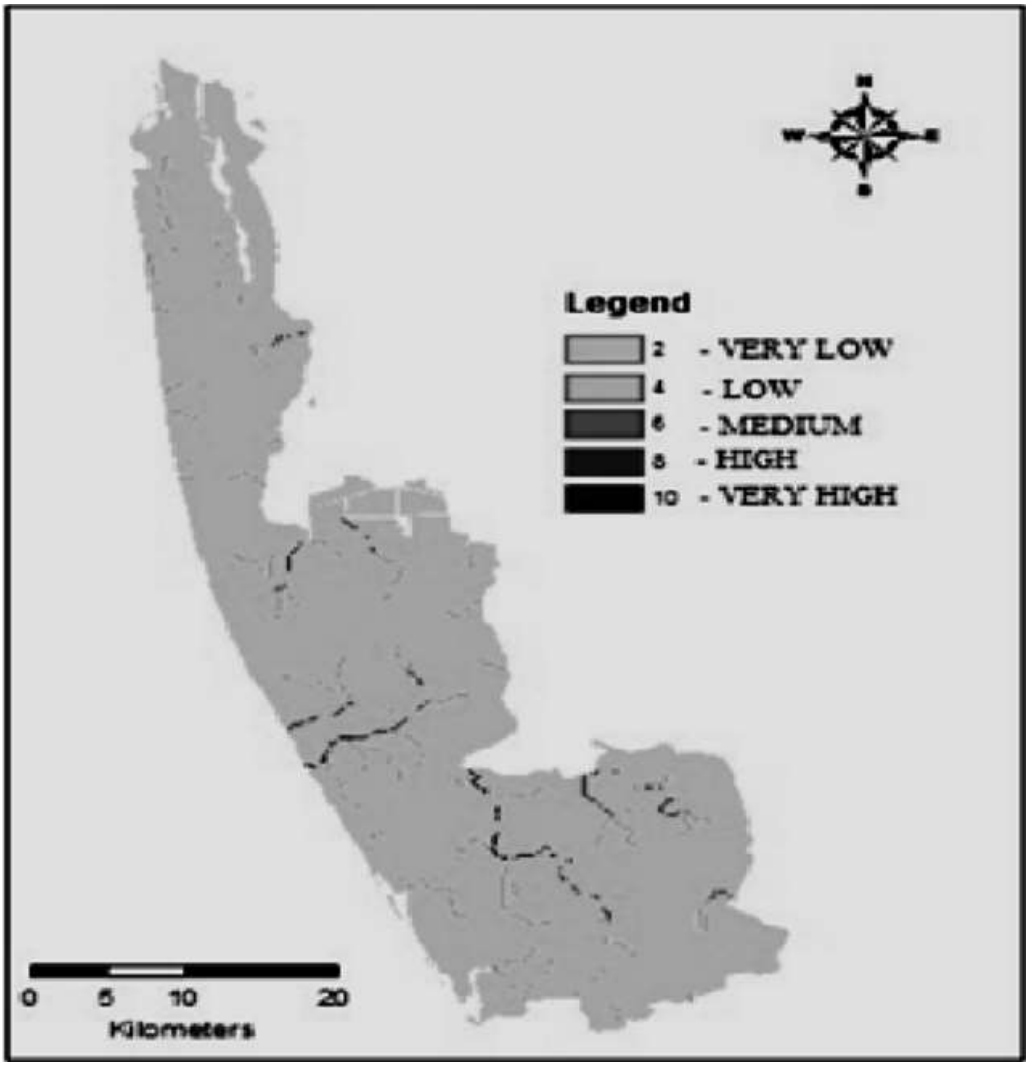


Figure 4.5: Flow Accumulation in Kuttanad and Adjoining Panchayats

Source: *Analysis undertaken by Syamlal G.S and Manu V, GIS Consultant*

As the Kuttanad region is formed out of slow and steady geographical evolution, it can be observed that the area exhibits feature of a smooth slope devoid of any deformities except in the periphery areas to restrict water flow.

Hence the area ought to be regarded as non-flooding region and hence it will be able to withstand the usual rains observed in this part of the world.

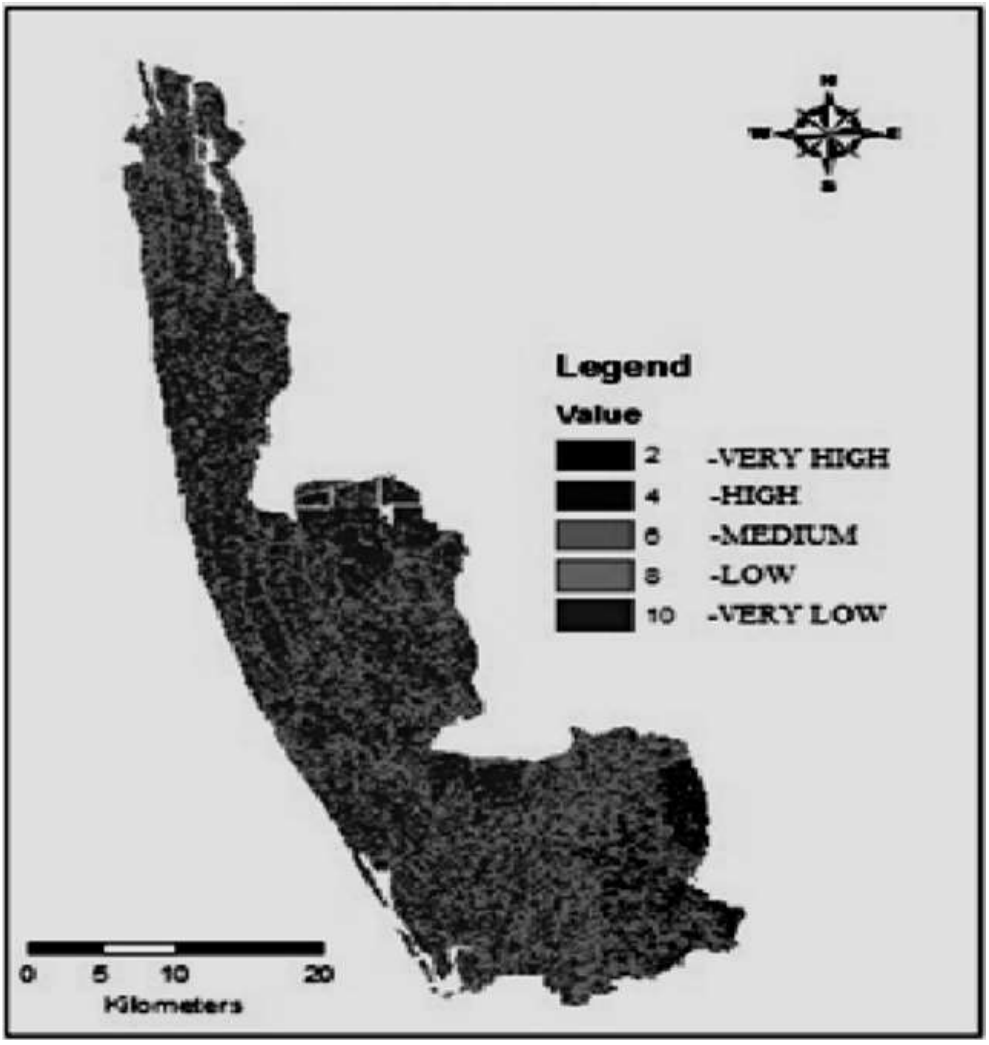


Figure 4.6: Slope of Kuttanad and Adjoining Panchayats

Source: Analysis undertaken by Syamlal G.S and Manu V, GIS Consultant

Agriculture Mapping – Slope Map: From the Slope Map, Researchers can identify the incidence of flooding. It can be observed that the slope map derived from Arc GIS conveys that Kuttanad and the adjoining areas are evenly sloped with minimal possibility of flooding.

Agriculture Mapping – Soil Map: Geographical studies and other excavations undertaken in this area convey that this area was once a forest land with sufficient plant growth. Researchers are of the view that the soil is highly acidic due to the presence of toxic salts in the form into acidic sulphates (Mathew et al., 2004) because of the heavy presence of decayed matter (Ajay Kumar et al., 2008). These sulphates, through capillary action especially during the dry seasons or even when the water levels rise, water seeps into the plant nodules and adversely affects its growth.

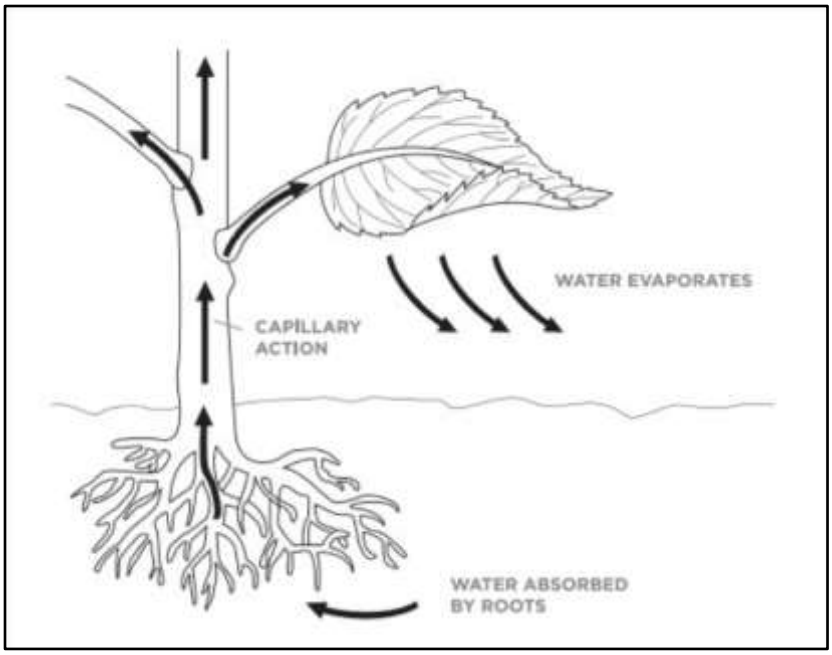


Figure 4.7: Soil Acidity and Capillary Action

As per the official records of Kerala Soil Health Information System (KSHIS), Government of Kerala, the soils found in Alapuzha district are Sandy loam, Sandy soil along with Clay loam with much acidity. The spread of these soils among various regions in the district are as follows.

Table 4.1: Details of Soil Types in Kuttanad

Type of Soil	Regions
Sandy Loam	Karthikappally and parts of Mavelikkara talukas
Sandy Soil	Cherthala and Ambalapuzha talukas
Clay Loam with acidity	Kuttanad, Chengannur and parts of Mavelikkara talukas

Source:
http://www.kerenvis.nic.in/WriteReadData/UserFiles/file/District%20wise%20Soil%20Types%20in%20Kerala.pdf

The pictorial description of the soil types is shown in the diagram given below where one can clearly observe that the coastal like in Kuttanad, one can observe the presence of coastal sandy soils.

The study depended on the secondary sources (Kerala Soil Health Information System) to get an insight regarding the soil reaction and pH values. As per the data, it can be observed that most of the soils, about 69 % are strongly acid to moderately acid where the pH value ranges between 4.5 to 6.0.

When the soil becomes too acidic, certain vital nutrients like phosphorous becomes less active that are essential for plant growth and productivity.

Moreover, high acidic values neutralize bacterial growth and certain elements like aluminium and manganese rather than supplementing plant growth and productivity levels, takes toxic forms.

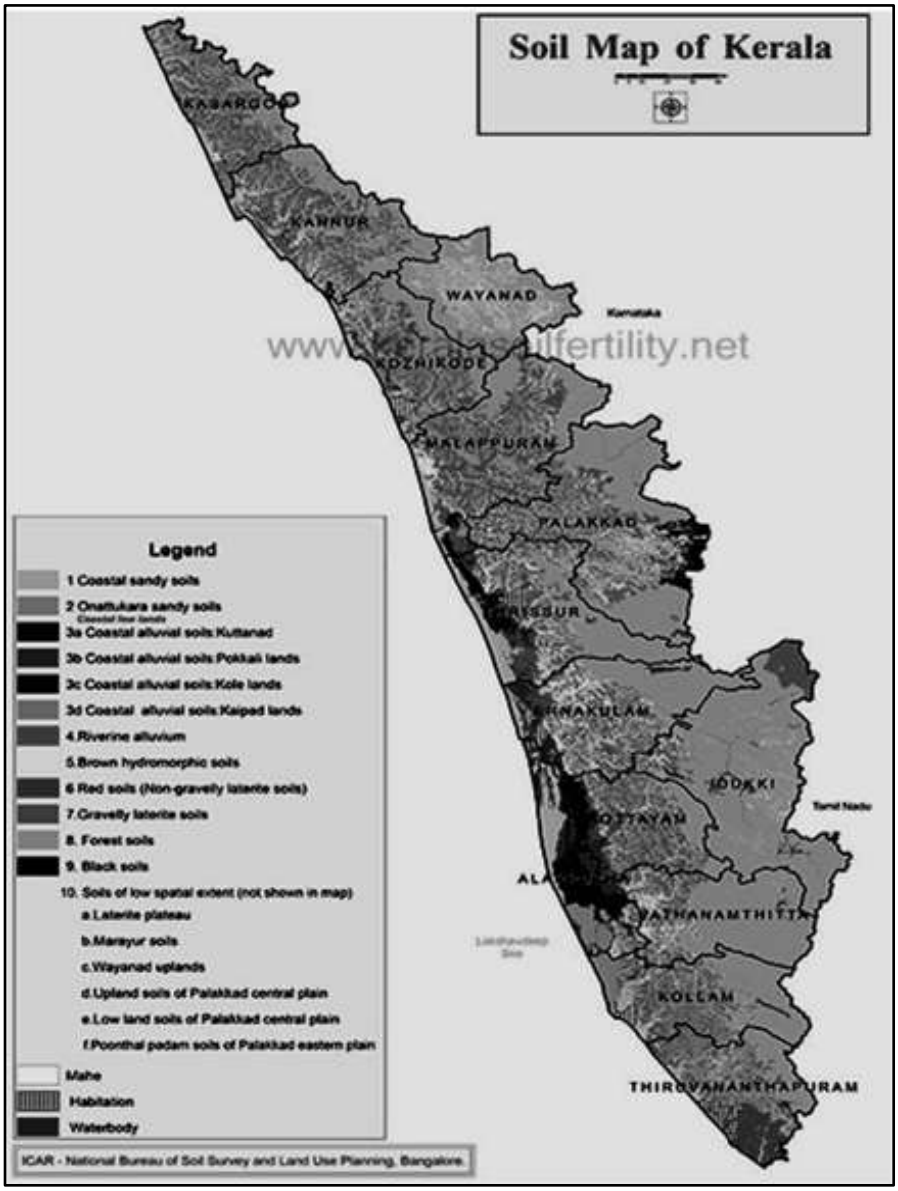
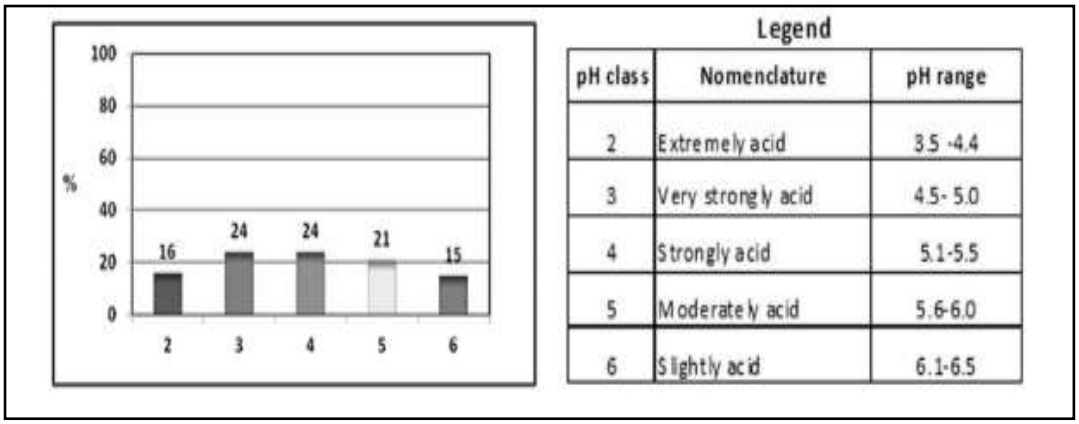


Figure 4.8: Soil Map of Kerala

Source: Kerala Soil Health Information System



Legend

pH class	Nomenclature	pH range
2	Extremely acid	3.5 -4.4
3	Very strongly acid	4.5- 5.0
4	Strongly acid	5.1-5.5
5	Moderately acid	5.6-6.0
6	Slightly acid	6.1-6.5

Figure 4.9: Soil Reaction Levels in Kuttanad

Source: Kerala Soil Health Information System

From the data source provided by Kerala Soil Health Information System, it can be observed that the soils in the study region had high carbon levels along with high phosphorous levels. The presence of high carbon levels in the agricultural lands of the Kuttanad region is a positive sign that even after periodic mono-cropping in these areas, the carbon levels or the organic carbon matter had not depleted. Drastic change in the availability of soil organic carbon (SOC) will not only affect fertility and productivity but will also result in the enhanced emission of greenhouse gas[2]. Hence it can be opined that the agriculture fields in the Kuttanad region had not adversely affected the greenhouse gas emission of this part of the world.

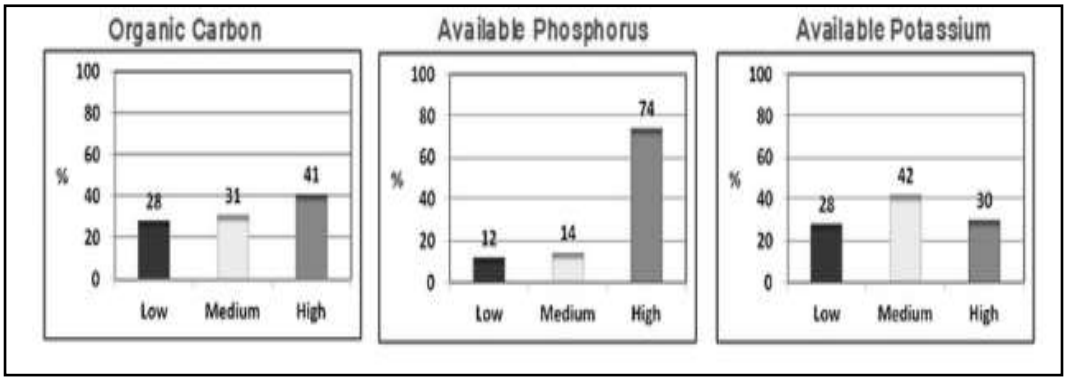


Figure 4.10: Major Nutrient Levels in Soils of Kuttanad Region

Source: Kerala Soil Health Information System

[2] https://www.hindawi.com/journals/tswj/2013/546750/

4.5 Conclusion:

Based on the scientific analysis with the used of GIS tools it can be concluded that though there is a decline in agriculture activities in the 'Rice Bowl of Kerala', yet it can be concluded that the increased agriculture activities had not adversely affected the emission levels with respected to various greenhouse gas.

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Chapter 5

Transition to Low Carbon Economy

5.1 Need for a Transition:

Climate change is expected to intensify and will create innumerable number of problems in all productive sectors. This is more critical in agriculture and allied occupations due to its peculiar nature like excessive dependence on forces of nature like rains and other climatic factors, inequality in distribution of land and other resources, limited access to credit and other financial support systems by the farmers, lack of integration of research and development into real time agriculture activities etc. Recently we are witnessing an increase in temperature, heavy rains, and floods along with erratic rains coupled with other climate changes is adversely affecting life and livelihood in many parts of the world especially the developing countries. As majority of the population is linked to primary and other allied occupations, such scenarios will jeopardise the growth and development of these regions. The only solution is to shift from a carbon centric production process to a carbon neutral production strategy.

5.2 High Carbon to a Low Carbon Economy:

It can be opined that there exists a strong relation between Climate change and agriculture related activities. All the output derived from this sector is derived from the plants and hence this sector can be regarded as the main source of carbon dioxide (CO_2). As the plant grow, the dried and dead plants will fall into the ground which then becomes part of the earth crust due to a slow decaying process. During the process of decaying, the dead plants, leaves and other plant materials release methane (CH_4) into the atmosphere. Both the CO_2 and CH_4 can be regarded as most important Greenhouse Gases (GHGs) that adversely affect the carbon levels in the atmosphere.

As per the research studies undertaken, it can be observed that GHGs can be regarded as any atmospheric gas that absorbs and re-emits heat thus making the planet's atmosphere warmer and sustains life on earth. Out of these GHGs, the most important are - water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone.[1]

5.2.1 Livestock and Climate Change:

An important component that is vital in the agriculture related productive activities is manure. In traditional societies, as a part of doubling the income and to enhance their earning, the agriculturist used to rear cattle, goat, poultry etc. Cow dung is regarded as the by-product of livestock which was used as manure for all the agriculture operations.

[1] https://ecometrica.com/assets/GHGs-CO2-CO2e-and-Carbon-What-Do-These-Mean-v2.1.pdf

Based on the studies conducted all over the world, we are of the view that the Cattle Wealth of India or rather Kuttanad can be effectively used in restoring vital soil nutrient essential for plant growth and to achieve agriculture practices. Cow dung can boast of having healthy bacteria content which will assist in the agriculture process through enhancement of nutritional levels and sustaining plant growth.

Table.5.1: Emission Levels of Various Agricultural Inputs

Greenhouse Gas	**Global Warming Potential (GWP)**
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide(N_2O)	298
Hydrofluorocarbons (HFCs)	124 – 14,800
Perfluorocarbons (PFCs)	7,390 – 12,200
Sulfur hexafluoride (SF_6)	22,800
Nitrogen trifluoride (NF_3)	3 17,200

Source: IPCC - 2007

5.2.2 Chemical Fertilizers and Climate Change:

The peculiarity of paddy cultivation is 'mono cropping' which means a single crop is cultivated in a greater number of times in the same piece of land. Based on our research it was observed that majority of the farms are over 30 years old and to sustain agriculture, the fertility of the land should be enhanced by adding liberal doses of fertilizers. The popular fertilizer that is used among the famers is NPK. Based on the data provided by IPCC, the emission levels of the important fertilizers are shown in Table: 5.1.

Due to various human activities like agriculture, burning of fossil fuels, waste water from household and industries results in the increase in the nitrogen levels in the atmosphere. It is even stated by researchers that a one pound of N_2O is 300 times more harmful than one pound of carbon dioxide.[2] Nitrous Oxide is emitted when the human beings get involved in agriculture operations as they are expected to employ liberal does of nitrogen to ensure productivity. Along with this, for transportation of food grains they depend on fossil fuels like petrol and diesel and the harmful smoke from the exhaust contains enough harmful N_2O. Farmers also depend on various synthetic products as agriculture implements which also uses nitrogen as an important component. Hence the only solution for sustainability irrespective of sectors under consideration is to depend on non-conventional sources for mobility of men and materials. For agriculture practices there is an urgent need for a shift from nitrogen/carbon centric production activity to an organic centric production activity.

[2] https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/TBI_nitrogen_cycle.pdf

5.2.3 Nitrogen Loss, Cost Escalation and Climate Change:

As explained earlier, the proportion of NPK, the most popular fertilizer in Kuttanad is 7:5:6. This proportion conveys that there is excessive dependence on nitrogen which when compared to Indian Standards is very high. Moreover, the prevailing ecology in Kuttanad comprises of many water bodies which will result in excess fertilizer (nitrogen) seeping into the water bodies. Erratic occurrence of rains also further causes various ecological disturbances. This seepage of costly nitrogen fertilizers will not only drain the financial resources of the farmers at their disposal but is also harmful to the environment. So, the study is of the view that proper farm management practices should be adopted under the guidance of Agriculture Scientist to limit the excessive dependence on poisonous N_2O.

5.2.4 Soil Acidification, Erosion and Climate Change:

Lack of effective agriculture management practices will result in adverse effects on the ecology of Kuttanad. Farmers based on their intuition are adopting a very high proportion of NPK in their farms. As a result of this surplus deposition of nitrogen in the atmosphere will create ammonium ions that will finally result in soil acidification. Soil acidity is measured based on pH scale that measures from 1 to 14. From the Illustration – 4.2, it came be observed that the acidity levels of majority Kuttanad Soil ranges from strongly acidic to very strongly acidic and even to extremely acidic. If the soil is acidic, water will be eroded through it and results in high soil erosion. If water is eroded from the roots, then the plants even can die. So, the general trend in Kuttanad to adopt excessive fertilizer and water should be discouraged. They should be educated regarding effective agriculture management practices and the long-term benefits of it. Such a strategy for Effective Management Practices should be quickly adopted to limit erosion in Kuttand and to restore the confidence of agriculturist.

5.2.5 Water Consumption and Climate Change:

As a part of increasing efficiency in agriculture operations, farmers need reliable and sufficient sources of water supply. Hence it can be opined that 'Water Security' is an important component not only for sustaining agriculture operations but also to maintain life on earth. Earlier it was the crop nutrients that hampered agriculture operations, but now it is the other important components like nitrogen, water, salt etc that is going to adversely affect the agriculture operations in Kuttanad. Scientist observed that nitrogen in the form of chemical fertilizers can supplement plant growth, but the excessive dependence on nitrogen supplements had resulted in destruction of the ecosystem.

5.2.6 Marine Wealth and Climate Change:

Another important issue faced by Kuttanad is the contamination of water bodies including ground water table through fertilizer run-off. Such a process is known scientifically as eutrophication that results in the accumulation of algae on the water surface. As and when the alga dies it sinks to the bottom of the shore and finally decomposes. These dead or decomposed algae consume the dissolved oxygen which is very indispensable for the existence of marine life.

As a result of this farmers are of the view that at times they saw dead fishes floating on the water surface that point towards lack of effective agriculture practices in Kuttanad. To sustain livelihood of the fishing community that had integrated into the ecosystem of Kuttand, efforts should be initiated to discourage excess use of chemical fertilizers and to achieve a transition to organic fertilizers which are not only ecologically friendly, but carbon neutral as well.

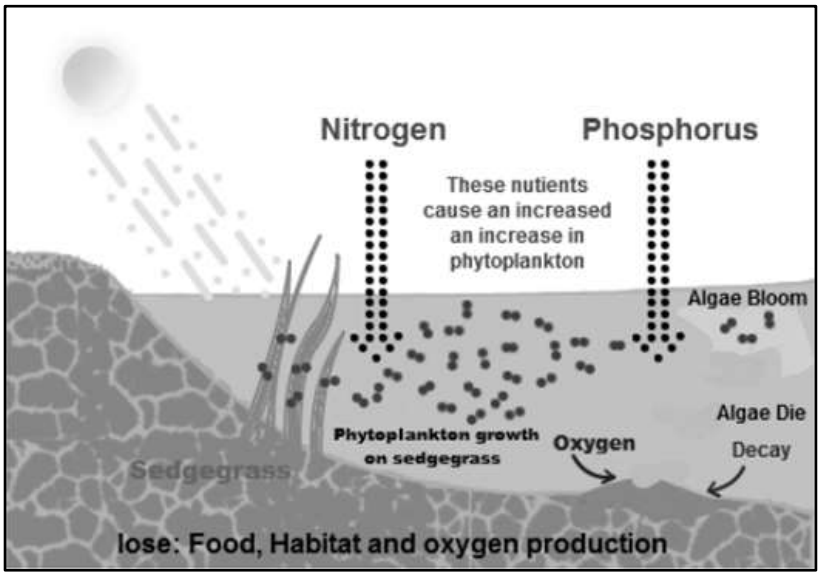

Figure 5.1: Fertilizer run-off and Eutrophication

5.2.7 Need for Value Chain Analysis and Climate Change:

The norm with respect to Climate Change Analysis is that it generally focuses only on production mode only and ignores various other related components. Another important component that needs serious attention is the value-chain analysis especially with respect to climate change analysis in developing or less developed countries where most farmers are small and marginal ones. They need support to enhance access to input markets, assistance, and guidance in achieving diversification and value addition along with final marketing support. Climate change strategies can be adopted in each stage of these value chain components.

At the input and production stage, strategies for supporting climate-smart value chains include the following: improving access to input markets, supporting diversification and value addition, provision of climate-smart production technologies, dissemination of climate information services, and making financial and insurance services available. At the harvesting, processing and marketing stages, useful interventions would include strengthening farmer organization, investing in climate-proofed infrastructure including roads and facilities for storage, processing and improving access to output markets. Finally, climate-change adaptation along the value chain would be improved by strengthening existing institutions, exploring public-private partnerships and adopting coherent local policies.

5.3 Development of Policy Formulation:

Based on this research study we are putting forward certain suggestions that can aid in effective policy formation which will ensure effective participation not only the rich farmers bit also the small and marginal farmers as well.

5.3.1 Local Level Periodic Analysis of Nitrogen Foot Print:

Through the initiation of Local Level Analysis of Nitrogen Foot Print, farmers can be given a clear insight regarding the amount of nitrogen pollution resulting from his activates. As these traditional farmers who prefer to undertake agriculture operation respecting the rules and regulations of mother earth, they all will be whole heartedly cooperating in this endeavour. Through these activities, we will not only able to pass on the information regarding the reduction in the use of nitrogen but will also be able to involve them in climate protection initiatives at the local level.

5.3.2 Local Level Periodic Analysis of Carbon Foot Print:

Through the local level analysis of carbon emission, a farmer along the other stake holders will be calculate the amount of greenhouse gases emitted by him. These initiatives will not only open new avenues for financial savings but will also make his produce eco-friendlier in nature.

5.3.3 Local Level Periodic Analysis of Methane Foot Print:

It is also suggested that others GHGs should also be effectively monitored to ensure that local level strategies are strengthened to achieve global level agenda of Climate Change. Farmers are used to supplement the chemical fertilizers with decayed materials of plants in their locality. Strategies like biogas plants should be devised or adopted by farmers to regulate the emission of poisonous methane gas in the atmosphere. Government and non-governmental agencies through the incorporation of subsidies scheme should encourage farmers to incorporate biogas plants in their respective fields and to be part of green development programme.

5.3.4 Initiation of Climate-Smart Agricultural Value Chains:

To make the agriculture sector more sustainable, climate- smart agriculture value chains are needed that will play a proactive role in adaptation and mitigation strategies. The impact of value chains is different in different crops as some of the perishable agriculture products produced destroys while transporting from one place to another. Many R and D centres in India like the University of Agricultural Sciences (UAS), Bangalore, had developed hybrid variety of paddy - KRH-4 requires only less water than compared to other varieties.[3] As per the recent report, Government of India had developed 41 varieties of rice and 22 varieties

[3] https://www.thehindu.com/news/national/karnataka/farmers-opt-for-paddy-variety-that-needs-less-water/article4108970.ece

of wheat that require less water for irrigation[4]. Such climate-smart varieties not only save input cost but also provide more yield as well. Government should incorporate various types of extension and demonstration projects through which the local farmers in Kuttanad will also shift towards this climate smart technologies.

5.3.5 Improvement in Crop Insurance Coverage:

Report of the Committee to review the implementation of crop insurance schemes in India under the Chairmanship of Dr. P. K. Mishra, Ex-secretary, Department of Agriculture and Cooperation revamped the crop insurance scheme in India and introduced the Pradhan Mantri Fasal Bima Yojana (PMFBY). Now the coverage includes losses on account of prevented sowing due to deficit rainfall or adverse weather conditions, yield losses due to non-preventable risks, post-harvest losses, localized calamities and specified add-on covers.

Though the new scheme had taken into consideration various components of climate change, yet farmers are apprehensive because of issues related to claims assessment, settlement and quantum of support. The Insurance programme ought to be made effective during these adversities through the effective incorporation of information technology and smart phones in coverage and assessment, quick and easy settlement of claims, strengthening the distribution network of the insurers and intermediaries etc.

5.3.6 Adoption of Eco/Green Labelling:

For an effective participation of all the stakeholders in addressing the climate change phenomena, the study suggests the incorporation of Eco/Green Labelling. Through this method, policy makers can empower the consumers to make their purchase decisions based on the environmental performance and ecological sensitiveness of the product under consideration.

They also can assist in developing the Government Procurement policies giving due importance to climate change. This can be regarded as the best and prudent policy without any undue pressure on the financial exchequer or on political hurdles.

5.3.7 One India One Carbon Tax:

For further enhancing the climate change programmes in India, it is suggested that India must focus on carbon-taxing as an instrument for its carbon mitigation strategy and meeting the targets envisaged under the Millennium Development Goals (MDGs). It is estimated that there are 26 carbon tax system prevailing among developed and developing countries. Government of India should first identify the sectors that can be covered under the carbons tax and should adopt a Progressive Carbon Taxing System which will encourage market participation in an effective manner.

[4] https://economictimes.indiatimes.com/news/economy/agriculture/india-develops-low-water-consuming-varieties-of-rice-wheat/articleshow/9943353.cms

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