PLANNING FOR SUSTAINABLE DEVELOPMENT TO BUILD RESILIENCE IN THE KUTTANAD WETLAND REGION – A CASE OF ALAPPUZHA

THESIS REPORT

Submitted by

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M. Plan (2021-2023) BATCH

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in

Urban Planning

DEPARTMENT OF ARCHITECTURE
THANGAL KUNJU MUSALIAR COLLEGE OF ENGINEERING
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DECLARATION

I hereby declare that the Project entitled **"Planning for sustainable development to build resilience in Kuttanad Wetland Region – A Case of Alappuzha"** is a bonafide record of mine carried out under the supervision of **Dr.Annie John,** Head of the Department of Architecture. I declare that the work reported here in does not form any part of any other project report or thesis based on which a degree or award was conferred on an earlier occasion to any other candidate. This study is done as a part of the fourth semester M. Plan (Urban Planning), Post Graduate Degree Course in the Department of Architecture, Thangal Kunju Musaliar College of Engineering, Kollam.

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CERTIFICATE

This is to certify that the thesis report **"Planning for sustainable development to build resilience in Kuttanad Wetland Region – A Case of Alappuzha"** submitted by **Arundhathy S** (TKM21MUP006) of MUP (2021-2023) Batch, in fulfillment of the requirements for the fourth-semester final examination in Thesis, under the **APJ Abdul Kalam Technological University** is a bonafide work carried out under our guidance and supervision.

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Dr. Annie John

HEAD OF THE DEPARTMENT
Dr. Annie John

INTERNAL EXAMINER

EXTERNAL EXAMINER

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ABSTRACT

One of India's most susceptible wetlands regions is the Kuttanad region. The area is one of the few in the world where farming is practiced between 1.2 and 3.0 meters (4 to 10 feet) below sea level and has the lowest altitude in the entire country of India. There is a sensitive and closed marine eco-framework at Kuttanad. The improvement of the environment has harmed ecology. Stream floods, environmental factors that elevate ocean levels, and other problems that have a detrimental influence on the region's lives, health, and economy have significantly harmed its propensity. Planning carefully for resilience is necessary to reduce these problems. Increased risk exposure in wetland zones is a result of urbanization as well as the beginnings of climate change, which has led to a rise in the frequency and severity of natural disasters. Increased resistance to these challenges is the most practical approach to bettering urban planning and management. Promoting sustainable development would raise the region's quality of life and increase its resistance to climate change and natural disasters.

The major goal of this study was to identify vulnerabilities while taking into account socioeconomic, physical, and geological elements to establish a resilient planning strategy for the Kuttanad region. The approach for determining the most vulnerable region was examined, and case studies were received to understand how to create resilience in wetland areas using natural methods. The study identified the most vulnerable location in the Kuttanad region of the Alappuzha district using the adaptive resilience index approach. The most vulnerable area in Kuttanad and the region with the lowest adaptive resilience score is Neelamperoor, which is followed by Pulikkunnu and Ramankary village. The development of sustainable, efficient, and effective region-specific adaptation and resilience plans for the site is aided by identifying the most susceptible areas in Kuttanad.

Keywords: Climate change, Vulnerability assessment, Adaptation, Resilience

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AC	Adaptative ability
ACI	Adaptive capacity index
ADB	Asian Development Bank
ANERT	Agency for New and Renewable Energy Research and Technology
DDI	Disaster Deficit Index
EI	Exposure index
FAO	Food Agriculture Organisation
GIS	Geographic Information System
GIAHS	Globally Important Agricultural Heritage System
IAY	Indira Awas Yojana
IPPC	Intergovernmental Panel on Climate Change
KLDC	Kerala Land Development Corporation
LSGD	Local Self Government Department
MSSRF	MS Swaminathan Research Foundation
MSME	Micro, small, and medium-sized enterprise
NAS	National Adaptation Strategy
Nbs	Nature based solutions
NEPP	National Environmental Policy Plan
NGO	Non government organization
PACS	Primary Agricultural Credit Societies
PMAY	Pradhan Mantri Awas Yojana
PM KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan
RUP2021	Resilience for the Urban Poor Forum 2021
RKVY	Rashtriya Krishi Vikas Yojana
RIDF	Rural Infrastructure Development Fund
Ri I	Intrinsic resilience index
Ri	Intrinsic resilience
RFTR	Room for the River
SEZ	Special Economic Zone
SDG	Sustainable Development Goal

SDCC	Sustainable Development and Climate Change Department
Sv	Factors of survival
TCI	Transformational capacity index
TC	Transformational capacity
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nation Environment Programme
UCCRTF	Urban Climate Change Resilience Trust Fund
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND STUDY

One of India's most vulnerable wetlands areas is Kuttanad, a wetland region. The region is one of the few in the world where farming is performed between 1.2 and 3.0 metres (4 to 10 feet) below sea level and has the lowest height in the entire country of India. There is a sensitive and closed marine eco-framework at Kuttanad. The effects of environmental improvements on the ecosystem have been negative. Stream floods, environmental factors that elevate ocean levels, and other problems that have a detrimental influence on the region's lives, health, and economy have all had a significant impact on its tendency. Planning for resilience is crucial to reducing these problems.

Rising risk exposure in wetland regions is a result of urbanisation as well as the frequency and severity of natural disasters brought on by the start of climate change. The capacity to resist and bounce back from unforeseen shocks brought on by natural disasters and climate change is resilience. Enhancing urban planning and management is the most efficient way to address building resilience to these hazards. Promoting sustainable development would increase the region's resilience to natural disasters and climate change in addition to raising the standard of living there.

1.2 NEED OF THE STUDY

- The Kuttanad wetlands area is one of India's highly vulnerable wetlands area.
- Two or three times a year, severe floods in Kuttanad disrupt daily life.

Figure 1:1:Flood occurred in 2018
Source: Data from Kuttanad taluk office

- Due to the extreme climatic change, Kuttanad's population growth has slowed down over time. The general development of the area will be impacted by this.

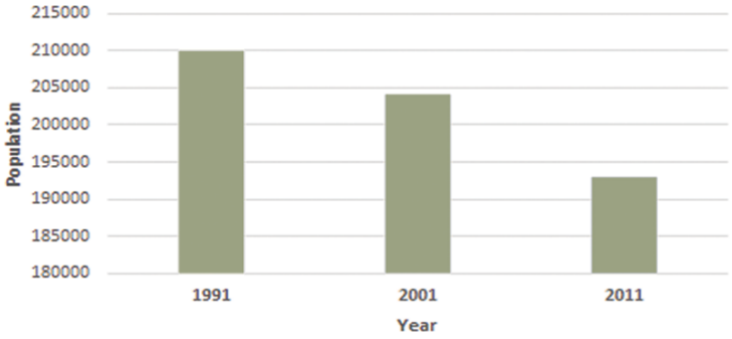

Figure 1:2: Population trend over the years
Source: Data collected from Census, 2011

- The migration rate in Kuttanad is higher in these times due to climate change and lack of infrastructure development. It was observed that 4588 families which is 10% of the total population migrated to new places and some people are abandoning their houses.

Figure 1:3: Abandon house in Kuttanad
Source: Photos were collected from taluk office

- A decline in paddy area is brought out by statistical analysis of the land use map between the four decades of 1973 and 2014, 100.6 sq. km of wetland paddy fields were reclaimed into uplands.

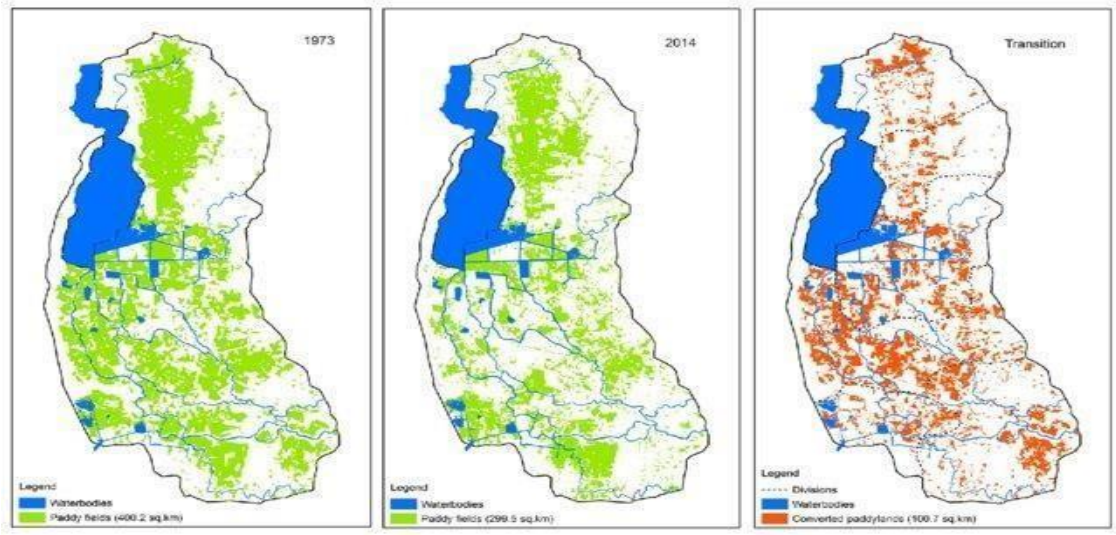

Figure 1:4: Paddy field distribution in Kuttanad delta in (a) 1973, (b) 2014 and (c) transition map
Source: (K.G. Sreeja, 2021)

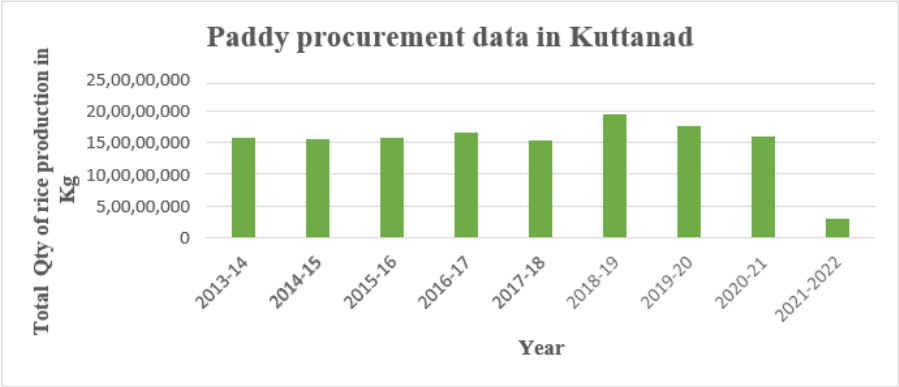

Figure 1:5: Paddy procurement data in Kuttanad (2013-14 to 2021-2022)
Source: Data obtained from agricultural statistics department, Alappuzha

- Since the Kuttanad region lies below sea level, it is susceptible to seawater intrusion because of the sea's rising level, which is thought to be caused by climate change. If the hazard is not sufficiently addressed, any rise in the amount of carbon in the air will eventually cause an increase in atmospheric temperature.
- The study aids in the discovery of fresh approaches to resilience planning that assist the residents of Kuttanad in ensuring better living conditions.

1.3 RESEARCH QUESTION

What kind of sustainable planning can be done in Kuttanad region for building resilience ?

1.4 AIM

To prepare a development plan for building resilience in the Kuttanad region in a sustainable way.

1.5 OBJECTIVES

- To study the resilience concepts in wetland regions.
- To study the existing situation of Kuttanad and identify issues and potentials.
- To study vulnerability concept and analyse the vulnerability assessment in the Kuttanad region.
- To prepare a development plan for building resilience in the Kuttanad region.

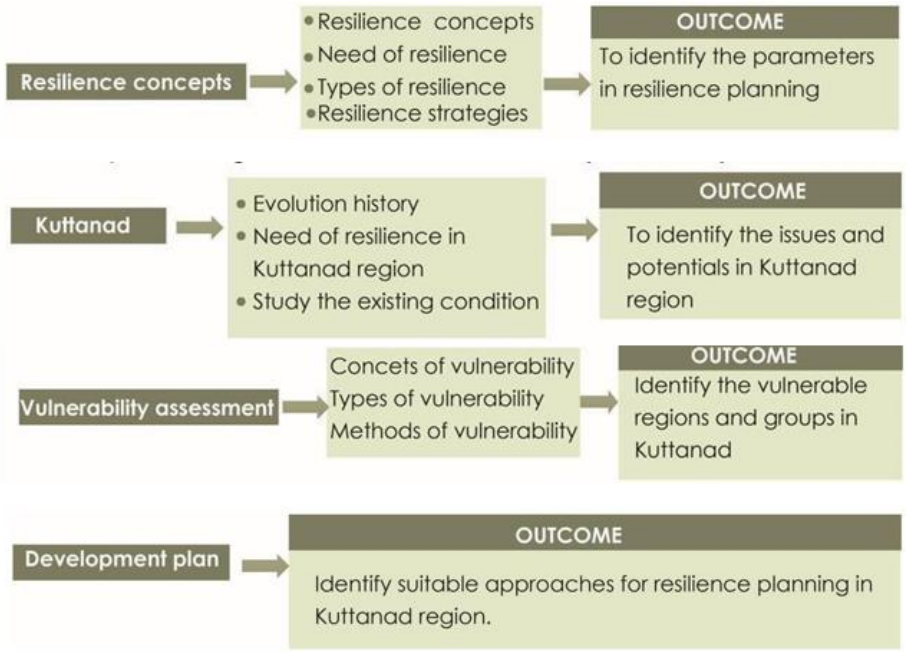

Figure 1:6: Objectives and respective tasks

1.6 OUTCOMES OF THE STUDY

The overall goal of the development plan is to improve agricultural productivity, adaptive capacity and livelihoods of smallholders to climate and economic changes by building resilience.

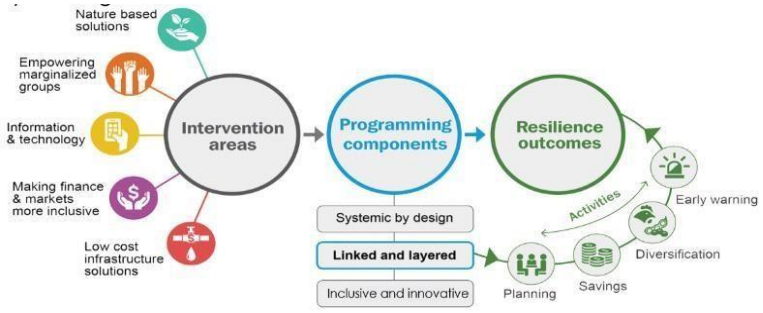

Figure 1:7: Graphical representation of resilience outcomes in planning
Source: (Resilience Insights, 2022)

1.7 METHODOLOGY

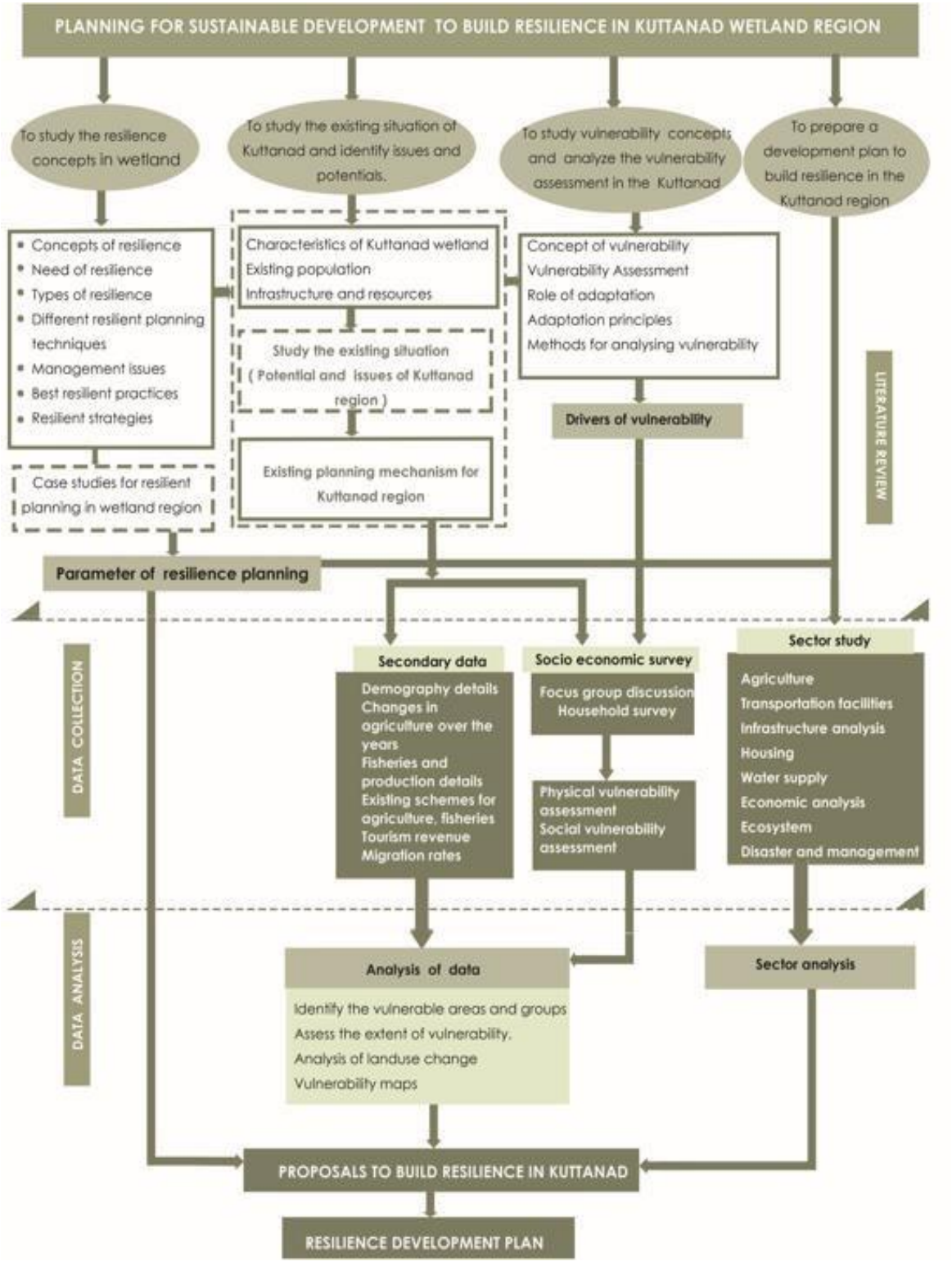

Figure 1:8: Methodology

1.8 SCOPE OF THE STUDY

- The study helps to identify various resilience planning possibilities in the Kuttanad region and improves their living conditions.
- It also helps to revitalize the region's overall development by planning the integration of all sectors.
- This study helps to build community resilience in the most vulnerable groups.
- Resilience is a central concept which helps in policy frameworks dealing with developmental, social, economic, and environmental problems in ways that clearly cross traditional disciplinary boundaries.

1.9 LIMITATION

The scope of the study is restricted to the 14 villages in Kuttanad wetland region in Alappuzha district, and it only looks at resilience using a variety of dimensions and indicators.

1.10 BACKGROUND STUDY OF THE SITE

1.10.1 KUTTANAD WETLAND REGION

Kuttanad is a part of a huge estuarine region from Kayamkulam Lake to Kol Lands including the longest Vembanad Lake, occupying four districts. Uniqueness of this wetland is that its larger part is located down to 2.6m below MSL. Six rivers feed the estuary from south and east. A unique ecosystem is supported by the round the year hydrological dynamics. Kuttanad has 1,10,000 ha area, of which 50 % is reclaimed and 88 % is under agriculture. Kuttanad wetland is located at the southern portion of India’s largest Ramsar site in the Vembanad-Kole wetland. Kuttanad is primarily a deltaic formation of five river systems: Meenachil, Pamba, Manimala, Muvattupuzha and Achencovil, located in the fertile low-lying areas of Vembanad Lake. The wetland is characterised by intersecting canals below-sea level paddy cultivation and a dense population (700 persons per square kilometre). Total 225 taxa of birds belonged to 15 orders 59 families were identified from Kuttanad wetlands (Neelakantan, 1996). Most of the land birds were seen at the eastern boundaries of Kuttanad, where Kuttanad wetlands meet midland areas of Kerala. Kuttanad is a region covering the Alappuzha, Kottayam, and Pathanamthitta districts in Kerala, India. Compared to Kerala's Kole wetlands, the Kuttanad wetland exhibits a higher species variety, particularly among wetland birds. The main threats to bird survival include pesticides, habitat modification, hunting, and cutting down nesting trees.

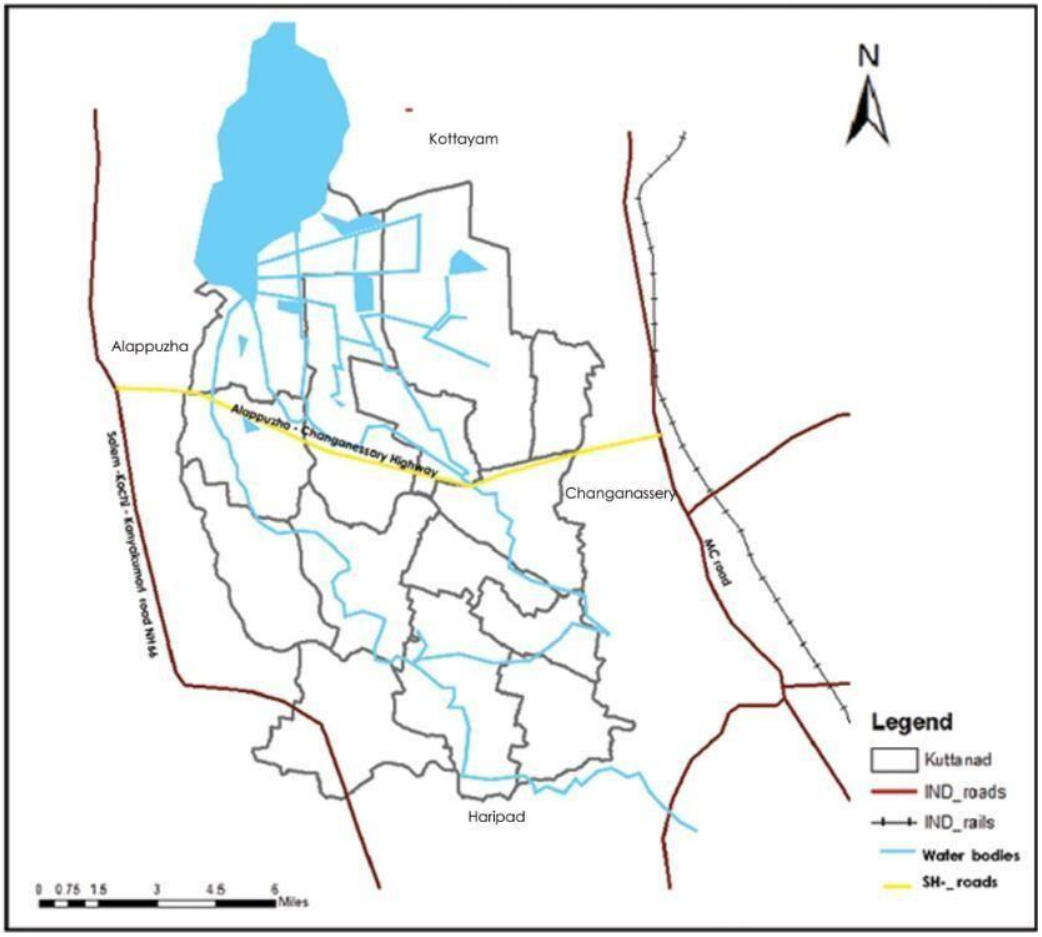

Figure 1:9: Base map of Kuttanad
Source: Arc GIS

According to mythology, the Kuttanad region was previously covered with forest, but after a forest fire decimated, it was given the nickname Chuttanad, or the burnt spot. If we delve deeply into the soil in Kuttanad, we can still see Kari or coal, indicating that the area was previously a forest that was destroyed by wildfire. It is stated that Chuttanad eventually changed to become Kuttanad. Kuttanad is recognised by history as an area that belonged to the Chera dynasty, who ruled over ancient Kerala at the time. Cheran Chenguttavan, one of the dynasty's well-known monarchs is claimed to have ruled his sizable kingdom from Kuttanad. At the time, the location was also a well-known Buddhist centre. Thus also known as Buddhanad, which may have evolved into Kuttanad in the past. Lower, Upper, and North Kuttanad are the three main divisions of the overall Kuttanad region. Famous villages that make up Kuttanad include Kainakary, Ramankary, Chennamkary, Nedumudi, Kumarakom, Edathua Kavalam, Pulinkunnu, Kidangara, Muttar, Neerettupuram, Thalavadi, Champakkulam, Payippad, Karichal, Cheruthana, Karuvaatta, Narakathara, Mamkompu, and Thayankary.

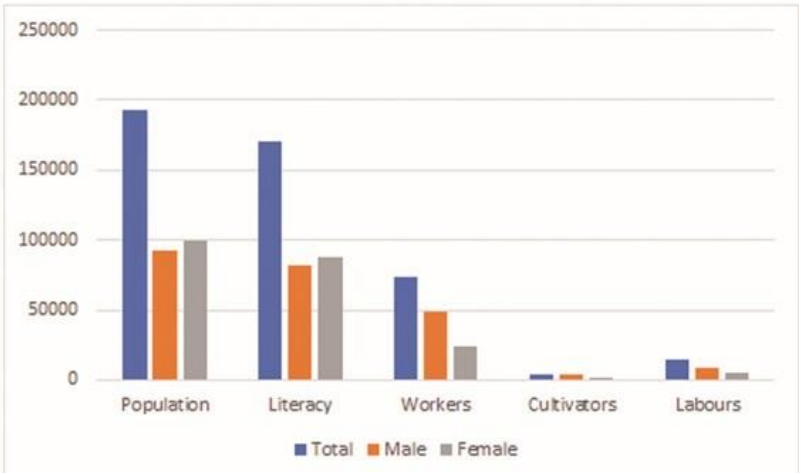

Figure 1:10: Illustrations of the population, literacy, and labor-producing households in Kuttanad
Source: Data collected from Census, 2011

The Kuttanad population chart is a graph that shows the distribution of all demographic groups, Literacy percentage is 88.21%, out of these 42.54% is male literates and 45.67% is female literates. Total Workers percentage is 37.88%, out of these 25.48% is male workers and 12.40% is female workers. Total Taluk Agriculture farmers percentage is 2.20% in Kuttanad, out of these 2.05% is male farmers and 0.15% is female farmers. Kuttanad labour percentage is 7.59%, out of these 4.80% is male labour and 2.78% is female labour.

Table 1:1: Demographic details of Kuttanad

VILLAGES	POPULATION (2011)	MALE	FEMALE	HOUSEHOLDS
Muttar	9200	4437	4763	2264
Thalavady	20556	9767	10789	5250
Edathua	21699	10378	11321	5468
Thakazhy	15758	7469	8289	3858
Nedumudi	14601	7049	7552	3668
Champakkulam	15848	7636	8212	3932
Ramankary	10755	5187	5568	2611
Veliyanad	12501	6025	6476	3041
Neelamperoor	5841	2858	2983	1421
Kunnumma	14252	6961	7291	3420
Kavalam	13089	6433	6656	3142
Pulikunnu	15210	7368	7842	3652
Kainakary South	15405	7364	8041	3770
Kainakary North	8292	4081	4211	1919

Source: Data collected from Census, 2011

History demonstrates ongoing and expanding human involvement in this distinctive ecosystem through a variety of endeavours, Kuttanad Development Scheme being one of them. The Vembanad lake serves as the primary source of livelihood in the Kuttanad region providing reclaimed ground for paddy agriculture, fishing, tourism, etc. However, numerous disputes have arisen in the area as a result of numerous human interventions and bad management. The State government approved the Kuttanad Development Scheme (KDS) which primarily comprises of three elements to address the fundamental problems of this wetland system.

1. Thottapally Spillway

The Thottappally spillway was built as the initial phase of Kuttanad's development and work on it began in 1951. The construction of a spillway at Thottapally for the quick drainage of flood water to the Arabian Sea is the result of efforts to find a long-term solution to the problem of floods and crop loss in Kuttanad. The Pampa, Manimala, and Achenkoil river's excess flood water was intended to be flushed into the sea by the spillway in order to prevent Kuttanad from flooding. However, saltwater intrusion through the spillway has turned into a constant worry for the local farmers due to poor installation, administration, and up keep. Flood control has not been significantly improved by the spillway's completion.

2. Thanneer Mukkam Bund (A salt-water barrier)

The Thaneermukkam Bund was built in 1955 to stop sea water intrusion into the paddy fields. However, due to inadequate planning, management, and implementation only in the eastern and western portions of the iron shutters were finished leaving the centre section unfinished. The bund has been effective in avoiding saline intrusion during the summer, but its incomplete construction slowed the flood water passage during the monsoons causing serious alterations in the ecology. The iron shutters of the bund have been a source of dispute between farmers and fishermen since 1976. The fisherman have been protesting against it and are now backed by several farmer groups. Environmentalists argue that the closure of the regulator has caused significant degradation and modification of the Kuttanad wetland ecosystem leading to stagnant water and industrial effluents, human, animal, and agricultural wastes being dumped into the system.

3. Alappuzha Changanassery road

The third component was the 24 km long Alappuzha to Changanassery road that was built in 1957. The route of this road runs through the heart of Kuttanad. The low-lying flood plains were later crossed by a number of roadways and bunds. This has caused floods in the area by

obstructing the flow of water. The development of tourism, contemporary farming methods, the need for freshwater by the local people and the disposal of municipal waste into Vembanad and the rivers feeding it have all contributed to an increase in conflicts over time. Additionally, these actions had a negative influence on the region's overall ecology, agricultural output, fishing, fresh water needs, public health and hygiene, etc.

1.10.2 HISTORY OF HUMAN INTERVENTION IN KUTTANAD WETLAND ECOSYSTEM

The Kuttanad region was once a part of the Arabian Sea's shallow coastal region; as a result of a geological uplift, a shallow bay was created into which several rivers discharged; the silt deposited at river mouths gave rise to the present delta; and the shallow bay eventually transformed into a lake-lagoon backwater system opening on to the Arabian Sea through the Kochi bar mouth. This area was referred to as "Chuttanadu," which is Hindi for "burned land," hence the name Kuttanad. The entire region has the appearance of a dense forest, rich in organic waste and locally known as "kari" or burned wood logs. Locally referred to as karappadam, kayal, and kari lands, Kuttanad deltaic formation is categorised according to elevation, geological formation, and soil characteristics.

The Kuttanad region experienced land reclamation in the late 19th century, including the Moncompu Rice Research Station, an agricultural workers union, and the Thottapally Spillway. The 24 km long link road between Alappuzha and Changanassery was finished in 1957 for easy communication and transportation. The whole area was converted to high yielding dwarf varieties in the 1960s. The Thottappally spillway was commissioned in 1965. The Lands Reforms Act was signed into law in 1970, making it one of the major landmarks in the history of Kuttanad. In order to carry out the first Kuttanad Development Project, the Kerala Land Development Corporation Ltd. was established in 1972. The Thanneermukam regulator was established in 1975 and "Bhadra" rice was first made available in 1989. The outbreak of epizootic ulcerative syndrome and Japanese encephalitis in Kerala had its beginnings in Kuttanad, which saw the introduction of group farming in 1991. A series of initiatives were suggested by the M.S. Swaminathan Research Foundation in 2007 to lessen agrarian hardship in the Alappuzha & Kuttanad Wetland System.

CHAPTER 2 LITERATURE STUDY

This chapter includes the roots of the study which discussed on the basic concepts of resilience planning and its need in Kuttanad wetland region. It also focuses the study of various vulnerability assessment tools. This chapter also discusses the various types of resilience and the study of various resilience strategies for mitigating the effect of climate change.

2.1 CLIMATE CHANGE IN KUTTANAD

The Kuttanad wetland system, which is a portion of the Vembanad wetland system, is renowned for the cultivation of paddy on land made by draining delta swamps in brackish waters at a depth of one to two metres below sea level. The area is praised for its picture-perfect backwaters, lagoons, and canals as well as the resilient character of its inhabitants in the face of adversity. But still, as they deal with the devastating effects of climate change, the inhabitants of Kuttanad, who inhabit 62 grama panchayats in Alappuzha, Kottayam, and Pathanamthitta, are currently most concerned about recurrent floods, torrential downpours, and the incursion of saline water from the sea. (Paul A, 2022). In addition to CO_2 emissions from fuel wood, other gas emissions such as SO_2, NO_X, and even methane from rice fields are also contributing to the climate change in Kuttanad. The Kuttanad region is also characterised by background radiation that naturally occurs from the thorium-rich coastline and spreads throughout the entire wetland system, but its effects on the greenhouse effect have not yet been well studied and quantified. The Kuttanad region is also below sea level, making it susceptible to seawater intrusion due to the sea's rising level, which is thought to be caused by climate change. If the hazard is not sufficiently addressed, any rise in the amount of carbon in the air will eventually cause an increase in atmospheric temperature (perhaps by roughly 10^0C in the next 50 years or even less) (*IRTCBSF*, 2022).

A delicate and closed coastal eco-system exists in Kuttanad. The climatic changes have had severe consequences on its ecosystem. River flooding, sea level rise caused by climate change, and other factors have severely harmed the environment. This has caused wetlands to change and caused coastal erosion, flooding, and frequent storm events. It is anticipated that saline infiltration into fresh water aquifers in the state's coastal region would increase.

2.2 RESILIENCE PLANNING

Recent years have seen an increase in the use of the term "resilience" to describe how cities and communities can prepare for disasters and reduce their vulnerability and risk to both natural and man-made risks. Building resilience is a key step in achieving the 2030 Agenda for Sustainable Development, and the UN system plays a key role as a coordinator of many actors working together to reduce the systemic risks that have been carefully woven into the operation of our society (UN, 2020). Resilience is defined by the United Nations General Assembly as the capacity of a system, community, or society to withstand, absorb, accommodate, and recover from a hazard in a timely and effective manner, including through the preservation and restoration of its fundamental basic structures and functions (Walker et al. 1969; Holling 1973). Resilience is defined by the Resilient Cities Network as the ability of people, communities, organizations, enterprises, and systems within a city to endure chronic stressors and abrupt shocks while adjusting and growing is known as resilience.

The adaptability of the natural and social systems is a crucial sign of sustainable development. The system's capacity to adapt to change and create long-term well-being for people and places are some traits that closely identify resilience (Bhamra, 2015). Any urban system's measurable capacity to maintain continuity while constructively adapting and developing in the direction of sustainability together with its population. (*Resilience and Risk Reduction | UN-Habitat*, n.d.)

Resilience is the ability of individuals, families, communities, cities, institutions, systems, and societies to foresee, resist, absorb, adapt, respond, and recover in a way that doesn't jeopardize the long-term prospects for sustainable development, peace and security, human rights, and everyone's well-being (UN, 2020). The ability of a system to withstand any disruption and return to its initial state is known as resilience. The concept of ecological system resilience was created by Canadian ecologist C. S. Holling to explain the persistence of natural systems that have been repeatedly altered by human activities over the past several centuries (Kiran Kumar S, 2022). As a result of climate change's effects such as rising sea levels, there is an increasing need for environmental protection and conservation. Extensive land clearing, commercial agriculture, and related practises endanger the sustainability of natural resources. Intensifying efforts to adapt and mitigate the consequences of climate change as well as incorporating disaster risk reduction into national and sectoral planning are all made

possible by using financing for the environment and climate (*Resilience and Sustainable Development | United Nations Development Programme*, n.d.)

Resilience planning allows for the identification of potential risks and hazards followed by the development of plans for adaptation, mitigation, and recovery. In the face of potential pressures and shocks, a system that is striving for sustainability will show resilience. Different people with different experiences and working in different sectors have different ideas about what the term "resilience" means when it comes to climate change, natural disasters, infrastructure, emergency management, economic development, health and education, and the environment among other things. In the context of planning, it is an essential characteristic of the administrative structure to support the growth of sustainable communities, places, and people. The framework provided by planning for place enables the many government organisations, governance frameworks, companies, and communities that contribute to building resilient communities to come together and understand the advantages, disadvantages, and values of that site. It is possible to balance, coordinate, and situate social, cultural, economic, environmental, and built interests to satisfy regional needs and goals.

Figure 2:1: Components of Resilience
Source: Resilience planning | Planning. (n.d.). Planning. https://www.planning.nsw.gov.au/policy-and-legislation/resilience-and-natural-hazard-risk/resilience-planning

Building resilience impacts various industries and governance structures including planning and design, infrastructure, emergency management, economic development, health and education, the

natural environment and heritage, and emergency management (*Resilience Planning | Planning*, n.d.).

2.3 NEED OF RESILIENCE PLANNING IN WETLAND REGIONS

Rapid urbanisation turning wetlands into agricultural land, and water exploitation are draining and destroying wetlands as habitats. These people are overusing and extracting their resources. They are therefore vanishing three times as quickly as forests. Wetland preservation and replenishment are essential for achieving the goals of the Paris Agreement. In comparison to tropical rainforests, coastal wetlands can store carbon up to 55 times more quickly. 12% of the carbon reserve in the world is found in wetlands. Millions of tonnes of carbon dioxide equivalent as well as other dangerous elements like arsenic are released when we drain them. Wetlands make local communities more resilient to extreme weather.

Table 2:1: Terminologies in resilience planning

TERM	DEFINITIONS
Asset	A tangible item of value or something intangible, such as a good name.
Hazard/ Threat	Something that has the potential to cause harm to property, disease, or human mortality.
Impact	Negative impacts caused by a risk or threat.
Risk	The likelihood that a danger or threat will materialize, as well as any potential consequences.
Vulnerability	Vulnerability to the negative effects of hazards and dangers.
Recovery	To reduce the danger to assets and adapt to the environment, actions were taken.
Adaptation	Actions are taken in response to the situation in order to reduce the risk to assets.
Mitigation	Actions were done in an effort to minimize or lessen the danger posed by a hazard as well as its likelihood or severity.

Source: (UNDRR, 2009)

INFERENCE : The Kuttanad region consistently floods each year, and there is a severe scarcity of drinking water, which contributes to tension in the neighbourhood. The ideas for promoting resilient wetland regional development are offered together with these local concerns and problems.

2.4 TYPES OF RESILIENCE

There are various sorts of resilience for a Kuttand region's growth. The key forces behind the growth of the Kuttanad region include climate resilience, economic resilience, social resilience, environmental resilience, ecological resilience, and engineering resilience, among others.

2.4.1 Climate resilience

The capacity to bounce back from or lessen vulnerability to climate related shocks like floods and droughts is known as climate resilience. Both climate change and the deadlock in policy pose a serious ecological threat to Kuttanad, a distinctive wetland complex in Central Kerala. It is a territory that is below sea level and has (UNEP, n.d.) been the subject of extensive research and discussion. Kuttanad is the downstream deltaic formation of five in flowing rivers that have their head waters in the Western Ghats. The two primary issues in this region are flooding brought on by excessive precipitation in the higher catchments of the inflowing rivers and the rise in sea levels caused by global warming. 50,000 houses were fully or partially damaged by the 2018 Kerala floods, which also forcibly evicted residents from their homes and utterly ruined the landscape. In other locations, two lakh people received interim rehabilitation. A total of 10,000 palm trees were uprooted by the floods and 1.5 lakh hectares of paddy were destroyed. Additionally, the people suffered large losses in cattle and poultry. Backwater tourism, the major industry of the area, stopped. Therefore, Kuttanad area has to be resilient to climate change.

2.4.1.1 Methods for measuring Climate Resilience Index

There are two approaches (means) to measure the climate resilience index. The first technique involves changing the sensitivity dimension by modifying the system's internal resistance (survival). The computation of the exposure index (EI), intrinsic resilience index (Ri I), adaptive capacity index (ACI), and transformational capacity index (TCI), under the assumption that the hazard has a value of "1" (one), yields the climatic resilience index (RI). The factors of survival (Sv) and adaptative ability (AC) make up intrinsic resilience (Ri). The inclusion of the transformational capacity (TC) element, which takes into account the roles played by the state and civil society helps to increase future resilience.

Ri I = Sv I*ACI

When adding the transformative capacity, then the equation becomes: **Ri I = Sv I*(ACI+TCI)**

Sv, AC, and TC are positively correlated to climate resilience, while exposure (E) is negatively correlated and the final result of the measurement is calculated by the equation:

RI1 = (Ri I*TCI)/EI

As another alternative or second method, by using sensitivity (S) that is part of the vulnerability, it can be done by developing equation (or VI= SI/ACI) by reversing (vulnerability and resilience are inversely proportional) and add exposure dimension (E):

RI2 = (ACI*TCI)/(EI*SI)

2.4.1.2 Selecting Climate Resilience Indicators

Following are the indicators of climate resilience that were chosen based on each factor's criteria:

Hazard: The possible occurrence of a natural or human induced physical event, trend, or physical impact that could result in fatalities, serious injuries, or other health effects, as well as destruction of property, infrastructure, livelihoods, service delivery, ecosystems, and environmental resources. The term "hazard" in this report typically refers to physical climate-related trends, events, or impacts (similar to the definition of "exposure" in IPCC AR4, 2007).

Exposure: It is the existence of things like people, their means of subsistence, species, or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in contexts where they could be negatively impacted. (New factor in AR5 and not the same as the exposure definition in AR4).

Sensitivity: A system's internal state showing the degree to which it is susceptible to influence (IPCC AR4, 2007).

Adaptation: The process of adjusting to the effects of the current or predicted climate. In human systems, adaptation aims to reduce or prevent harm or take advantage of advantageous chances. Human involvement may help some natural systems adapt to the predicted effects of the climate (IPCC AR5, 2014).

2.4.2 Economic resilience

Economic resilience may comprise a number of steps in order to maintain local employment and carry on delivering goods and services to support the neighbourhood both during and after a stress or shock. (Hallegatte; Stephane, 2014). Economic resilience is an important strategy for reducing expenses associated with disasters (Rose A, 2007). The main source of income for the family is impacted by the flood in Kuttand. It has an impact on the livelihood of those whose sources of income include the agricultural, fishing, and tourism sectors, and it is crucial to

building economic resilience in the Kuttand region to overcome the communities historical economic vulnerability.

2.4.3 Social resilience

One aspect of social resilience is preserving the social fabric, values, and identity that are vital to why people choose to live, work, and play where they do.

2.4.4 Environmental resilience

Environmental resilience may be defined as fostering the ability of the environment to tolerate pressures and shocks and to bounce back quickly from catastrophes. The most upsetting of the issues in the Kuttanad region is the great degradation of the aquatic environment, primarily caused by human participation, which has led to the loss of fisheries resources and health problems for the populace. Environmental sustainability is therefore essential for the development of the Kuttanad region.

2.4.5 Ecological resilience

It evaluates how much disturbance a system can endure before changing the way its components are organized or how its control mechanisms operate.

2.4.6 Engineering resilience

It includes methods for evaluating risks using quantitative standards and determining how quickly a system is anticipated to recover or bounce back after an occurrence. Kerala's physical characteristics are changing due to the climate, making it increasingly vulnerable to flooding and the issues that come with it. More adaptability is required for flood hazard mitigation strategies, calling for the development of unique housing types that promote resilience in the most vulnerable populations. The largest population of Kuttanad, a low-lying deltaic region is impacted by floods every year. For the economically disadvantaged section of this region, a flood-resistant dwelling is an aim. After the devastating property losses caused by the 2018 Kerala floods, it was decided to construct something that would survive with water without hindering its flow. Amphibian housing is a sustainable flood mitigation strategy that coexists peacefully with the flood's natural cycle in flood-prone areas. For the enhancement of the housing and agricultural sectors as well as the consequences of climate change, Kuttanad needs more engineering robust solutions.

2.5 ADAPTATION PRINCIPLES TO BUILD RESILINCE

Climate change has a significant impact on people's lives and means of subsistence in many nations. Since these dangers cannot be completely eradicated, governments must take strong action to support organizations and individuals in managing these risks. To do this, it is vital to plan ahead and put proactive measures into place that not only reduce climate risk but also accelerate growth and reduce poverty. The adaption techniques that need to be created are as follows (*World Bank Group - International Development, Poverty, & Sustainability*, n.d.).

- Provide firm foundations while encouraging rapid and inclusive growth.
- Establish strong foundations while promoting quick and inclusive growth.
- One of the most significant predictors of vulnerability to climate change is poverty and lack of access to essential services like infrastructure, financial services, health care, and social protection. In other words, the likelihood that a community would suffer from the effects of climate change increases with its level of poverty.
- Promote both individual and corporate donations.
- Despite the fact that many people and organizations presently have incentives to adapt, there are still obstacles they must overcome, including a lack of information and finance, behavioural biases, and unstable markets. Governments may enlighten people about climate risks, specify roles and responsibilities, promote creativity and access to cutting-edge technology and ensure that everyone has access to financing, particularly for solutions with high upfront costs. The most vulnerable populations who cannot afford to invest in adaptation will also require their direct assistance.
- Revise land-use plans and protect vital infrastructure.
- In addition to directly assisting people and businesses, governments are obligated to safeguard public investments, assets, and services. Water, power, and transportation losses are thought to cost more than $390 billion yearly in developing nations alone. However, the additional cost of improving the resilience of new infrastructure assets is little, only amounting to about 3% of total investments, if governments have access to the right data, risk models and decision making tools. Since long-term climatic hazards have a substantial influence on considerable private investments in housing and productive assets, it is essential that urban and land use plans adapt to changing long term climatic hazards to prevent people from being stranded in high risk places.

- Facilitating quicker and more efficient recovery for people and organizations
- It is impossible to totally remove all effects and dangers. Governments must create preparations to ensure that people and businesses can survive a disaster without devastating long-term repercussions and can recover quickly. Preparedness reduces losses because to improved hydromet data, early warning systems, and disaster management systems. Shuttering windows, for instance, can reduce damage by as much as 50% before a storm. The benefits of providing everyone with access to global early warning systems have repeatedly been found to greatly outweigh the costs by a factor of at least 4 to 10. Then a key element in assisting organizations and people in getting back on their feet is financial inclusion, which includes access to emergency loans and social protection. In order to cover more people and provide more assistance after a disaster, adaptive social protection systems require delivery and financing mechanisms that must be put in place before a crisis.
- Large scale effect management
- Climate change will have an impact on the financial situation and tax receipts through a variety of repercussions across a wide range of businesses from floods affecting housing values to changes in ecosystems affecting agricultural productivity. Certain effects on significant sectors especially exporting ones can have an effect on a country's trade balance and capital flows. In addition to the current contingent liabilities and debt levels, additional investment is needed for adaptation and resilience, which would further burden the state budget. The stability of the macro economy, the viability of state finances and debt and the larger financial sector could all face new risks as a result of the interaction of these factors. Governments will need to control these risks. The huge uncertainty surrounding macro economic forecasts of future climate change consequences must be taken into consideration while developing strategies to strengthen the economy's resilience.
- Determine priorities based on needs, implement across industries, and monitor outcomes.
- Governments must establish a robust institutional and legislative framework as well as a dependable technique for tracking initiative’s success in addition to prioritising efforts to make sure they are consistent with the capabilities and resources at their

disposal. The major objective of an adaptation and resilience strategy is to make sure that it is adopted by all government departments and public agencies and is mainstreamed into all of their decisions. Governments are also urged to regularly assess the results of their choices and activities in order to rectify any problems and change their plan of action as needed.

2.6 VULNERABILITY ASSESSMENT

Vulnerability is described by the Intergovernmental Panel on Climate Change (IPCC) as a system's propensity or predisposition to experience damage. It includes sensitivity or susceptibility to harm as well as a lack of ability to handle stress and adapt. It is a system's dynamic intrinsic quality. Through vulnerability analyses, it is possible to identify how vulnerable a natural or human system is to the negative effects (or positive effects) of climate change. Vulnerability is influenced by sensitivity, exposure, and adaptation. In contrast to impact assessments, vulnerability assessments recommend adaptive management or policy changes that might lessen (or amplify) their impacts. Most practical vulnerability analyses are "place-based" and designed to focus on a particular resource or system of interest. The management or conservation actions are typically based on these analyses. Vulnerability therefore forms an aspect of risk. To assess the risk, we will focus on the "vulnerability" element in our study. Additionally, vulnerabilities might take many different shapes. Our main concern here is with social flaws. Defining vulnerability in this article, we set it apart from biophysical vulnerability.

Thus, vulnerability is connected to "stability" or "resiliency," which is made up of a system's sensitivity (see table 2.2) and its capability for coping, as well as the exposure to hazards (see table 2.3). Extreme climatic occurrences like floods, droughts, and heat waves are frequently correlated with climatic dangers. Exposure encompasses the degree of the system's influence throughout time and space.

Table 2:2: Vulnerability rating of sensitivity

	Resilience/adaptive capacity	
Sensitivity	High	Low
High	Vulnerable	Very vulnerable
Low	Not vulnerable	Vulnerable

Source: (Birkmann, et al., 2012)

Table 2:3: Adaptive capacity for hazard, exposure

		Adaptive or coping capacity	
		High	low
Hazard	High	low vulnerability	high vulnerability
Exposure	Low	Very low vulnerability	low vulnerability

Source: (L. Engle, 2010)

2.6.1 NEED OF VULNERABILITY ASSESMENT

It is useful to evaluate vulnerability to both the short-term (current) and long-term (future) climate change scenarios. We focus on this part of the evaluation in the present because creating adaptation strategies based on the current assessment of climate sensitivity is a trustworthy and "no-regret" method to lessen current vulnerability and create long-term resilience under climate change. This stage marks the beginning of any vulnerability assessment that aims to reduce risk in the face of uncertainty assessing by evaluating vulnerabilities we can:

1. Identify the system (biophysical and social), the current and recent stresses on that system, and the system's current state. Some of this material may incorporate local or specialized knowledge due to data limitations.
2. Determining the system's sensitivity and resistance to current changes.
3. The likely modifications that could happen as a result of various system pressures.
4. The system's potential effects of these alterations
5. The responses that must be created and put into practice given the system's sensitivity and resilience.
6. The system's desired results.
7. During implementation, monitoring and adaptive management to ensure the path to the targeted goals.

Given the damaged state of many wetlands throughout the world, the strategy described here goes beyond mapping susceptible areas and emphasises the need for designing and implementing solutions that would assist lessen the vulnerability of the system. Numerous obstacles still exist and will need to be overcome:

- Why a wetland's natural dynamics, sensitivity to past and current stresses, potential thresholds, inertia, or lag effects cannot be determined by the absence of geographic and temporal data collected throughout time at appropriate scales. Each of them is a part of ecological character.

- Complexity of the numerous and interconnected influences that frequently have an impact on wetlands (such as changing land use and land cover, climate change, etc.)
- Creating a metric to assess the wetland's susceptibility to the various pressures

2.6.2 DIMENSIONS OF VULNERABILITY

Assessments cover a variety of thematic areas in addition to the main vulnerabilities. Social, environmental, economic, and institutional vulnerability are a few examples of key dimensions of vulnerability. For example, cultural or gender aspects can be used to better define and enhance these dimensions.

1. Social dimension of vulnerability

In addition to individual strength, the social dimension of vulnerability also addresses issues of fairness, social distinction, and societal structure (Adger and Kelly, 1999; Adger, 2006; Birkmann, 2006a, 2006b, and 2006c; Birkmann, 2011b; O'Brien et al., 2008; Few, 2007). In numerous studies, the social dimension of vulnerability has been defined as issues like poverty, social exclusion and powerlessness, demography (vulnerable age groups), social networks, education, health, and well-being; migration and displacement; and risk perception are also increasingly taken into account but are still challenging to measure (Dwyer et al., 2004). Furthermore, (Cannon et al. 2003, p. 5) contend that a person's social vulnerability is connected to a variety of qualities such as their:

• Initial health (nutrition, physical and mental well-being)
• Livelihood and adaptability (resources, income, and qualifications)
• Self-defence (ability and desire to create a safe house and use a safe site).
• Social security (preparation and mitigating actions)
• Social and political networks, as well as institutional environments (such as social capital).

2. Economic dimension of vulnerability

A second group of approaches looks at economic vulnerability as the susceptibility of an economic system or the inability of a system, such as an individual household or a state, to absorb and deal with a specific magnitude of damage and economic loss. On the other hand, economic vulnerability can refer to specific occupational and livelihood patterns and economic assets of households at risk. (Hochrainer-Stigler et al ; Rose, 2004; Mechler et al., 2010; Cardona et al., 2010).

While the latter focuses on a state's, a private organization's, or a household's ability to handle loss and damage as well as business interruption costs, another method looks at how vulnerable various professions and ways of life are to, say, climate changes and specific risks. In this respect, a household's variety of employment may be utilised as a microscale indicator of economic fragility. The underlying theory is that communities that are able to switch to alternative livelihoods and income-generating activities in the face of adverse events may experience lower losses and greater ease in recovering than communities that are heavily dependent on one occupation (for example, farming or fishing).The second school assesses economic vulnerability differently than the first by concentrating on macro economic issues like the economic impacts of a potential disaster on the gross domestic product (GDP), consumption, and the fiscal position (Mechler et al., 2010). Examples of assessments that examine these economic vulnerabilities at the macro economic level are the Disaster Deficit Index (DDI) and the CATSIM model (Hochrainer-Stigler et al.,volume. chapter 20). The Disaster Deficit Index, for example, determines the potential economic loss that a country might incur in the event of a catastrophic event and the implications for the resources needed to address the issue, such as the amount of money needed to compensate and rebuild damaged infrastructure and other items. Cardona and Carreo's Chapter 10 in this volume is where you can find more information. Low levels of income, a low GDP, limited tax revenue, low domestic savings, and a high level of debt with limited access to external financing are only a few of the factors that contribute to macro economic fragility (Mechler, 2004; Seth and Ragab, 2012; Barrito, 2008; Briguglio et al., 2009).

3. The Environmental Dimension of Vulnerability

Environmental vulnerability has received more attention in recent years. Even while the environment is the domain where natural hazards and climate variability originated, it is also a valuable resource for many individuals who are severely exposed to these dangers. The GAR of UNISDR (2009, 2011), as well as the publications of the Partnership for Environment and Disaster Risk Reduction (PEDRR, 2012), emphasize the significance of ecosystem services and function as a modifier of human vulnerability or of the vulnerability of socio-ecological systems. Precise guidelines on how to assess the environmental dimension of vulnerability are still lacking though.

4. The Institutional Dimension of Vulnerability

The capacity or incapacity of (formal) organizations to deal with risks and adaptation challenges is also referred to as the institutional dimension of vulnerability (Adger, 1999, 2000; Lebel et al; Fund for Peace, 2011). The institutional dimension of vulnerability frequently refers to modes and constraints in governance, underlying rules, and norm systems that govern society. A few institutional vulnerability theories also stress the significance of the political economy and, as a result, refer to modes of production or economic regulation (Wisner, 1978). The case for defining institutional vulnerability as a separate dimension is more pragmatic even though many of the concerns included under it may also affect and regulate such as social vulnerability or economic vulnerability. The majority of assessments fall short of adequately assessing governance related concerns as one of their fundamental components. Therefore, addressing institutional issues as a separate vulnerability dimension may aid in the development of better evaluation techniques for determining how various aspects of governance affect the vulnerability of individuals or social-ecological systems.

2.6.3 VULNERABILITY TO CLIMATE CHANGE

The IPCC states that a system's vulnerability is determined by its sensitivity, capacity for adaptation, and the kind, scale, and rate of climatic variation to which it is exposed. A more specific definition of vulnerability includes the three components of exposure, sensitivity, and adaptive capability. The biophysical effects of climate change on ecological systems have been discussed in the literature using the word "exposure." Long-term variations in the mean climate, the intensity and duration of weather events, and the geographical and temporal characteristics of climate variability, such as droughts and heavy rains (temperature and precipitation), all constitute exposure. The degree to which a nation will be vulnerable to global climate change depends on a variety of physical, environmental, economic, and political factors that influence a nation's susceptibility to climate change and its potential for adaptation. Examining the present vulnerabilities, demands, and coping mechanisms of disadvantaged communities is vital for adaptation and mitigation plans to be effective, taking important factors like gender equality into account (ADB, 2009).

2.6.4 ASSESSING VULNERABILITY IN COMMUNITIES

Any resilience-strengthening initiative needs to be based on a comprehensive assessment ofthe vulnerability factors that need to be addressed. There are three main approaches to carrying out a vulnerability assessment in a community. The socioeconomic approach assesses vulnerability

based on the socio-economic status of individuals or groups and theircharacteristics. This approach emphasises the capacity of individuals or groups to cope, adapt and thrive in the face of shocks and stresses based on long-standing socio-economic and individual vulnerability factors preceding their occurrence. The bio-physical or risk hazard approach, which is predominantly used in disaster risk assessments, emphasises place based vulnerability factors linked to the degradation of biophysical conditions as a result of a shock or a stress. To analyse the intricate and multifaceted processes of vulnerability, the integrated approach blends socio economic and risk hazard techniques (Tesso, Emana, & Ketema, 2012). The framework created by the IPCC to conceptualise climate change is an illustration of an integrated approach to measuring vulnerability (IPCC, 2001). This brief uses an integrated methodology to evaluate vulnerability. Based on the variety of elements that worsen the environment where individuals live, vulnerability is evaluated. Their financial situation may make them more susceptible to exposure and/or sensitivity to shocks and stresses, or it may lessen their ability to deal with such stresses and prosper as a result.

Such elements include a person's residence, financial situation, and personal traits: one of the factors affecting vulnerability is the built and natural based vulnerability factors which are associated with the accessibility and availability of high-quality, affordable, and resilient infrastructure, services, and amenities (such as public spaces, health facilities); the nature, health, and resilience of environmental systems to which a group has access; the availability of effective systems required to ensure adequate access to land and housing. Economic standing also affects susceptibility because some social groupings do not have the financial means to change with the times. These categories include those with low incomes, those who are unemployed or underemployed, those whose industries are comparatively more susceptible to shocks and stressors, or those who are less able to change their occupations or economic activities, specific characteristics such as those relating to gender, age, ethnicity, and disability, may also make a person more vulnerable.

2.6.5 IDENTIFICATION OF DRIVERS OF VULNERABILITY

Human activities often referred to as pressures or direct drivers of change affect wetland functioning in many ways both directly and indirectly. These pressures affect the ecological character of wetlands specifically through changes in hydrology. At the global level, human activities have caused and will continue to cause a loss and/or degradation of wetlands through

climate change, land-use and land-cover change, including drainage, urbanisation and changes in flow regime; water pollution (through land and/or air); water abstraction and diversion of water to intensively managed ecosystems and urban systems; habitat fragmentation; selective exploitation of species; introduction of non-native and/or invasive species; and stratospheric ozone depletion. (Parry, et al., 2007). Wetland functioning is impacted by human activity in numerous ways both directly and indirectly and is frequently referred to as pressures or direct causes of change. These pressures specifically changes in hydrology have an impact on the ecological character of wetlands. Globally, human activities have led to and will continue to lead to the loss and/or degradation of wetlands due to climate change, changes in land use and land cover, including drainage, urbanisation, and changes in flow regime; water pollution (through land use and/or air); water abstraction and diversion to intensively managed ecosystems and urban systems; habitat fragmentation; selective exploitation of species; and introduction of non-native and/or invasive species. (IPCC 2002; Berghall and Watson 2003; MA 2005). According to MA (2003), economic, demographic, socio political, scientific, and technical variables are the primary drivers of these shifts. The factors causing change interact, for example climate variability and change can increase the frequency and severity of floods and droughts, which can then affect groundwater flow and surface water flow, which can then have an impact on the establishment or spread of invasive species. Therefore, it's crucial to take into account the connections between these factors when evaluating the impacts and subsequently creating management strategies for wetlands.

Inference: In the Kuttand region, there are three key macro-vulnerability areas that may be found in the economic, social, and environmental spheres.

2.6.6 METHODS FOR DETERMINING VULNERABILITY

There are three typical methods for evaluating vulnerabilities. Each of these methods seeks to comprehend vulnerability in a unique way. None of these alone provides a whole picture, even though they all contribute to understanding some aspects of vulnerability.

- Risk-hazard analyses seek to determine what is vulnerable to certain climate impacts, where and when impacts may happen, and what potential consequences may result. The risk-hazard approach evaluates end point or outcome vulnerability as it is commonly known. This method defines vulnerability as the remaining effects of climate change after practical adaptations have taken place. Most frequently end-point

vulnerability isemployed to prioritise foreign assistance initiatives and for technical climate change adaptations. This method frequently includes spatial analysis utilizing Geographical Information Systems (GIS). It can be used to map the exposure of geographical features or infrastructure (such low-lying coastal areas) to specific climate impacts.

- The political economy-political ecology approach analyses how social and economic factors contribute to people's vulnerability to the effects of climate change. They want to know how susceptible groups are vulnerable, why some populations are more vulnerable than others, and who is most likely to be harmed by climate change. In policy and social development contexts, these methods are most frequently employed to evaluate starting-point or contextual vulnerability.
- According to ecological resilience theories, climate change affects the dynamic interactions between and within natural and human systems (or social-ecological systems). These methods acknowledge the variety of social-ecological system states, some of which may be more preferable than others. When applying ecological resilience to climate vulnerability, the goal is to either encourage a system to move towards a more sustainable state or to identify and avoid thresholds that could shift it to a new, less desirable state.

CHAPTER 3 CASESTUDIES

This chapter discusses various case studies discussing the methods and procedure for vulnerability assessment. Further it also discusses on some resilience strategies and proposals which are adopted in different scenarios.

3.1 VULNERABILITY ASSESSMENT- A CASE STUDY OF HAI PHONG CITY IN VIETNAM

Hai Phong City is dealing with a number of issues including rising urbanisation, environmental degradation, dangers of natural disasters, and sea level rise. Unexpected stressors and disruptions may also emerge particularly in the context of climate change. Given the situation, it is imperative for the city to adapt and develop in order to face a variety of difficulties in a constantly changing environment. In the context of the impacts of climate change, the city must figure out how to strengthen its resilience in the face of such pressures, disruptions, and uncertainties. Resilience should thus be acknowledged and utilised as a fundamental foundation for city growth.

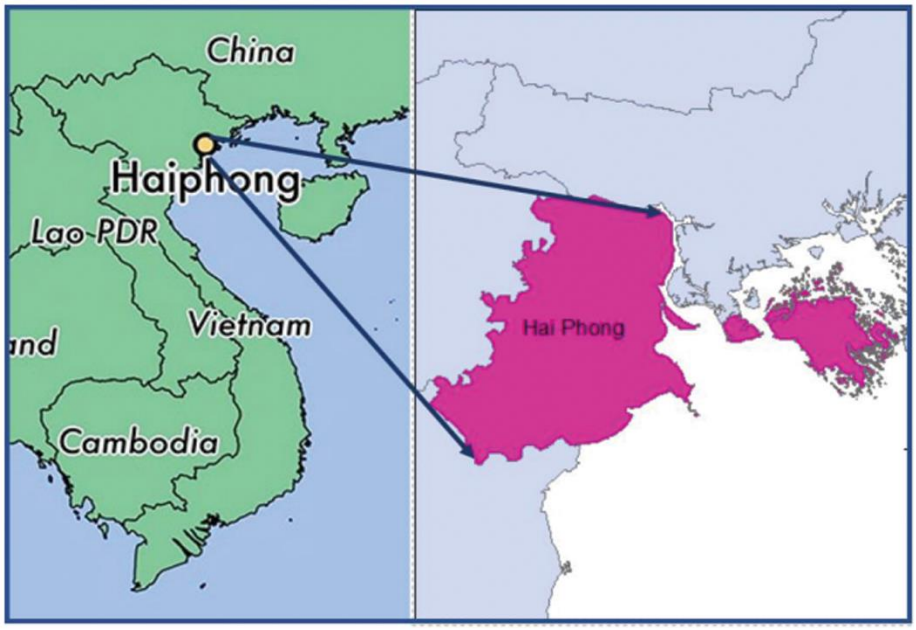

Figure 3:1: Location of Hai Phong City in Vietnam
Source: (Thanh & Tien, 2015)

3.1.1 DEVELOPMENT OF ADAPTIVE RESILIENCE INDEX FOR HAI PHONG CITY

It is required to select a group of relevant variables that characterise a system in order to study and determine its state (Cumming, 2011). Additionally, depending on the particular goals of the research, the choice of quantities, classes, and types of variables describing a system state is changeable (Beisner et al., 2003). In this study, the process of examining the local situation, developing, and identifying the pertinent elements impacting the resilience of the city is carried out using grounded theory and qualitative analysis in order to produce an adaptive resilience index for Hai Phong City.

A hierarchical structure is used to arrange the adaptive resilience index. Four dimensions - Social, Economic, Environment & Infrastructure, and Governance reflect the fundamental building blocks for coping with and adapting to the effects of climate change and are included in the first level of this hierarchy. The second level of each theme creates a few sub-dimensions that might be viewed as factors in the resilience of those regions. The third level includes an indicator set, which is a group of factors that can affect how much certain dimensions and sub dimensions matter.

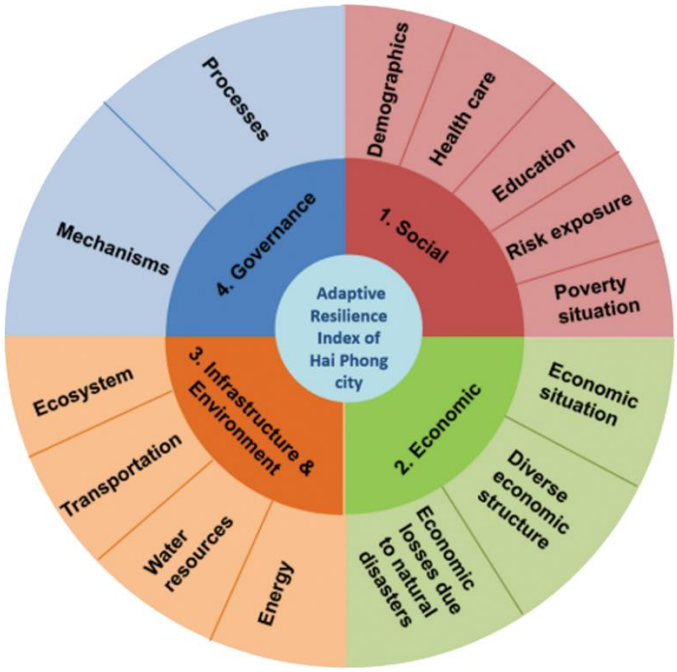

Figure 3:2 : Adaptive Resilience Index of Hai Phong city
Source: (Do Thi Thuy Hong, 2018)

The choice of these three tiers of variables which include dimensions, sub dimensions and indicators is often made after reviewing the available research consulting with experts and soliciting opinion from various stakeholders including Hai Phong local government officials. It should be emphasised that these factors do not all contribute equally to the relevant resilience to the effects of climate change; hence, stakeholders were consulted in the selection and weighting of the dimensions, sub-dimensions, and indicators.

Table 3:1 : Adaptive Resilience Index Structure of Hai Phong city

Social	Economic	Environment & Infrastructure	Governance
Demographics Population growth rate Population dependency ratio Population density Unemployment rate Rate of employment trained	GRDP growth rate of the city GRDP per capita Index of Industrial Production Growth rate of agricultural production Growth rate of fishery production Economic losses due to natural disasters Losses on housing due to natural disasters Damages of infrastructure	**Ecosystem** Forest area cover change rate Annual newly planted forest area Biodiversity Increase of green space	Integrated development planning Stakeholder participation Climate change Adaptation strategies Good data management Effective land use
Health care Public health facilities Public health capacity Health care services Health insurance coverage		**Transportation** Road density Use of public transport	
Education Literacy rate		**Water resource** Clean water access ratio Drinking water quality Drainage system and wastewater treatment Rain water harvesting Access to electricity	
Risk exposure Population exposed to hazards Mortality number due to disaster		**Energy** Use of renewable energy	
Poverty situation Poverty rate			

Source: (Do Thi Thuy Hong, 2018)

Indicators are rated on this basis both numerically and qualitatively in accordance with the clarifications provided by the data and information gathered. Data aggregation was done to get a score for the sub-dimensions based on the score of the relevant indicators set from scoring the outcomes for each indicator.

3.1.2 ANALYSIS OF THE ASSESSMENT RESULTS FOR HAI PHONG CITY USING THE ADAPTIVE RESILIENCE INDEX

Based on the developed Adaptive Resilience Index, data was gathered from primary sources through meetings and interviews with experts and government officials at the national and local levels as well as secondary sources such as researchers, reports, and policy documents of relevant sectors, departments, and agencies of the City. On a scale of 1 to 5, each dimension, sub-dimension, and indicator were given equal weight, and the scoring was done using references from the literature and input from the appropriate stakeholders. Based on stakeholder opinions, pertinent criteria and national rules such as targets in plans and strategies for the city, a score rating of 1 to 5 is assigned to each indication. Data aggregation was done to get a score for the sub-dimensions based on the outcomes for each indicator.

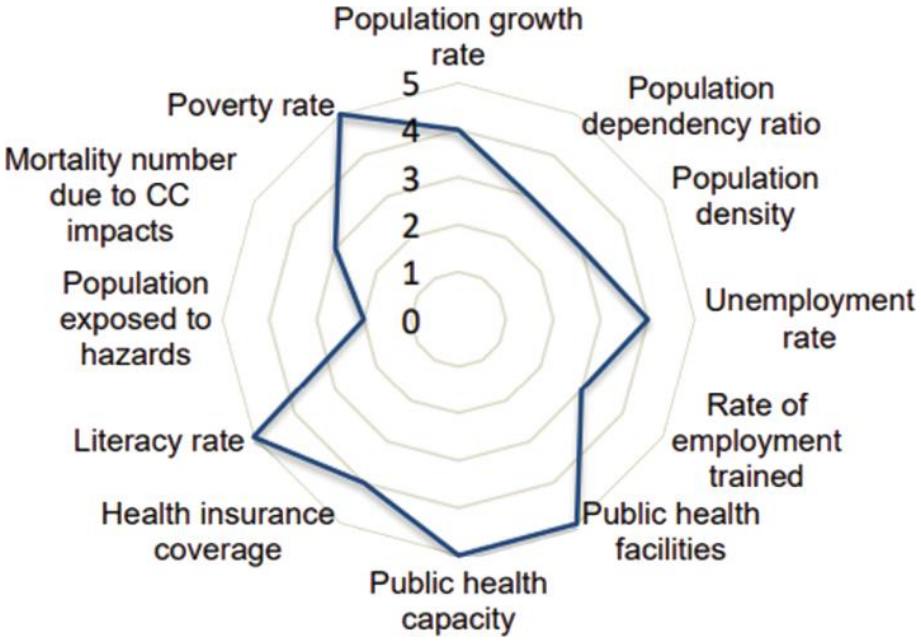

Figure 3:3 : Social dimension
Source: (Do Thi Thuy Hong, 2018)

Figure 3:4 : Map of exposure of districts in Hai Phong City
Source: (Do Thi Thuy Hong, 2018)

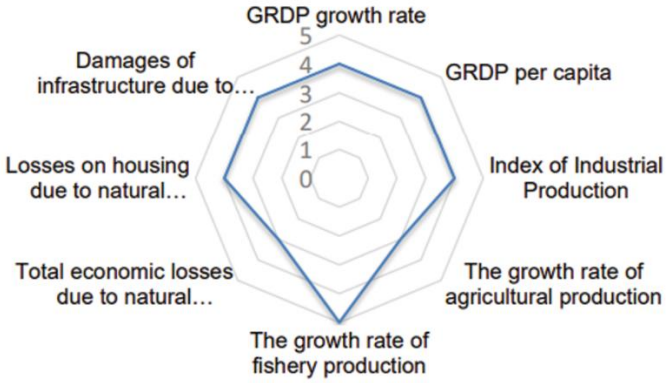

Figure 3:5 : Economic dimension
Source: (Do Thi Thuy Hong, 2018)

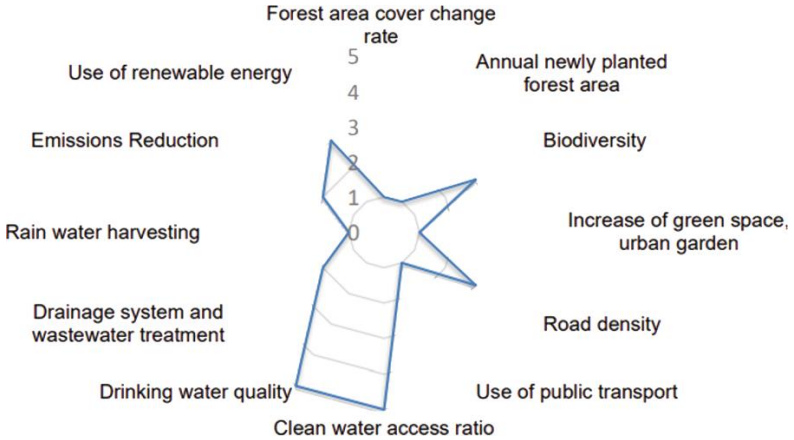

Figure 3:6 : Environment and Infrastructure dimension
Source: (Do Thi Thuy Hong, 2018)

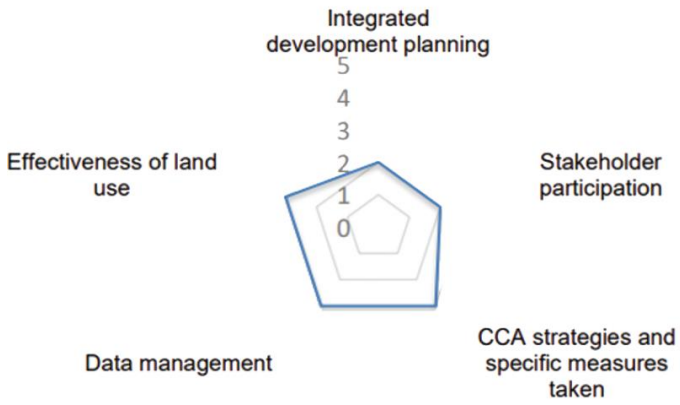

Figure 3:7 : Governance dimension
Source: (Do Thi Thuy Hong, 2018)

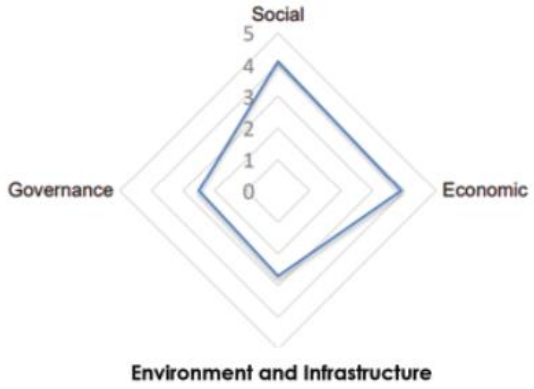

Figure 3:8:Adaptive Resilience Index assessment
Source: (Do Thi Thuy Hong, 2018)

According to the evaluation results and analysis shown above, there are a total of 37 indications. There are 10 items on this index that are scored from 1 to 2, and are consequently considered to have had a poor performance. The following are the city's most urgent problems right now.

- The population exposed to hazards
- Forest area cover change rate
- Annual newly planted forest area
- Increase of green space, urban garden
- Use of public transport
- Drainage system and wastewater treatment
- Rainwater harvesting
- Emissions reduction from energy consumption
- Integrated development planning
- Stakeholder participation

3.1.3 ANALYSIS OF STATE AND NON-STATE EFFORTS OF HAI PHONG CITY

- Around 47.4% population of the city is exposed to natural hazards, mainly in Tien Lang, Vinh Bao and Thuy Nguyen and partly of Kien Thuy.
- Zoning disaster risks; warning of various types of natural hazards to have appropriate prevention and mitigation policies for critical areas.
- Building and upgrade sea dyke and river dyke system
- Reviewing, proposing and adjusting regulations and technical guidelines for construction in areas frequently affected by natural hazards to ensure it will be in line with climate change.
- Applying new methods and techniques for building new urban centres, new residential areas, industrial parks, transport works, and other infrastructure works.
- Developing biotechnology in agricultural production, strengthening the insurance system to share risks in agriculture and enhancing the control system to avoid epidemics of plants and animals in the context of climate change.
- Applying environmentally friendly building materials, design and build works with energy efficiency and saving that can tolerate well the effects of climate change and sea level rise.
- Building the planning of the network of search and rescue adaptative to climate change
- Forest area cover change rate and annual newly planted forest area
- National Target Programme on Forest Protection and Development 2015-2020 in the city.
- Revising and rehabilitating the area of coastal, and land conservation.
- Increase of green space, and urban gardens
- Renovation, upgrading and construction of parks and gardens, for instance, Ho Dong Park, Tan Thanh Park, Thien Van Forest Park, Flower Garden in the centre of the city.

3.2 NATURE-BASED SOLUTIONS TO ENHANCE URBAN FLOOD RESILIENCE -A CASE STUDY OF BANGKOK IN THAILAND

The application of nature-based solutions in Bangkok, Thailand is examined through the use of a case study. The capital of the Kingdom of Thailand includes the megacity of Bangkok. The city which occupies about 35% of the total land area and is located in the Chao Phraya River basin's Delta region, is situated in a low-lying coastal region.

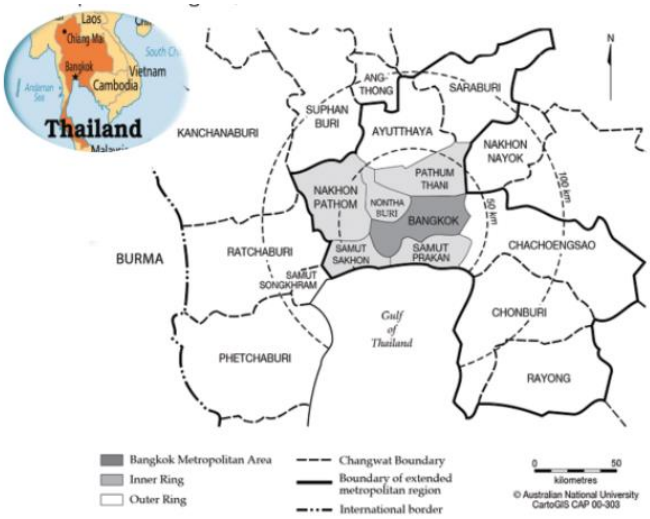

Figure 3:9: Location of Bangkok in Thailand
Source: (Irvine, et al., 2023)

3.2.1 ISSUES FACED IN BANGKOK

Bangkok still faces numerous difficulties today. The first is its topographical setting. Its location makes the city vulnerable to rising sea level, storms, and heavy rainfalls. The city is frequently inundated with severe flooding during the rainy season which is exacerbated by the rapid urbanisation and high percentage of hardstanding areas that cannot manage the runoff. Economic possibilities are not equally accessible. The degree of pollution is high.

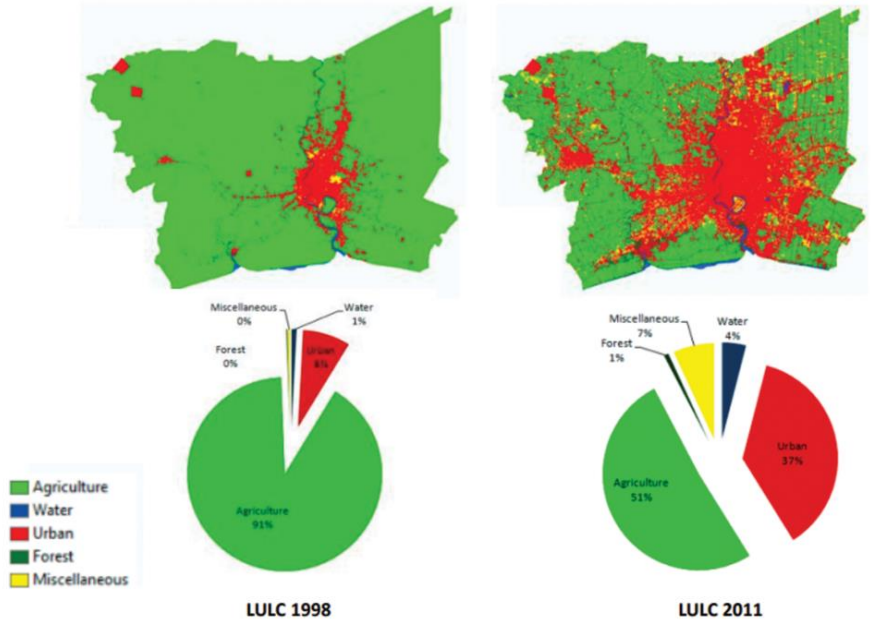

Figure 3:10 : Land Use and Land Cover (LULC) classifications using satellite images
Source: (Irvine, et al., 2023)

The significant change in land use and land cover since the 1980s: agriculture LULC decreased by approximately 44%. The maps comparison also shows the City of Bangkok becoming predominantly urban within 13 years. National and local plans and strategies will help to tackle these challenges meanwhile bottom-up community and private initiatives will be necessary to achieve resilience for Bangkok.

3.2.2 NATURE-BASED SOLUTIONS TO ENHANCE URBAN FLOOD RESILIENCE

At a regional level, the idea of retreat, adapt, and defend was investigated to start tackling fluvial flood challenges. This conceptual design identified locations where green infrastructure and open space would accept flood and waterways (Retreat), while other regions would require structural (building) adaptation to floods (Adapt), or improved green and hard engineering flood protection (Defend). The Retreat idea incorporates improved naturalisation and pond storage areas together with temporary water storage on agricultural land (mainly rice fields).

Figure 3:11 : Regional plan to manage fluvial foods following the Retreat, Adapt, and Defend concept.
Source: (Irvine, et al., 2023)

Survey results establish that the Nava Nakorn community is vulnerable to both fluvial and pluvial flooding and that there is a varying level of resiliency to flooding. Some industries temporarily shifted production during the 2011 food, while Nava Nakorn Public Co. Ltd. strengthened and heightened the flood wall surrounding the industrial estate and increased

pumping capacity to move water from the internal drainage canals to outside receiving canals. These latter hard engineering measures are consistent with the general trend in Thai flood management discussed. Most of the economic impact from flooding was absorbed somehow by the community.

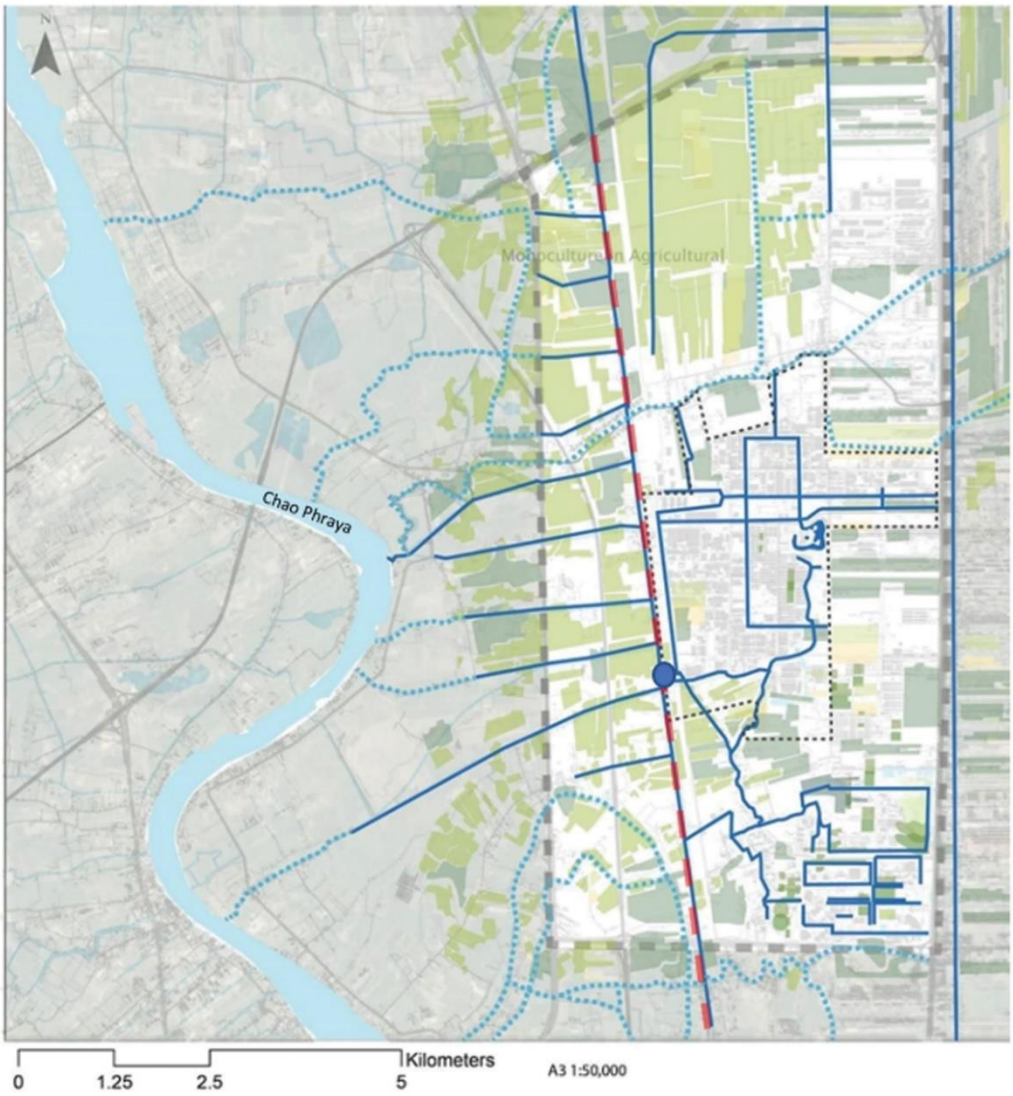

Figure 3:12: Connectivity of canals, waterbodies and the Chao Phraya River associated with the TUNN Smart District.
Source: (Irvine, et al., 2023)

The connectivity of canals, waterbodies, and the Chao Phraya River with the TUNN Smart District is depicted in the above figure. The intended Eco-corridor is shown by a red dashed line, while the wetland treatment park is indicated by a blue circle. It depicts how the district's extensive, existing canal system may be used to connect regions for fluvial food management

and habitat, and it also shows where a proposed 'Eco-corridor' development would be located in relation to a bigger canal and a train line. The Eco-corridor would incorporate linked channels and wetland storage to strengthen flood resilience as well as possibilities for lifelong learning, leisure, and biodiversity to improve community liveability. This design also adheres to the "monkey cheeks" method of flood planning that is now used in Thailand. It describes low-lying areas near large rivers that are utilised to temporarily store food and water, similar to how a monkey stores food in its cheeks. These areas are mostly rice paddies with some natural wetlands.

1. A SECTION OF THE ECO-CORRIDOR PLAN

The portion is depicted in figure 3.13 as it is right now, with a mixture of swamp and secondary growth forest. Figure 3.14 depicts the proposed wetland treatment park's masterplan view, while Figure 3.15 details the design cross section along A-A. Wetland treatment park would improve natural habitat and biodiversity, water purification through settling basins, natural vegetation, and maximising hydraulic residence time, as well as recreational and educational opportunities via the boardwalk and observation tower. The Eco-corridor design which spans the full longitudinal plane offers connectivity between the canals' blue and green landscapes as well as a purposely diversified patch habitat.

Figure 3:13 : Existing situation of Southwest of Nava Nakorn.
Source: (Irvine, et al., 2023)

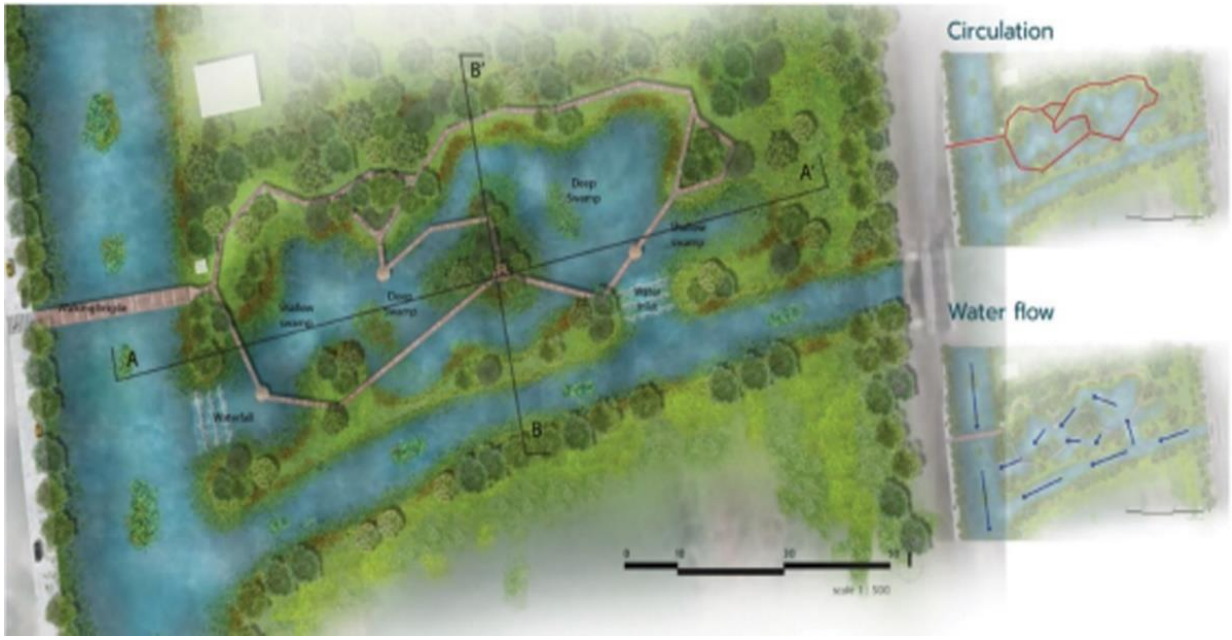

Figure 3:14: Masterplan view of the proposed Wetland Treatment Park
Source: (Irvine, et al., 2023)

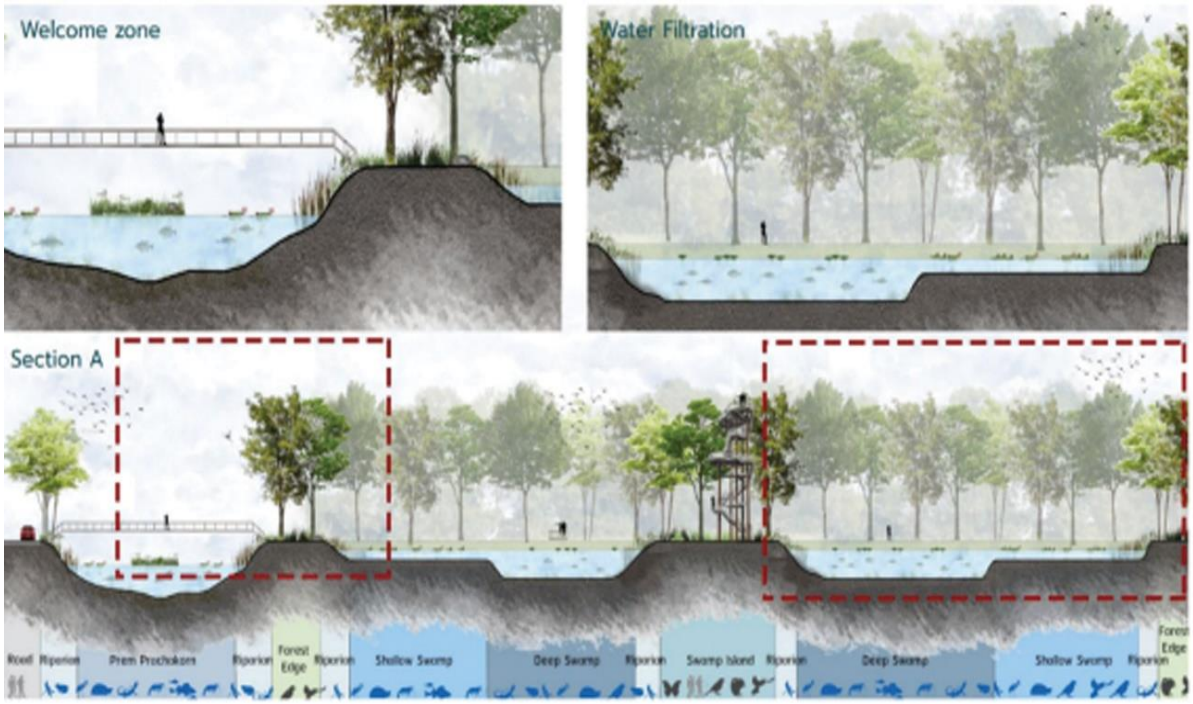

Figure 3:15: Design cross section of AA' in the Masterplan of Wetland treatment park
Source: (Irvine, et al., 2023)

Figure 3:16:Existing situation of North of Nava Nakorn
Source: (Irvine, et al., 2023)

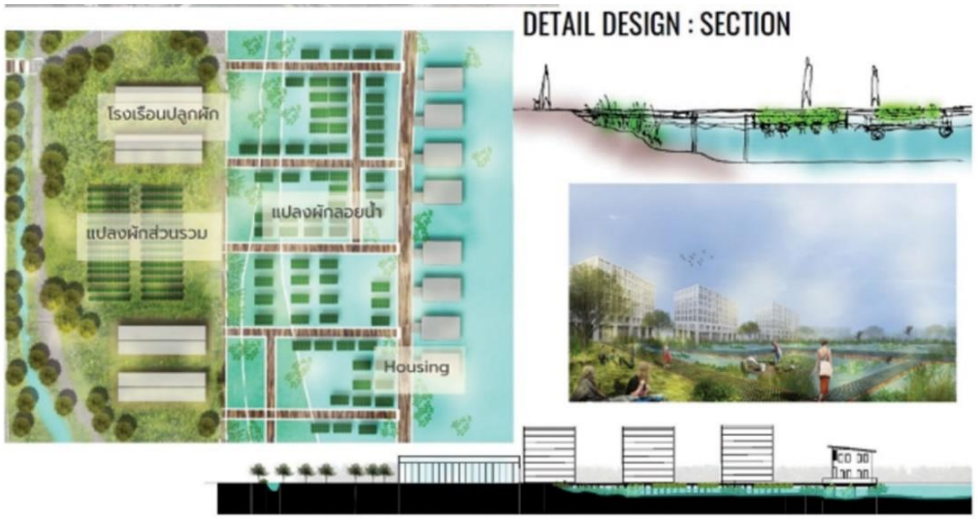

Figure 3:17: Ecovillage and its master plan
Source: (Irvine, et al., 2023)

It symbolises the expanding region to the immediate north of Nava Nakorn. The region is now removing land for construction, and there is a 7.5 ha pond feature that is partially confined by a bund. The image of the eco-village depicts the region as it is right now, with cleared, unoccupied, and crumbling ground encircling the enormous pond. The upper shot was taken from a point that is indicated by a blue circle in the middle image which displays the masterplan vision of the intended Eco-village development. The lower image displays the Eco-village's design plans, which combine natural features, outdoor activity areas, and planned greenspace. The detailed design suggests using water resources for urban farming as well as for watering buildings that are either residential or commercial.

2. AMPHIBIOUS STRUCTURES

Eco-village is resilient, amphibious housing and commercial opportunities are incorporated into the design. Amphibious structures also could be designated as emergency healthcare and logistics centres during extreme foods.

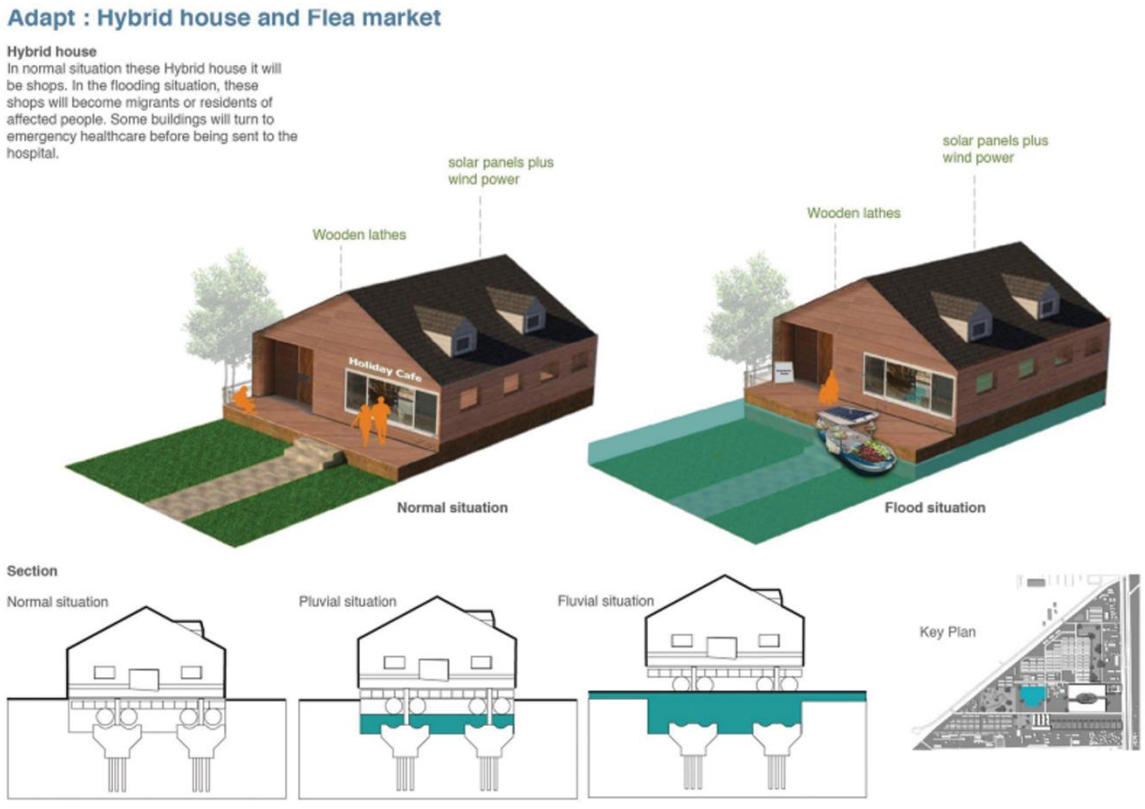

Figure 3:18: Amphibious structures and its design
Source: (Irvine, et al., 2023)

3. DESIGN OF ARTERIAL ROADS

Nava Nakorn's main thoroughfare has been designed with underdrain raingardens that connect to surrounding waterways, smart transportation features including walkable and bicycle lanes, and more vegetation.

Figure 3:19:Condition of roads in the Central area of Nava Nakorn during floods
Source: (Irvine, et al., 2023)

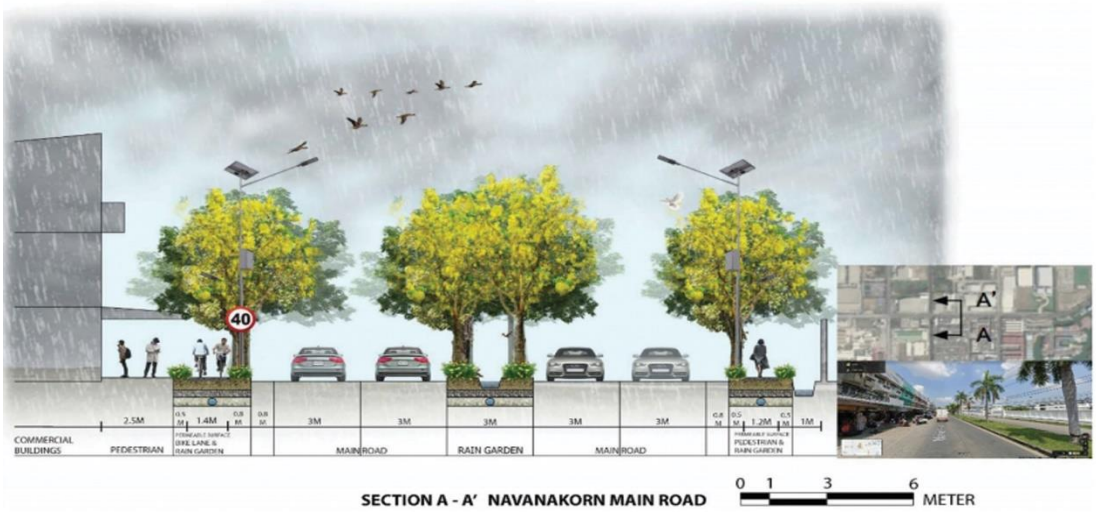

Figure 3:20: Design of arterial road in the Central area of Nava Nakorn to enhance greenery, smart mobility
Source: (Irvine, et al., 2023)

4. GREEN SPACE AND WSUD REDEVELOPMENT IN CENTRAL NAVA NAKORN

Figure 3:21: Present situation of Central Nava Nakorn
Source: (Irvine, et al., 2023)

Figure 3:22: Master plan of Central Nava Nakorn for providing green spaces
Source: (Irvine, et al., 2023)

Figure 3:23: Perspective vision of the area in Central Nava Nakorn
Source: (Irvine, et al., 2023)

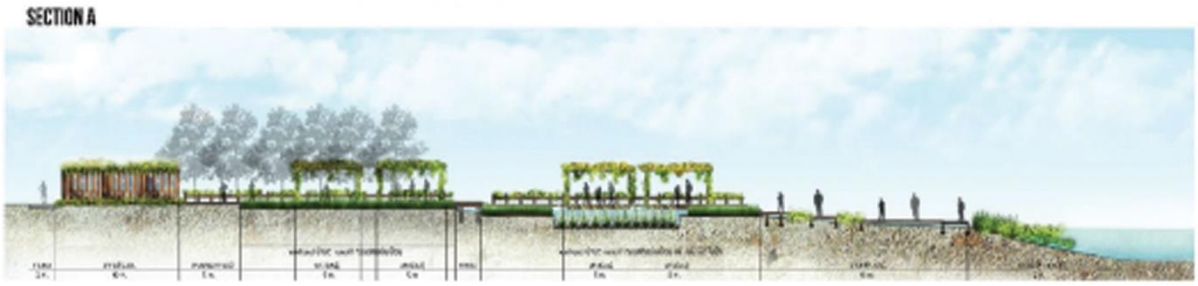

Figure 3:24: Cross section design along transect A in the Master plan of Central Nava Nakorn
Source: (Irvine, et al., 2023)

Figure 3.22 depicts the current state of Central Nava Nakorn and its master plan, as well as the locations where new green areas should be created in order to soften the shoreline. Figures 3.23 and 3.24 show a perspective view of the region and a cross section along Transect A, respectively. A learning Centre for Nava Nakorn sustainability is also included with the aim of encouraging green technologies for the urban development along with the retention and redevelopment of some of the buildings for new office spaces. Greenspace with raingardens softens the coastline, while pond features with floating wetlands enhance the water quality. Because of their high water absorption capacity, the pavements can reduce peak flood flows and the urban surface runoff coefficient.

Figure 3:25 : A plan view and perspective of a re-visioned parking lot with bioswales, pervious pavement and shoreline having a vegetated bufer zone
Source: (Irvine, et al., 2023)

One of the existing unofficial parking spaces may be seen to the right in the higher photograph. The centre picture shows a perspective plan view of a parking lot that has been redesigned with bioswales, pervious pavement, and a coastline with a planted buffer zone. This layout makes it easier for water to flow from the region and also lessens the amount of dirt that collects there after a flood. By establishing environmentally friendly drainage systems that link to canal networks, this further aids in preventing the devastating effects of flooding in that area.

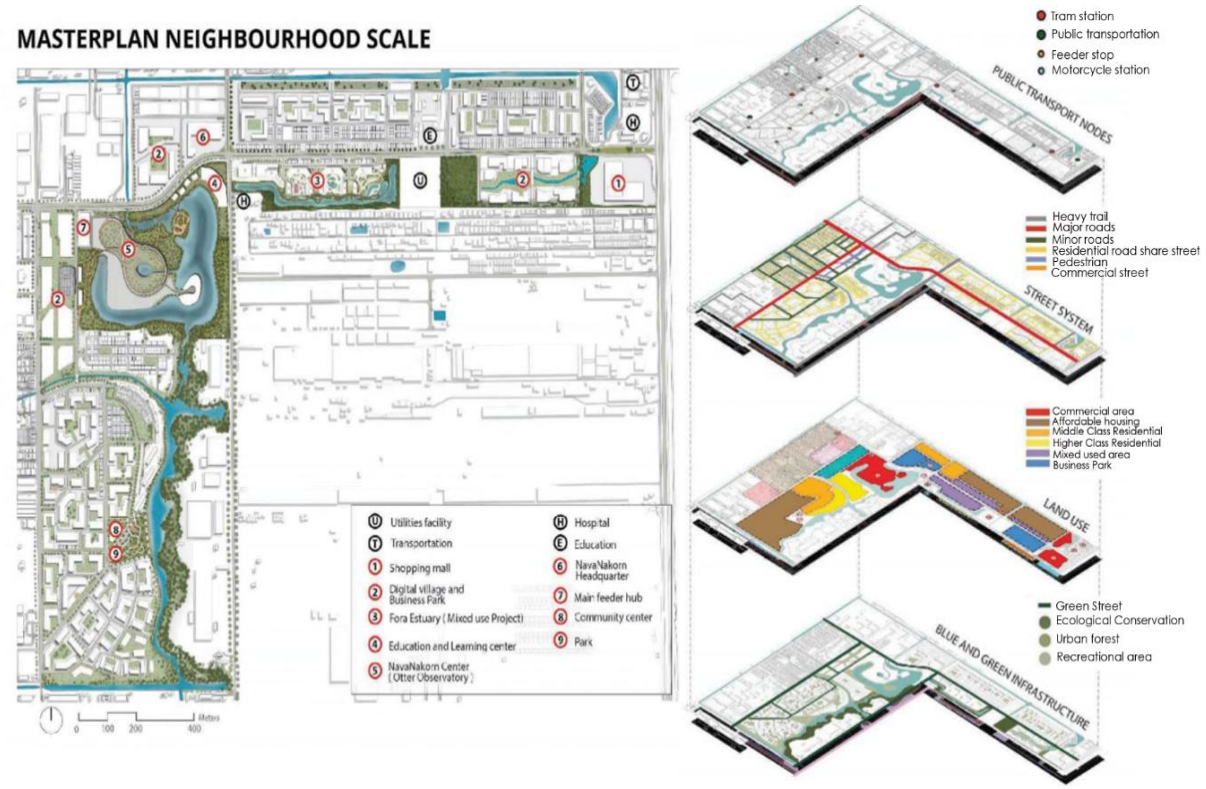

Figure 3:26 : Enhanced, connected green space and WSUD features , Central area of Nava Nakorn.
Source: (Irvine, et al., 2023)

Figure 3:27 : Perspective for Community Center and Park to improve community space by enhancing connectivity, liveability, well-being
Source: (Irvine, et al., 2023)

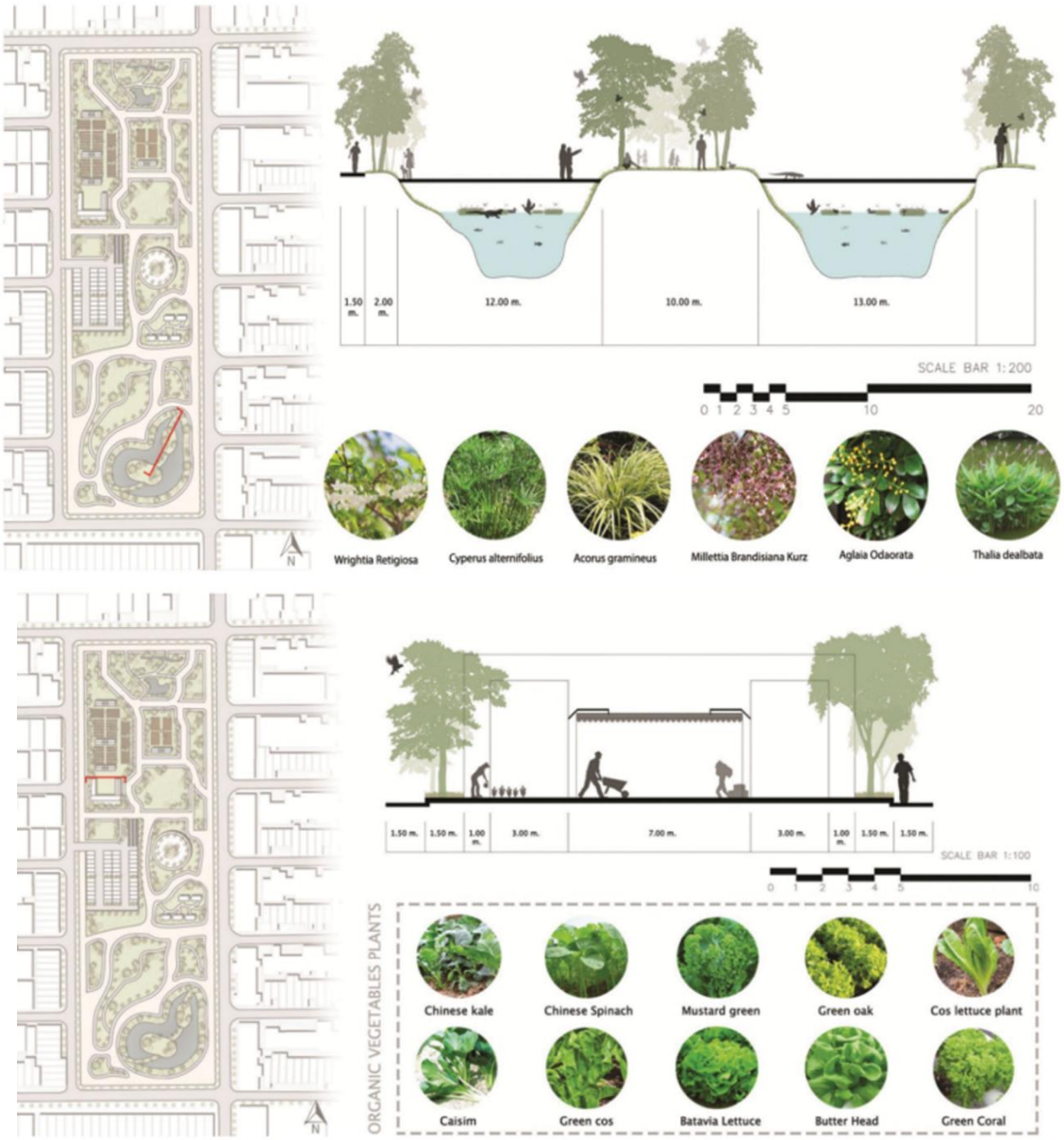

Figure 3:28 : Park area example details for a community organic farm, or Agrihood and a retention pond with observation board walk
Source: (Irvine, et al., 2023)

To increase community resilience to flooding, traditional hard engineering methods have been relied upon. The neighbourhood was unhappy with the present areas and had specific ideas on how green spaces should look. The integrated landscape architecture visioning for both pluvial and fluvial flooding scales became crucial since the community reaction did not take into account the usefulness of green space/NbS as a water management technique. The section examines these problems and offers designs as potential solutions for future flood control and nature-based development.

A number of ecosystem services would be offered by the NbS planning and designs including lessened flood damage, improved runoff quality, improved recreational and community space, increased biodiversity, educational and lifelong learning opportunities, food provisioning (Agrihood), and increased diversity and resiliency in housing.

3.3 THE NETHERLANDS' NATIONAL RECOVERY AND RESILIENCE PLAN

The Hague is the Netherlands' third-largest city. Its population is the most diverse and divided of any Dutch city. Due to its geographical location, the city is especially susceptible to the effects of climate change, especially flooding. Due to increased urbanisation, prolonged heatwaves and droughts have grown more frequent.

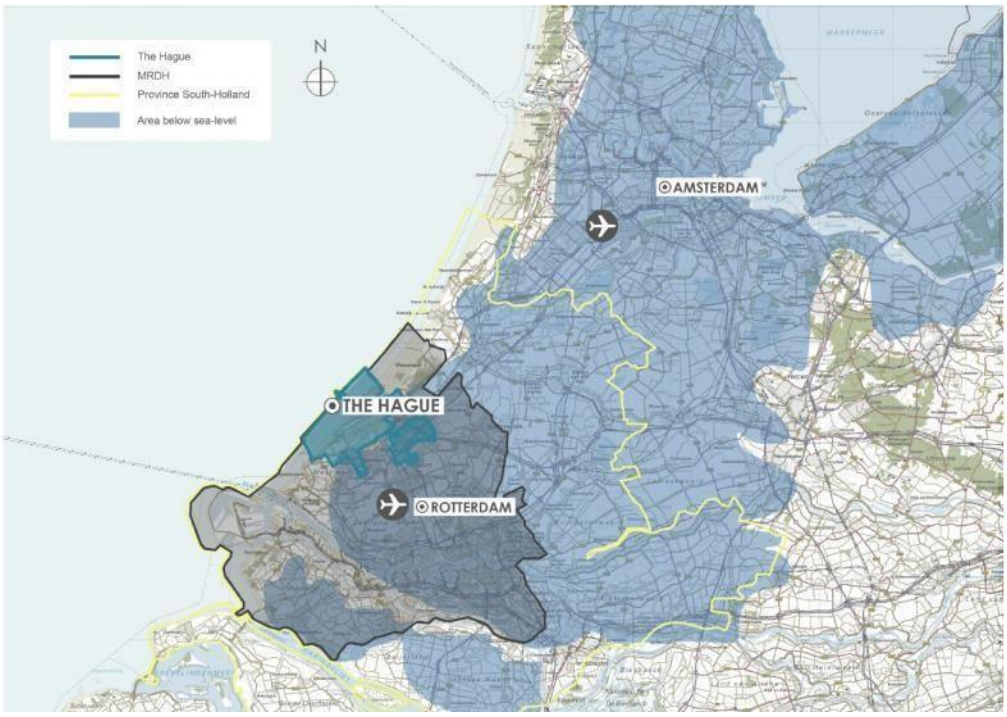

Figure 3:29: Location of Hague
Source: International master city resilience design and management

In the Netherlands, studies on resilience in urban design, water management, and climate change solutions are being conducted at the national, regional, and municipal levels. Even though the term "resilience" has only lately begun to show up in planning agendas, some of its components are not. In the regularly flooded nation, water management has a lengthy history. In the Netherlands, tiny towns have worked together administratively to control water and prevent flooding since the middle ages. Local water supplies have been overseen by the forerunners of the contemporary Dutch water boards since the thirteenth century. The "National

Water Agency," which at the moment acts as the Ministry of Infrastructure and Water Management's executive branch, was established in 1798.

Figure 3:30: Overview of the RFTR spatial planning measures
Source : International master city resilience design and management

The RFTR was recognised as the first to use a multi-level governance strategy where NGOs and private stakeholders and government are actively engaging in managing flood risk at the

national, regional, and local levels. This relates to the governing strategy that made such a transformation possible. In 2009, integrated water management was made easier by the passage of the "Water Act," which establishes rules for the use and management of water across the entire country.The law consolidated the previously disjointed Dutch water regulations in order to lighten the administrative burden on citizens and businessowners and improve the effectiveness of water management.

3.3.1 FROM WATER TO PEOPLE: IMPLEMENTING COMMUNITY RESILIENCE BY EMPOWERING CITIZENS

The Hague's Resilience Strategy is offered as a framework that builds on existing capabilities in order to promote innovation, new possibilities, and capacity building. It serves as a guide for constructing the city's short and long-term resilience to handle heightened dangers and fresh challenges. Urban resilience which is also referred to as community resilience is defined by the Hague's resilience plan as "the ability of groups or communities to cope with external pressures and disturbances as a result of social, political, and environmental change."

3.3.2 INTEGRATING COMMUNITY AND REVOLUTIONARY SOCIO TECHNICAL INNOVATION IS COVERED IN SECTION

In a socio-economic pillar, resilience is further discussed in relation to developing social and technology skills in preparation for the Hague's one-sided economy's impending digital transition. Citizens must consequently improve their digital literacy, especially the younger generations. The plan so builds on the Netherland's overall national "Digitalization Strategy" from 2018, which relates resistance to digital risks. The Hague's "Economic Vision," which was released in 2019 and acts as a guide for the city's economic development is also in line with its objectives. The strategy's use of themes from local and national plans demonstrates that its socio-economic considerations are based on them. The "Agenda Space for the city 2016–2040," the foundation of the city's new spatial policy further details the economic shift in the Hague. The roadmap also addresses difficulties associated with the transition to a resilient society, intelligent urban planning, and organisational capacity.

3.3.3 CLIMATE RESILIENCE FOR A SUSTAINABLE CITY DEVELOPMENT

The Resilience strategy emphasises resilience in relation to climate change adaptation in addition to the socio-economic component. It is said that climate change is a stressor that amplifies shocks. Extreme weather events like heavy rain, flooding, protracted hot weather, droughts, pandemics, and the breakdown of vital infrastructure become more likely to occur

and have more severe effects. The latter must be made to be more shock and stress resistant, responsive, and adaptable. The policy also emphasises the necessity for the city and its residents to be risk-aware and prepared for emergencies related to infrastructure failure. Not just in terms of infrastructure, but also in terms of risk-aware behaviour and risk management in general. Even though climate resilience in the Hague addresses both adaptation and mitigation, the Resilience strategy focuses primarily on adaptation and takes medium-term action. While the adaptation strategy focuses mostly on soft measures like green and blue infrastructures, mitigation is covered in the long-term transformation of energy and transportation systems away from carbon emissions. These actions also fit with the NAS and the long-term projects "Delta Works" and "Delta Programme." Additionally, The Hague wants to develop reliable essential infrastructure and improve people's and business's emergency preparedness.

CHAPTER 4 SITE ANALYSIS

This chapter discusses the study area context and also discusses the sector study for adaptive resilience index assessment. It also discusses the most vulnerable regions for resilient planning proposals.

4.1 STUDY AREA CONTEXT

In the Indian state of Kerala, the region of Kuttanad includes the districts of Alappuzha, Kottayam, and Pathanamthitta. It is renowned for its sizable paddy fields and unique geological features. The area is one of the few in the world where farming is practised between 1.2 and 3.0 metres (4 to 10 feet) below sea level and has the lowest altitude in all of India. The state's top rice producer and a significant location in South India's ancient history is Kuttanad. Biosaline farming is a well-known practice among Kuttanad farmers. The Kuttanad Farming System has been designated as a Globally Important Agricultural Heritage System (GIAHS) by the Food and Agriculture Organisation (FAO) (Mariamma J, MM Mathew, JG Ray, 2018). Kuttanad of Alappuzha district, Kerala South India, is now known as a 'globally important agricultural heritage systems (GIAHS), the second of its kind in India. The declaration of the Food and Agricultural Organization (FAO) for the GIAHS to Kuttanad came out in a conference held from May 29 to June 1, 2013, in Ishikawa, Japan. The declaration was the result of a project submitted by the MS Swaminathan Research Foundation (MSSRF) and the government of Kerala in 2011. The GIAHS is a unique scheme of the FAO started in 2002 for conserving "remarkable land use system and landscape, which are rich in globally significant biological diversity evolving from the co-adaptation of a community with its environment and its needs and aspirations for sustainable development" (MS Swaminathan Research Foundation, 2011). One of the two largest rice-producing tracts in the state, Kuttanad is located in the fertile deltaic region of the five Western Ghat river basins of Meenachil, Pamba, Manimala, Muvattupuzha, and Achencovil. It spans an area of about 1100 sq. km. After emptying the Kuttanad delta, these rivers, which have their origins in the western slopes of the Western Ghat mountains, converge at the Vembanad backwaters before flowing into the Arabian Sea. The entire area is a patch work of backwaters, rivers, and countless waterways and canals, as well as vast polders of paddy fields surrounded by dykes and coconut groves dotted with multi-cropped homesteads.

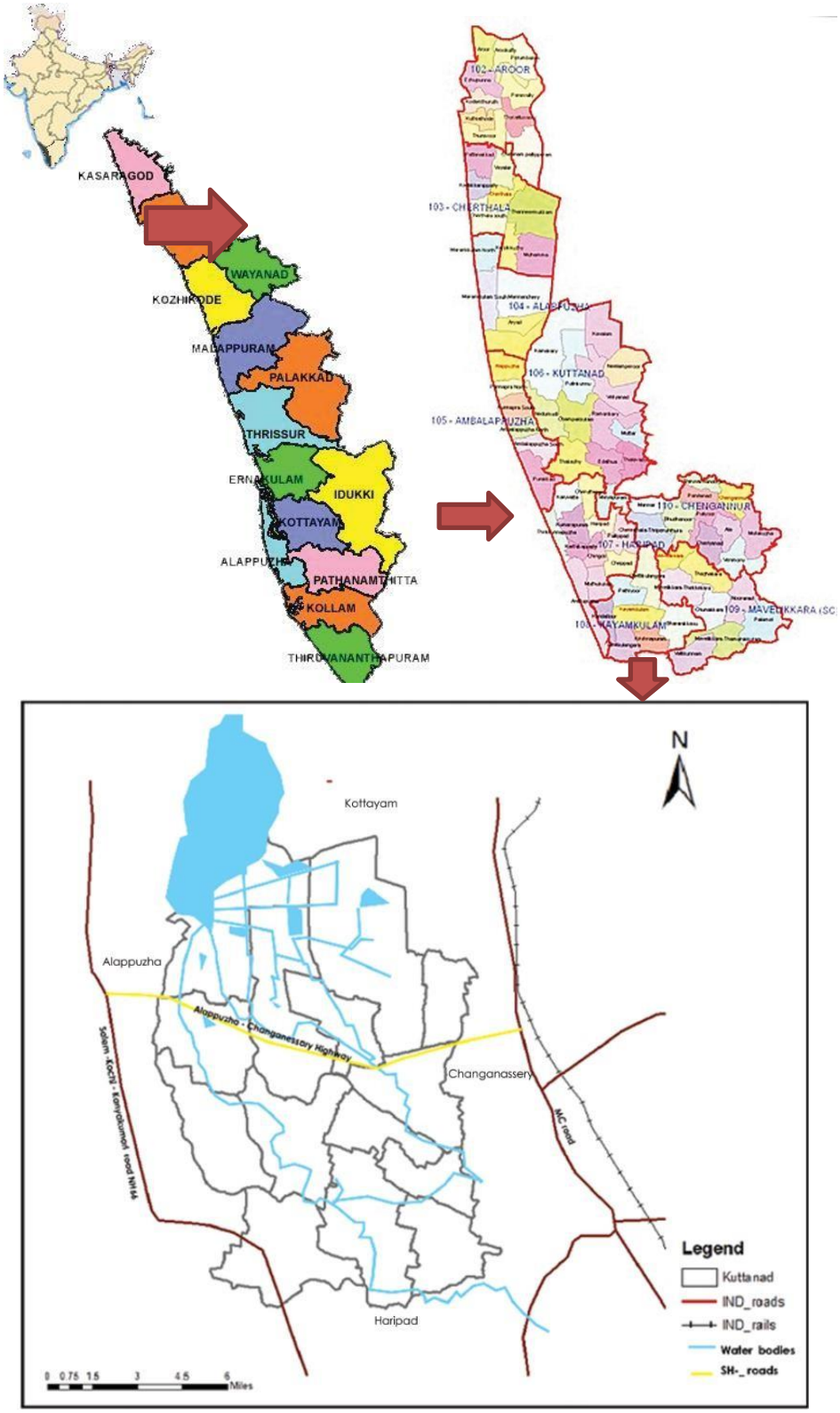

Figure 4:1:Base Map of Kuttanad region in Alappuzha district
Source: ArcGIS

Along with CO_2 emissions from fuel wood, other gas outflows from Kuttanad include SO_2,

NO_X and even methane from rice fields, which all contribute to the region's changing ecosystem. The Kuttanad region is also unique due to consistent background radiation from the thorium-rich shore that spreads across the entire wetland system. The impact of this background radiation on the greenhouse effect has not yet been properly studied and quantified. The Kuttanad region is also below sea level, rendering it defenseless against interruptions in ocean water due to the ocean's rising level which is believed to be the result of environmental change. If the risk isn't well handled, any increase in the carbon content of the air would eventually lead to an increase in climate temperature (which might be roughly 10°C greater in the next 50 years or even less).

A sensitive and closed marine eco-framework exists in Kuttanad. The advancements in the environment have had regrettable effects on the ecosystem. Flooding of streams, an increase in ocean levels caused by the environment, and other factors have had a devastating effect on its inclination. This has led to changes in wetlands and beachfront disintegration, immersion, and constant tempest events. It is expected that saline water would enter freshwater springs near the state's beaches.

4.2 CLIMATE

The Kuttanad Region has a humid tropical climate with generally consistent annual temperatures ranging from 21°C to 36°C and extremely high relative humidity (>80%). The two major rain-producing seasons that contribute most to the country's average annual rainfall of roughly 3250 mm are the South West (SW) monsoon.

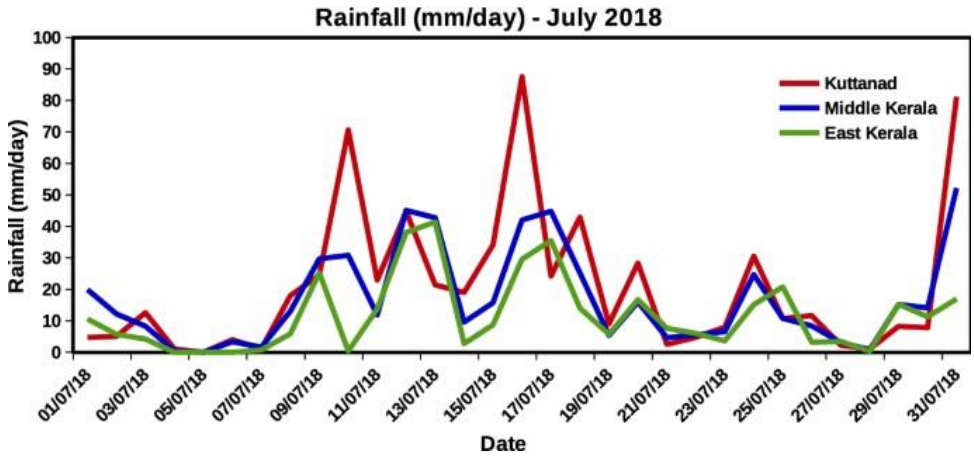

Figure 4:2: The time series of rainfall (mm/day) in July 2018
Source: Indian meteorological department

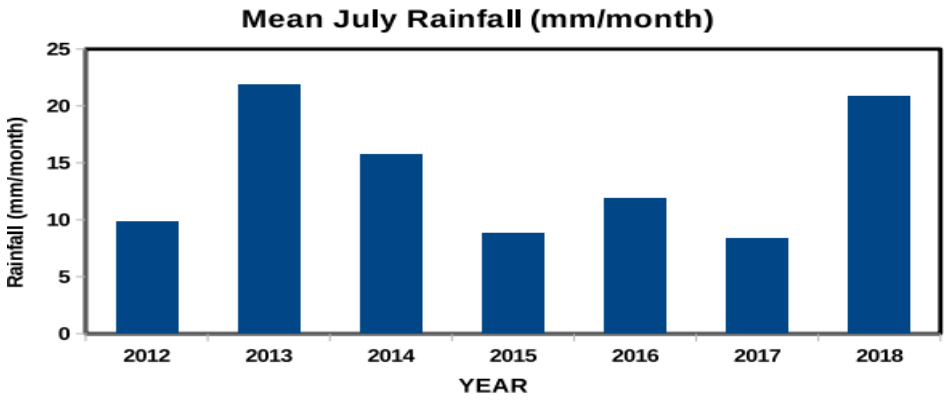

Figure 4:3: Mean July Rainfall (mm/month) over the years
Source: Indian meteorological department

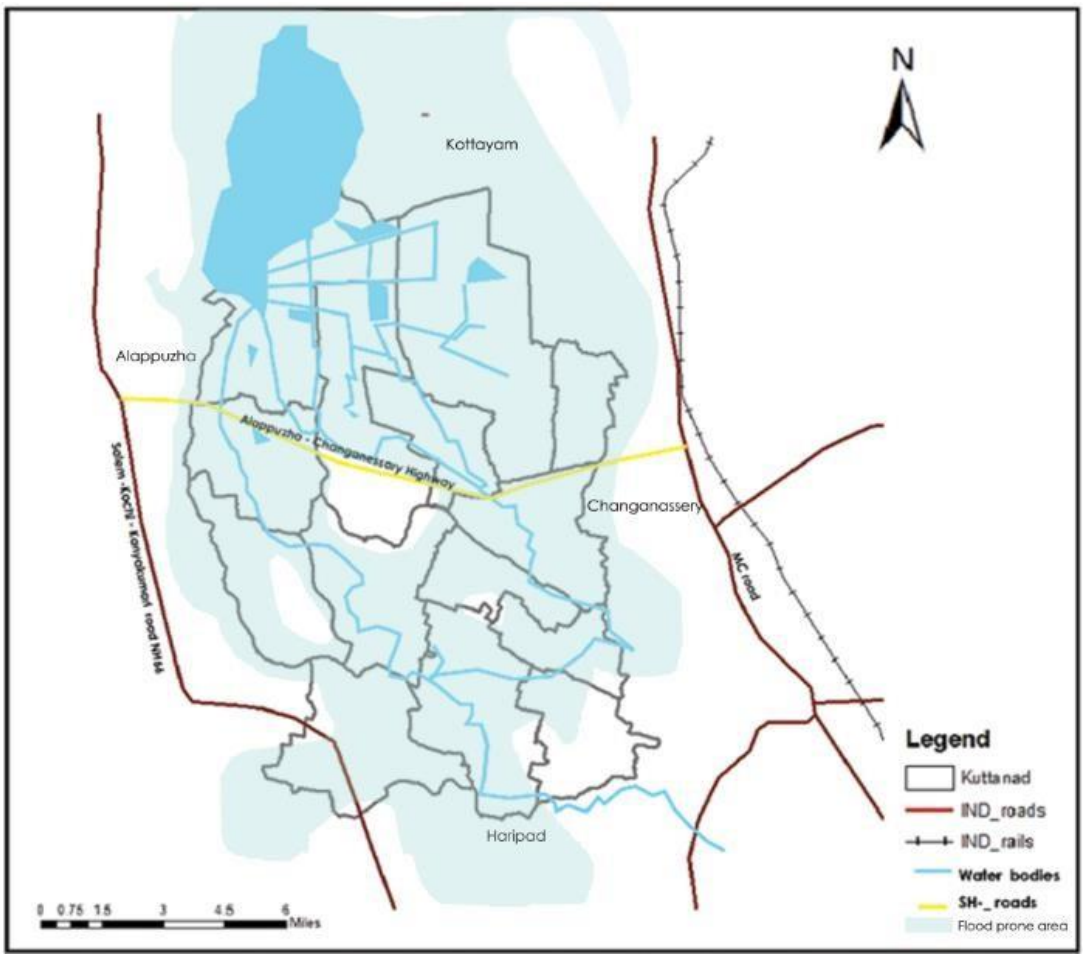

Figure 4:4: Flood-prone area of Kuttanad
Source: ArcGIS

4.3 SOIL TYPOLOGY IN KUTTANAD

Kuttanad is separated into six agroecological zones based on the soils, geomorphology, and salinity intrusion. (Nelson, 2019)

(i) Upper Kuttanad

(ii) Kayal lands

(iii) Vaikom Kari

(iv) Lower Kuttanad

(v) North Kuttanad

(vi) Purakkad Kari (Nelson, 2019)

Different ratios of sand and clay make up the soil in Kuttanad. In many places, it contains decomposing organic waste, particularly decomposing timber logs. The soils in Kuttanad's low-lying sections have a high quantity of harmful salts and are quite acidic in nature. These potentially acidic sulfate soils with poor drainage also contain significant amounts of pyrites. The soils of Kuttanad are divided into Karappadam and Kari lands based on their morphology.

4.4 ISSUES FACED IN KUTTANAD

The main problems affecting Kerala's wetlands include pollution, eutrophication, encroachment, reclamation, mining, and loss of biodiversity. Our biodiversity in wetland areas has been greatly devastated by several development activities such as the construction of major buildings, roads, trains, and other infrastructure, as well as township development. The natural habitats of these species are additionally harmed by destructive fishing practices including dynamiting, poisoning, will full destruction of spawners, habitat alteration for hydroelectric projects, etc., as well as the building of barrages, bunds, anicuts, dams, etc.

1. Species loss

In many places, encroachment, mining, and reclamation result in biodiversity loss and alter the way that ecosystems function.

2. **Waterborne and zoonotic diseases**

Organic and inorganic contaminants, as well as pathogenic microorganisms of numerous water-borne diseases like typhoid, cholera, and dysentery, are present in untreated sewage. Numerous latrines, many of which are the single leach-pit variety, are located along the estuary's banks, where they directly contribute to fecal contamination.

3. Obstruction to navigation

The reduction in the depth of watercourses along numerous stretches caused by encroachment, mining, and reclamation has also harmed water transportation in many locations. Eutrophication-induced excessive weed growth causes a wetland to become shallower as a result of high rates of siltation.

Figure 4:5: Eutrophication in water
Source: Photo taken during Primary survey, 2022

4. Decrease in agriculture production and productivity

Due to the conversion and reclamation of lowlands and other wetland areas for construction and other uses, agricultural land has significantly decreased during the past three decades.

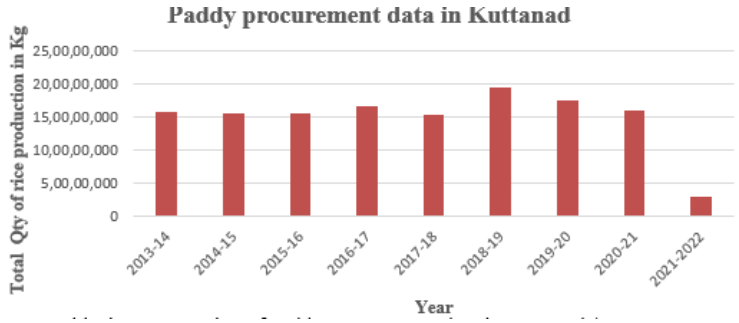

Figure 4:6:Paddy procurement in Kuttanad (2013-14 to 2021-2022)
Source: Data obtained from the agricultural statistics department, Alappuzha

5. Scarcity of potable water

In many areas of Kerala, a major problem is the lack of potable water, particularly during the heat. The main causes of this are salt intrusion and subsequent eutrophication in wetland areas.

Figure 4:7: Drought in Kuttanad
Source: Photo taken during Primary survey, 2022

6. Flood and drought

The area has seen excessive monsoon floods as a result of the reclamation and conversion in numerous places.

Figure 4:8 Flood level in Champakulam village in 2018
Source: Data collected from Kuttanad taluk office

Figure 4:9: Flood level in Muttar in 2018
Source: Data collected from Kuttanad taluk office

7.Aesthetic value depletion

The aesthetic value of many wetland zones has been severely diminished as a result of encroachment, reclamation, and garbage dumping activities. A nice illustration of this is Thiruvananthapuram's Vellayani Kayal. The Keralan wetlands' eutrophication and pollution issues also have significant aesthetic effects, particularly on the tourism industry

4.5 PARAMETERS FOR ADAPTIVE RESILIENCE INDEX

4.5.1 LANDUSE

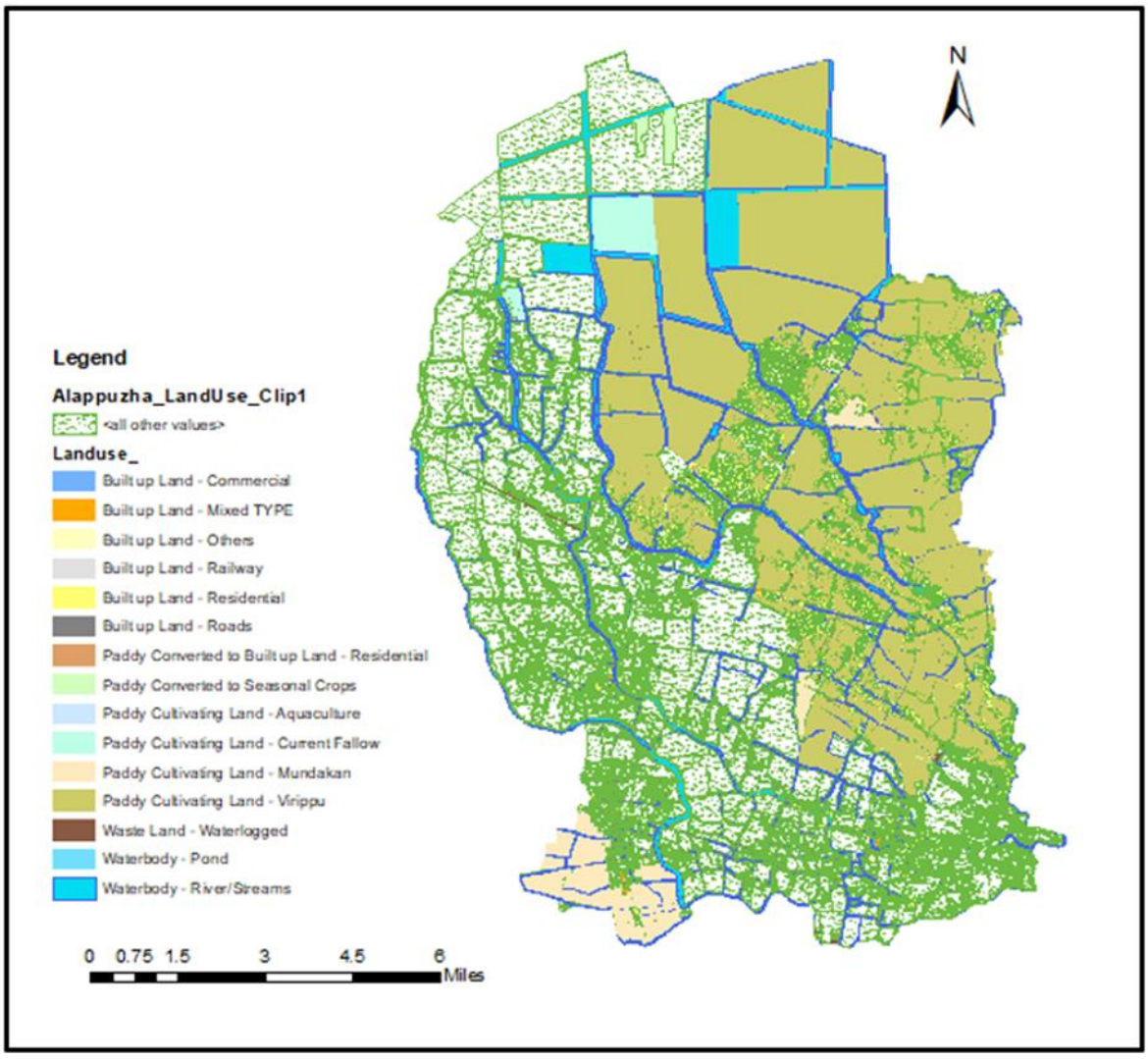

Figure 4:10: Landuse map of Kuttanad
Source: Arc GIS

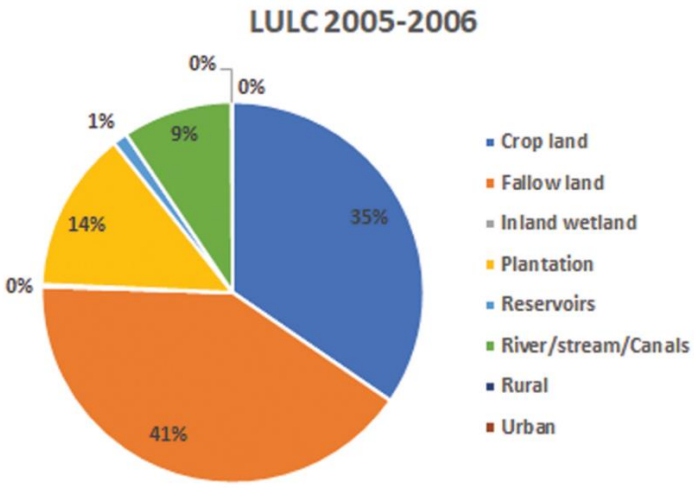

Figure 4:11: LULC OF 2005-2006 in Kuttanad taluk region
Source: Data collected from Bhuvan thematic dataset

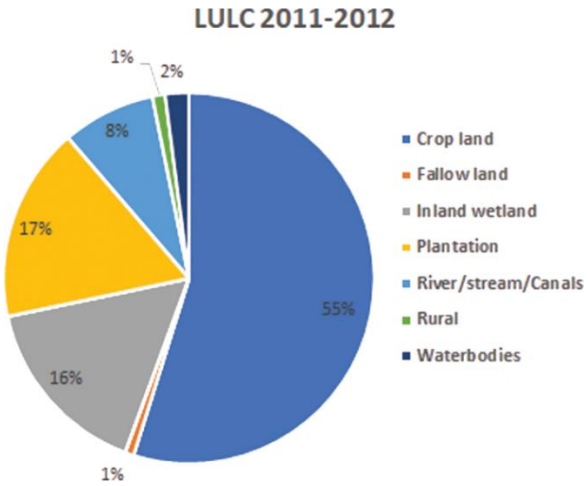

Figure 4:12: LULC OF 2011-2012 in Kuttanad taluk region
Source: Data collected from Bhuvan thematic dataset

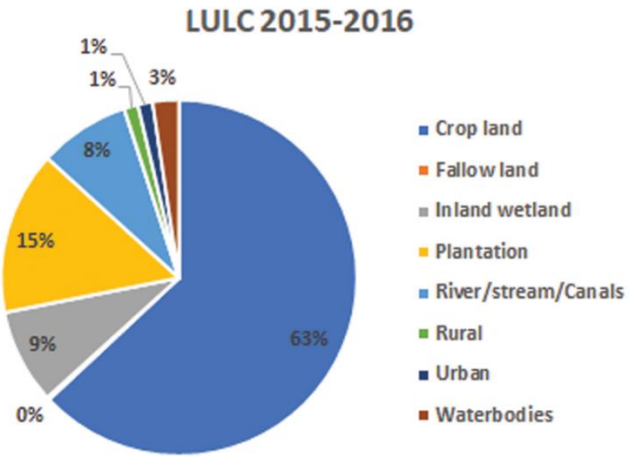

Figure 4:13: LULC OF 2015-2016 in Kuttanad taluk region
Source: Data collected from Bhuvan thematic dataset

Wetland reclamation is a direct or indirect impact of the development activities. The spread of human settlements near wetlands has brought this deterioration. The wetland degradation was observed at 7% in total area of the land use map. A decline in paddy area is brought out by statistical analysis of the land use map. It has observed a 100.6 sq. km of wetland paddy fields were reclaimed into uplands in the region either into coconut groves or into homesteads with mixed crops.

4.5.2 DEMOGRAPHY

The statistical study of human populations is known as demography. Population dynamics and dimensions are examined and measured through demographic analysis, which can be applied to entire civilizations or specific groups based on factors like education, ethnicity, nationality, and religion.

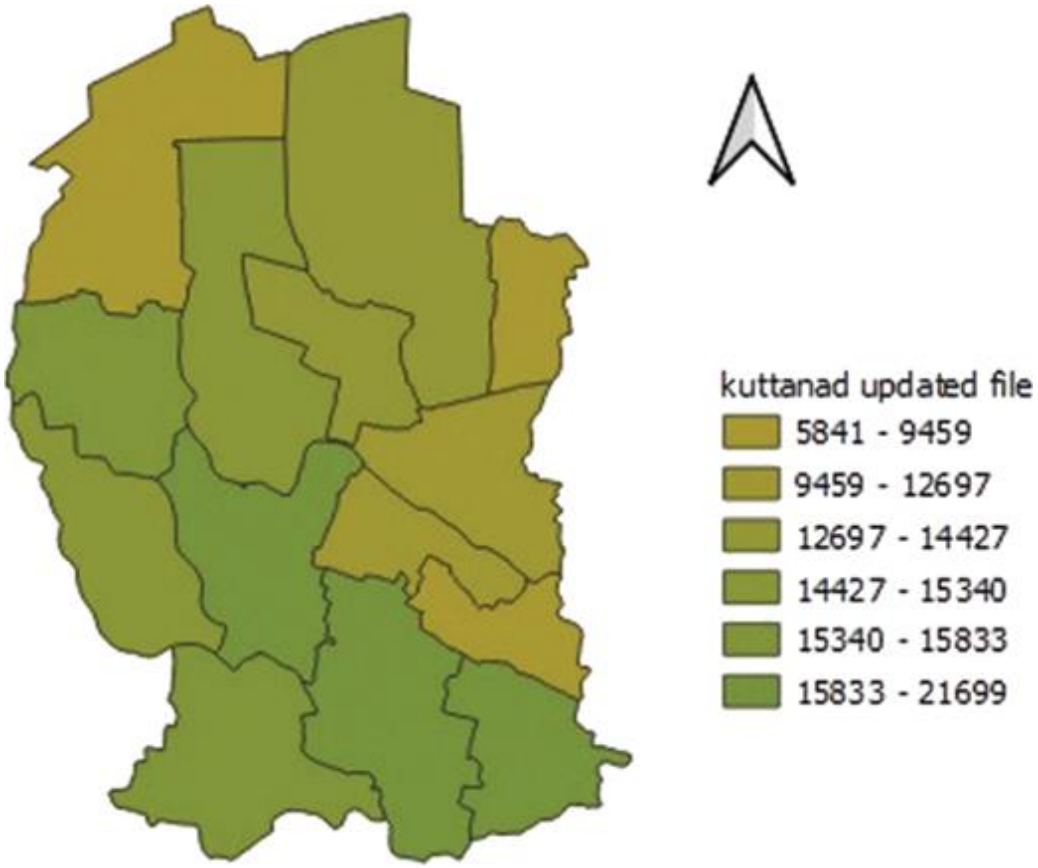

Figure 4:14: Population map of Kuttanad taluk region
Source: Author generated in QGIS with respect to the Census data

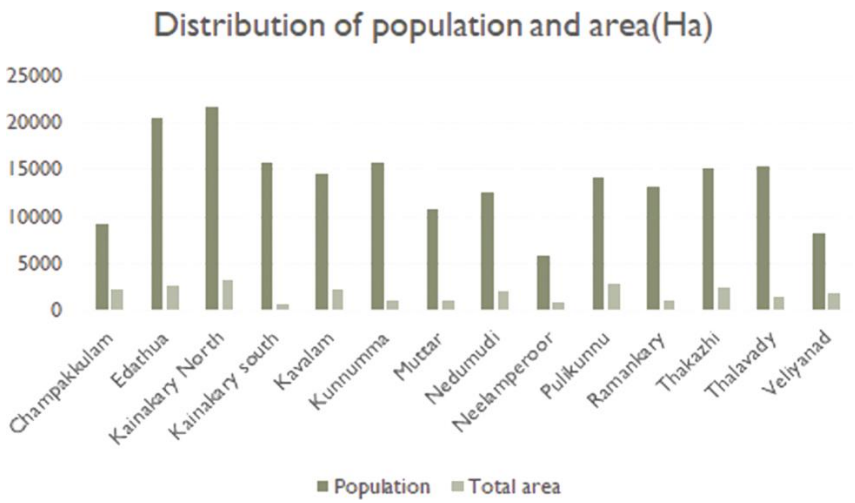

Figure 4:15: Population and area distribution in Kuttanad taluk region
Source: Data collected from Census, 2011

According to statistics from the 2011 census, Edathua village has the most highest population among the villages in the Kuttanad Taluk area and Neelamperoor having the lowest number (5841). In comparison to the other 13 villages in Kuttanad, Kainakary North has the highest area and Neelamperoor has the lowest area in the taluk region of Kuttanad.

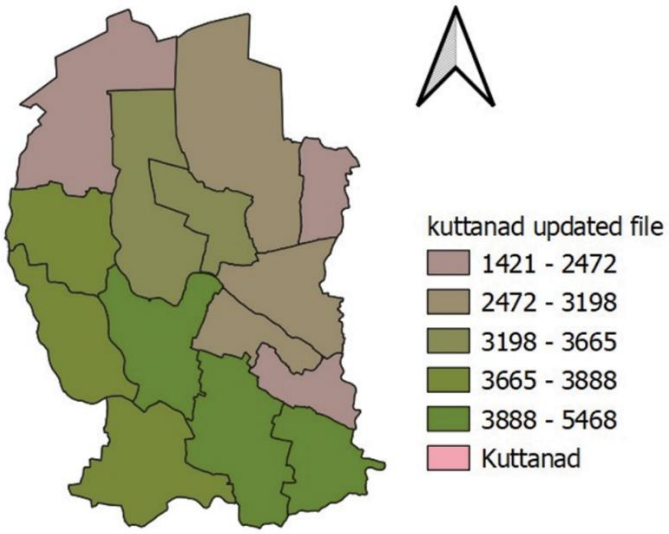

Figure 4:16: Distribution of households in Kuttanad taluk region
Source: Author generated in QGIS with respect to the Census data

The most households (5468) are located in Edathua Village, and the fewest (1421) are found in Neelamperror. This household distribution in the Kuttanad taluk region provides a general indication of the total number of families living there.

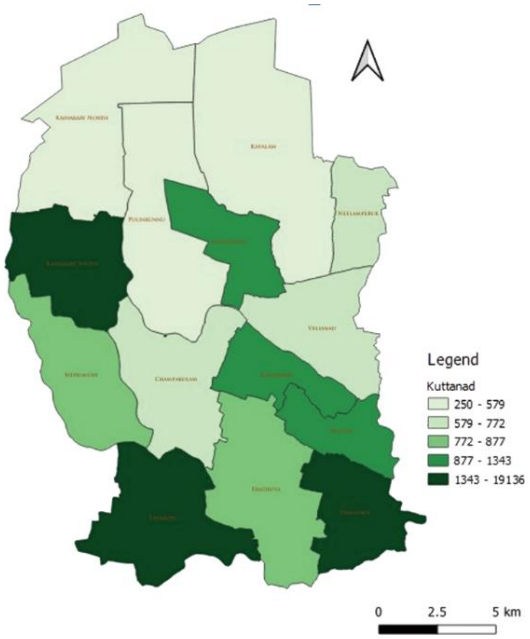

Figure 4:17: Population density map of Kuttanad taluk region
Source: Author generated in QGIS with respect to the Census data

The villages with the greatest population density in the Kuttanad taluk are Thakazhi, Thalavady, and Kainakary South. Compared to other Kuttanad taluk villages, Kainakary North, Kavalam, and Pulikunnu villages have the lowest population densities.

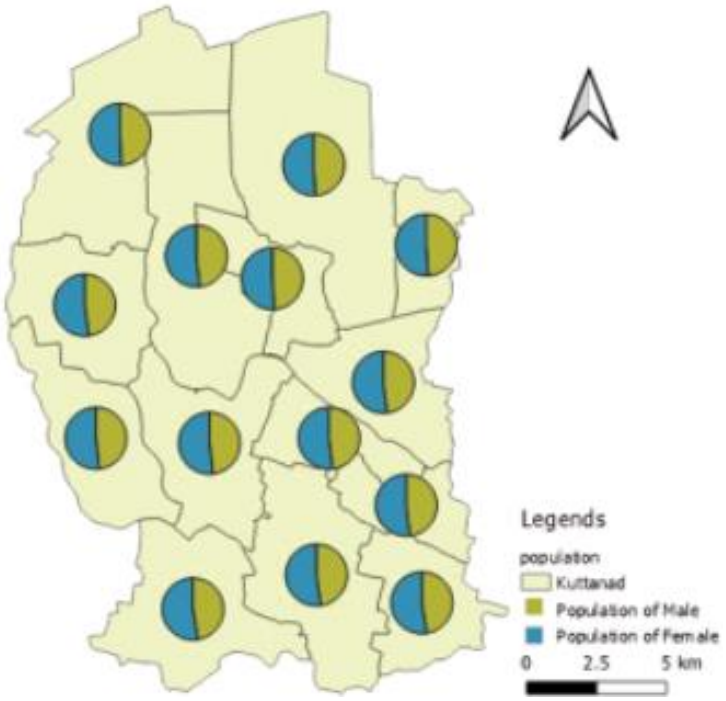

Figure 4:18:Population of males and females in Kuttanad taluk region
Source: Author generated in QGIS with respect to the Census data

With 11321 females and 10375 men, Edathua has the greatest female population. With 2983 females and 2858 males, Neelamperoor has the lowest population of both genders.

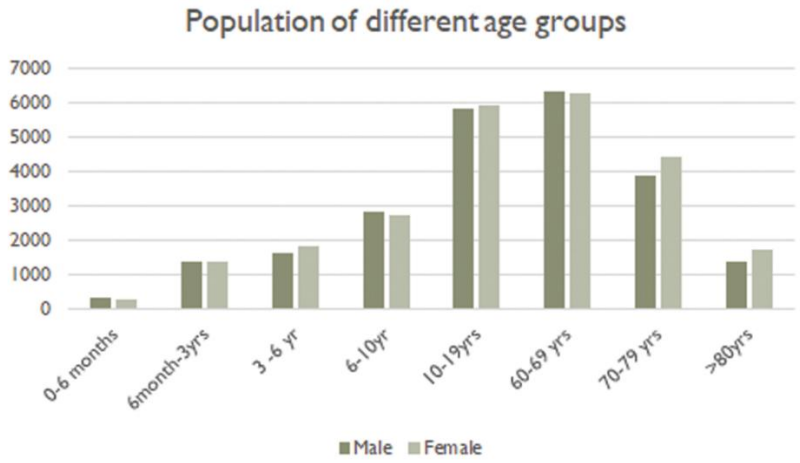

Figure 4:19:P opulation of different age groups Kuttanad taluk region
Source: Data collected from the statistics report of 2022, Statistics department

It has been noted that the Kuttanad taluk region's overall dependence ratio is 33.28%. It highlights significant patterns in social support requirements and the probable impacts of shifting population age structures on social and economic growth.

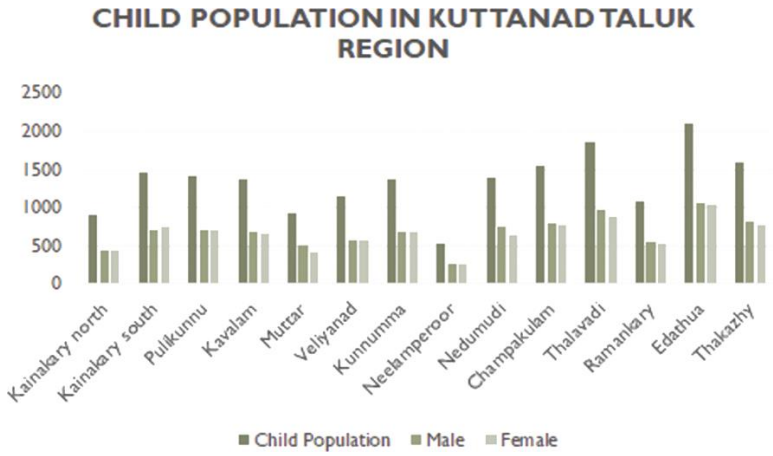

Figure 4:20:Population of children of 0-6years age group in Kuttanad taluk region
Source: Data collected from District Census Handbook, 2011

10% of Kuttanad Taluka's population is under the age of six, with 51% males and 49% girls. The subdistrict has roughly 47 thousand households, with 4 people residing in each family on

average. Edathua and Thalavady are the places with the most children, both male and female. Children are more prevalent in Kainakary (South), Kunnumma, and Thalavady.

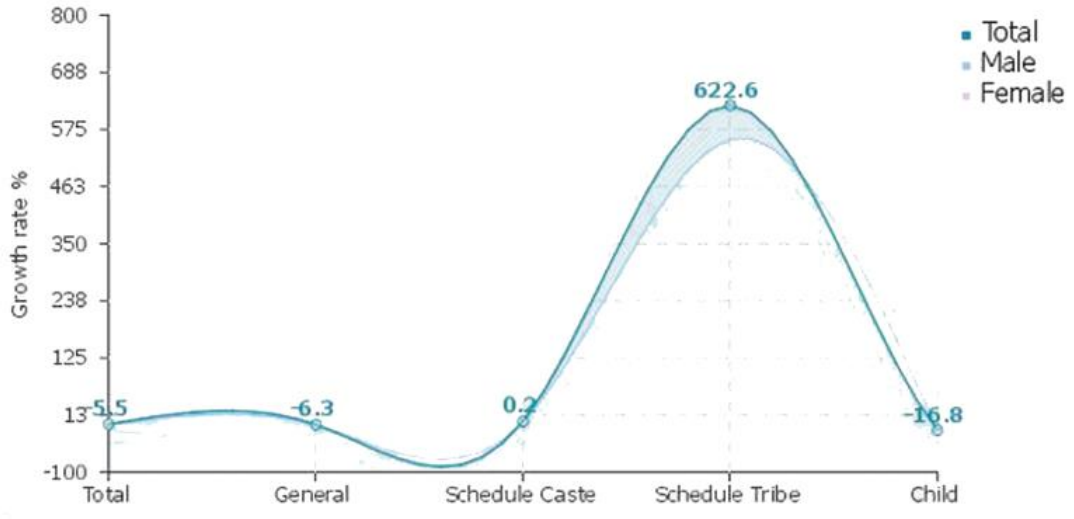

Figure 4:21:Population growth rate (2001-2011) in Kuttanad taluk region
Source: Data collected from District Census Handbook, 2011

The growth rate of the subdistrict's population has decreased; in the previous 2 lakh people, the overall population increased by about 5.5%. The population has declined by 6.3%, and the population of Schedule castes has increased by 6.7%. The female population growth rate is 4.5%, which is 2.2% greater than the male population growth rate. In Kuttanad Taluk, the population of scheduled tribes and general caste increased.

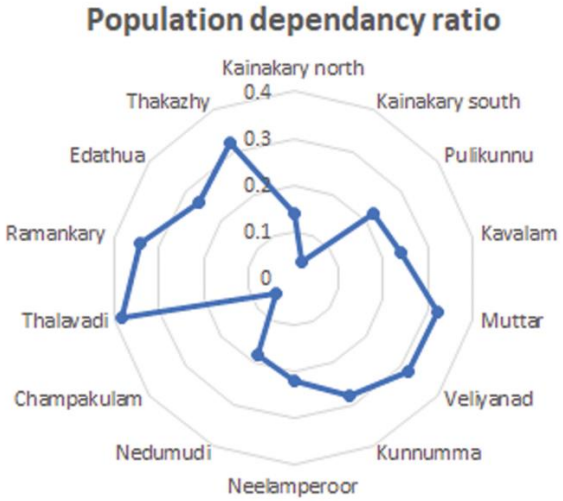

Figure 4:22:Population dependency ratio
Source: Data collected from Statistics department

The largest population dependence ratio is in Thalvadi. The area with the lowest population dependence ratio is Kainakary South. Kainakary South has a higher level of adaptive ability and resilience than other communities as a result.

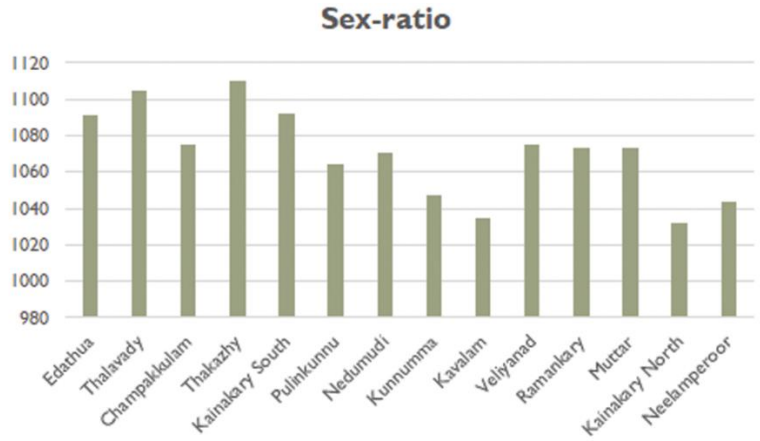

Figure 4:23:Sex ratio of various villages in Kuttanad taluk
Source: Data collected from Census data, 2011

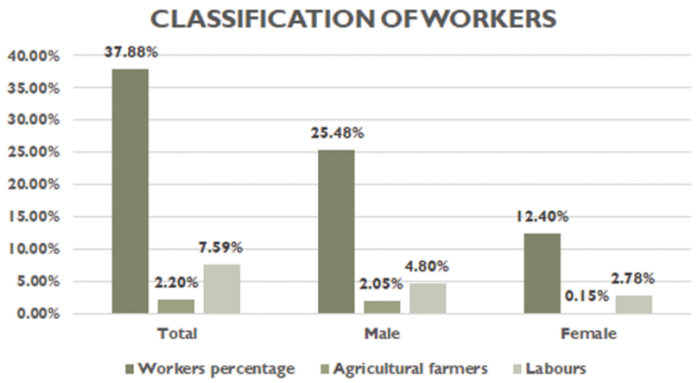

Figure 4:24 :Marginal workers in Kuttanad taluk
Source: Data collected from Census data, 2011

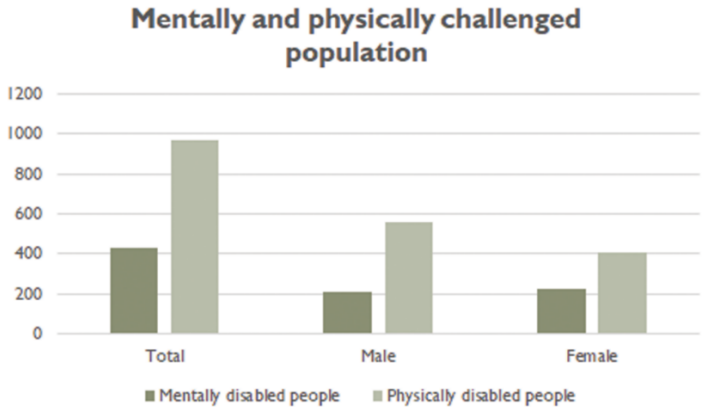

Figure 4:25: Population of mentally challenged and physically challenged population
Source: Vikasanapadhathi report of 2022-2023, Statistics department

There are 428 mentally impaired people and 967 physically handicapped people in total. In the Kuttanad taluk region, there are more physically challenged people, which makes the area more vulnerable.

4.5.3 POVERTY RATE IN KUTTANAD TALUK REGION

Table 4:1: Details of ration cards

RATION CARD DETAILS	
AAY	4101
PHH	26973
NPS	8957
NPNS	13106
NPI	301

Source: Data collected from Kuttanad taluk office

The number of AAY and PHH groups in Kuttanad is bigger when one takes into account the information above. This suggests that the population of Kuttanad Taluk is more often defined as being below the poverty line (BPL). The area becomes more susceptible as a result.

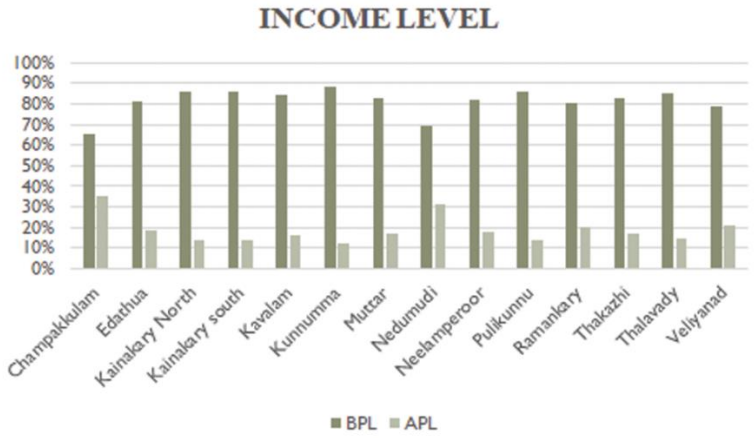

Figure 4:26: Categorization of income over the villages
Source: Primary survey conducted on March, 2023

4.5.4 GOVERNMENT ALLOWANCE

Government assistance recipients assist those who are weak in overcoming their circumstances more quickly.

Table 4:1: Details of government allowance for vulnerable people in Kuttanad taluk region

Pension	Total	Male	Female
Oldage pension	6512	3379	3133
Widow pension	3747	3747	0
Disabled pension	1037	623	414
Farmers pension	8749	4222	4527

Source: Data collected from Kuttanad taluk office

4.5.5 HOUSING

In the Kuttanad taluk area, 34 notified colonies that extend 14 villages are present. We may also determine the region's susceptibility from the state of the colonies there. The vulnerability grade will be high if the condition is bad, and vice versa.

Table 4:2 : Number of colonies in Kuttanad taluk region

Name of Villages	Number of colonies
Neelamperoor	5
Veliyanad	3
Ramankary	9
Kavalam	4
Pulikunnu	2
Muttar	3
Thakazhi	2
Thalavadi	2
Edathua	2
Champakulam	1
Kainakary	1

Source: Data collected from Kuttanad taluk office

There are 34 colonies total in the Kuttanad region, with Ramankary having the most with 9 colonies, followed by Neelamperoor and Veliyanad. Champakulam and Kainakary have the fewest 1 colonies overall.

Figure 4:27: Colony in Champakulam village
Source: Photos taken during primary survey conducted on March ,2023

4.5.5.1 ISSUES FACED IN COLONIES

Lack of access to clean water for drinking. Colonists in the colonies purchase water to drink. Poor folks wouldn't be able to afford it. Lack of access to the colonies via roadways. Some colonies with limited access to the highways are found on the corner side of agricultural production. colonies' lack of infrastructural facilities.

Figure 4:28 : Colony which have less accessibility
Source: Data from Kuttanad taluk office

4.5.5.2 HOUSING SCHEMES

LIFE Mission Kerala Housing Scheme to provide free and affordable housing to homeless in the State. The scheme is in its third phase and aims to provide housing opportunities to the needy within the next five years.

Table 4:3: Details of Life Mission Phase 2

Panchayat		Agreement	Work completed
Champakulam	SC	5	3
	General	47	43
Edathua	SC	11	10
	General	52	47
kainakary	SC	10	8
	General	104	101
Nedumudi	SC	10	9
	General	91	89
Thalavdi	SC	4	4
	General	70	67
Thakazhi	SC	13	6
Neelamperoor	SC	4	2
	General	56	54
Veliyanad	SC	6	4
	General	62	59
Kavalam	SC	12	8
	General	68	65
Pulikunnu	SC	9	7
Ramankary	General	48	45
	SC	11	8
Muttar	SC	12	9

Source: Data collected from the Statistics department

Table 4:4 : Details of Life Mission Phase 3

Panchayat	Landless		Houseless	
	Target	Completed	Target	Completed
Champakulam	90	70	419	356
Edathua	240	240	589	550
Kainakary	138	136	1035	1035
Nedumudi	126	126	658	659
Thalavadi	182	176	627	616
Thakazhi	119	106	808	807
Neelamperoor	86	62	202	198
Veliyanad	112	94	358	315
Kavalam	90	78	426	364
Pulikunnu	84	76	536	432
Ramankary	121	105	256	198
Muttar	94	81	208	202

Source: Data collected from Statistics department

IAY AND PMAY SCHEMES

This scheme helps to measure to solve homeless people. As per 2021-22, the government provide 10 houses for general, 24 ST category and 6 for minority groups.

4.5.6 ECONOMIC SECTOR

The main income of Kuttanad people is from agriculture farming, animal husbandry and tourism.The chief agricultural products in Kuttand are coconut, paddy, sugarcane, areca nut, fruits, etc. Every year a huge chunk of revenue comes from these agricultural products helps in its economy to a great extent. Though the Kuttand is scantily industrialised but yet it has some

small scale industries of coir and coir products, marine products, handlooms, different types of handicrafts, toddy tapping.

4.5.6.1 INDUSTRY SECTOR

A part of the economy known as the industrial sector is made up of companies that help other companies with the production, transportation, or manufacture of their goods.

Table 4:5 : Details of industrial units in Kuttanad

Type of units	Nos
Food and agro basis food products	26
Readymade garments	29
Wood manufacturing units	2
Cement producing manufacturing units	10
General engineerings	23
IT Mobile phone	5
Rubber products	4
Electronics	4
Plastics units	9
Paper products / Printings	3
Service units	7
Wax manufacturing units	8
Other units	41

Source: Data collected from Statistics department

Issues : Kuttanad has a limited supply of land for industrial buildings. Units associated with agriculture are not used. Due to floods, the majority of the units are closed.

4.5.6.2 ANIMAL HUSBANDRY

Animal husbandry is becoming one of the crucial farming sectors that may improve Kuttanad's food security and provide more jobs. Residents of Kuttanad rely heavily on it.The Animal Husbandry Department's efforts are directed at making livestock husbandry a significant element of Kuttanad's overall development process.

Table 4:6 : Details of productivity of cattle farming in Kuttanad taluk region

Items	Nos	Production (Yearly)
Cow	2980	3685225 Litre
Calf	336	11400Kg
Goat	3729	901557 Litre
Buffalo	155	153385 Litre
Chicken for eggs	53379	2887143
Chicken for meat	18510	240450kg
Duck	337266	9715000eggs ,75000kg
Kada	7350	4515000 eggs

Source: Data collected from Economics Statistics department

Table 4:7 Details of facilities for cattle farming in Kuttanad taluk region

Items	Facilities
Diary farm	23
Goat farm	35
Chicken for meat	3
Chicken for eggs	21

Source: Data collected from Economics Statistics department

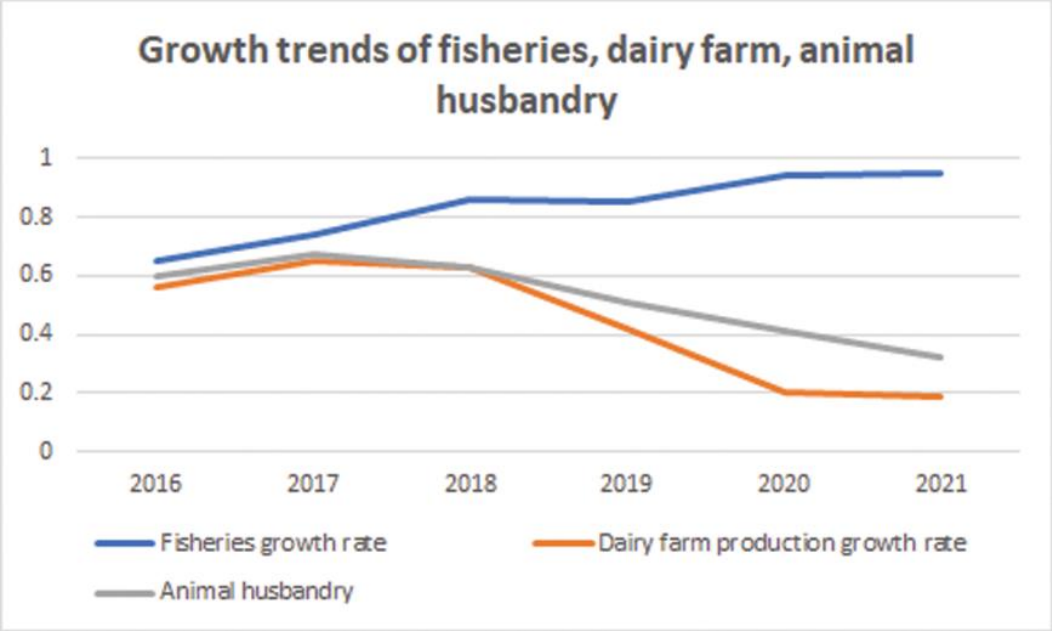

Figure 4:29 Annual growth trends in Kuttanad region
Source: Data collected from Economics Statistics department

There is a declination of growth trend in cattle farming and diary production in Kuttanad taluk region. The main reason for this declination is the frequent occurrence of floods in Kuttanad region. The relocation of cattle population finds difficulty during floods.

4.5.6.3 AGRICULTURE SECTOR

The primary agricultural activity in Kuttanad is paddy agriculture. The majority of the state's food grain supply comes from there. In spite of Kuttanad's continued loss in paddy acreage and productivity over time, the State reached 50% self-sufficiency in the production of rice in 1972–1973.

In Kuttanad, agriculture is reliant on the whims and fancies of nature. Weather and climatic conditions are unpredictable. Younger generations are drawn to alternative industries and even positions abroad, which encourages migration. Farming has a workforce shortage as a result of migration. The complicated set of circumstances caused a significant shift in the social and economic situations of Kuttanad's farmers.

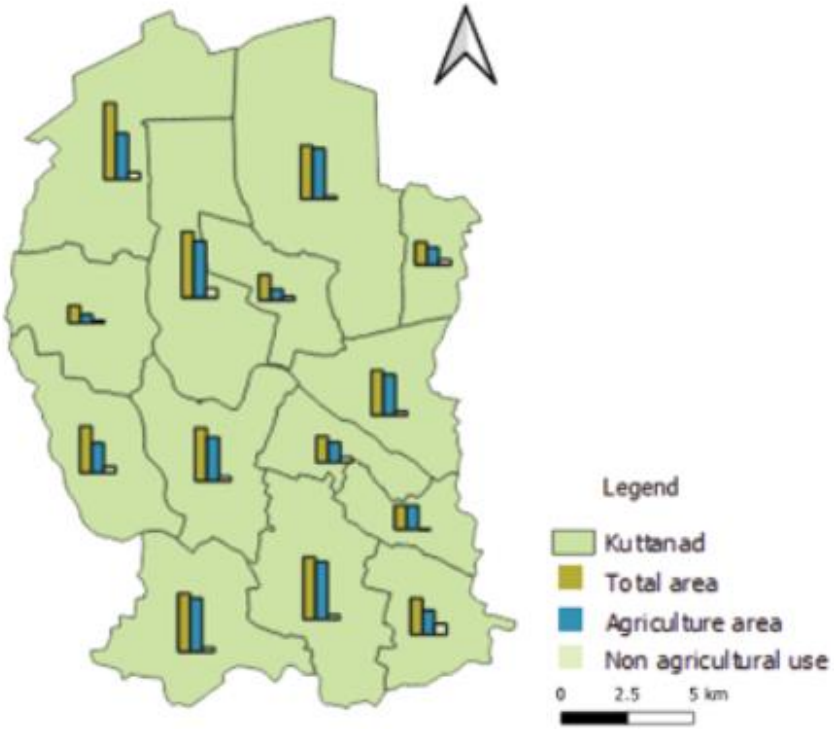

Figure 4:30 : Map showing the distribution of agricultural, non agricultural area over the villages
Source: Data collected from Statistics department,2023

The availability of agricultural land is higher in Edathua followed by Pulikunnu and Thakazhi. It has a higher area of 2500.61 ha.

Table 4:8 Agricultural production in Kuttanad taluk

Items	Area (Ha)	Production (MT)	Production capacity(T/Ha)
Paddy	25310.344	49916.86	9.5
Coconut	3525	65175.5	35
Banana	490	6185	75
Vegetables	220	1240	35
Tapioca	58	690	11.27
Sweet potato	65	1090	21
Spices	47		20
Others	170		

Source: Data collected from Statistics department, 2023

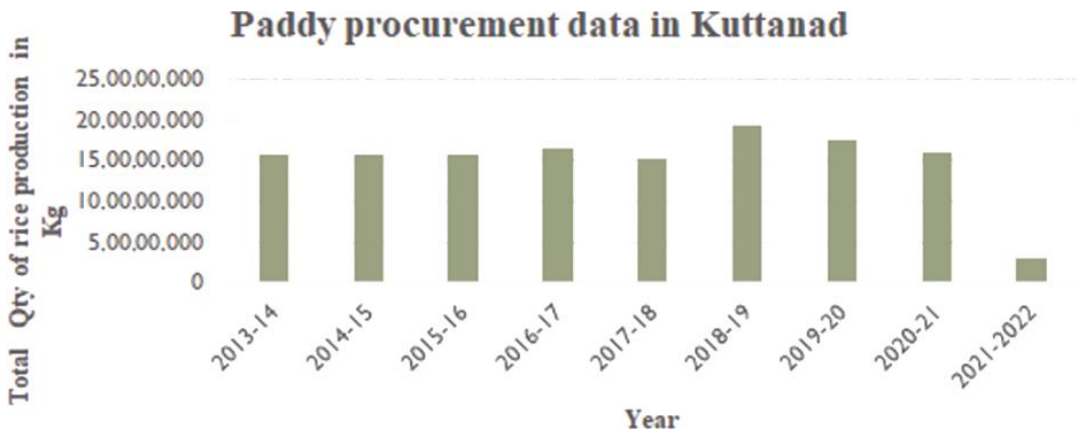

Figure 4:31: Graphical representation of paddy procurement data in Kuttanad (2013-14 to 2021-2022)
Source: Data obtained from the agricultural statistics department, Alappuzha

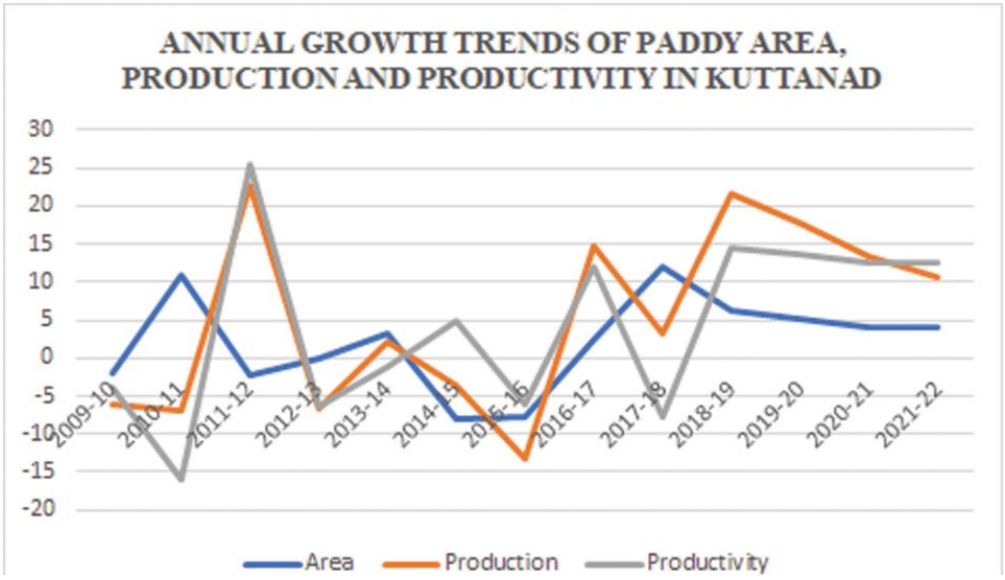

Figure 4:32 Figure: Annual growth trends in area, production and productivity over the years
Source: Data obtained from the agricultural statistics department, Alappuzha

The paddy production in Kuttand region is declining over the years . The main reason of this declination is the loss that occurred during the floods and there is large scale crop loss/damage due to pest attacks. Paddy cultivation has become highly uneconomical in Kuttanad. The cost of cultivation has increased tremendously. The required labour force has become scanty and the cost of labour has become quite high. Many of the enterprising farmers have left the place, and their fields are either remaining fallow or are given to others on a lease. As per a research estimate, only 60 % of the paddy fields in Kuttanad are cultivated now, and about 11% of the land remains as cultivable wastelands.

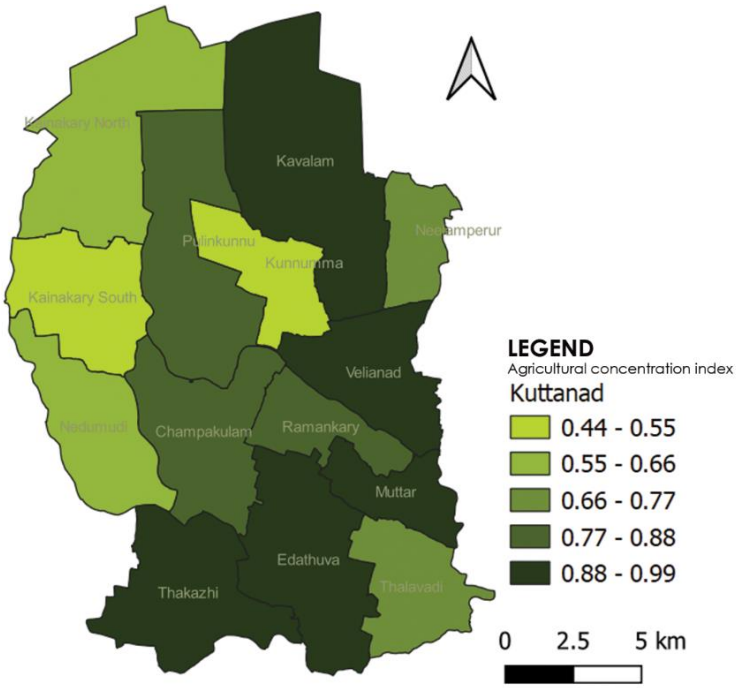

Figure 4:33 Map showing agricultural concentration index over the villages
Source: Q GIS

The areas with the biggest concentrations of agricultural activity include Muttar, Kavalam, Edathua, and Thakazhi. The lowest concentration index is in Kunnumma, followed by Kainakary South.

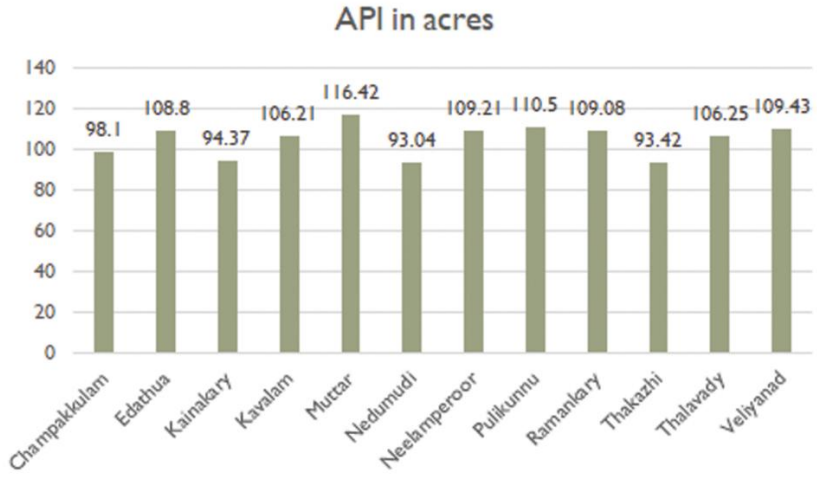

Figure 4:34 Figure: Average production index in Kuttanad taluk (2014-2018)
Source: Data obtained from the agricultural statistics department, Alappuzha

Average production index is higher in Muttar panchayat and lower in Nedumudi panchayat.

1. SCHEMES AND PROGRAMMES

I. National Biogas Development Project

Under the scheme, assistance will be provided for setting up of bio gas plants of the normal type as well

II. Farmer Welfare Fund Board

The pension schemes and welfare programmes implemented . An amount of ₹ 100.00 lakh is earmarked under this programme for operational expenses of the Board.

III. International Research and Training Centre for Below Sea level Farming, Kuttanad

An outlay of ₹ 25.00 lakh is provided for popularizing innovative activities, resolving field problems of Kuttanad region

IV. Natural Calamities and Pests and Disease Endemic

An amount of 750.00 lakh is provided for the activities and creation of buffer stock of short duration varieties of paddy, pulse and vegetables for distribution to affected farmers in the event of natural calamities.

V. Kerala State Warehousing Corporation – Share participation

State Government has to provide share participation to the Kerala State Warehousing Corporation to match the flow of funds from the Central Warehousing Corporation. An amount of Rs.25.00 lakh is provided for this purpose during 2022-23.

VI. Punarjani

The scheme envisages to revive the damages caused in floods and landslides of previous years. Employment and income generation activities will be given more thrust. An amount of ₹ 185.00 lakh is set apart.

VII. Kerala State Horticultural Products Development Cor Ltd

An amount of ₹ 100.00 lakh is allocated to Horti corp as share capital for the year 2022-23.

Out of the total outlay, an amount of ₹ 1200.00 lakh is earmarked for infrastructure development of various padasekharams in Kuttanad region and for establishment of Vertical Axial Flow pump/submersible pump sets 10-50 HP replacing the conventional Petti & Para, including construction of raised platforms for installation. Convergence of infrastructure development works of various padasekharams undertaken under RKVY, RIDF and LSGD will be ensured. The infrastructure works carried out by KLDC shall also be integrated into this. During 2022-23, in order to reduce the dependence on conventional energy sources, the centrally sponsored scheme PM KUSUM will be implemented by the Department in collaboration with ANERT to utilize solar energy in agriculture. Accordingly, 30% of the expenditure in setting up solar powered pump sets will be met from the central funds with equal

contribution from ANERT. 20 % of the expenditure in capital expenditure will be met from the State Plan funds as top up subsidy. The beneficiary contribution will be 20 %. An amount of 500.00 lakh is allocated for meeting the top up subsidy. ₹ Preference will be given for energisation of pumps in Kuttanad region. For small, marginal and medium farmers with less than 5 acres, there will be provision for availing loans from PACS. The annual repayment of loans can be met from sale of solar energy generated. No direct cash subsidy will be provided under the scheme. Coconut Development was ensured through the Keragramam scheme. Organic farming was promoted in potential areas with assured forward and backward linkages. Distribution of quality coconut seedlings was taken up under Kerasamrudhi programme. Rejuvenation of the spices economy was continued under the scheme "Development of Spices". Establishment of new Agro Service Centres and new Plant health clinics was also given emphasis. Programs under marketing included Market Intervention support, Market Infrastructure, and Market Development.

2. ISSUES FACED IN THE AGRICULTURE SECTOR IN KUTTANAD

Burning of rice straw after the harvesting of rice in Kuttanad. This creates air pollution in Kuttand region. Agricultural leaching out for decades has been causing the entire pool to remain eutrophicated and toxic. As the waterlogged, wetland paddy zone, the primary environmental challenge in Kuttanad is that of water pollution. Lack of waste management systems along the rivers in the upstream regions also causes flowing down of the entire waste of all those towns to reach Kuttanad regularly. The coconut crop in the region is also destroyed by the root-wilt disease. Damage due to rodents in paddy crop is 8-10% during the various seasons.

4.5.7 TRANSPORTATION

Figure 4:35 : Map showing the major road network in Kuttanad taluk
Source: Data collected from Kuttanad Taluk Office

State Highway 11 (SH 11) is a State Highway in Kerala, India that starts in Kalarcode, Alappuzha and ends in Perunna, Changanassery.The road is popularly known as AC road (Alappuzha Changanassery) road. The highway is 24.2 km long. The road runs parallel to AC Canal. The A-C canal, which runs along 99% of the length of the road on its southern side is meant to empty the flood waters of upper Kuttanad into the Nedumudy river and the Pallathuruthy river near Alappuzha, which reach the Vembanad lake but did not come into effect so far, resulting in the submerging of the road even when the symptoms of a flood is seen in monsoon. The road crosses no. of canals and 3 rivers, namely Pallathuruthi, Nedumudi, and Kidangara, tributaries of Manimala and Pamba rivers. AC Road is the first road which is passing through Kuttanad Paddy fields. The road passes through scenic paddy fields, coconut groves in Kuttanad and backwaters in Alappuzha.

Table 4:9 : Details of roads present in Kuttanad taluk region

Type of roads	3m width road	3m – 6m width road	More than 6m width	Total length	Roads need repair works	Roads which are to be constructed
Mud road	1728	12	12	1743	1283	1617
Metal road	567	241	0	808	562	748
Tar road	335	138	0	473	226	925
Concrete road	128	0	0	128	0	0
Concrete footpath	645	0	0	645	0	0
Interlock road	4	0	0	4	0	0
Footpath	3352	0	0	3352	0	0
Total length				7153	2071	3290

Source: Data collected from Vikasanapadhathi of Kuttanad in 2022

4.5.7.1 ONGOING PROPOSAL

The Government of Kerala had announced the construction of Alappuzha-Changanassery elevated road project under the Kuttanad package. The completion would take 2-3 years. The 24.14-km AC road, under the Kerala State Transport Project, is being reconstructed as a semi-elevated highway at a cost of ₹649.76 crore. The project, which is aimed at preventing flooding of the road during the monsoon season.

Figure 4:36 : Ongoing construction of AC road in Kuttanad taluk
Source: Photo taken during primary survey conducted, 2023

4.5.7.2 WATER TRANSPORTATION

Water transport is also an important transportation facility in a kuttanad taluk region. Most of the panchayts is accessible only through water transportation. It plays an important role in attracting tourist in Kuttanad taluk region. Enjoying the serenic beauty of backwaters in Kuttanad is a major attraction for tourists. Most of the emergency rescues were done through water transport in Kuttanad taluk region.

Figure 4:37 : Loading of goods into a boat
Source: Photo taken during primary survey conducted, 2023

Figure 4:38 : Rescue mission of people from Kuttanad to higher upland area
Source: Data collected from Kuttanad taluk office

A Kuttanad Houseboat is a sizable boat that tourists utilise in the Kuttanad waters; oddly, it was not created or introduced for tourists. Kerala boasts a distinctive environment and a thriving freshwater body. Bulk cargo may be transported through water with ease. Large water vessels that glide regal and worthily through Kerala's waters a land fondled by raindrops were first adopted in the past to manage effective heavy cargo transporting. These boats, known as "Kettuvalloms" or "Kuvuvalloms," are the forerunners of what we now refer to as "houseboats."

Figure 4:39 Figure: Houseboats in Kuttanad taluk region
Source: Data collected from Kuttanad taluk office

4.5.7.3 CULVERTS IN KUTTANAD TALUK

Culverts were identified as permanent or temporary structures over any water body which are/could be used for walking by people and animals. The culverts play a very important role in connecting various parts of the panchayat in Kuttanad since the taluk is transversed by rivers and canals. The culverts often run along the rivers where canals meet the river where the access to the canal is possible on a boat only by passing under the culvert.

Table 4:10 : Panchayat-wise total number of culverts/bridges captured

PANCHAYAT	NUMBER OF CULVERTS MAPPED
Kainakary	101
Neelamperoor	206
Pulincunnoo	191
Kavalam	201
Veliyanadu	191
Ramankary	182
Champakulam	160
Thakazhy	186
Edathua	231
Muttar	153
Thalavadi	216
Nedumudi	156

Source: Kerala State Disaster Management Authority. (n. d).http://sdma.kerala.gov.in

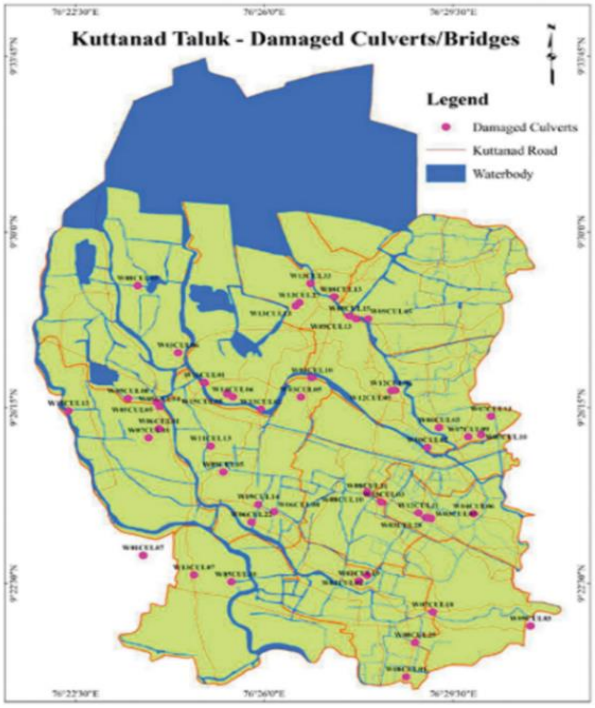

Figure 4:40 Map showing damaged culverts in Kuttanad taluk
Source: Kerala State Disaster Management Authority. (n. d).http://sdma.kerala.gov.in

It was observed that there were 49 damaged culverts/bridges. It includes partially/completely damaged culverts, bridges, temporary structures like iron pipe.

Table 4:11 : Number of damaged culverts/bridges in each panchayat

PANCHAYAT	NUMBER OF GRUEL CENTRE
Kainakary	1
Neelamperoor	0
Pulincunnu	4
Kavalam	7
Veliyanadu	7
Ramankary	2
Champakulam	7
Thakazhy	3
Edathua	5
Muttar	5
Thalavadi	1
Nedumudi	7

Source: Kerala State Disaster Management Authority. (n. d).http://sdma.kerala.gov.in

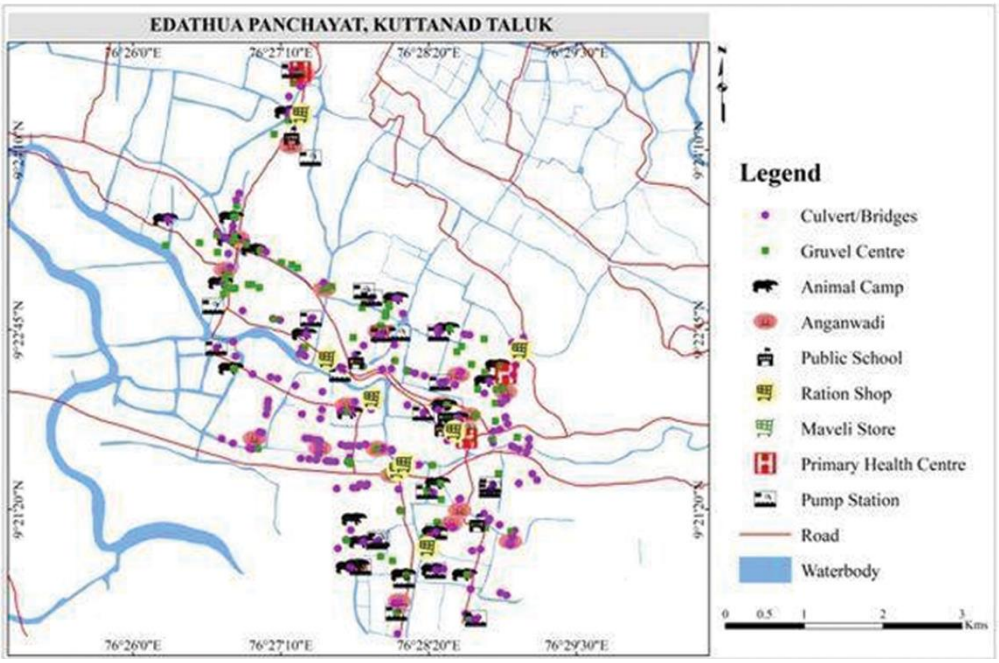

Figure 4:41 Map showing damaged culverts in Kuttanad taluk

Source: Kerala State Disaster Management Authority. (n. d).http://sdma.kerala.gov.in

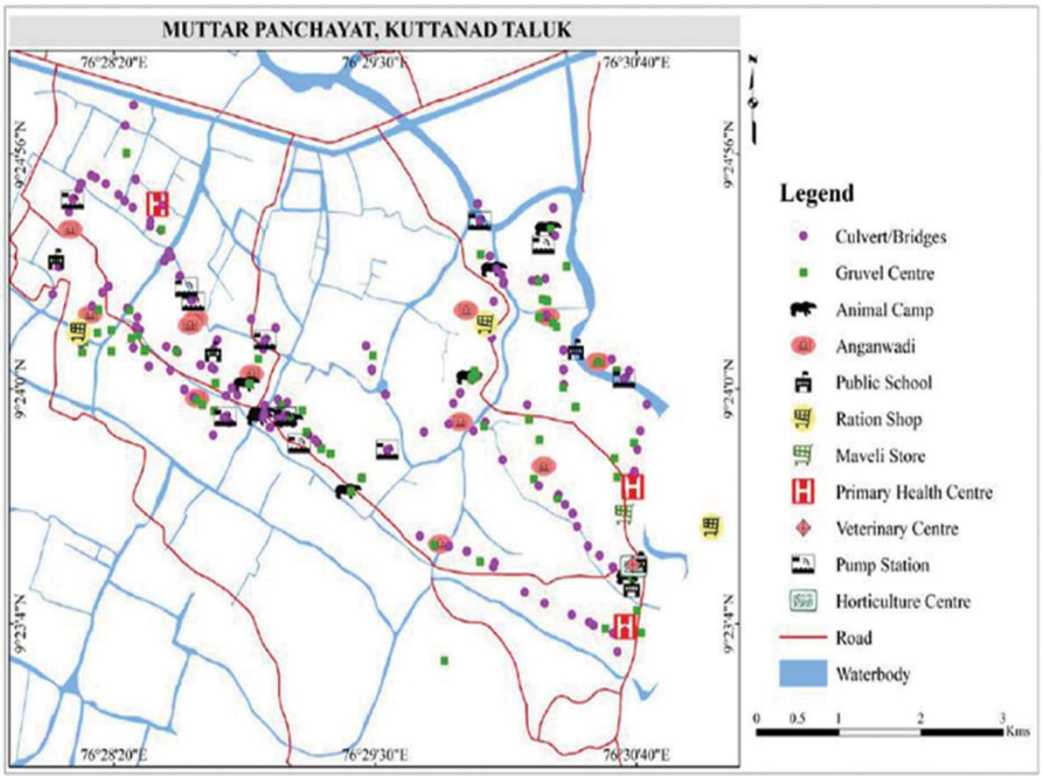

Figure 4:42 : Map showing damaged culverts in Kuttanad taluk

Source: Kerala State Disaster Management Authority. (n. d).http://sdma.kerala.gov.in

The maps developed for Edathua Panchayat which has the highest population in Kuttanad feature for , and the maximum number of culverts connectivity in the region. Observing the

map, indicate that it is a key it is clear that culverts and bridges are located close to the accessible main roads in the region and also provide accessibility to the areas un via the road especially the rations shops located on the roads. The map from Muttar Panchayat further confirms the point that culverts being situated along the rivers and the small rivulets are key in ensuring smooth transportation in the region.

4.5.7.4 USE OF PUBLIC TRANSPORT

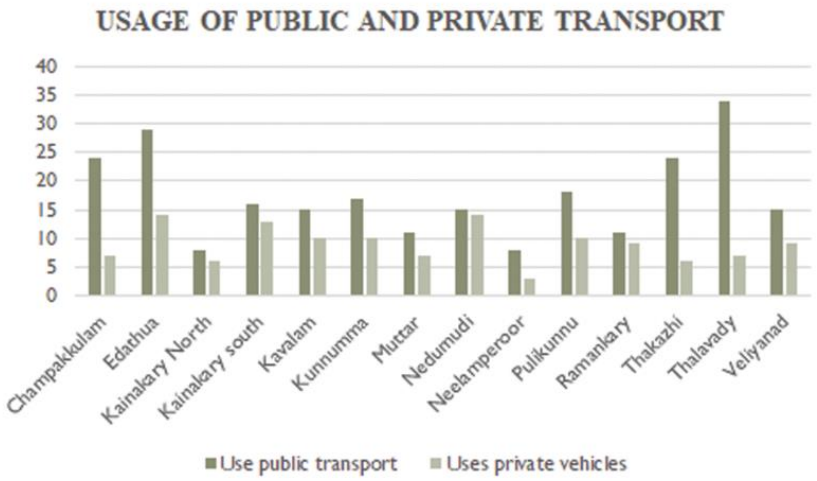

Figure 4:43 : Usage of public and private transport
Source: Kerala State Disaster Management Authority. (n. d).http://sdma.kerala.gov.in

4.5.7.5 INFERENCE

People in Kuttanad depends both road and water transportation for travelling . There are many areas where people can access only through water transports. Most of the areas from pulikunnu village is accessible through water transport. Edathua village has the highest connectivity in Kuttanad region

4.5.8 EDUCATION

The literacy rate of the population in various villages in Kuttand taluk is high. The Pulikunne village has the lowest literacy rate as compared to other villages in the Kuttanad taluk. Kainakary north, Nedumudi and Ramankary have the highest literacy rates. The education level of the population helps to attain knowledge to take actions to reduce their vulnerability to disasters. The higher education helps in creating higher resilience in a sustainable way and it also helps to identify different opportunities for their sustainable livelihood.

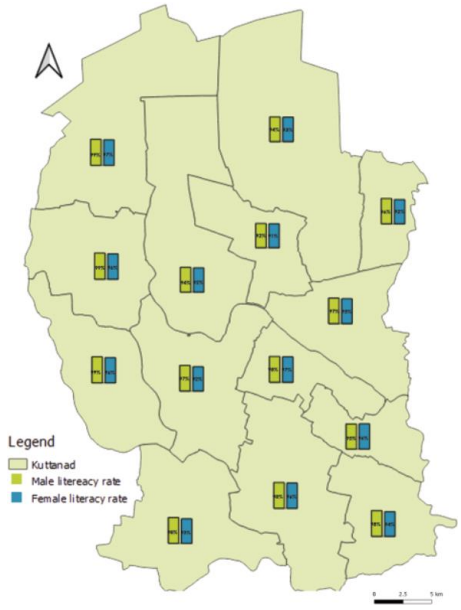

Figure 4:44 Map showing the literacy rates over the villages in Kuttanad
Source: Statistics report of Vikasanapadhathi 2021-2022 from Champakulam and Velliyand block office

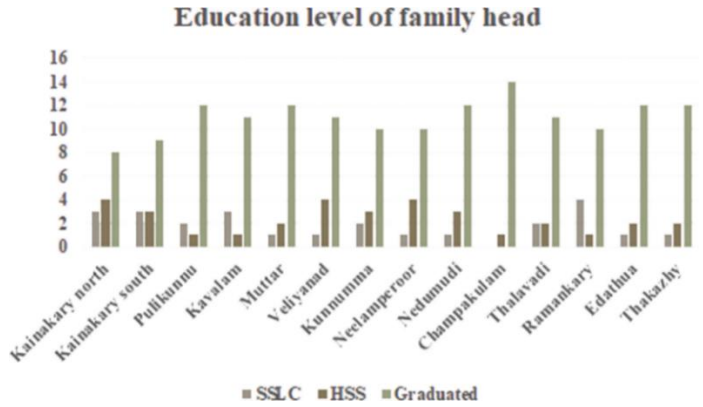

Figure 4:45 : Education level of family heads over the villages in Kuttanad
Source: Primary Survey conducted on March, 2023

Most of the family heads in Kuttanad are graduates. Kainakary noth and Kainakary south have a very lower percentage of people who have only done SSLC.

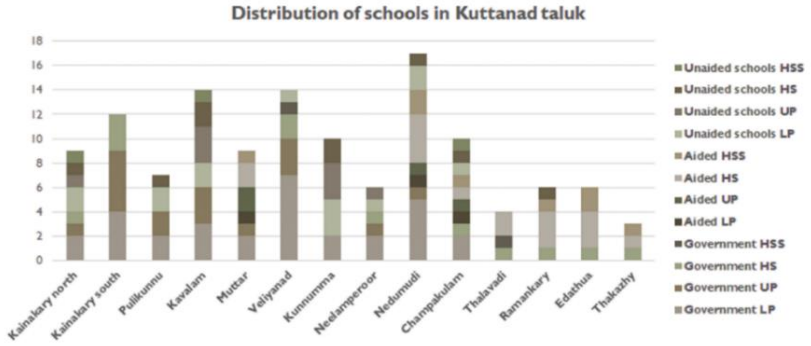

Figure 4:46 : Distribution of schools over the villages in Kuttanad
Source: Statistics report of Vikasanapadhathi 2021-2022 from Champakulam and Velliyand block office

The two villages in Kuttanad taluk with the most schools are Veliyanad and Kavalam. The least number of schools are located in Kuttanad Taluk, specifically Thakazhy Village.

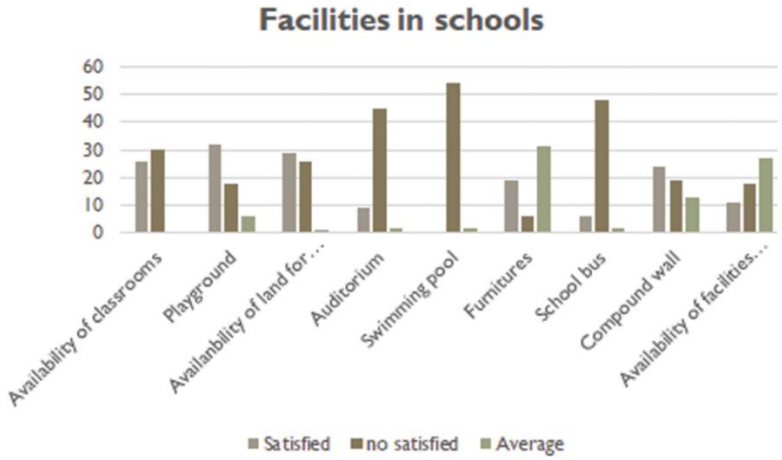

Figure 4:47: Facilities in schools
Source: Statistics report of Vikasanapadhathi 2021-2022 from Champakulam and Velliyand block office

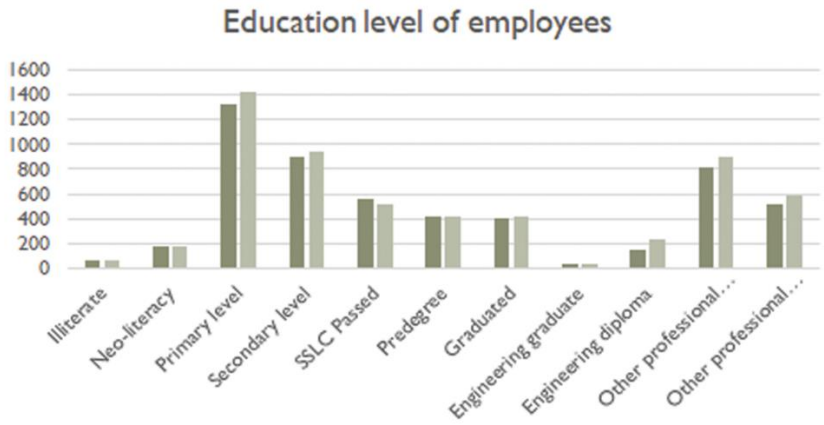

Figure 4:48 : Education level of employees
Source: Statistics report of Vikasanapadhathi 2021-2022 from Champakulam and Velliyand block office

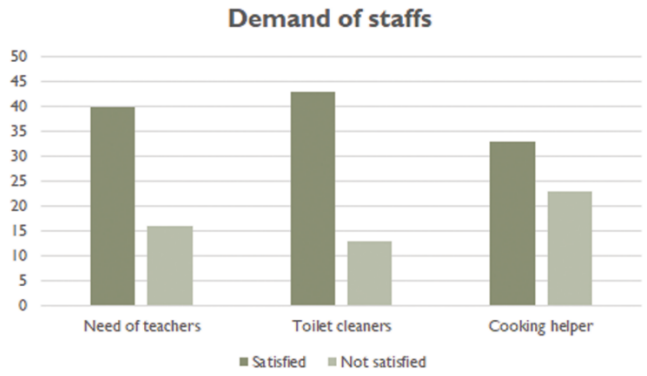

Figure 4:49: Demand of staffs in schools
Source: Statistics report of Vikasanapadhathi 2021-2022 from Champakulam and Velliyand block office

The infrastructure facilities in the school are not satisfactory with demand of Kuttanad population. The availability of classrooms are really low in Kuttanad taluk region. The demand of teaching and non - teaching staffs are also not satisfied as per the statistics report of Kuttanad taluk office. The highly qualified professional graduates are seen very low in Kuttanad region compared to other courses.

4.5.9 HEALTH

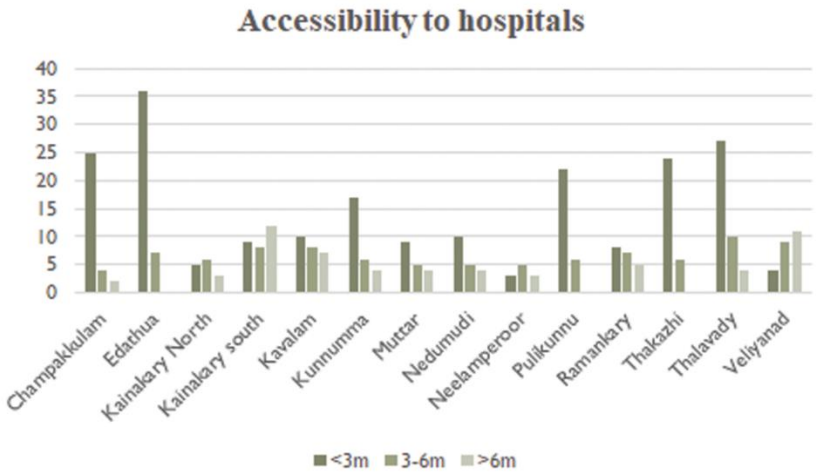

Figure 4:50 : Accessibility of hospitals in Kuttanad
Source:Data collected in primary survey, 2023

Edathua village has the highest accessibility in Kuttanad taluk and Veliyanad and Kainakary South has the lowest accessibility in Kuttanad taluk.

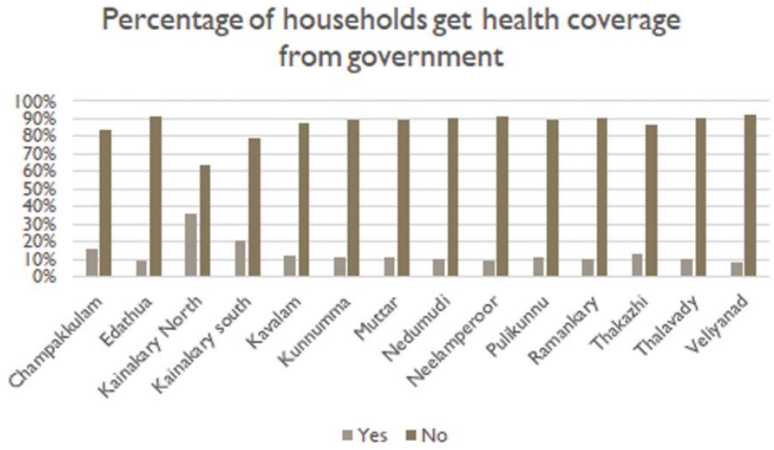

Figure 4:51 : Percentage of households get health coverages in Kuttanad
Source: Data collected in primary survey, 2023

In Kainakary North, a larger percentage of families have access to health insurance. The palliative care professionals do routine checks on them. They receive aid and free medications from PHC.

ISSUES FACED IN KUTTAND TALUK HOSPITAL

The present condition of the hospital is deplorable when it rains, the area becomes waterlogged and muddy. The building for the operation theatre was constructed during the tenure of VS government with funds received from the NRHM. But when the building was found to be weak, it stopped functioning. The hospital was completely submerged in the 2018 floods. In addition, the floods that occur every year also affect the operation of the hospital. Unavailability of sufficient infrastructure facilities in taluk hospital. Unavailability of sufficient doctors in taluk hospital. Unavailability of sufficient OT facilities in taluk hospital.

4.5.10 WATER SUPPLY

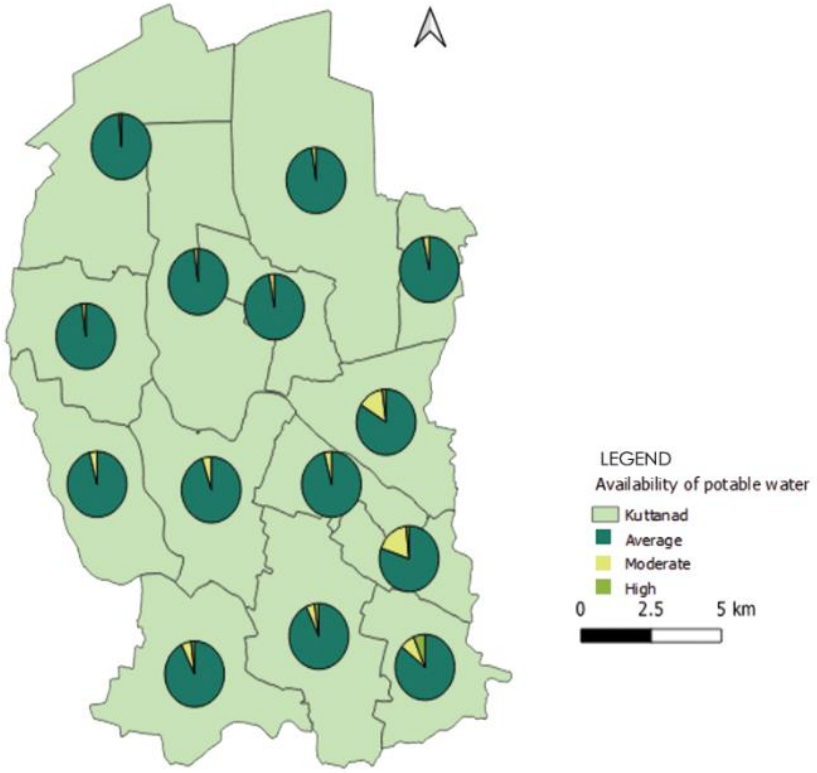

Figure 4:52: Map showing availability of potable water

Source: Author generated in QGIS with respect to the data collected in primary survey, 2023

The availability of potable water is less in Kuttanad region. Kainakary North, Kainakary South, Pulikunnu, Kavalam ,Kunnumma and Neelamperoor have faced critical issues in water supply. The shortage of drinking facilities is the main issues that faced in Kuttanad taluk region. Most

of the people buy potable water for drinking facilities. Dumping of waste materials in open water resources also cause serious treats in Kuttanad region.

Table 4:12 Details of people depends on various water sources for drinking

Total houses	People who depend on well	People depend on Public well	People who have pipeline connections	People depends on KWA pipeline for water	People who depends on water distribution services	Depends on other sources	People depends on neighbourhood well
51480	6600	610	26642	13494	543	1430	132

Source: Data collected from statistics report of 2022 , Statistics department

It has been observed that a KWA pipeline extension should be needed for all panchayats. It has been observed 47000 people from various panchayats need pipeline extension connections.

4.5.11 SOLID WASTE MANAGEMENT

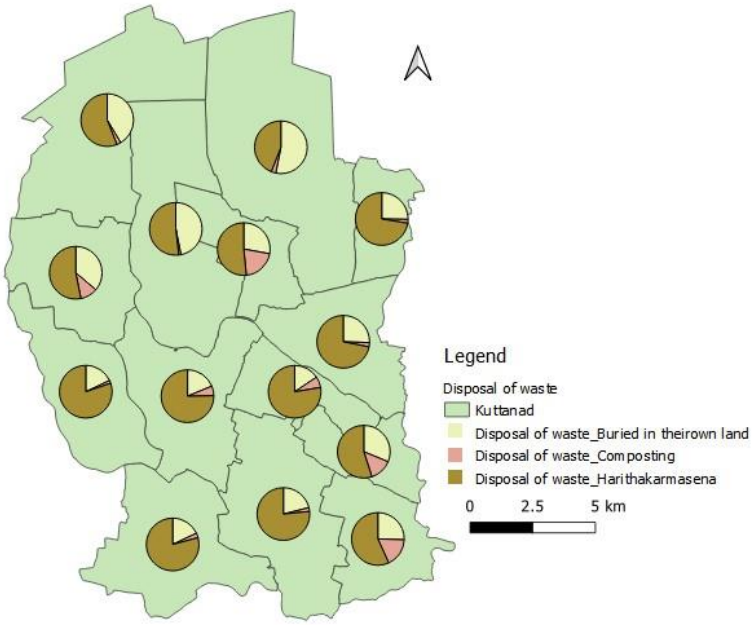

Figure 4:53 Map showing the percentage of disposal of waste
Source: Author generated in QGIS with respect to the data collected in primary survey, 2023

Most of the households depends on harithakarmasena for waste disposal. Due to the delay in collection of waste from houses by harithakarmasena workers made the residents to buried their waste in their own land or either burn the waste. Some residents use their biodegradable waste for composting and it can be used for agricultural farming. Thalavadi, Muttar, Kainakary south ,Pulikuune villages uses biodegradable aerobic waste units for composting.

4.5.12 ENERGY

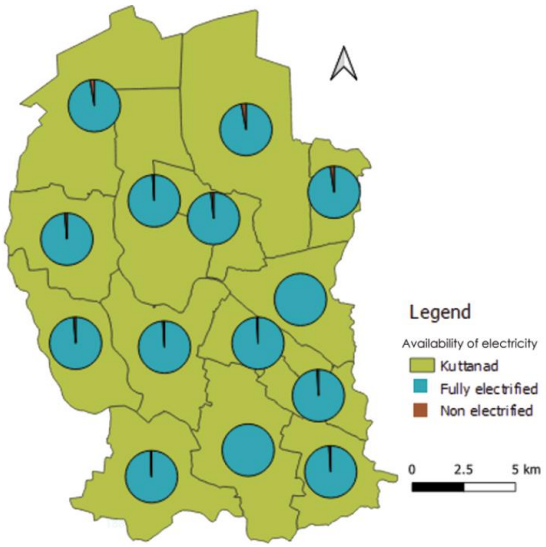

Figure 4:54 : Map showing the percentage of electrified and non electrified houses in Kuttanad
Source: Author generated in QGIS with respect to the data collected in primary survey, 2023

Most of the villages in Kuttanad are electrified. Kainakary North, Kavalam and Neelamperoor has reported highest number of non electrified houses in Kuttanad taluk region. Edathua and Veliyanad village shows fully electrified houses in Kuttanad taluk region. It was also reported that people in Kuttanad taluk losses electricity and it also causes losses in connection during floods.

4.5.12.1 USE OF RENEWABLE ENERGY

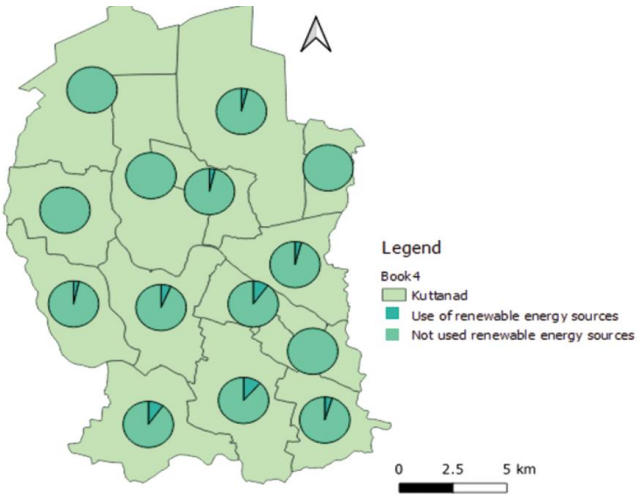

Figure 4:55 : Map showing the percentage of households using renewable energy sources
Source: Author generated in QGIS with respect to the data collected in primary survey, 2023

Kainakary North, Pulikunnu,Kainakary South, Pulikunnu, Neelamperoor, Muttar doesn't use renewable energy sources. Edathua has the highest number of renewable resources in Kuttanad taluk region.

4.5.13 DRAINAGE FACILITY

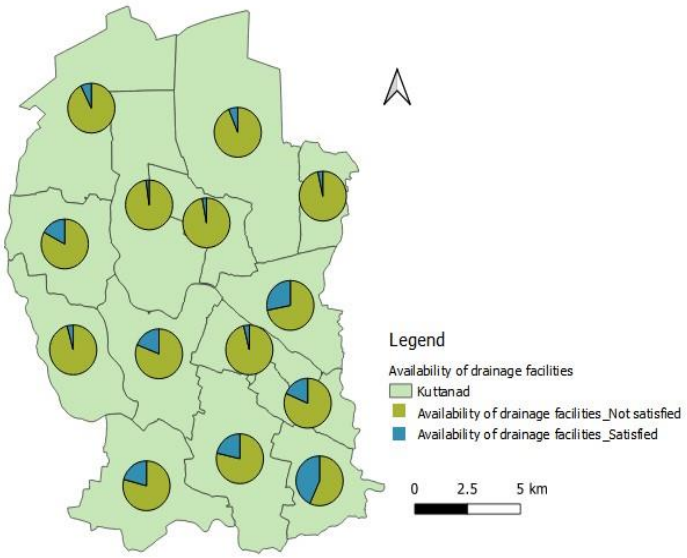

Figure 4:56 Map showing availability of drainage facility
Source: Author generated in QGIS with respect to the data collected in primary survey,2023

The availability of drainage facilities in Kuttanad region is low. Drainage problems have caused the agricultural production to remain low The problem is more severe in the acid sulphate soils of Kuttanad. Besides the problems inherent to acid sulphate soils, the area also experiences problems of flooding, lack of fresh water and intrusion of saline water from the Arabian Sea.

4.5.14 GEOMORPHOLOGY

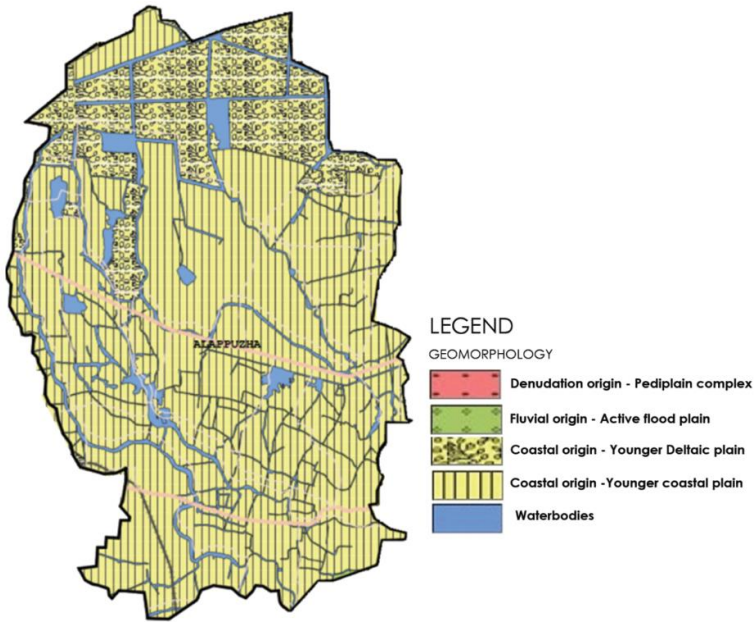

Figure 4:57: Map showing geomorphology
Source: Data collected from bhuvan thematic datasets

From the remote sensing data , the geomorphology of the study area was found to be coastal origin. Here the wetlands and the barren lands are highly vulnerable regions.

4.5.15 TOPOGRAPHY

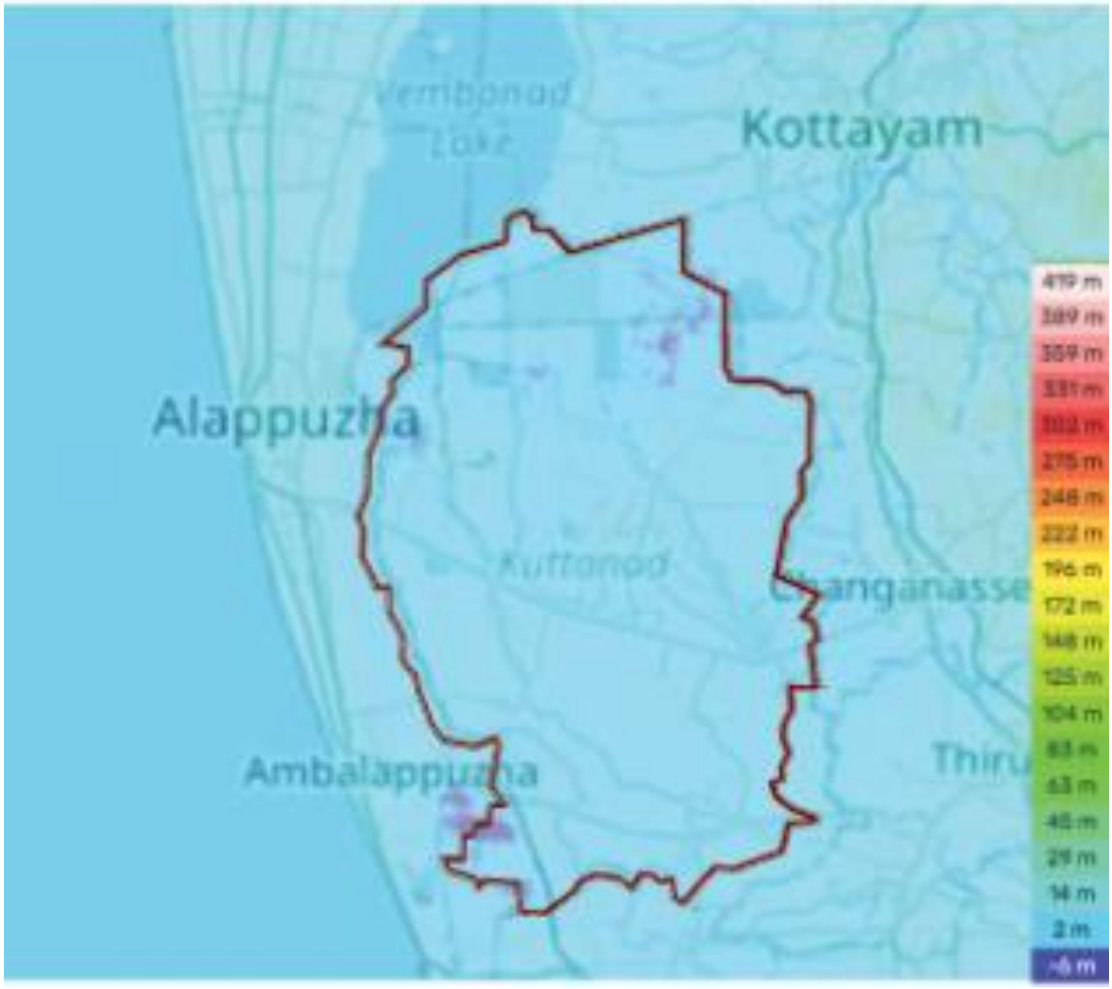

Figure 4:58: Map showing topography

Source: *Free topographic maps, elevation, terrain.(n.d). Topographic Maps.https://en-in.topographic-map.com/*

Kuttanadu is the region with the lowest altitude in India, with 500 square kilometres of the region below sea level. Its elevation ranges from 0.6 m above to 2.2 metres below sea level. Most of the area is covered with water throughout the year.

4.5.16 FLOOD INUDATION

Flood inundation mapping is required to understand the affects of flooding in a particular area and on important structures such as roadways, railways, streets, buildings. It provides important information, like depth and spatial extent of flooded zones, required by the municipal authorities to inform the citizens about the major flood prone areas and adopt appropriate flood management strategies.

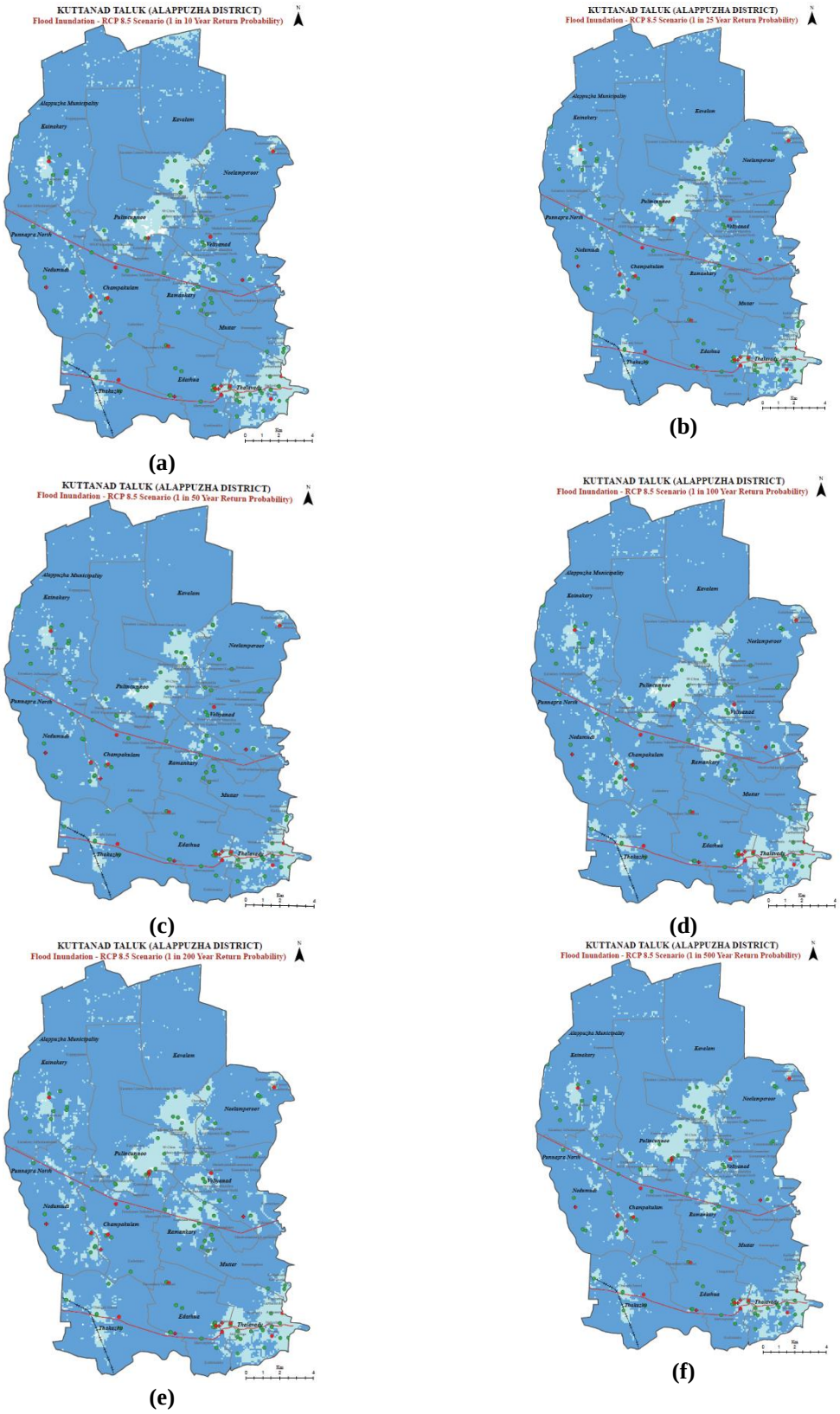

Figure 4:59: Map showing flood inundation (a) 1 in 10 year probability (b) 1 in 25 year probability (c) 1 in 50 year probability (d) 1 in 100 year probability (e) 1 in 200 year probability (f) 1 in 500 year probability
Source: Data collected from KSDMA

Table 4:13 : Flood inudation area and max flood level

LSG	Flood inundation area(Km2)	Max flood level (m)
Champakulam	23.31	5.59
Edathua	21.92	4.75
kainakary	46.18	5.69
Kavalam	41.71	5.74
Muttar	10.85	4.26
Nedumudi	27.37	5.58
Neelamperoor	21.99	4.81
Pulicunno	32.76	5.74
Ramakary	17.13	4.67
Thakazhy	28.51	5.71
Thalavady	15.98	4.21
Veliyanad	19.38	4.84

Source: Data collected from KSDMA

Pulikunnu panchayat has the maximum flood level followed by Kavalam and Thakazhy. Flood inudation area is higher in Kainakary followed by Kavalam and Pulicunnu.

4.5.17 RISK EXPOSURE IN KUTTANAD TALUK

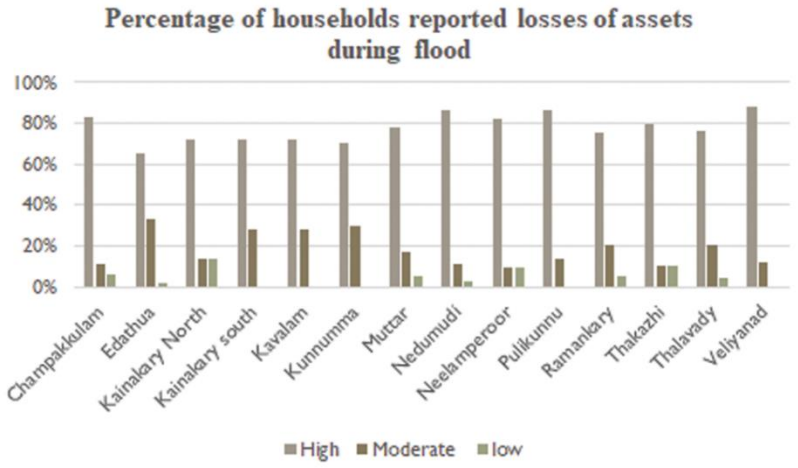

Figure 4:60 : Percentage of households reported losses of assets during flood

Source: Primary survey conducted on March, 2023

Kuttanad taluk faces a lot of losses of assets during flood. Most of the people losses their houses and shops during the floods. Champakulam reported heavy loses and Edathua faces less compared to others.

Figure 4:61: losses of assets during flood
Source: Data collected from Statistics department

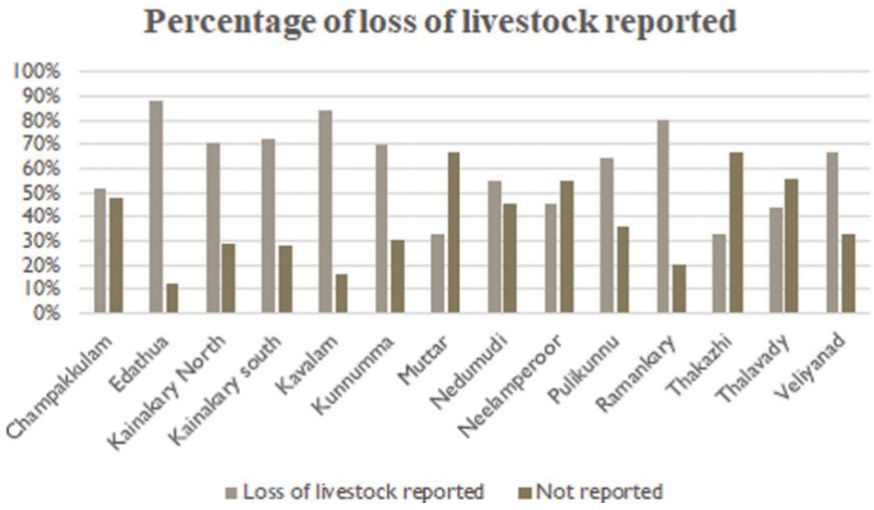

Figure 4:62 : Percentage of households reported losses of livestocks during flood
Source: Primary survey conducted on March, 2023

Kuttanad taluk faces a lot of losses of livestocks during flood. Most of the people refuses to shift their place because of their livestock s during floods.

Figure 4:63 : Losses of livestocks during flood
Source: Data collected from Statistics department

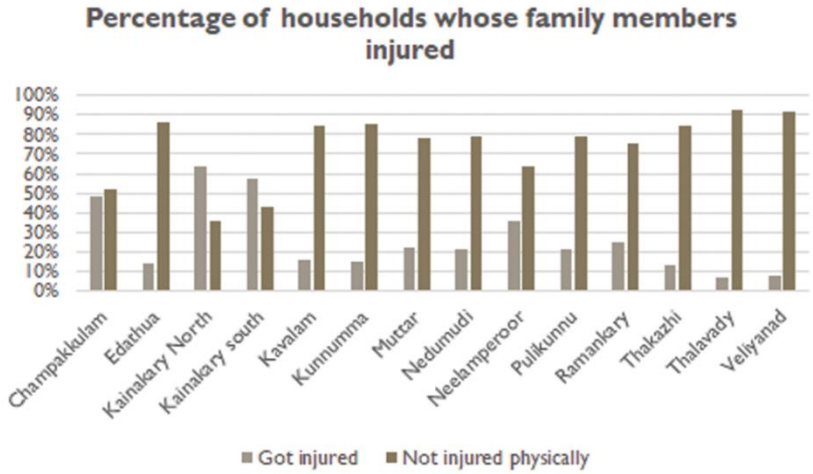

Figure 4:64 : Percentage of households whose family members injured during flood
Source: Primary survey conducted on March, 2023

Kainakary North recorded the highest percentage of injury cases, followed by Kainakary South. In the Kuttanad taluk region, Thalavadi has the fewest reported injury cases.

Figure 4:65 : Emergency rescue of people during flood
Source: Data collected from Statistics department

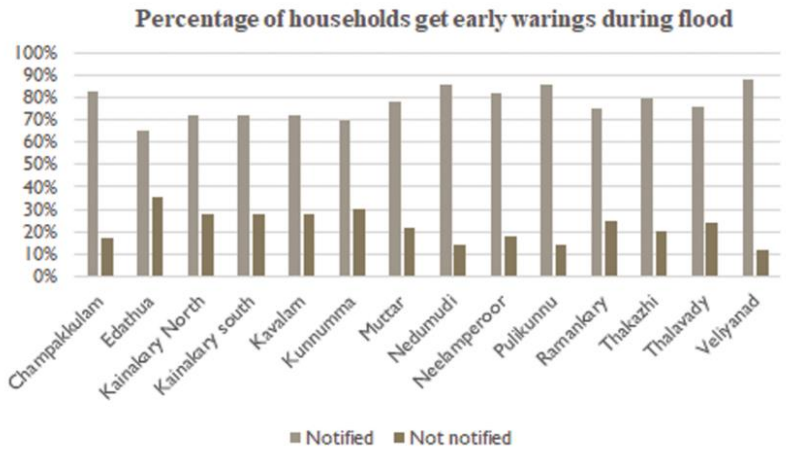

Figure 4:66: Percentage of households get early warnings during flood
Source: Primary survey conducted on March, 2023

During previous flood occurrences, the majority of the communities in Kuttanad Taluk received early warnings. They refuse to relocate despite receiving government warnings because of their livestock, etc. When the flood level suddenly rises, this causes panic among the people. Correct warning systems are delayed in passing because to strong winds and power outages.

INFERENCE

By taking into account all the variables, including elevation, geomorphology, proportion of households reporting losses in livestock and other assets, flood level, area of flood inundation, and risk exposure, the research area's vulnerability is determined. Early warning systems are crucial for determining a disaster's level of susceptibility. When compared to other locations, an area is more vulnerable if its risk exposure is higher.

4.5.18 ASSESSMENT FOR ADAPTIVE RESILIENCE INDEX

First and foremost, the adaptive Resilience Index can be utilized to evaluate a city's resilience through time. Second, by adapting the tool to a particular urban context, the Index offers insight into the numerous elements that influence and contribute to the resilience of the city.

Table 4:14 Parameters considered for adaptive resilience index

Parameters	Dimensions	Sub dimensions	Very Low (1)	Low (2)	Medium (3)	High(4)
Social	Demography	Population density	<500	500-1000	1000-1500	>1500
		Population dependency	>20%	20-15%	15-5%	<5%
		Growth rate	<0.2	0.2-0.4%	0.4-0.6%	0.6-0.8%
	Health	Public healthcare facilities	Not satisfied	Facilities are there but in poor condition	Scope of more improvements	Highly satisfied
		Accessibility	>6m	5-6m	3-5m	<3m
	Education	Literacy rate	<90%	90%-95%	95%-97%	>97%
		Accessibility	>6m	5-6m	3-5m	<3m
	Risk exposure	Loss of infrastructures during floods	Very low damages	Low damages	Moderate damages	High damages
	Housing	Facilities in colonies	Poor	Average	Moderate	High
Economic	Agriculture	Production in each village	<500Ha	500-1000Ha	1000-1500Ha	>1500Ha
	Fisheries	Growth rate	0.2	0.2-0.4	0.4-0.6	>0.6
	Animal husbandry	Production rate w.r.t cattle	0.4	0.4-0.6	0.6-0.8	>0.8
Environment and Infrastructure	Transportation	Accessibility	>6m	5-6m	3-5m	<3m
	Water resources	Clean water access		No		Yes
		Presence of drainage system		No		Yes
	Energy	Fully electrified		No		Yes
		Use of renewable energy		No		Yes
Governance	Policies and schemes provided for the integrated development			No		Yes

Source: Modified from (Do Thi Thuy Hong, 2018) and (UN, 2020)

Table 4:15 : Weightage score for adaptive resilience index

	Social dimension	Economic dimension	Environment &Infrastructure	Governance
Weightage score	3	1	4	5

Source: (UN, 2020)

The Adaptive Resilience Index (ARI) comprises four dimensions including Social-cultural; Economic; Environment and Infrastructure, and Governance. Then it is formulated with the use of criteria weighting, as illustrated in equation :

ARI = (S.Sw) + (E.Ew) + (I.Iw) + (G.Gw)

In this formula:

ARI is the Adaptive Resilience Index

S is the socio-cultural score

Sw is the socio-cultural weighting

E is the economic score

Ew is the economic weighting

In is the infrastructure/environment score, Inw is the infrastructure/environment weighting

G is the governance score

Gw is the governance weighting

Accordingly, since each dimension consists of several subdimensions, then the adaptive resilience of each of the four dimensions is calculated by applying a sub-dimension weighting as well, for example:

The adaptive resilience of the Socio-cultural dimension is calculated as in equation :

S = (Sd1.Sdw1) + (Sd2.Sdw2) + … + (Sdn.Sdwn)

Table 4:16 : Assessment for adaptive resilience index

	Social resilience	Economic resilience	Environment and infrastructure	Governance	Adaptive resilience
Champakulam	8.67	1.67	11	20	40.92
Edathua	9	1.33	11	20	44.33
Kainakary North	9	2.33	9	20	40.33
Kainakary South	10.67	2	11	20	43.6
Kavalam	6.33	3.67	8	20	37.97
Kunnumma	5.67	3.67	8	20	37.27
Muttar	7.33	1.67	10	20	39
Nedumudi	8.67	1.33	10	20	39.93
Neelamperoor	6.33	2	8	20	36.33
Pulikunnu	6.33	2.33	8	20	36.33
Ramankary	6.67	2.33	8	20	37
Thakazhi	8.33	1.67	10	20	40
Thalavadi	6	1.67	10	20	37.47
Veliyanad	7.33	1.67	10	20	39

Source: Author generated with respect to secondary sources and primary survey conducted on March, 2023

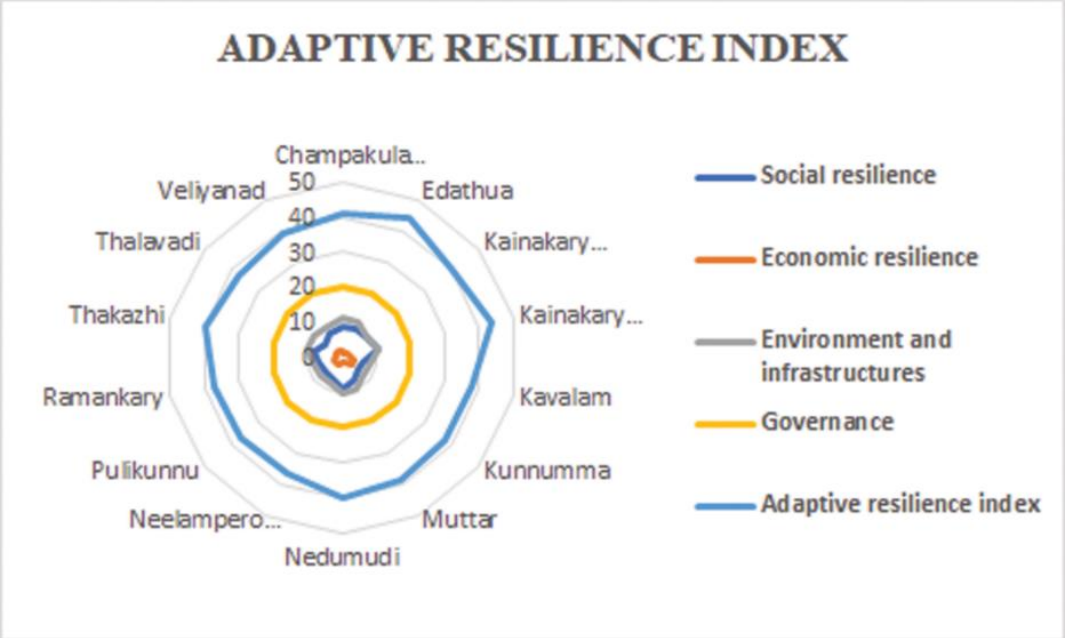

Figure 4:67 : Resilience index for adaptive resilience index

Source: Author generated with respect to secondary sources and primary survey conducted on March, 2023

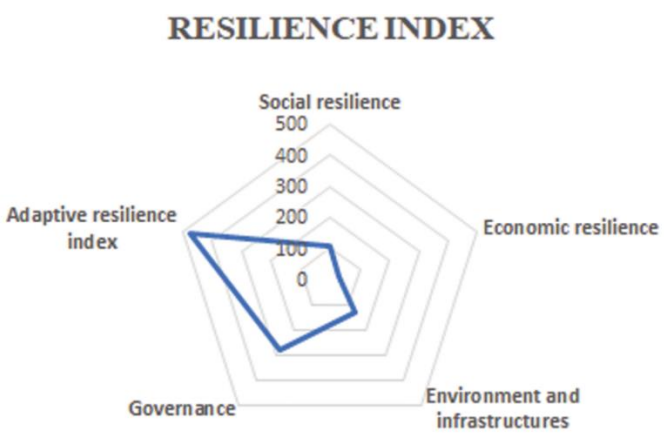

Figure 4:68 : Resilience index for adaptive resilience index

Source: Author generated with respect to secondary sources and primary survey conducted on March, 2023

The economic resilience in Kuttanad region is low as compared to other three factors . Due to this reason people couldnot earn sustainably throughout their life with changing climate change.The resilience of the economic sector is really in a bad condition to cope up with vulnerability facing in that region. Social resilience of Kuttanad region is high compared to other regions.

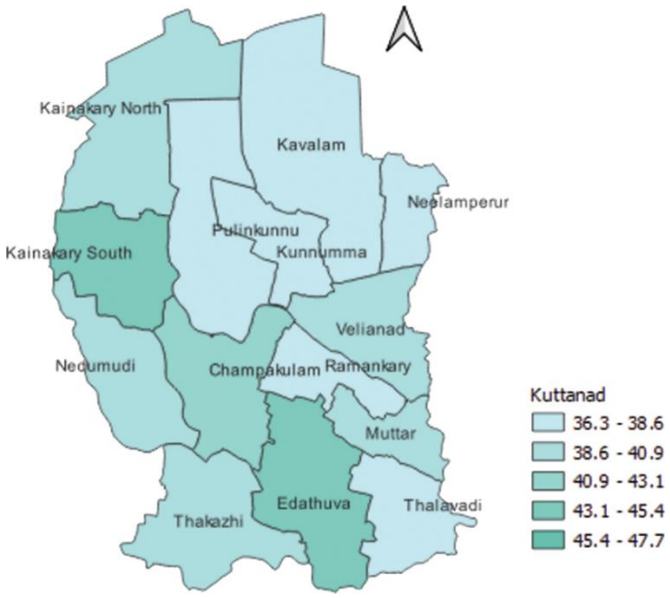

Figure 4:69 : Map of adaptive resilience index of Kuttanad taluk region

Source: QGIS

The adaptive resilience index is higher in Edathua and Kainakkary South region. Due to the high resilience capacity in these regions will helps to cope up with the vulnerability of that region.

Table 4:17: Assessment of adaptive resilience index

Dimensions	Indicators	Parameters	Weightage given	Champakulam	Edathua	Kainakary North	Kainakary South	Kavalam	Kunnummana	Muttar	Nedumudi	Neelamperoor	Pulikunnu	Ramankary	Thakazhi	Thalavady	Veliyanad
Social resilience	Demography	Population density		2	2	4	4	1	3	2	2	2	1	2	4	3	2
		Population dependancy ratio		2	2	1	4	2	2	1	1	2	2	2	2	1	2
		Unemployement rate		2	3	3	3	3	2	2	2	1	1	2	2	1	1
	Health	Accessibility to health infrastructure	3	3	4	2	4	1	1	3	4	2	2	2	4	2	2
		Facilitation of health centers		3	3	4	3	2	1	3	3	2	2	2	2	2	2
	Education	Literacy rate		2	4	4	4	2	2	3	4	3	2	4	3	3	3
		Accessibility to education institutions		4	4	4	4	4	1	4	4	2	4	2	2	2	3
	Risk exposure	Loss of infrastructures during floods		4	3	4	4	3	4	2	4	4	3	3	3	2	3
	housing	Facilities in colonies		2	2	4	4	1	1	1	2	1	2	1	3	2	4
Social resilience= Wt *(Sd1 + Sd2+…)/n				8.67	9	9	10.67	6.33	5.67	7.33	8.67	6.33	6.33	6.67	8.33	6	7.33
Economic resilience	Economic	Growth rate of agriculture production		2	2	3	3	4	4	2	4	3	3	3	3	3	3
		Growth rate of fisheries production	1	2	1	3	2	4	4	2	2	2	2	3	1	1	1
		Growth of milk production		1	1	1	1	3	3	1	1	1	2	1	1	1	1
Economic resilience= Wt *(Sd1 + Sd2+…)/n				1.67	1.33	2.33	2	3.67	3.67	1.67	1.33	2	2.33	2.33	1.67	1.67	1.67
Environment and infrastructures	Transportation	Accessibility		4	4	3	4	2	2	4	1	2	2	2	4	4	4
		Use of public transport		4	3	4	4	4	4	3	4	3	3	3	3	3	3
	Water resources	Clean water access	4	2	3	1	2	1	1	2	3	2	2	2	2	2	2
		Drainage facilities		1	1	1	1	1	1	1	2	1	1	1	1	1	1
Environmental resilience= Wt *(Sd1 + Sd2+…)/n				11	11	9	11	8	8	10	10	8	8	8	10	10	10
Governance	Governance	Initiatives and schemes	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Governance resilience= Wt *(Sd1 + Sd2+…)/n				20	20	20	20	20	20	20	20	20	20	20	20	20	20
Adaptive resilience index				40.92	44.33	40.33	43.6	37.97	37.27	39	39.93	36.33	36.33	37	40	37.47	39

Source: Author generated with respect to secondary sources and primary survey conducted on March, 2023

4.6 SWOT ANALYSIS

Table 4:18: Swot analysis

SECTOR	STRENGTH	WEAKNESS	OPPORTUNITIES	THREATS
Landuse	The agricultural land use zone has a greater concentration compared to other land use zones. So it can be used for development activities.	Vacant agricultural land act as less productive zone	Mixed landuse can be developed to create energy efficient environment	The encroachment of wetlands forced the conversion of green areas and agricultural land. Conversion of agricultural land to uplands also has an environmental impact.
Agriculture	Agriculture sector has the potential of increasing economic growth rate.	Floods caused significant losses in the agriculture sector.	There are several prospects for development in the agricultural industry. To advance the agriculture industry, we may promote agro tourism and other innovative technologies.	Floods cause significant losses to the agricultural sector, causing people to evacuate their properties and look for alternative means of subsistence. Since Kuttanad is regarded as Kerala's primary rice bowl, this will have an impact on the state's ability to feed its citizens.

Transportation	Easy accessibility of roads and waterways. Water transportation has a higher potential in Kuttanad for easy evacuation.	Roads were damaged during the floods.	Water transportation has a large potential in the Kuttanad region for easy evacuation, and it also helps to provide easy accessibility of services to the needy people in the region. Proper utilization of canal networks can help reduce the impact of floods	Damage to culverts acts as a threat in the Kuttanad region.
Health	Active PHC in Kuttanad region .	Unavailability of infrastructure facilities in hospitals for highly emergency situations	The government has taken the initiative for the development of health infrastructure in the Kuttanad region.	Lack of mangement
Education	Literacy rate in Kuttanad region is high	Infrastructure facilities in the schools are not satisfactory for the demand of the Kuttanad population.	The opportunities for educated people in Kuttanad are high due to the future developments in the region.	Highly qualified professional graduates are seen very low in Kuttanad region
Waste management	Harithakarma sena helps in waste management . Non biodegradabl e waste are	The burning of agricultural waste in the fields adds to carbon emissions and causes air pollution. Dumping waste	Composting can be promoted in households for efficient waste management	Dumping of waste in public places and open drainages leads to spread of diseases among people.

	recycled by clean Kerala	into water bodies causes water pollution and the breeding of rats. Rats further damaged the agricultural fields by biting them.		
Energy	Kuttand has the strong potential for the development of renewable energy resources such as solar and wind energy	Renewable energy is not utiliszed due to lack of awareness and initial cost.	Vacant agricultural land can be converted to solar farms, agrivoltaics and urban parks.	Burning of agricultural straw causes carbon emissions .
Housing	Active management and governance in the housing sector	There are 34 colonies in the Kuttanad region. The lack of infrastructure facilities is the main issue. Lack of drinking water is a major issue in the Kuttanad region.	The government has different schemes and proposals for the development of the Kuttanad region.	The lack of accessibility to roads to the colonies makes the region more vulnerable.

Source: Author generated with respect to study conducted in Kuttanad

CHAPTER 5 PROPOSALS

This chapter discusses the vision , goal, and proposals to reduce the impact of most vulnerable regions in Kuttanad in Alappuzha district. It discuses adaptation strategies and actions adopted which are robust yet flexible, with short term and long – term approaches to build resilience in sustainable way.

5.1 AIM

The main aim of the development plan is to build resilience in Kuttanad region in a sustainable way to face the impacts of frequent occurance of floods by taking measures to protect the natural resources and public and private assets to improve the quality of life.

5.2 VISION

The vision is to provide a safe, livable and sustainable city for everyone who resides in Kuttanad.

5.3 OBJECTIVES

- To increase the quality of life in Kuttanad region.
- Reduce the risk and increase the adaptation
- To develope a strong and competitive economy for Kuttanad region

5.4 GOALS

GOAL : Increase action on awareness, preparedness and adaptation

Develops interactive impact projection maps in order to create efficient early warning systems and hazard mitigation plans.

GOAL : Prepare communities to build resilience

Focuses on strengthening certain social and economic systems that can assist people in getting ready prior to a flood disaster by enhancing community capacity for recovery and assisting preparedness beyond physical interventions.

GOAL : Facilitating area and community based economy in Kuttanad region

Focuses on using various forms of subsistence activity to strengthen the local economy even during times of flooding.

GOAL: Enhance infrastructure resilience for better living condition

Provide Floating or elevated roads which act as an evacuation route Flood-resilient latrines should be designed for the Kerala context Strengthening ecological infrastructure and drainage

systems by developing sponge city concept for flood management.

GOAL: Enhance tourism by developing agricultural hub and aquaculture

Increase agricultural production by giving incentives to the farmers or taking up the land by the government to promote agricultural activities.

Promote ecotourism by providing awareness and training programmes.

Promote pisciculture farming and agro-tourism in Kuttanad.

Development of infrastructure projects such as recreational parks, waterfront development to promote ecotourism.

Development of sustainable methods of fish culturing and crop cultivation which preventing artificial fertilizers and protecting wilderness and it promotes aquaponics farming and permaculture farming.

GOAL: Promote pollution free environment

Clearance certificate and pollution certificate should be manadatory for houseboats.

Urban forests can be created using the Miyawaki method and are intriguing, complex ecosystems that are in harmony with the soil and climate of the day

5.5 PROPOSALS

5.5.1 GOAL : DEVELOP EFFECTIVE EARLY WARNING SYSTEM

MONITOR THE AREA WITH THE ESTABLISHMENT OF NEW DISASTER MANAGEMENT CELL

The establishment of a distinct cell within the municipal corporation would institutionalize the resilience-building process at the city level.

MONITOR GROUNDWATER CONDITIONS

Aquifer management and anticipated changes in water quantity and quality will be informed by knowledge of and models of groundwater conditions. Models may be built using monitoring data for changes in aquifer water level caused by saltwater intrusion.

REDUCE THE INFILTRATION IN THE SEWER SYSTEM

Sewer models can calculate the effects of the increased rainy weather flow on the capacity and operations of the waste water collecting system and treatment facility.

STRICT ENFORCEMENT FOR THE REGULATION OF THOTTAPPALLY SPILLWAY

For the management of shutters in the Thottapally spillway, strict enforcement is needed.

5.5.2 GOAL : PREPARE COMMUNITIES TO BUILD RESILIENCE

Create programmes and services to help vulnerable communities understand their flood risk and how to access resources for mitigation, readiness, and recovery. The three most susceptible villages in the Kuttanad area of the Alappuzha district are Neelamperoor, Pulikunu, and Ramankary.

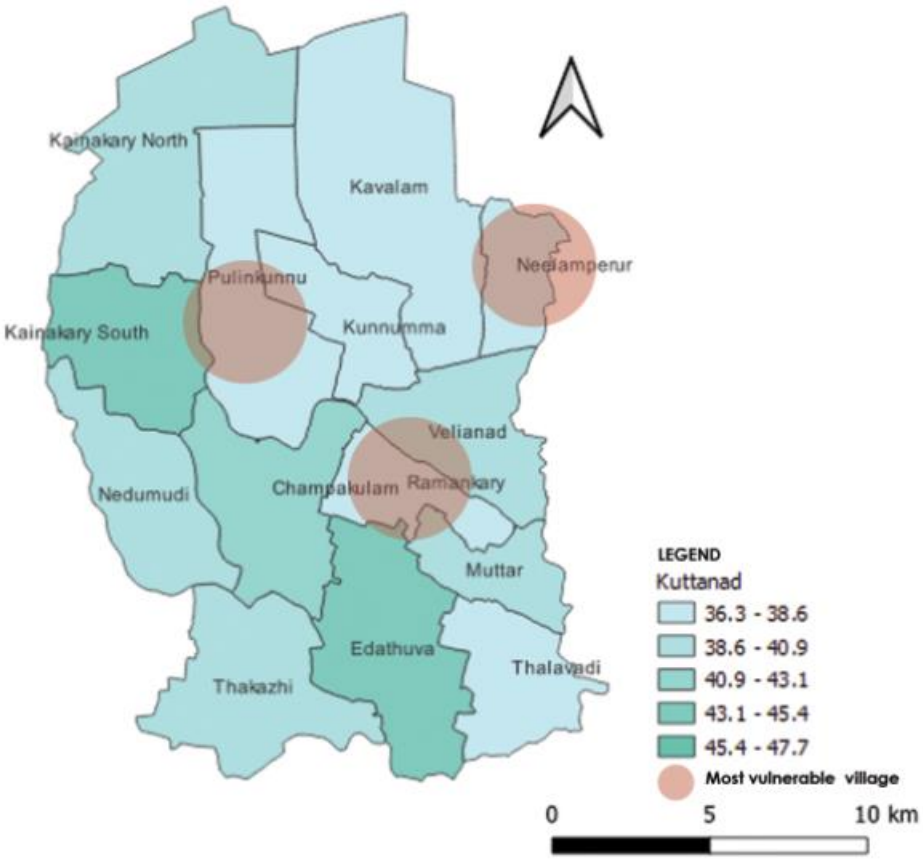

Figure 5:1: Location of most vulnerable communities
Source: ArcGIS

The areas in the Kuttanad region of the Alappuzha district that are most vulnerable include Neelamperoor, Pulikkunnu, and Ramankary. Community involvement, therefore, has a greater impact in these areas when a flood strikes. Should collaborate with neighbourhood non-profit organisations to inform residents about possibilities, including saltwater intrusion and conservation easements. Significant opportunities exist to interact with younger inhabitants through collaborations with youth organisations, schools, and public areas.

EDUCATIONAL WORKSHOPS

Seminars on community flood mitigation should be held to highlight fresh and creative methods that households may reduce and prepare for flood risk.

Figure 5:2: Education workshops and community participation during floods
Source: India, T. O. (2018, August 18). From Army's temporary bridges to Navy's tricky airlifts: Rescue operations in full swing in Kerala. The Times of India. https://timesofindia.indiatimes.com

5.5.3 GOAL : HEALTH AND WELLBEING FOR ALL THE RESIDENTS

- For disadvantaged groups, free routine checkups are provided to avoid communicable illnesses.
- To reach all the needy people during floods, medical camps should be conducted on houseboats.
- During floods, rescue boats should be prepared for any emergency circumstance.
- Knowing your community's evacuation route and warning signals, and identifying areas prone to flooding.
- Additionally, free veterinary treatments are made available on houseboats.

Figure 5:3: Emergency healthcare units during floods
Source: (Wani & Wani, 2021)

Implementation: Department of health in Kuttanad joined as a team with the asha workers for implanting this strategy.

5.5.4 GOAL : ALTERNATE LIVILIHOOD OPTIONS

Aim to reduce the prevalence of activities deemed to be environmentally damaging by substituting them with lower impact livelihood activities that provide at least equivalent benefits. Develop an agricultural farming calendar by utilising contemporary technology.

5.5.5 GOAL : ADOPT RESILIENT INFRASTRUCTURES

To enhance infrastructure resilience for better living condition

AMPHIBIOUS STRUCTURES

An amphibious house is a structure that is normally on the ground, but whenever there is a flood, the entire structure rises up in its dock and floats on the water. Instead of 2m above the ground level, as would be the case with a static house, the floor level could be set at less than 1m.

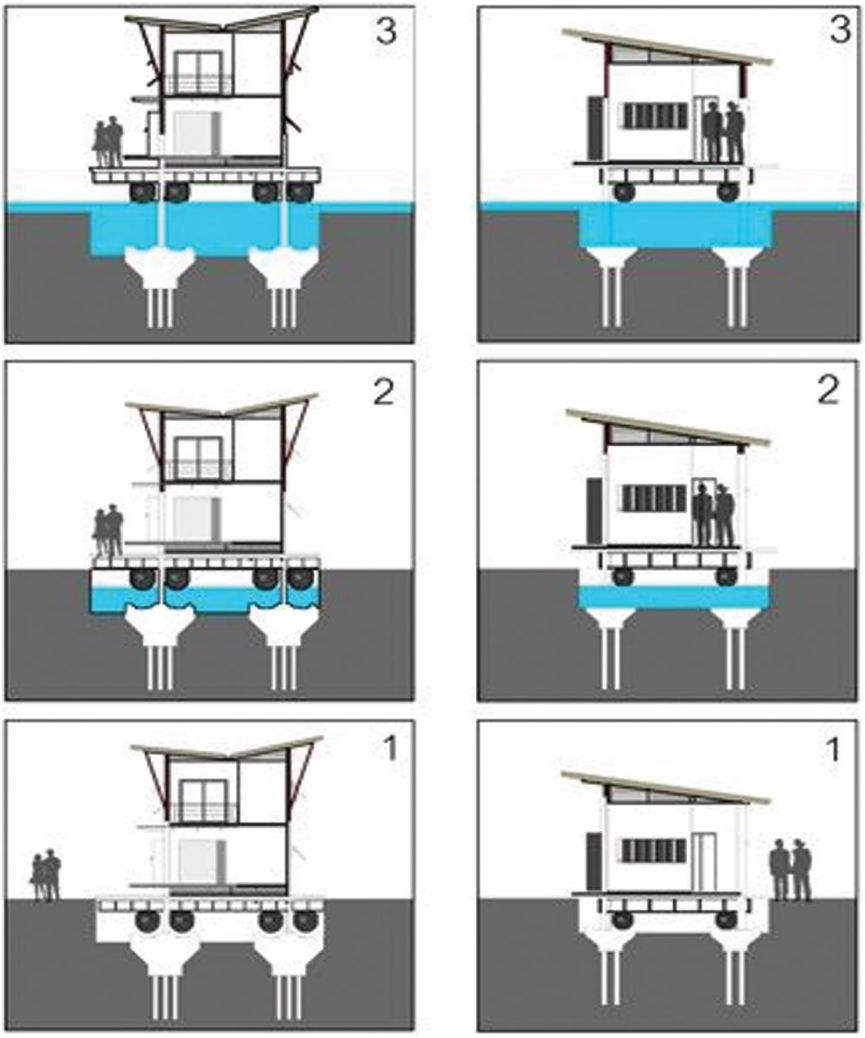

Figure 5:4: Foundations in Ambhibious structures
Source: (Chung, 2015)

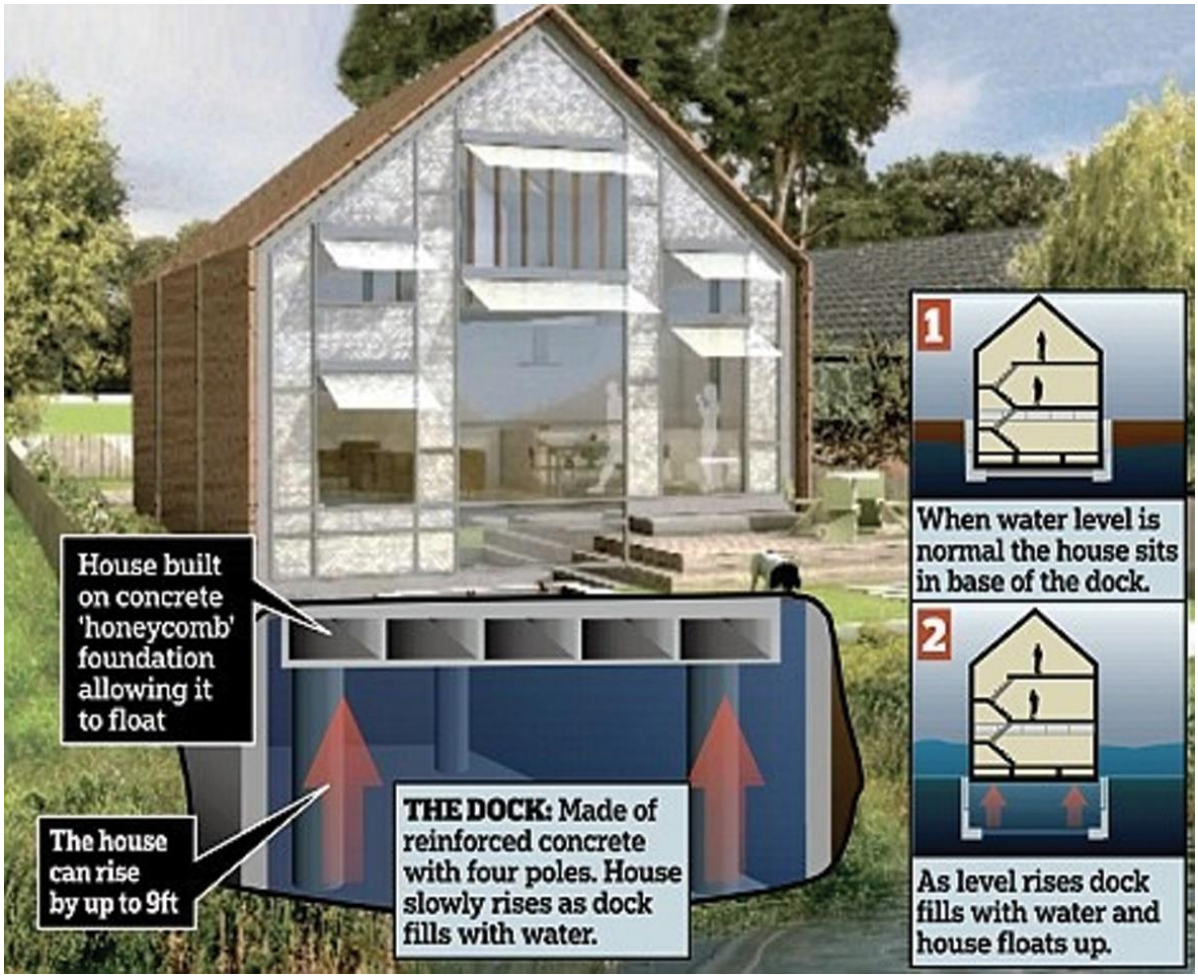

Figure 5:5: Working representation of foundations in amphibious structures
Source: Pinterest. (n.d.). Pinterest. https://www.pinterest.com/

Recommendations : Incentives would be offered to anyone building amphibious constructions in Kuttanad to promote resilient infrastructures.

ABSORBENT STREETS

Roads that absorb water: Permeable pavement, also known as porous pavement, is a hardscaping surface that has been constructed to permit water to pass through it. This contrasts with conventional pavement varieties, which are impermeable and turn the majority of rainwater into runoff.

Implementation: Ministry of road transport and highway, State government

Figure 5:6: Water absorbent roads
Source: (Chung, 2015)

Recommendations : Construction of water-absorbing roadways in Kuttanad is necessary to control runoff during floods. For improved quality of life, the government should use this innovative technology for the road construction.

FLOOD-RESILIENT LATRINES SHOULD BE DESIGNED FOR THE KUTTANAD

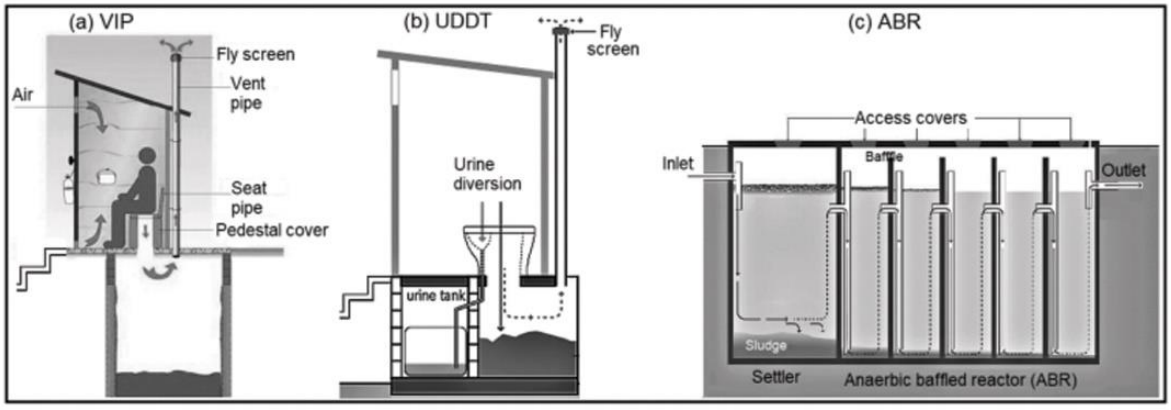

Figure 5:7 IIustrations of (a) Ventilated Improved Pit (VIP) latrine, (b) Urine Diversion Dry Toilet (UDDT) , and (c) Anaerobic Baffled Reactors (ABR)
Source: (Samuel Getahun, 2020)

Recommendations : To lessen the problems caused by severe floods, flood resilient latrines should be developed at the household level. The installation of latrines that are resistant to flooding prevents communicable illnesses and enhances the quality of life.

5.5.6 GOAL: PROVIDE INFRASTRUCTURE FACILITIES IN KUTTANAD TO PROMOTE TOURISM

FLOODABLE PARKS

By storing excess floodwater and progressively releasing it after the risk of flooding has gone, floodable parks can be constructed to control flow rates and reduce flow peaks.

Figure 5:8 : Schematic representation of floodable park
Source: (Berg, 2023)

This project aims to lessen the effects of floods in Kuttanad and allows people to enjoy the park even during floods. The proposed park is constructed in the very flood-prone area in Pulikunnu panchayat.

Proposed site 1: Floodable park

Location: 1.2 Ha in Kunnummana gramapanchayat

Ownership: Private owned land

Implementation: Alappuzha's tourism department works with the state planning board to put this into practice.

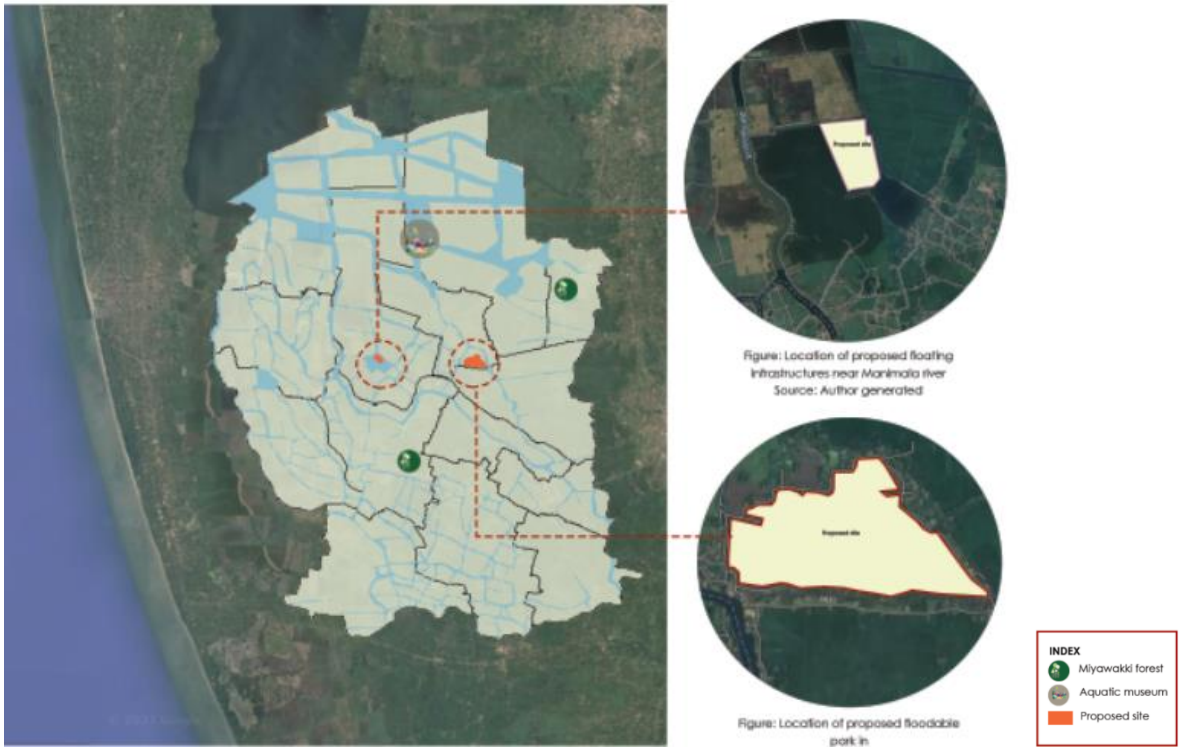

Figure 5:9: Location of proposed sites in Kuttanad
Source: Google earth explorer

5.5.7 GOAL: PROVIDE INFRASTRUCTURE FACILITIES IN KUTTANAD TO PROMOTE TOURISM

TO CREATE FLOATING ISLANDS IN KUTTANAD TO PROMOTE TOURISM

Figure 5:10: Schematic representation of floating infrastructures for tourism development
Source: This entrepreneur has built an island out of plastic waste. (2023, March 7). World Economic Forum. https://www.weforum.org/agenda/2019/12/island-built-from-plastic-waste-ivory-coast-africa/

The floating infrastructures are created in a way that is environmentally benign and sustainable. In order to build floating infrastructure, old plastic bottles are utilised. Solar panels are also used for energy generation. The traveller may still enjoy the Kuttanad region's picturesque

splendour even during floods because to the floating infrastructure. In order to increase the region's economic resilience, this will assist Kuttanad locals in generating income from the tourist sector.

Figure 5:11: Proposed site for floating infrastructure and floodable park
Source: Author generated with respect to Snazzy map

Proposed site 2: Floating infrastructures

Location: 0.6 Ha in Pulikunnu panchayat

Ownership: Government owned land

Implementation: Alappuzha's tourism department works with the state planning board to put this into practice.

Recommendations: Clearance certificate and pollution certificate should be mandatory for houseboats.

TO DEVELOPE FLOATING MUSEUM FOR VARIETY OF AQUATIC SPECIES

Figure 5:12 : Schematic representation of floatable aquatic museum
Source: Gallery of Museum for Aquatic Plants | Interval Architects | Media - 1. (n.d.). Archello. https://archello.com/story/68720/attachments/photos-videos/1

The floating museum for aquatic species contributes to the preservation of the variety of aquatic species in Kuttanad and attracts tourists to the area. The museum will be set up in a floating structure, which will enable it to withstand the effects of major flooding.

Figure 5:13: Proposed site for Floating museum
Source: Author generated with respect to Snazzy map

Proposed site 3: Floating museum for aquatic species

Location: 0.2 Ha in Pallikkayal in Kavalam panchayat

Ownership: Government owned land

Implementation: In the Alappuzha district, the tourism department works in partnership with the Department of Fisheries.

Recommendations : Development of sustainable methods of fish culturing and crop cultivation which preventing artificial fertilizers and protecting wilderness and it promotes aquaponics farming and permaculture farming

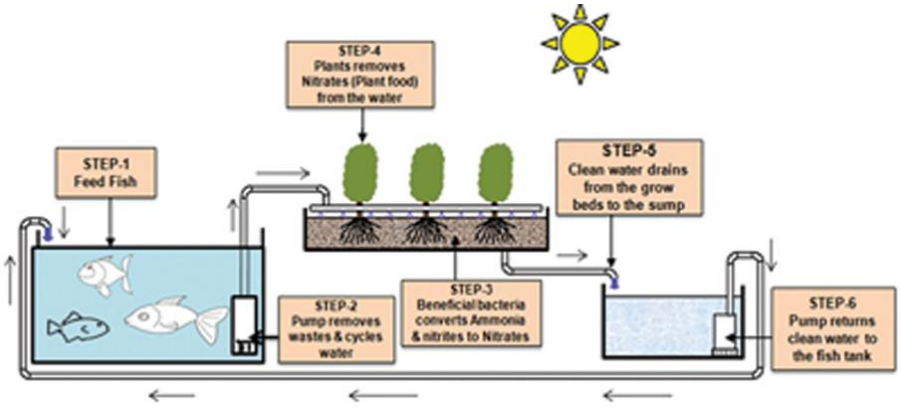

Figure 5:14: Working of aquaponics
Source: (Alok Kumar, 2020)

Figure 5:15 : Permaculture
Source:(Smith, 2018)

5.5.8 GOAL : PROMOTE POLLUTION FREE ENVIRONMENT

Urban forests can be created using the Miyawaki method and are intriguing, complex ecosystems that are in harmony with the soil and climate of the day.

Figure 5:16 Concept of miyawaki technique
Source: (The Concept of Miyawaki Forest, 2023)

An efficient technique for creating mini-forests quickly is Miyawaki Forest. The goals of a Miyawaki technique include improving biodiversity, sequestering carbon, increasing green cover, lowering air pollution, and preserving the water table.

POTENTIALS

They help lower temperatures i, reduce air and noise pollution, attract local birds and insects, and create carbon sinks. Afforestation was largely a means to generate income from timber and other products.

5.5.9 GOAL: ESTABLISH A FARMING CENTRE IN KUTTANAD TO ADVANCE AGRITOURISM

A new market for travelers is agricultural tourism. The mystery surrounding the individual's work gives the possibility of interacting with people that one might not interact with on any level at a given time. People's interactions with agricultural life often include an educational

component. People frequently find it interesting to learn about things and procedures that they will not immediately use.

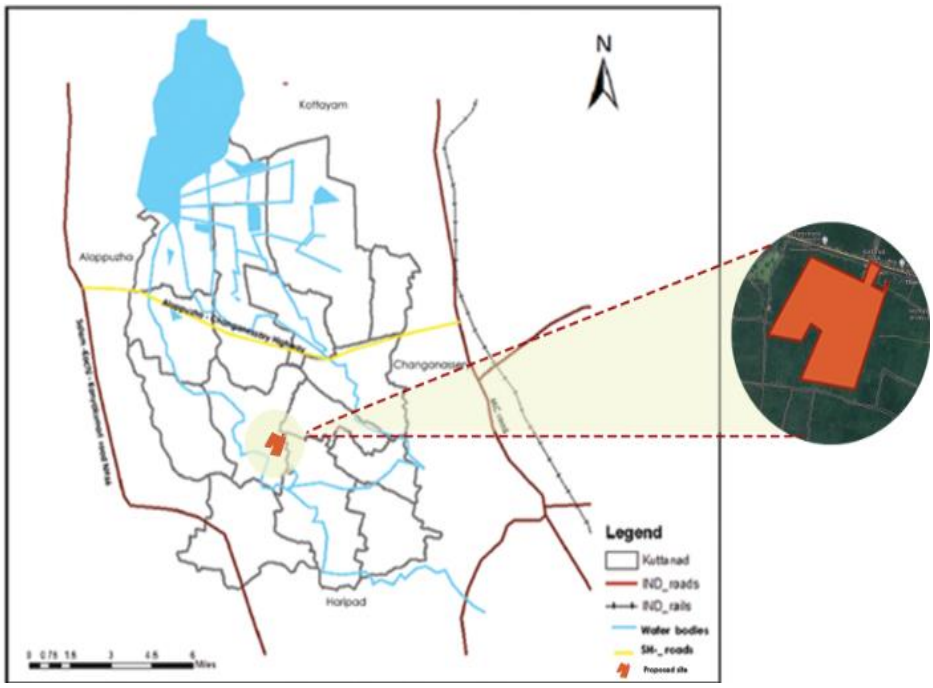

Figure 5:17 : Location of proposed agriculture hub
Source: ArcGIS

Figure 5:18: Proposed site for agricultural site
Source: Author generated with respect to Snazzy map

Implementation: Alappuzha's tourism department and agriculture department works with the state planning board to put this into practice.

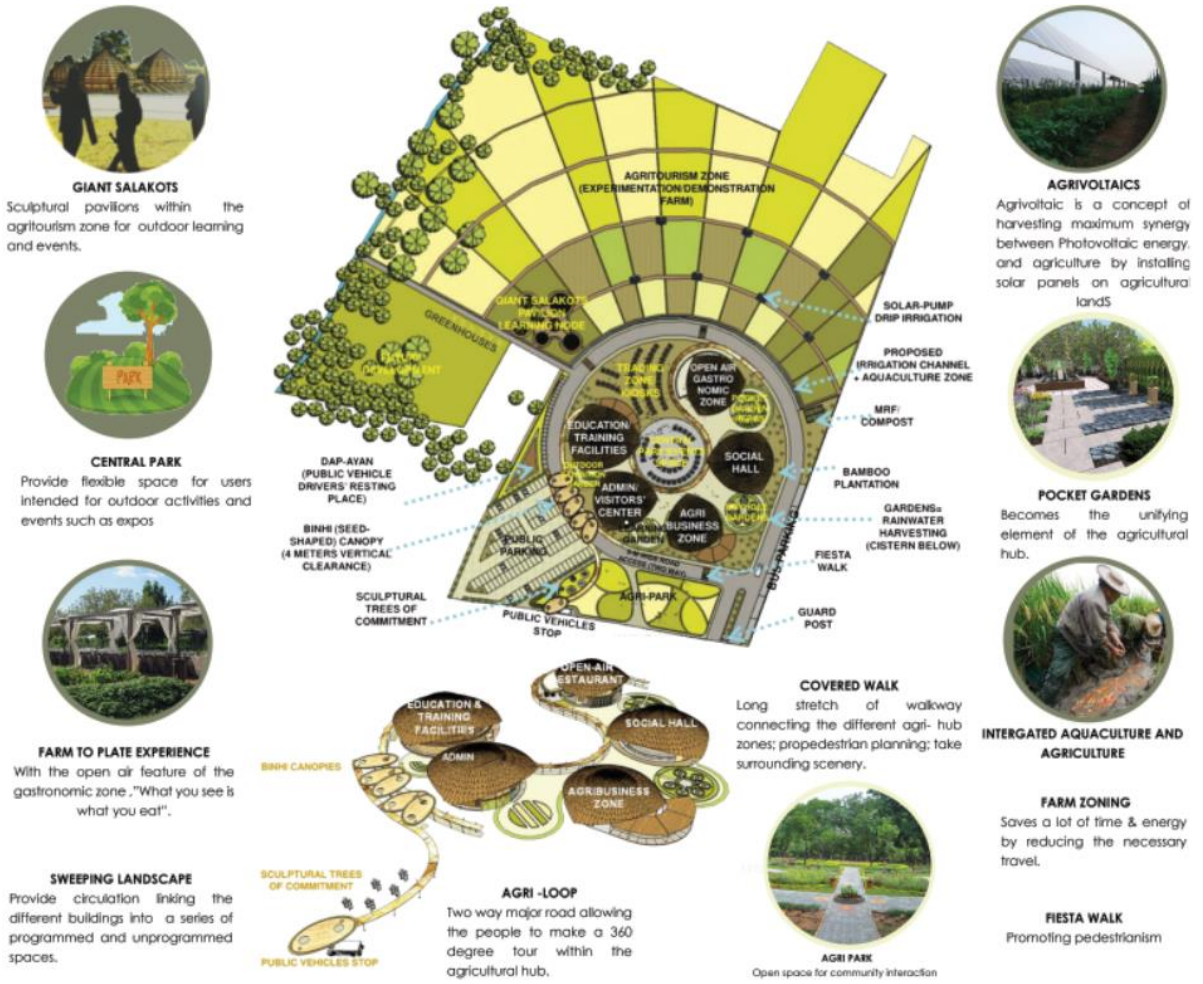

Figure 5:19: Design of agricultural hub

Source: Modified from *Eco tourism: Scope and Opportunities in RPCAU* . (n.d). https://www.slideshare.net/8763463618/eco-tourism- scope-and-opportunities-in-rpcau

DESIGN RECOMMENDATIONS

We use amphibious constructions and brick technology for a long time to resist floods when developing the agricultural center. During extreme weather, amphibious structures may also serve as emergency medical and logistical hubs. The roadways have been constructed with smart transportation elements, such as pedestrian and bicycle lanes, underdrain rain gardens that connect to nearby rivers, and more greenery. A parking area with pervious pavement, bioswales, and a vegetated buffer zone . This design facilitates water drainage from the area and reduces the amount of dirt that collects after a flood. Further assisting in preventing the disastrous effects of flooding in that area is the establishment of environmentally friendly drainage systems that connect to canal networks.

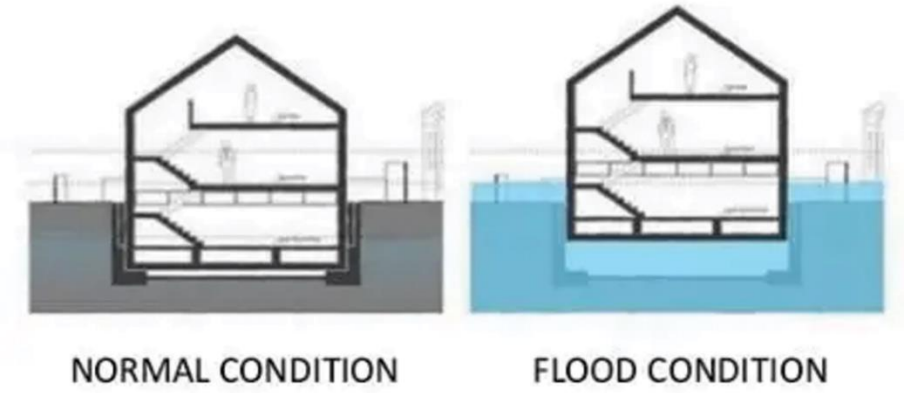

Figure 5:20: Design of amphibious structures

Source: Contents, W. (2014, October 26). This three-story house will float during a flood. *World Architecture Community*.https://worldarchitecture.org/article-links/chcfp/this-three-story-house-will-float-during-a-flood.html

Figure 5:21: Model of amphibious structures

Source: Murphy, C. (2014, November 19). *Amphibious House -BACA Architects*.Pinterest.https://www.pinterest.com/pin/48146301638883310

Figure 5:22: Brick bottle technology

Source: K, N. S. (2021). Building Construction with Plastic Bottles- Walls, Roofs and Benefits. *The Constructor*. https://theconstructor.org/construction/plastic-bottle-building-construction-benefits/16141/

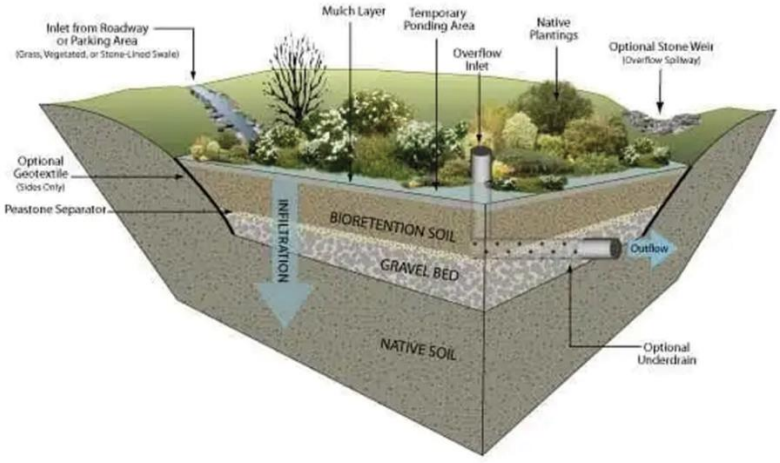

Figure 5:23: Bioretention basin

Source: Webadmin. (2022, April 20). *Blog*.https://www.adpc.net/urce-norad/index.php/2022/04/20/climate-smart-nature-based-solutions-for-building-urban-resilience-to-climate-extremes-2/

Bioswales are designed to remove pollutants and silt from contaminated groundwater.

Figure 5:24: Resilient park

Source: *Coastal Ecologies – Object territories*.(n.d).OBJECT TERRITORIES.https://object-territories.com/coastal -ecologies

"Waterfront parks can be designed to enhance neighborhoods and the waterfront by providing open space for passive and active recreation, enhance access and connections throughout, natural landscapes, carbon mitigation, heat island reduction, and stormwater flood mitigation."

Figure 5:25: Activities for tourist

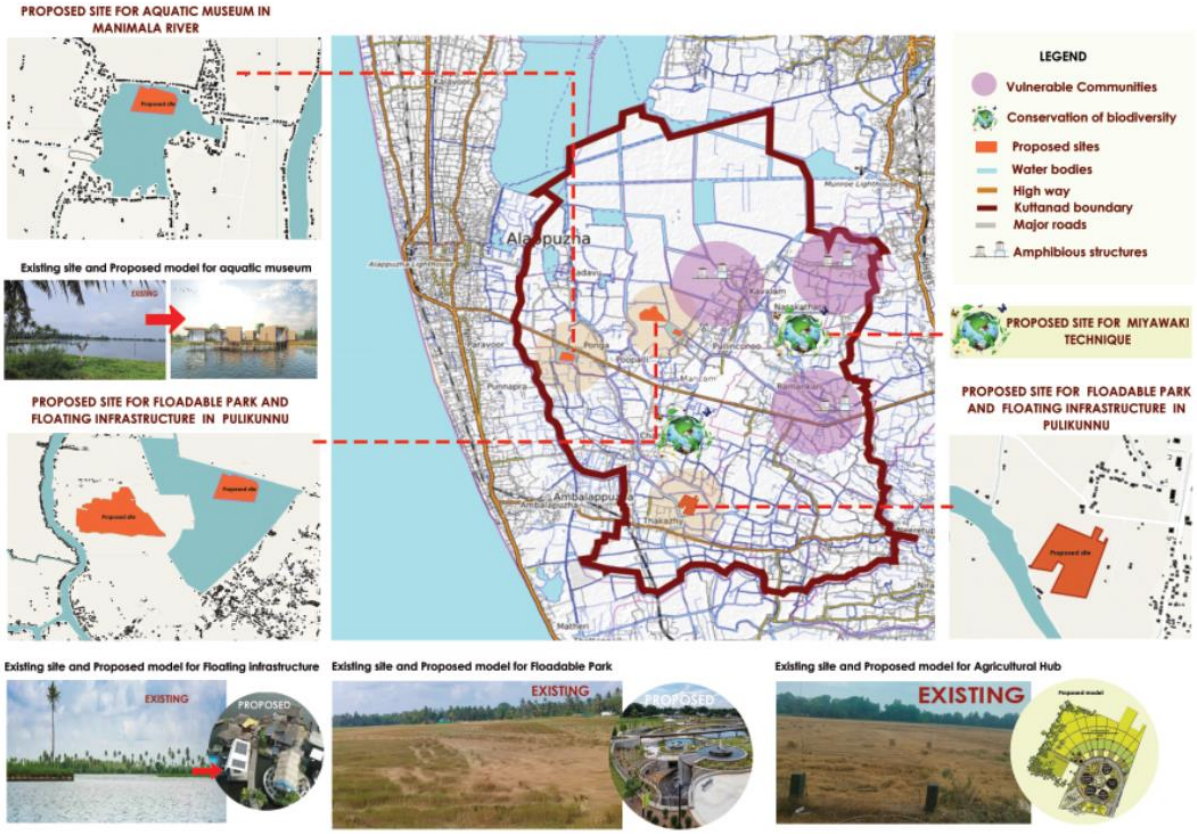

Figure 5:26: Location of proposed sites

Source: Author generated with respect to the data collected from Kuttanad taluk office

Action plan is prepared for the development of Kuttanad region to enhance its economic resilience, agriculture resilience and tourism development for the betterment of life.

CHAPTER 6 CONCLUSION

In order to improve the quality of life, this study aimed to sustainably increase resilience in Kuttanad. Through the specified parameters, planning based proposals are made. The importance of developing resilience in the Kuttanad wetlands is investigated, along with the identified conditions needed to raise environmental standards. Secondary data were gathered from a variety of sources for this thesis. To ascertain the general characteristics of the study area and comprehend its growth potential, the obtained data were examined and analysed. The main surveys were carried out to ascertain the problems encountered by the Kuttanad population in everyday life. Some parameters are considered to identify the most vulnerable communities in Kuttanad by calculating the adaptive resilience index. From the swot analysis and background study, a vision and goals are developed. Action plans are proposed under agriculture, tourism sector to enhance the economic resilience in the most vulnerable communities in Kuttanad region. The engineering solutions helps the people in Kuttanad to live a better living condition.

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ANNEXURE

1. Ward Name, House No:
2. Name of the nearest land mark:
3. Name of the family head:
4. Number of family members:
5. Number of working people, Occupation:
6. Whether migrated (Tick all that apply).

   Yes ☐ No ☐

7. If yes, (time period): 0-20 years ☐ >20 years ☐

8. Reason for migration

   Work ☐ Education ☐ Better living condition ☐

9. Are you willing to relocate:

   Yes ☐ No ☐

10. If yes , why? (Mark only one oval).

    ☐ Lack of employment opportunities

    ☐ Lack of infrastructure facility

    ☐ Better education opportunities

    Other:

11. Nearby hospitals:
12. Source of drinking water.

    ☐ Well

    ☐ Public Tap

    ☐ Bore Well/ Tube Well

    ☐ River / Canal

    ☐ Water authority water supply

13. Availability of water:

    ☐ No scarcity ☐ <6 months ☐ 6-12 months

14. Duration of water supply

☐ All day ☐ More than half day ☐ Less than half day

15. Housing typology

☐ kutcha house ☐ Semi pucca house ☐ Pucca house

16. Recreational facilities nearby

☐ Park ☐ Open ground ☐ Open spaces

17. Do you experience pollution:

☐ Air Pollution ☐ Water Pollution ☐ Soil Pollution

18. Nearby market:

19. Name the hazard you faced previously.

☐ Flood ☐ Drought ☐ Landslide ☐ Other

20. Location of the hazard affected area:

21. Depth of the flood level:

22. Income category: ☐ Economically backward ☐ General ☐ Other

23. Is there any sanitation facility (septic tank, soak pit)?

☐ Yes ☐ No

24. Reason for flood:

25. Remedial measures taken to overcome:

26. Connectivity access: ☐ No access ☐ <3m ☐ 3-7m ☐ >7m ☐ Other

27. Duration of flood: ☐ Hours ☐ Days ☐ Weeks ☐ Months ☐ Others

28. Impact of flood: ☐ Severe ☐ Moderate ☐ Less

29. Type of losses: ☐ Infrastructure ☐ Agriculture ☐ Animal ☐ Others

30. If you Relocated or not during floods? (If yes , where and duration)

31. How you managed your basic requirements if you are not relocated?(sanitation , drinking water etc…)

32. Are you satisfied with the camp facilities ?(Sanitation , water supply etc..)

☐ Yes ☐ No

33. Occurrence of flood before or after 2018 flood (Duration, flood level , impact , month, frequency).

34. Reason for the occurrence of flood continuously.

☐ Lack of drainage facility ☐ Flooding of canal ☐ Waste dumping

☐ Paddy field filling ☐ New development plans ☐ Encroachment of land

Other:

35. Location specific disaster risk management techniques used previously?

36. Any social infrastructures nearby?

☐ Schools ☐ Hospitals ☐ Community hall ☐ Police Station ☐ Fire Station

☐ Any govt offices ☐ Pumbing Station ☐ Electric Substation ☐ Transformers

Other: