TATA CENTER FOR TECHNOLOGY AND DESIGN-IIT BOMBAY

Phase one report submitted

on

SUSTAINABLE HOUSING SOLUTIONS FOR FLOOD-PRONE AREAS: CASE STUDY - KUTTANAD REGION, KERALA

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1. BACKGROUND

1.1. Introduction

Housing is identified as a basic human need and a key component of community building and has considerable effects on the psychological and physical well-being of its inhabitants. According to WHO, improved housing conditions can save lives, reduce diseases, increase quality of life, reduce poverty, and help in mitigating climate change. Further, it can be noted that it can also contribute towards the attainment of Sustainable Development Goals (SDGs) related to health (Goal 3) and sustainable cities (Goal 11). Housing can also be considered as a major entry point for the public health programs including primary prevention. The perception of housing has undergone a remarkable change over the course of last few decades (Nair, 2006).Today, it presents itself as more than a shelter, and as a component of the economic security and societal status of a household. This transformation into the understanding of housing as shelter and its morphing into a social asset has led to numerous unsustainable practices in the process of house development, mainly from unscientific land use planning of settlements to the use of unsustainable materials and technology practices. It is commonly accepted that the well-being of both individuals and families is substantially affected when the need for satisfactory housing is unmet. Access to adequate housing has long been viewed as a basic human right and is considered to be an integral factor for the enjoyment of other economic, social and cultural rights. According to the United Nations Committee on Economic, Social and Cultural Rights, a satisfactory housing consists of: legal security of tenure; availability of accessible services, facilities and infrastructure; habitability; accessibility (e.g., Access to employment, health services, schools, etc.); cultural adequacy; and affordability.

Sustainability is at the forefront of the current global discussions on climate change, equality and quality of life and the growing challenges of urbanization. Within its framework, sustainability encompasses both ecological as well as social aspects. Housing or housing sustainability is a primary objective in attaining sustainable development. It is well understood as a fundamental human right and is linked with essential aspects of human development, livelihoods and health and well-being. This study examines the tenets of

sustainable housing and develops a framework of gauging housing sustainability in flood-prone Kuttanad region in Kerala.

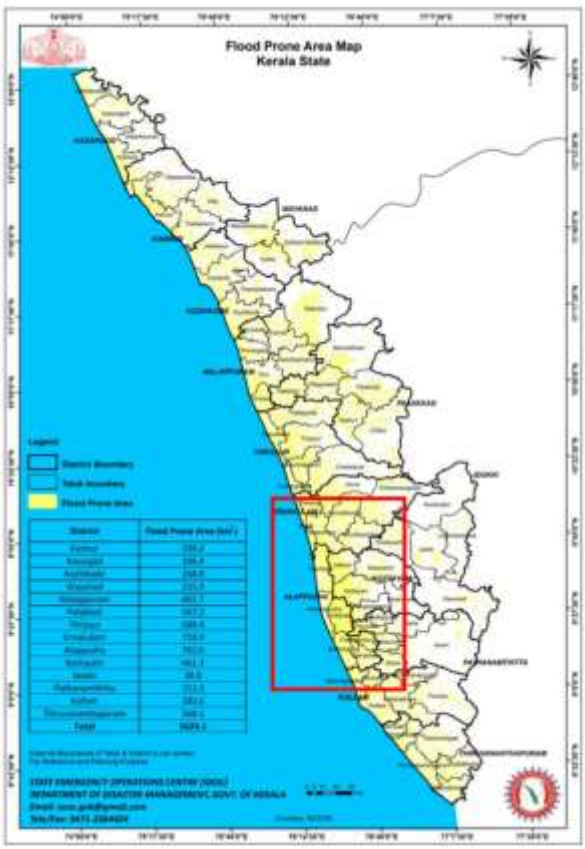
It is a well-known fact that Kuttanad is a highly flood-prone region. As a result of annual floods, significant numbers of houses in the region were destroyed or had undergone significant damage gradually. In recent floods which occurred in 2018, we have observed a total or partial destruction of significant number of rural houses making lakhs of people homeless. To a large extent, the patterns and causes of destruction seems to result from poor technical knowledge and wrong perceptions around housing. As a flood prone region, flood-related hazards have a strong influence on the sustainability of houses in the Kuttanad region. Knowing the vulnerability of the region is important to develop a strategy for sustainable housing projects. The resilience capacity of houses varies according to geography, land type, structure of houses and the socio-economic condition of inhabitants. The preliminary phase of the study mainly concentrated on the pre-existing issues within the geography, housing and the socio-economic conditions in the context of floods. The houses by low-income communities in rural areas are mostly owner-built without proper technical guidance and have additional constraints. There are some schemes for such groups like the “Life” project by the State government in Kerala. This study argues for the need for developing a housing pattern which is appropriate for flood-prone areas, where the suggested solutions are ‘cost-effective’ without compromising the quality and also being sustainable from an environmental, and socio-cultural backgrounds. With this perspective, It will also explore the current practices of low income housing to make the design better and more sustainable.

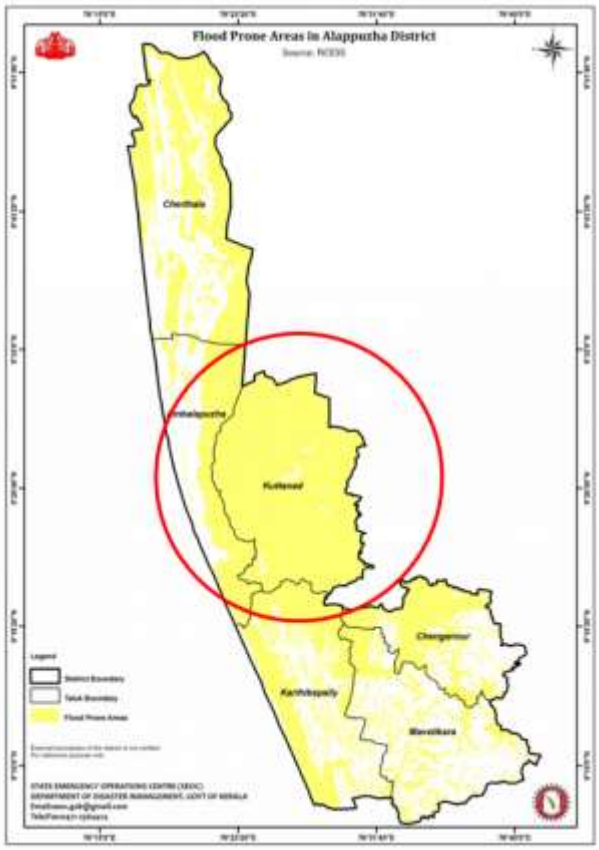
This chapter provides an understanding of the context, relevance and objectives of the study along with a detailed description of the study area. In chapter 2, a conceptual framework for sustainability was explained in detail. Further chapters include the studies conducted for evaluating the sustainability of housing in the region based on the conceptual framework. Chapters 3, 4 and 5 attempts for a situation analysis with different physical and socio-economic variables that determine the sustainability of housing. Each chapter is structured in terms of the methodology, processes, and results. Chapter 3 attempts to understand the existing housing conditions through a field-based study. Different housing typologies and housing trends and issues related to the floods are addressed in this chapter. Chapter 4

focuses on the physical vulnerabilities of the region. Through a detailed digital elevation modelling (DEM), this chapter brings out the macro picture of vulnerabilities in the region. Further, the chapter 5 discusses the detailed field study that was conducted for understanding the overall impact of the bio-physical and socio-economic variables. It explains the process of the 25-day field study which includes transect walk, FGDs, and household surveys for collecting socio-economic details and micro-level physical vulnerabilities. Chapter 6 puts an emphasis on the post-disaster housing strategies. This chapter addresses the various housing reconstruction strategies adopted across India. A detailed analysis of the 'LIFE' mission of Kerala Government has also been conducted as it is the predominant reconstruction strategy in Kuttanad after the 2018 floods. Understanding the gaps within the LIFE housing program in terms of the sustainability assessment can deliver effective recommendations to the program. It may also bring more practical results at the ground level. Finally, chapter 7 provides the details for the planning of the second phase for achieving the objectives mentioned.

1.2. Kuttanad

The Vembanad lake, the largest coastal lagoon (~250 km2) in the west coast of India, and its catchments cover an area of about 14,500 km^2 (Padmalal et al., 2008). The lake possesses unique physical characteristics in terms of physiography, climate and hydrology. Physiographically, the area is divided into 3 distinct zones—the highlands (>75 m above msl), mid- lands (8–75 m) and the lowlands (<8 m);(Padmalal et al., 2008). The Kuttanad wetland is located at the southern portion of the Vembanad wetland. Primarily, it is a deltaic formation of five river systems: Meenachil, Pamba, Manimala, Muvattupuzha, and Achencovil, located in the fertile low-lying areas of Vembanad Lake. It is a Globally Important Agricultural Heritage System (GIAHS), as declared by the Food and Agriculture Organization (FAO).



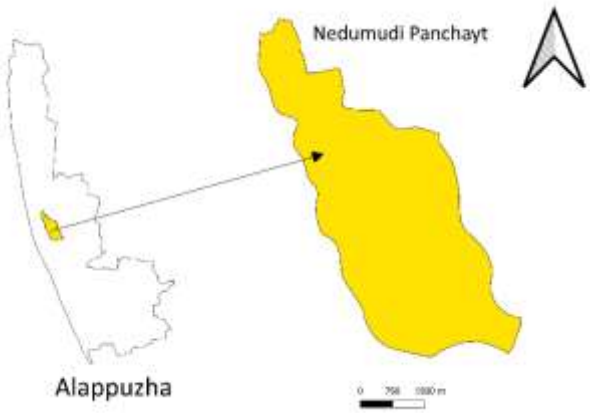


A substantial part of these lands were reclaimed by peasants from the Vembanad Lake. These lands are not contiguous as channels and waterways surrounds each strip of land. The garden lands comprises of about 304 km^2. It looks like islands of varying sizes and shapes. The natural blending of land and water coupled by the high fertility status of soil makes this land-water ecosystem ideal for agricultural purposes (State & Board, 2019). Nearly 57 per cent of Kuttanad is shared by Alappuzha district with 32 panchayats and about 30 per cent is shared by Kottayam district with 27 panchayats. About 13 per cent is shared by Pathanamthitta district with 5 panchayats. Together, this formsabout 2.5 per cent of the State's total geographical area. The boundary of the Kuttanad region is loosely defined and the extent of its area has been variously computed at different times.Today, it encompasses 79 revenue villages, 10 Taluks, and 3 Districts (Dwivedi, 2011). The key feature of Kuttanad is the cultivation of paddy at 1 m to 2 m below sea level in the wetlands formed by draining the delta swamps in brackish waters (State & Board, 2019). Nearly 95 per cent of the farm holdings in Kuttanad are small or marginal. Rice is the major crop in wetlands and coconut is the major crop in the garden lands. Banana, tubers, vegetables and tree spices are grown as intercrops (State & Board, 2019).

As a below sea level region the flood is a natural scenario in Kuttanad. Several indigenous flood adaptation measures were adopted in this region. Due to the influence of change in socio-economic and cultural practices, the landscape of Kuttanad has changed significantly. A huge portion of public spending occurred in this region as a part of the infrastructure development. The emerging tourism industry also fueled the increase in the number of roads and settlements in this region. Along with the infrastructure developments, several technological interventions also were conducted for controlling the flood and supporting agriculture in the region over the past few decades. A spillway was built at *Thottappally* with a clear span of 304 m, to divert flood water from Vembanad lagoon into the sea. Also the *Thanneermukkam* barrier was constructed across Vembanad lake which is 1250 m long and has 93 sluice gates each 12.2 m wide and 5.5 m high. This wasto prevent the intrusion of saline water from the Arabian sea during dry seasons (Government of Kerala, 1974; Government of Kerala, 2002 as cited in (Remani et al., 2010).But the present scenarios including the 2018 and 2019 flood events shows the failure of theses technological measures to prevent floods. It was one of the worst flood-affected regions in Kerala during the 2018 & 2019 monsoons.

1.3. Study area

1.3.1. Nedumudi grama panchayat



Nedumudi is one of the large villages in Kuttanad Taluka with a total of 3668 families are residing (Census, 2011). It belongs to the lower part of Kuttanad and like in any part of Kuttanad, agriculture is the economic mainstay of this panchayat. The panchayat is surrounded by the Pamba river and its tributaries. Two major rivers Pamba and Pookaitha determine its boundaries. According to the State Land use Board database, the three major land-use types in Nedumudi are, Paddy fields (71%), dry land including habitats and agriculture (19%), and water bodies (10%) (fig 1). The 2018 floods have drastically affected Nedumudi panchayat and most of the residents had relocated to rehabilitation camps. A relatively moderate flood from the 2018 event has also been repeated in this region in 2019. According to the flood level data collected from this region, the peak flood level occurred was 2.5 meters in 2018 and 1 meter in 2019.As per the

land use pattern, a major portion of the panchayat (81%) are water bodies and paddy fields. The 35.4 km (CANALPY survey 2019) long canal system spread over the panchayat serves as irrigation and drainage infrastructure to the paddy fields and settlements.

Most of the time, the high runoff from the rivers and the tidal variations determines the magnitude and duration of floods in this area. Along with the spatial vulnerabilities from the low topography, the region also has several economic and social vulnerabilities to the flood. 42% of the total population of this region is under the below the poverty line and 9.4% under the SC community (Nedumudi panchayath annual plan, 2018; Census, 2011). As per the Nedumudi panchayat 2017 annual report, 43% of its population is dependent on the agriculture sector and 31% is working as daily wages workers (Figure 1). Within the agriculture sector more than half of the population are marginal labors (Figure 2) (Census, 2011). The dependency on sectors that are highly vulnerable to the floods and the large proportion of marginal workers escalates the economic impact of floods. Also, the topography of the region has a significant influence on the social structure. More socially backward classes are residing in the low elevation flood-prone areas.

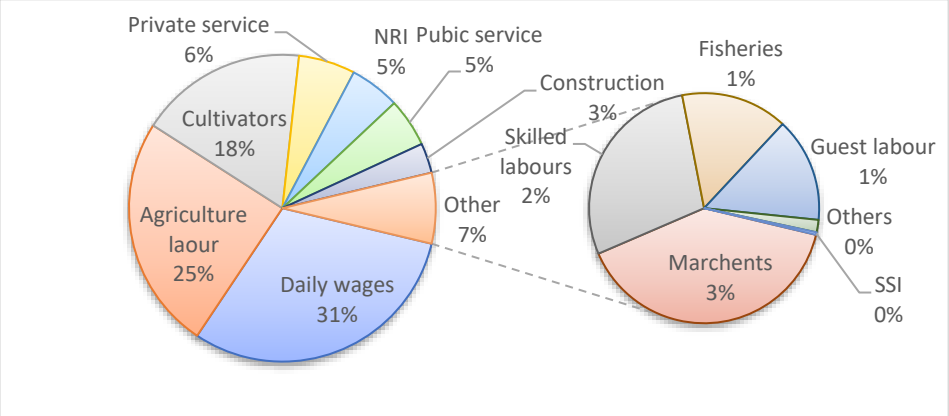


Figure 1 : Ouccupational information of Nedumudi panchayat (Annual master plan 2018, Nedumudi GP)

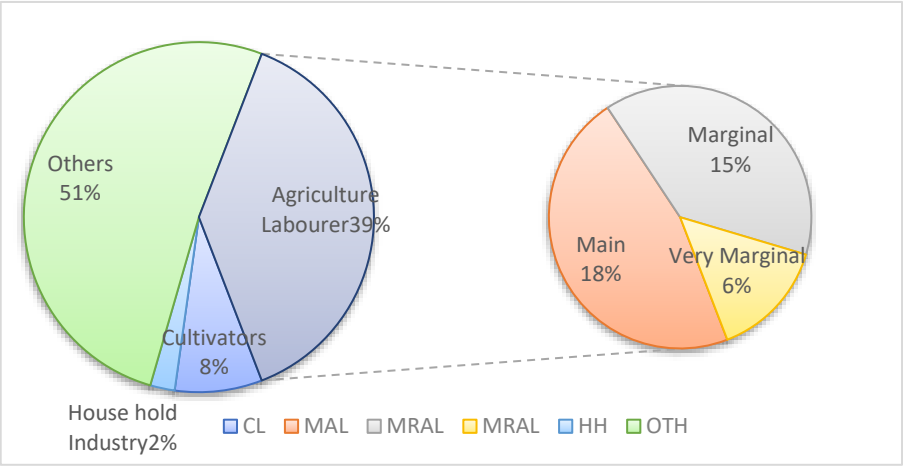


Figure 2 : Marginal labors in Nedumudi panchayat (Census 2011)

1.3.2. Kainakary grama panchayat

One of the stories around the word 'Kari' or 'Kary' as an ending to many of the place names in Kuttanad is because, it is believed that Kuttanad was a forest and it was burnt into ashes due to a major fire. Then the word 'kari' associated with place names which means charcoal. The word is attached with 18 areas within Kuttanad and Kainakary is one among those places. Also, the paddy cultivation and related activities of the region were believed to be led by a person called 'Kanakan' which further modified to the name Kainakary as Kanakan's Kari. The Vembanad lake in Kainakary was converted to paddy fields by digging mud from the Vembanad lake and is mainly done under the guidance of Ramaswamy Iyer, the Diwan of Travancore State at that time. The newly created paddy fields were Rani, Chithira, and Marthandam which were given as respect to the rulers of the Travancore kingdom. The conversion was led by Joseph Murikkan who was known as the 'Kayal King' in the second half of the 20th Century due to the widespread conversion of paddy fields under his leadership. The story of Kainakary is a story of labour

unions and struggles too. India's first labourers meeting convened under the leadership of 'Janaki' in this beautiful location of Kuttanad.

There are many myths about the origin of this small village. It is said to have been landlocked sea thousands of years ago. It is a collection of islets off the coast of Kerala, surrounded by water bodies including River Pampa and Vembanad lake. Also, the area is a symbol of the Kuttanad style of paddy cultivation by making bunds around the water bodies and by pumping out the water from the inside portion. Water bodies constitute 59.87 percent of the total area of the panchayath and the main reservoirs are the Vembanad Lake and the Pampa River. This fertile soil, sown in the mud of the backwaters was completely built on the sweat and willpower of laborers in the region. The panchayat also has ancient shrines, holy churches and the birthplace of the blessed Saint Kuriakose Elias Chavara which crown the culture of this place with fame.

There are two villages in the Panchayat, Kainakary South and Kainakary North. The panchayat is located in the Kuttanad Taluka and is under Champakkulam block panchayat in the Alappuzha district. The total area of the panchayat is 36.64 sq. km and is divided into 15 wards. The total population is 26,862 with a population density of 733 people per sq. km. The sex ratio is 1046 females per 1000 males and has a literacy rate of 98%. Kainakary Panchayat lies 1.5-3 meters below sea level and 59.87 % area of the panchayat is covered with water bodies. Vembanad lake and the Pamba river are the two major water bodies in the region.

Like other regions in Kuttanad, the major issues of Kainakary people are also related to their water and sanitation needs. The number of people receiving formal education has increased drastically with the changes across Kerala over the years. But the employment opportunities after their studies are a challenge for Kainakary people as mentioned in the Panchayat Development plan of 1996. The document envisages the development of the panchayat in terms of health, education, transportation, livelihoods, telecommunications, etc.

1.4. Preliminary observations

A field survey of the physical conditions of the houses in the villages of Nedumudi and Kainakary in Kuttanad taluka, Alappuzha was conducted as a preliminary study to ascertain recovery and rehabilitation processes in the households. The central objective behind the survey was to ascertain the extent of structural damages caused to the houses in the region with the larger aim of establishing an overarching narrative around the settlements and building the construction patterns in the region and how they have developed over the course of time in an area that witness annual inundation. While it was assumed that the construction industry in the region has undergone significant changes with changing livelihood patterns, increase in income levels, changing household sizes, migration and changes in aspirations of the inhabitants, there was also an interest in determining how the design and construction of the houses themselves had adapted and morphed to the region's flooding patterns.

Key challenges for Kuttanad taluka can be subdivided into 4 primary heads:

1.4.1. Affordability

One of the major issues in the region is housing affordability. The challenge of affordability is linked not only to the financial decisions made by the family based on their aspirations, but also on the technical difficulties of building in the region. While building materials are transported from large distances, limited access via road increases transportation and labor charges. Soil condition and yearly flooding as mentioned below, drives up the cost of the foundations and plinths are constructed at a height to escape water level during floods. It is estimated that building in Kuttanad region is 1.6 times more costly than building in surrounding Alappuzha district.

1.4.2. Geography and Soil Condition/ Technical challenges

Kuttanad region, which lies 0.6-2.2m below means sea level, lies mostly submerged. The clay found in the region has undesirable engineering properties, with high compressibility, low shear strength and large percentage of organic matter. The soil tends to expand when wet and shrink when dry and has led to a large number of embankment and foundation failures. One of the key challenges in the region is to provide technical support in

soil stabilization for building structures in the region. Current systems, as described below, not only drive-up costs significantly but also harm the environment.

1.4.3. Environmental Sustainability

Given the unique terrain of the region, there is a need for special consideration given to flooring and foundations. This system includes raising the level of the soils by almost 2 m where rice fields are directly reclaimed due to increasing population. Since the region does not have any natural stone quarries, soil and stone for building foundation is transported large distances from the east (Kottayam district) leading to detrimental impacts on local biodiversity as well as the Western Ghats from where materials are mined. Second is the unregulated use of cement blocks and new trend of lifting houses on concrete pillars, which increases chances of structural failure due to soil settlement.

1.4.4. Design Challenges

New houses which are being constructed do not take care of the local climatic conditions and the indoor air quality (Kitchens). This has led to a very uncomfortable situation for living during the majority of the time. There is a need to look at building materials and practices in the region to increase thermal comfort of the houses through passive cooling techniques and also to bring down the cost of homes, and make them more environmental friendly.

This thesis will look at addressing these challenges in the building industry in the region and promote the use of innovative, local materials (such as developing light-weight clay bricks from Kuttanad soil), passive cooling techniques and issues of housing affordability, within a framework of developing a model for flood-resistant housing for Kuttanad. The model and design principles developed, can be modified and replicated in other flood-prone areas of the country and other developing nations

1.5. Objectives of the study

Objective 1: Building Context: A Framework of Sustainable Housing in the Context of Kuttanad

- Understanding the unique geography of Kuttanad and the annual patterns of flooding
- Understanding the premise of Sustainable Housing in flood prone regions and creating indicators to examine the current housing development in Kuttanad region
- Deriving a framework to analyze the existing housing development of Kuttanad from the lens of Sustainable Development - What are the key parameters that aligns with or move away from the notion of sustainability
- Outlining the implications of unsustainable housing development in the context of Kuttanad with a focus on flooding Methods:
    - Literature Review of Sustainable Housing Development and Housing in Flood Prone regions
    - Interviews with Experts (local architects and engineers), Panchayat Officials and Household surveys to understand the existing framework of sustainability in the context of Kuttanad
    - Document survey
    - Mapping and field surveys to understand the extent of flooding and flood damage to houses in Kuttanad region

Objective 2: Understanding the vulnerabilities of the region

- Creating a framework for Vulnerability assessment
- Regional analysis of compounding vulnerability in terms of bio-physical and socioeconomic condition with the help of GIS and RS tools
- Micro level analysis of compounding vulnerability in terms of bio-physical and socioeconomic condition with the help of GIS and RS tools

Objective 3: Documentation: Codifying the Methods of House Construction

- Mapping the shift in settlement patterns and patterns of land development in the villages of Kainakary and Nedumudi with special focus on vulnerable communities, and analyzing the role of flooding in the transformation or decision-making w.r.t. land and housing development
- Mapping and documenting the existing materials, methods and practices of house building in the region from a lens of sustainability indicators- affordability, ecological

footprint, technological feasibility and functionality, adaptability and cultural suitability

- Documenting existing house planning and design
- Documenting traditional methods of planning, design, construction and materials used, with a focus on the primary reasons for discontinuation
- Documenting emerging patterns of house construction from a lens of sustainability indicators and analyzing the role of flooding in changing construction methods

Objective 4: Measuring Impacts: Understanding and Framework Existing Coping Mechanisms

- Documenting the outcomes of the Flood of 2018: House and Community building activities and the emerging solutions (250 Houses by Habitat, Disaster Housing by World Vision)
- Study and analysis of existing policies, housing programs and government interventions
- Framing the 'Problem': Comparative Analysis between outcomes of field surveys and current policy and building interventions in Kuttanad region
- Key emerging issues and gaps Methods: Document Survey, Interviews with NGOs and social workers, Interview with govt. officials, mixed methods of research

2. CONCEPTUAL FRAMEWORK OF SUSTAINABLE HOUSING

2.1. Housing Sustainability in Kerala

Sustainable housing has its roots in the conceptual framework of sustainable development. The Agenda 2030 for Sustainable Development (Sustainable Development Goals, SDGs) adopted by UN Member States in September 2015 in New York set 17 ambitious goals with specific targets with the aim attaining them until 2030. Among them, some are more particularly linked to housing.

Sustainable Housing can be defined as 'accessible, affordable' housing that meets the socio-cultural and shelter needs for all, particularly the disenfranchised communities.

Housing poverty can be linked to Goal No 1 of the SDGs, "End Poverty in All its Forms". To build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters, investing in affordable housing is crucial. Thus, affordability or the economic capacity of an individual to pay for housing is a significant part of framing sustainable housing. Within this understanding, technology also plays a crucial role by acting as a catalyst with which to provide affordable options suiting various climatic conditions and cultural needs.

Sustainable Housing can be conceptualized as a framework built on 4 pillars of sustainability - Ecological Sustainability, Economic Sustainability, Technological Sustainability, and Socio-cultural Sustainability (Nair, 2006).

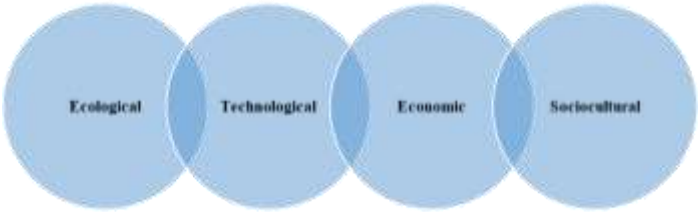


Figure 7: The 4 Pillars of Sustainable Housing (Nair, 2006)

2.1.1. Sociocultural Sustainability Indicators

(i) **Adaptability**: Flexibility in design to adapt to the changing needs of a household i.e. growth in family size, change in income-levels.

(ii) **Equality**: Equality in housing development refers to that, segregation or grouping of a particular group of people based on income, religion or any other criteria should not reflect in their housing and should not prevent them from participating in social activities. Different groups of people within the society should be able to participate equally ((Gopalakrisnan Nair, 2006) .

(iii) **Integration of Amenities and Services**: Sustainable housing requires integration of community specific amenities and services, such as the needs for privacy, provision of separate kitchen, etc.

(iv) **Participation**: Ensuring participation is a key principle of sustainable development as it is linked primarily to the idea that most housing in rural areas is beneficiary led housing, and key decisions about the design of the house and the choice of materials should be made in cognisance of the end-users of the house. This is particularly true for government led housing programs.

2.1.2. Ecological Sustainability Indicators

(i) **Renewable and Non-renewable Resources**: Stress on usage of low-carbon embodied materials, locally available materials and looking towards the conservation of materials used in building construction such as water management.

(ii) **Land conservation and proper planning**: minimizing the impact of housing on land resources and taking into consideration various factors such as drainage, distance from water resources and community services before building.

(iii) **Healthy environment**: Planning for healthy indoor environments such as smoke-free kitchens, thermal comfort, ventilation and other factors

(iv) **Infrastructure:** Proper integration of physical infrastructure such as sewage and drainage lines

(v) **Waste management and material efficiency**: reduction and management of solid waste produced by manufacturing of building materials and construction of buildings.

2.1.3. Technological Sustainability Indicators:

(i) **Feasibility and functionality**: Technology options should be both feasible in the local context as well as functional and adaptable. The theory of "Appropriate Technology" should be applied to the selection of material and building techniques selected and should be contextual, as well as affordable.

(ii) **Strength, durability, and reliability**: Technology options should be long-term, strong and durable and resilient to weather and climatic conditions.

(iii) **Environmental friendliness**: Technology options should employ environmentally friendly techniques and promote local materials and building techniques.

2.1.4. Economic Sustainability:

(i) **Affordability**: Housing should be affordable to the inhabitants, both for purchase or construction and for maintenance or payment of loans, if any. Affordability is understood as the capacity or ability to pay for housing. Access to land, resources and basic infrastructure is included as a pre-condition for affordable housing (Bhattacharya, 1994).

(ii) **Shelter Needs**: Affordable housing is only considered sustainable if it fulfils the basic facilities and amenities required for the well-being of its inhabitants.

2.2. Housing in Flood-Prone Areas

According to the estimates prepared by the *Rashtriya Barh Ayog* (National Commission on Floods 1980), the area prone to floods in the country is of the order of 40 million hectares out of which about 80% can be provided with reasonable degree of protection through various measures. The states falling within the periphery of "India Flood Prone Areas" are West Bengal, Orissa, Andhra Pradesh, Kerala, Assam, Bihar, Gujrat, Uttar Pradesh, Haryana and Punjab (The Flood Map of India is attached in Annexure 1).

Floods impact housing due to several reasons including depth and duration of floods, uplift caused by soil saturation, and horizontal forces created by flood waves (Ahmed, 2005). This is compounded by secondary hazards such as high winds and soil settlement. Kuttanad is particularly vulnerable due to the low bearing capacity of the clayey soil. Various degree of damage can be sustained by buildings submerged in flood water from staining of walls to structural collapse. Table 9 below adapted from ADPC, lists out the degree of damage sustained by buildings due to floods.

***Table 1** : Damage Sustained by building parts due to floods, Adapted from (Ahmed, 2005)*

Building Member	**Type of Material**	**Damage Sustained**
Foundation	Earthen	Bamboo or timber posts directly embedded into earthen plinths are extremely vulnerable to flooding and get completely destroyed in high intensity floods.
	Brick Perimeter	The typically shallow foundation of perimeter brick wall can become unstable due to instability and soil settlement
	Brick and Concrete	While this is relatively durable, in prolonged flood conditions foundation settlement can lead to structural failures in different parts of the building.
Walls	Bamboo Mat	Typically, bamboo mat walls have a life-span of 4-5 years (COSTFORD). Decay of bamboo mat walls is accelerated in floods, and floods can completely damage Bamboo mat walls
	CI Sheet	Prolonged floods can lead to corrosion and damage of CI sheets and panels can get washed away in high-intensity floods.
	Bricks	While relatively durable, brick walls can experience staining, peeling of paint, and weakening of mortar joints if submerged for prolonged durations. Cracks can occur due to settlement of foundation.
	Cement Blocks (Case of Kuttanad)	From survey conducted in Kuttanad region, cement blocks are most commonly used as walling material. It has been observed that due to varying degree of compression strength and unscientific methods of production, cement blocks develop cracks leading to structural damage in case of floods (survey, 2019)
Doors and Windows		Damage depends on the materials used. MS Steel frames tend to get corroded while timber frames, if not properly treated are severely damaged
Roof	Mangalore Tiles (case	Typical in Kuttanad region, Mangalore tiled roofs are relatively durable if timber posts are of good quality and properly seasoned. However

	of Kuttanad)	heavy rainfall can cause damage and breakage of tiles and leakage. In case of settlement of foundation, roof can collapse. (Survey, 2019)
	CI Sheets	Floods can cause corrosion if in contact with water for prolonged period, and can get swept away by high winds if not properly secured.
	RCC	Relatively durable and can withstand impact of heavy rainfall and high winds, but in case of foundation settlements or damage to walls, roof can collapse. It has been observed that flat RCC roofs offer refuge during flooding and are now being preferred/ desired in Kuttanad region.

2.2.1. Design Principles for Housing in Flooded Regions:

Housing design against flooding is determined largely by affordability of the inhabitants and prevalent building systems. The key design principles for housing in flood-prone areas can be divided into three (Tikul, 2018).

(i) **Building Robust Housing**: Enhancing the capability of housing materials to resist flood damage, such as building elevated houses or "Static Elevation Housing" and "Pile Dwellings (House on Pillars)", that allow water to move through rapidly. This concept looks at strong construction with permanent materials such as RCC for foundations and columns.

- [Data from (Anderson, 2014)]: One of the most common retrofitting methods is elevating a house to a required or desired Base Flood Elevation (BFE)[1]. When a house is properly elevated, the living area will be above all but the most severe floods. Houses on Piles are a type of housing built on top of concrete, steel or wooden poles and can be found in shallow water, coastal areas, or lakes where fluctuations in the water level can be predicted. **This type of dwelling typically rests 8-15 feet (2.4 to 4.6 m) off the ground** and has been used throughout the world as means of protection from water.

[1] High Flood Line (HFL) in Indian Context

Figure 8 : Typical Under-Construction House on Pillars in Kainakary, Kuttanad (Paul, 2019)

- **Timber pilings:** Timber pilings have been used for 6,000 years and continue to be one of the leading types of driven piles. Timber is often used in pile foundations because it is a readily available and renewable resource. Because it is light in weight, timber is also more easily handled, driven and cut than other types of piles. According to (van Alphen, 2020), timber pile foundation underwater will last indefinitely and timber piles partially above water can last up to 100 years or longer if they are properly prepared and treated. Evidence suggests that Coconut Wood was used to raise chalas in Kuttanad during flood season[2].

(ii) **Easily Repairable/Replaceable Components**: Under the framework of this concept, use of non-permanent, affordable, locally available and easy to maintain building materials such as bamboo mats for walls is explored.

- **Case-Example- "Nipa Huts":** The "Nipa hut" is the primary type of housing found in the Philippines. The walls of the living area are made of light materials. Posts, walls, and floors are typically made of wood or bamboo and other light materials. The thatched roof is often made of nipa or anahaw[3] (palm tree leaves). Thus, making it easier for the nipa huts to be moved if needed.

[2] Primary survey- oral testimony. Researcher searching for conclusive secondary evidence.
[3] Palm Trees

Figure 9 : Modern Nipa hut (left). Hut being moved to a different location by community members (right). Open Source

- **SEEDS[4] Bamboo House in Assam:**

Figure 10 : Bamboo Stilt houses in Golaghat, Assam by SEEDS NGO

SEEDS used community participation in the building of Bamboo Houses on Silts. The design of the house borrowed aspects of a traditional bamboo stilt house, while the building process was based on the local Hariya system, where villagers volunteered to help build a neighbour's house in exchange for meals. Built on an area of 23 sqm (247.5 sqft), the core houses are supported by 5-ft tall bamboo stilts that can

[4] Sustainable Environment and Ecological Development Society, a non-profit organization which drives disaster-management and rehabilitation efforts through their expertise in architectural design

cope with the rising water level during the floods. The main house comes with a large hall that can be partitioned into rooms based on the requirement, and a semi-open verandah for various activities like food preparation, socialization and basket-weaving. The elevation provided by the stilts on the other hand, in addition to protecting the house from over-flooding, also allows a space for other livelihood purposes like rearing livestock, weaving, recreation, storing boats etc. All the primary materials used, especially bamboo and rattan[5], were sourced from within a 6-km radius, keeping it a sustainable endeavour.

(iii) **Adaptable Buildings and "Amphibious Housing"**: Using water-resistant materials and exploring the use of amphibious structures or "floating house" (Tikul, 2018)

- [Data from (Anderson, 2014)] Floating and amphibious houses are built to be situated in a water body and are designed to adapt to rising and falling water levels. Floating houses are permanently in the water, while amphibious houses are situated above the water and are designed to float when the water levels rise. Amphibious homes are usually fastened to flexible mooring posts and rest on concrete foundations. If the water level rises, they can move upwards and float. Because floating or amphibious houses adapt to rising water levels, they are very effective in dealing with floods. During a sudden rise in water, a house will be lifted by the water, provided either by pontoons or a hollow basement, in order to ensure it remains dry, and will then return to the ground as the water recedes.
- **Case-Example: FLOAT house**: Developed to meet the needs and budget of families in New Orleans's Lower Ninth Ward, the FLOAT House is a prototype for prefabricated, affordable housing that can be adapted to the needs of flood zones worldwide. The FLOAT House sits atop a prefabricated raised base made comprised of expanded polystyrene foam coated in glass fiber reinforced concrete. The FLOAT House is connected to vertical guideposts which are **anchored to the ground by two concrete pile caps, each driven 45-feet (13.7 Meters) into the ground**. The vertical piles and the concrete pads on which the base sits are constructed on-site allowing the house to rise up to twelve feet as water levels rise.

[5] a climbing palm vine with a solid core that wraps itself around other trees

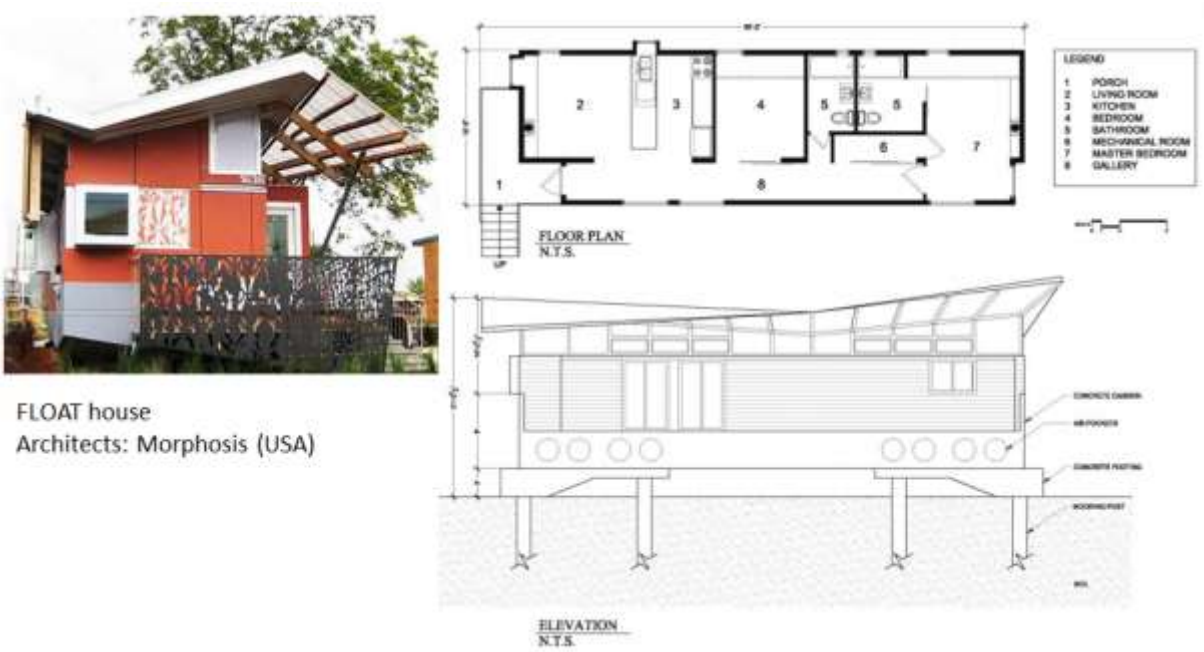


Figure 11 : FLOAT house (Amphibious Housing) Floor Plan and Elevation. Source (Anderson, 2014)

2.2.2. 'Room for the River' Concept

As part of the 'Rebuild Kerala' initiative, The Planning Board has suggested an adaptation of the Dutch concept of 'Room for the River' to the Kuttanad scenario christened 'Room for Pampa' ('Room for the River' model for Kuttanad, 2019). It is envisaged that the project will reduce flooding in upper and lower Kuttanad.

The Room for the River Program was started by the Dutch government in 2007 to manage higher water levels in rivers by lowering the levels of flood plains, creating water buffers, relocating levees, increasing the depth of side channels, and the construction of flood bypasses (Room for the River Programme, 2019). The key of the Room for the River approach is to restore the river's natural flood plain in places where it is least harmful in order to protect those areas that need to be defended (Room for the River Programme, 2019). The program has 8 key measures[6] as explained in figure below:

[6] A groyne, built perpendicular to the shore, is a rigid hydraulic structure built from an ocean shore (in coastal engineering) or from a bank (in rivers) that interrupts water flow and limits the movement of sediment. It is usually made out of wood, concrete, or stone.

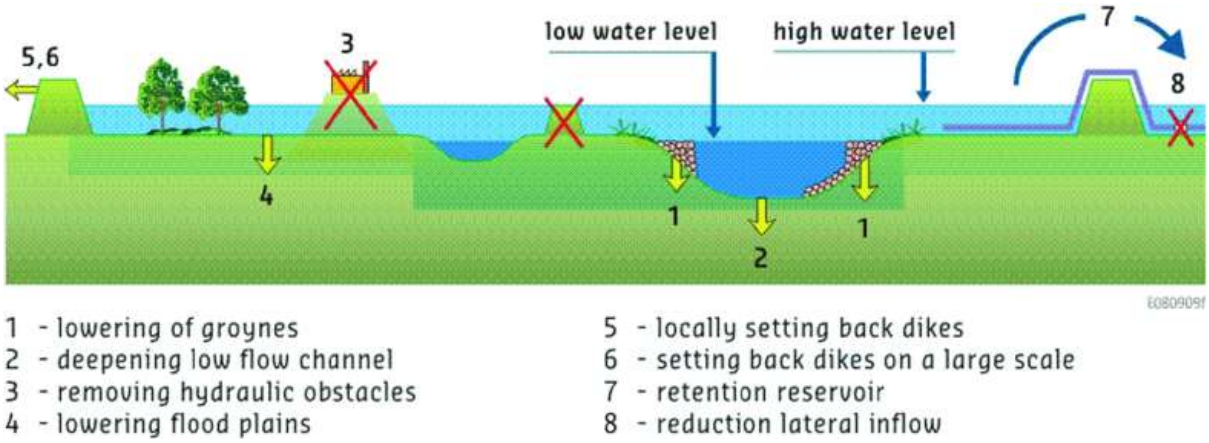


Figure 12: The eight measures for Room for the River by the Dutch Government (van Alphen, 2020)

(van Alphen, 2020) has argued that flooding situation in the Netherlands with the concept of 'Room of the River' implementation has reduced, however, this seeming paradigm shift in flood management was developed, ironically, by reviving much older traditions (van Alphen, 2020) has pointed out that housing on terps[7], a form of flood protection dating from the fifth century BCE, has been re-initiated, as has the method of diverting, which involves digging bypasses to drain surplus river water.

2.2.3. Framework for Sustainable Housing in Flooded Areas

Sustainable development of floodplains is closely linked to the sustainable flood mitigation measures (SHAH et al., 2017). For the Kuttanad region, the design of any housing needs to follow a framework of sustainability within the context of the floods, and suited to the climatic conditions and socio-cultural needs of the region.

[7] A large artificial mound in the Netherlands providing a site or refuge for a prehistoric settlement in a seasonally flooded area.

A Model of Sustainable Housing Indicators has been created by the researcher to rate any new designs for the region.

Table 2: Sustainable Housing Indicators for Kuttanad. Source: Author. Note: Work in Progress

S.no.	Sustainability Pillar	Indicator	Criteria	Measure/Threshold	Rationale
1	**Economic Sustainability (Affordable Housing)**	House Cost	Cost of House to be 5.1 Times the Total Annual Income of Household[8]	**~ 5.37 Lakhs**	Total BPL Family income @27,000 = 1.37 Lakhs Financial Assistance under LIFE = 4 Lakhs
2		House Maintenance	2% Total monthly income of household[9]	**~540 Rs/ Year**	Total BPL Expenditure @ 540 Rs/year
3	**Environmental Sustainability**	Reduction in Material Footprint	Use of Local Materials- Clay, timber, Stone, Bamboo, and salvaged / reclaimed materials	**~ 10 Km** ***(Up to 20 Km)***	Kuttanad Taluka stretches up to 20 Km from Vembanad Lake till Thakazhy village
4		Land for Housing	Use of natural landforms to manage flooding and control	Decrease in % flooding in settlement areas	

[8] HDFC/ India Standard
[9] Adapted from Total Household Expenditure of BPL families on housing

			reclamation of paddy fields		
5		Access to Infrastructure	Management of waste-water lines to STPs		
6	**Technical Sustainability**	Reduction in Flood Damage		% of expected damage	
7		Durability structure	Weather Resilient Structures		
8		Reparability	Easily/ self-repairable components at low-cost		
9	**Socio-cultural Sustainability**	Adaptability	Design of Incremental Spaces		
10		Thermal Comfort	Indoor environment		
11		Aesthetic Quality	Acceptance by communities		
12		Participation	Ensured community participation in design and contraction processes	% level of participation	

3. HOUSING CONDITIONS IN KUTTANAD: STUDY OF NEDUMUDI AND KAINAKARY PANCHAYAT

3.1. Preliminary field study

The flood waters remained stagnant in large parts of the Kuttanad region for periods of over a month, while in certain areas owing to the topography, the water receded quicker and households were able to return to their homes. The overall process of surveying and estimating the damages brought on by the floods was started after the water receded entirely from the region approximately 2 months after the flood. The main survey to assess housing damage was done via village authorities where a team lead by a civil engineer examined the structural damages to the houses. According to data released by the Govt. of Kerala, a total of 57597 houses were damaged by floods in Alappuzha district of which an estimated 56070 houses were partially affected by floods (Rebuild Kerala Data, 2019), while 1527 were completely affected by floods. In Kainakary gram panchayat, a total of 2886 houses were affected by floods of which 2699 were partially affected by floods, while 187 houses were completely affected and in Nedumudi gram panchayat, a total of 2891 houses were affected by floods of which 2859 were partially affected and 32 were completely affected by floods.

Figure 39: House completely damaged by floods, Primary Survey 2019

While a compensation of INR 10,000 was handed out to every household affected by floods, the housing damages were assessed based on degree of structural damage. The houses were divided into houses with concrete roofs and non-concrete roofs, and 5 categories were established by the authorities to assess housing damage namely: (i) up to 15% damage for houses that were submerged under 'knee deep' water with no visible damage (ii) 16%–29%; (iii) 30%–59%; (iv) 60%–74%; and (v) greater than 75% where there was structural damage to roof and walls. These houses were to be rebuilt entirely. There was also a category for 'complete loss of land and house'. However, under the last category for which there was a fixed compensation of up to INR 4 lakh, there were no houses in Alappuzha district as per data. Table below details the total number of houses damaged as per category in Kuttanad Region, however, village-wise data is not available.

Table 5 : Damage to Houses in Kuttanad Taluka, Source: District Disaster Management Authority (DDMA), Civil Station Alappuzha

REBUILD KERALA - FUND DISBURSAL FOR KUTTANAD TALUK		
Damage percentage	No. of beneficiaries paid	Total no. of beneficiaries
15%	13628	13918
16-29%	9327	8823
30-59%	2821	3857
60-74%	966	1282
>75% (self-construction)		1426 (OUT OF 2052)

It has been observed that 90% of all houses in Kuttanad taluka were submerged during the floods and have endured flood damage to varying degrees. According to data released by the District Collectorate, about 1426 houses were completely damaged by floods and need to undergo reconstruction.

In the backdrop of the floods that devastated the state of Kerala in 2018, a field survey of the physical conditions of the houses in the villages of Nedumudi and Kainakary in Kuttanad taluka, Alappuzha was conducted to ascertain recovery and rehabilitation processes in the households.

3.2. Primary Survey 2019

A total of 65 households were surveyed in 2019, approximately one year after the flooding of 2018. 35 houses in Nedumudi Village and 30 houses in Kainakary (North) were surveyed. Houses were selected on the basis of their access to canals and river fronts, and materiality and house condition. Map below indicated the location of the surveyed households.

Figure 40: Nedumudi Surveyed Households, 2019

3.2.1. Socio-economic Status of Surveyed Households

- Caste/Class: Of the Households surveyed, largest share was made by Christians (31%), followed by Hindu OBC (30%). Muslim population is negligible in the region.

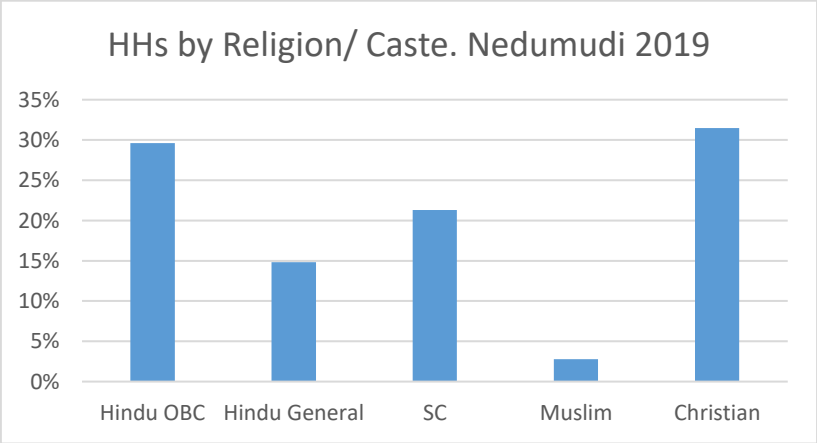


Figure 41: Households by Religion and Caste. Survey, 2019

- BPL Status (Ration Card Colours): Approximately 54% of Households surveyed have BPL (Below Poverty Line) ration cards. Hindu OBC and SC categories largely make up BPL and Antoydaya10 categories in the households surveyed. However, poverty is equally spread among all religions in the region.

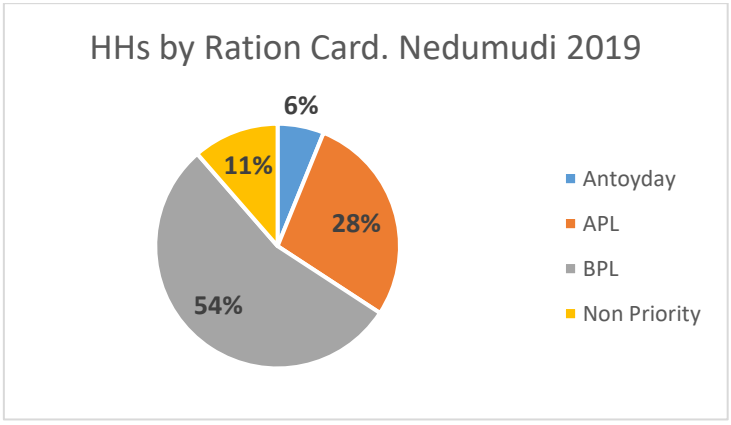


Figure 42: Households by type of Ration Card. Survey 2019

- Household Size: Average household size in Nedumudi village is 4.6

[10] Mission Antyodaya. National Social Assistance Programme.

- Occupation: Of households surveyed, 54% are engaged as daily wage workers or farm labours, while 19% are farmers. Rest 26% are engaged in other activities including fishing and tourism related activities among others.
- Average Size of land holding: Among households surveyed the average size of the landholding is approximately 1.8 acres.

3.2.2. Housing Typology

3.2.2.1. House Age

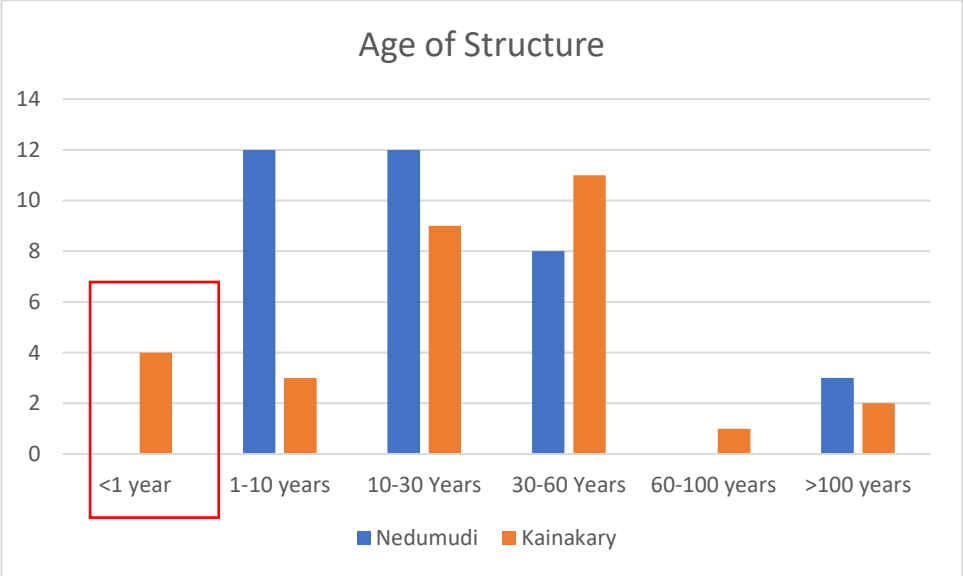


Fig 43: Age of Structure. Survey 2019

Note: Due to the severe flooding in Kainakary, there was more complete destruction of houses. The houses which are less than 1 year old are 'Temporary Shelters' which have been provided by NGOs, and the families living in these shelters are yet to commence work on their permanent houses. It should also be noted that the location of these houses was adjacent to a bund which collapsed in 2018, leading to severe flooding of the area and most houses got swept, while others were very badly damaged.

Figure 44: Levelled homes in foreground with Temporary Shelters provided by World Vision in the background. Kainakary 2019

3.2.2.2. Type of Roof

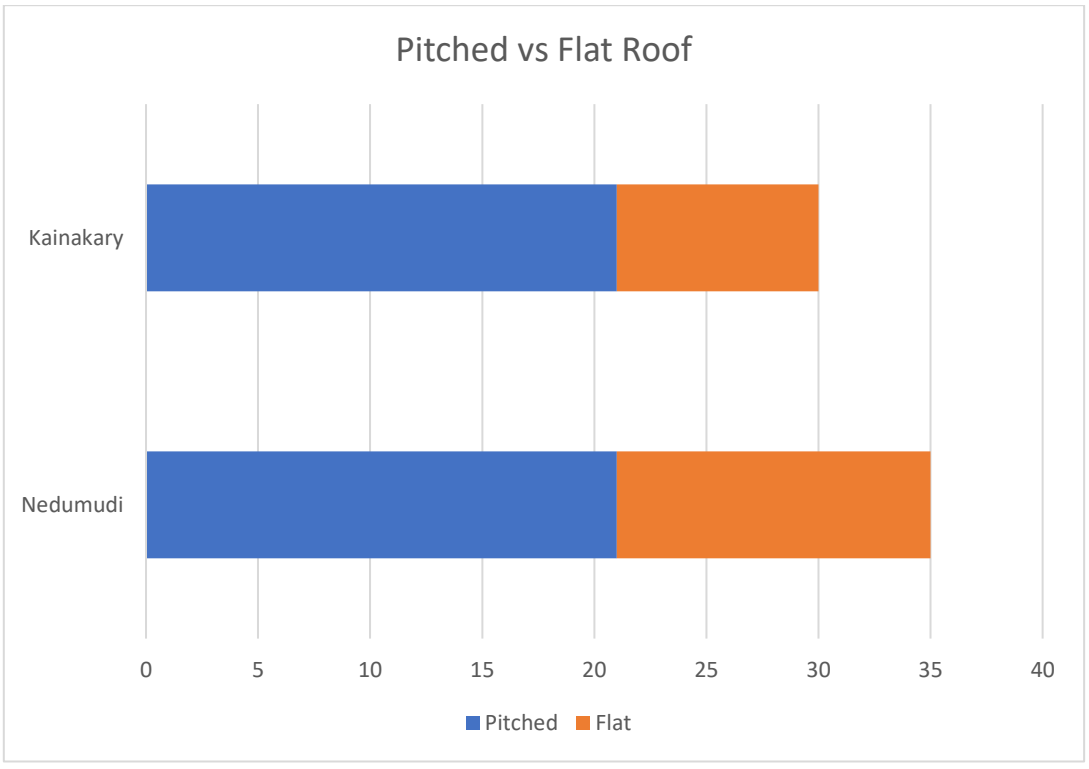


Figure 45: Type of Roof. Survey 2019

3.2.2.3. House Area

(Approximate House Area measured during survey):

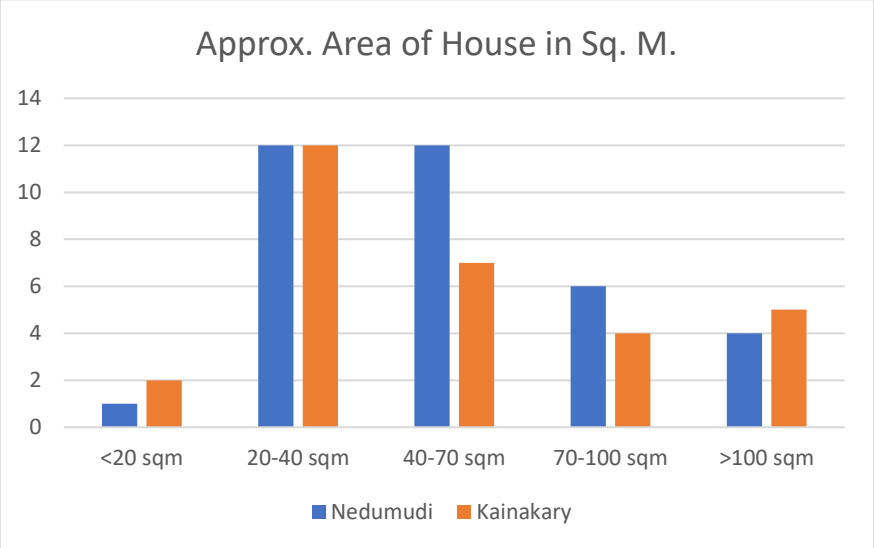


Figure 46: Approx. Area of house (sq.m.). Survey 2019

Note: While the houses in both villages (Nedumudi average house size = 68.47 sqm (737 sqft); Kainakary average house size = 57.88 sqm (632 sqft)), the average house size is skewed because of sample selection, there are few households with very constrained spaces (between 12sqm to 14 sqm). These houses were mostly occupied by elderly tribal occupants. According to Census of India, the average house size in India is 494 sq ft / 103 sq ft per person in rural areas. Accordingly, both Nedumudi and Kainakary are above average in India.

Figure 47: Small House Size in Kainakary (2 rooms) with attached temporary outdoor shed for storage of animals. 2019

3.2.2.4. **Number of Rooms** (including kitchen)

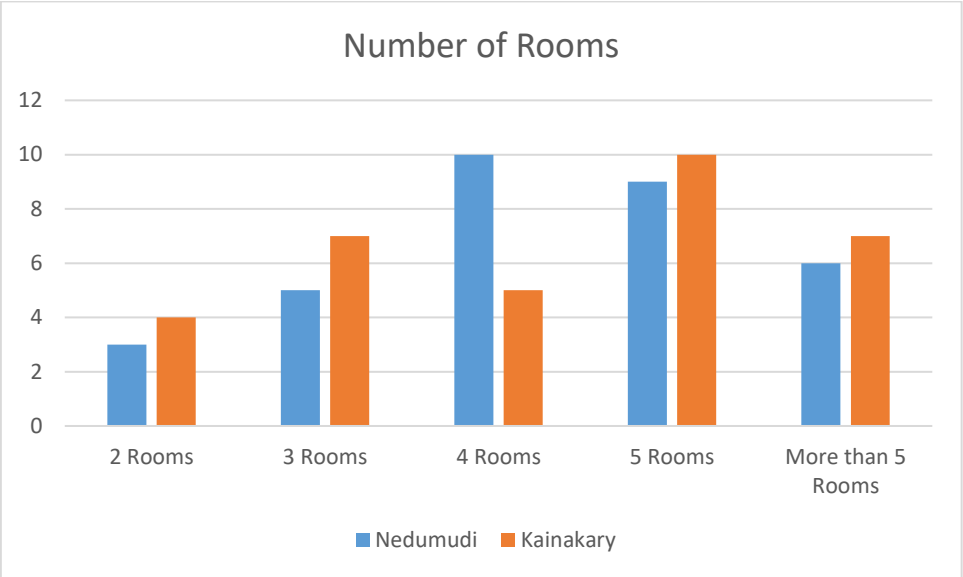


Figure 48: Number of Rooms including kitchen. Survey 2019

Kitchen is located within house except in 1 house in Nedumudi where it is located outside house due to flood damage. Toilets in all homes are located outside house and are not counted in number of rooms. Between 3 to 5 rooms is the most common configuration among houses surveyed.

3.2.2.5. **Structure Type** (Census Classification)

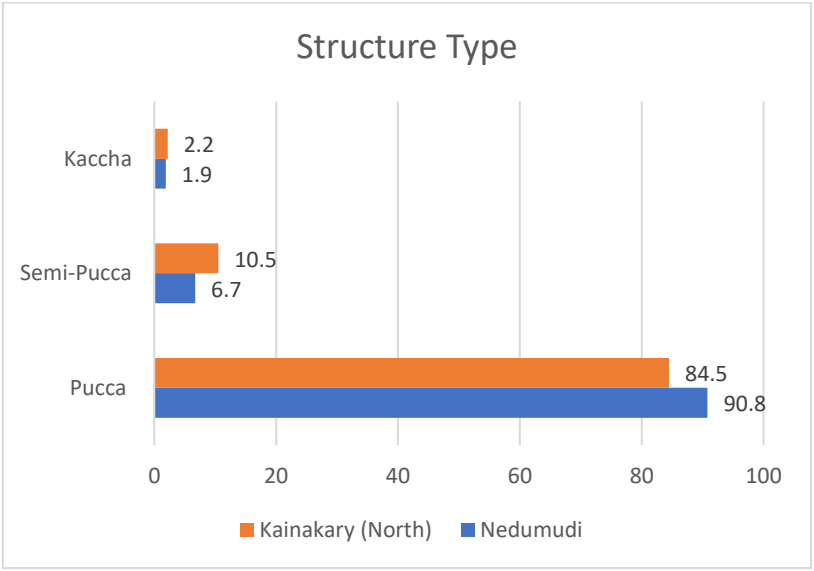


Figure 49: Type of Structure. Source: Census of India 201

3.2.2.6. **Structure Type** (Load bearing Vs Frame Structure)

Percentage distribution between surveyed houses in Nedumudi and Kainakary- 2019 Survey

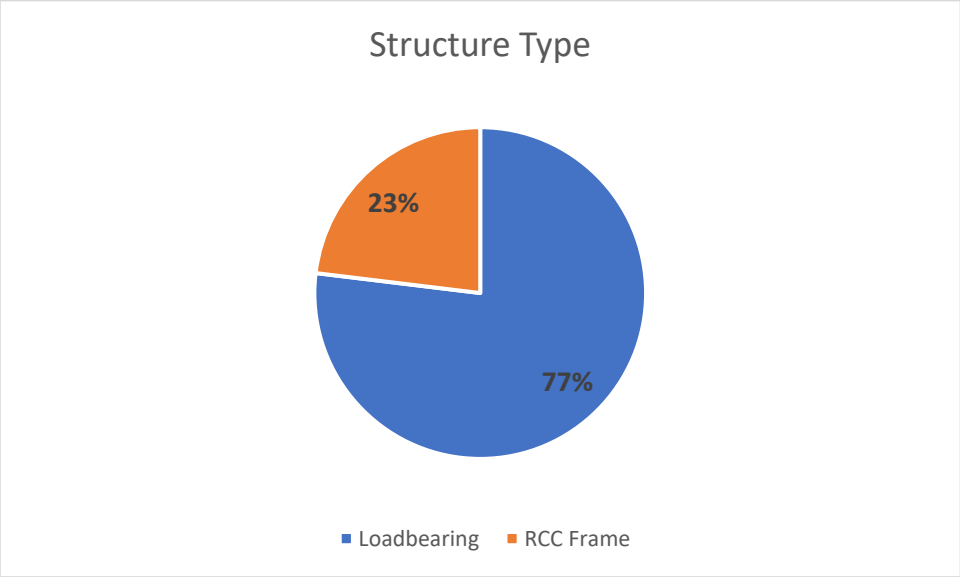


Figure 50: Distribution of houses by structure type. Survey 2019

3.2.2.7. **Age of house vs structure type**

As per survey data, 67% of the houses with RCC frame structures are less than 10 years old, while 20% are less than 20 years old. However, it should be noted that due to extremely small sample size [15 households surveyed with RCC frame structure], this data may differ. Further, most of these houses surveyed are in the process of construction.

3.2.2.8. **Structure Type vs Cost of House**

This data is not available but is very useful for understanding the changes in the building construction practises of the region. This has been partly covered in materials section; however, the financial aspect has not been covered. Though question was asked in survey, because of sample size and difference in age of houses, this cannot be treated as perfect data thus correlations cannot be extruded.

It should be noted however, that almost all buildings surveyed in the area were single storeyed structures, thus cheaper for load-bearing constructions. However, nature of "foundation" due to the bearing capacity of the Kuttanad soil led to new developments in construction. This has been detailed in section below.

Figure 51: Under construction Frame structure on Stilts in Kainakary, 2019

3.2.2.9. Ownership Type

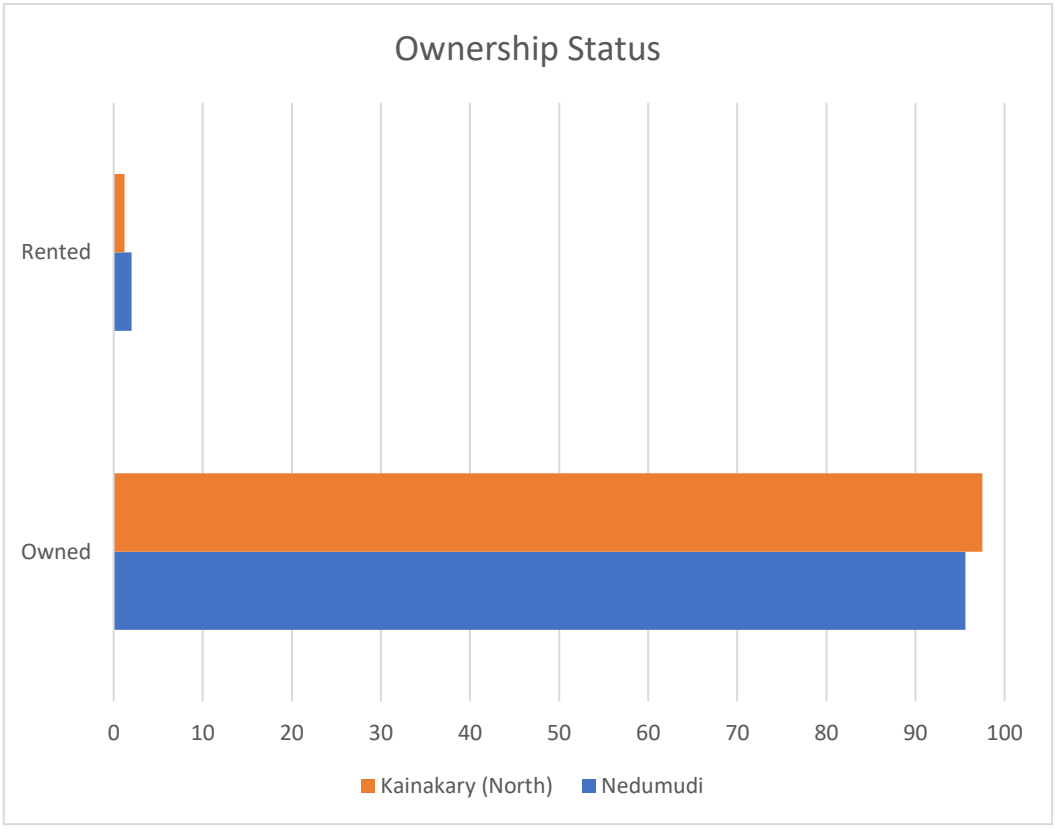


Figure 52: Onwership of Houses. Survey 2019

3.2.2.10. Housing Materials

Roof: In the materials used for roof, in the period between Census 2001 and Survey in 2019, it was observed that while there was not a major difference between the use of GI/Asbestos sheets for roofing, the percentage of RCC roofs went up considerably rising from 6.7% in 2001 to 20% in 2019 in Nedumudi village and from 6.1% in 2001 to 16% in 2019 in Kainakary village. It was observed in Kainkary village that the use of GI/Asbestos sheet went down, while the u2se of Machine-made tiles (Mangalore tiles) rose significantly. More than half the houses surveyed has Mangalore tiled roofing.

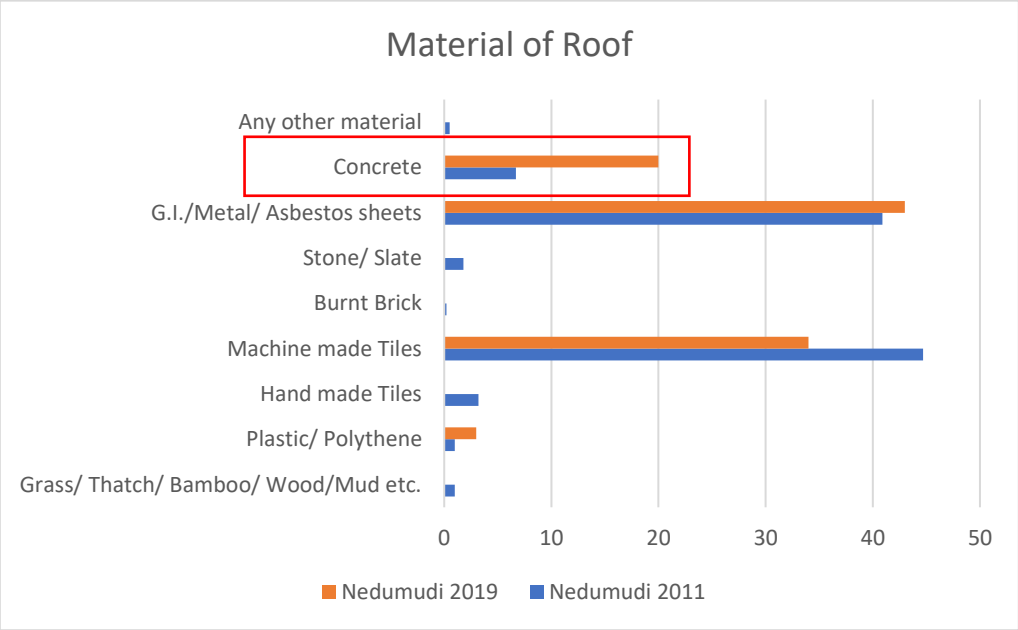


Figure 53: Roofing Materials in Nedumudi. Survey 2019

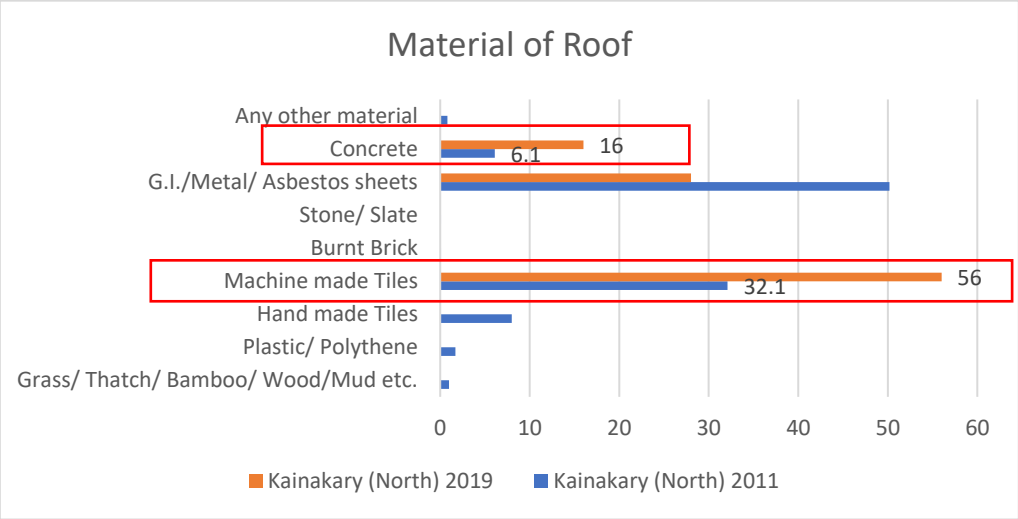


Figure 54 : Roofing Material in Kainakary. Survey 2019

3.2.2.11. Cost of Roof

Table 6: Cost of House with and without RCC Roofing in Kuttanad. Survey 2019

	Cost per sqft	Total Cost (in lakhs)
Cost of new construction with RCC roof for 500 sqft dwelling unit	INR 1912/sqft	9.56
Cost of new construction without RCC roof for 500 sqft dwelling unit	INR 1434/sqft	7.17
Difference	INR 478/sqft	2.39

Thermal Comfort: Almost all houses surveyed that had thatched roofs that were replaced by either RCC or with GI sheet agreed that the thermal comfort provided by thatched roof was superior to either of the newer materials. However, due to the constant maintenance required for the thatched roofs, as well as the shortage of skilled workers, the roofs are no longer in use, barring from cattle shelters.

According to TERI, Thatch is a natural insulator, and air pockets within straw thatch insulate a building in both warm and cold weather. A thatched roof will ensure that a building will be cool in summer and warm in winter. The most interesting fact about the settlement is that all the houses within the settlement are without any mechanical ventilation systems but still are able to provide comfort to the users throughout all seasons of the year.

Due to the climatic conditions in Kuttanad region, there is a need for bi-annual upkeep of the thatch roofs, which are usually made by weaving coconut palms. This process is labour intensive and requires skills which over a period of time have been lost. Newer houses prefer to build roofs in sheet which is cheaper and requires no maintenance, or with steel rafters and Mangalore tiles.

Walls : Primary difference observed between Census data in 2011 and Survey in 2019, is the dramatic increase/ introduction of cement blocks being used for walling. These blocks are manufactured locally without any building standards and have verying degrees of compression strengths making them a perilious material to use. However, they are cheap and

rapidly becoming the go-to option for housing in the region. The material which uses cement blocks and chips are unsustainable from an environmental point of view and also get easily damaged during floods.

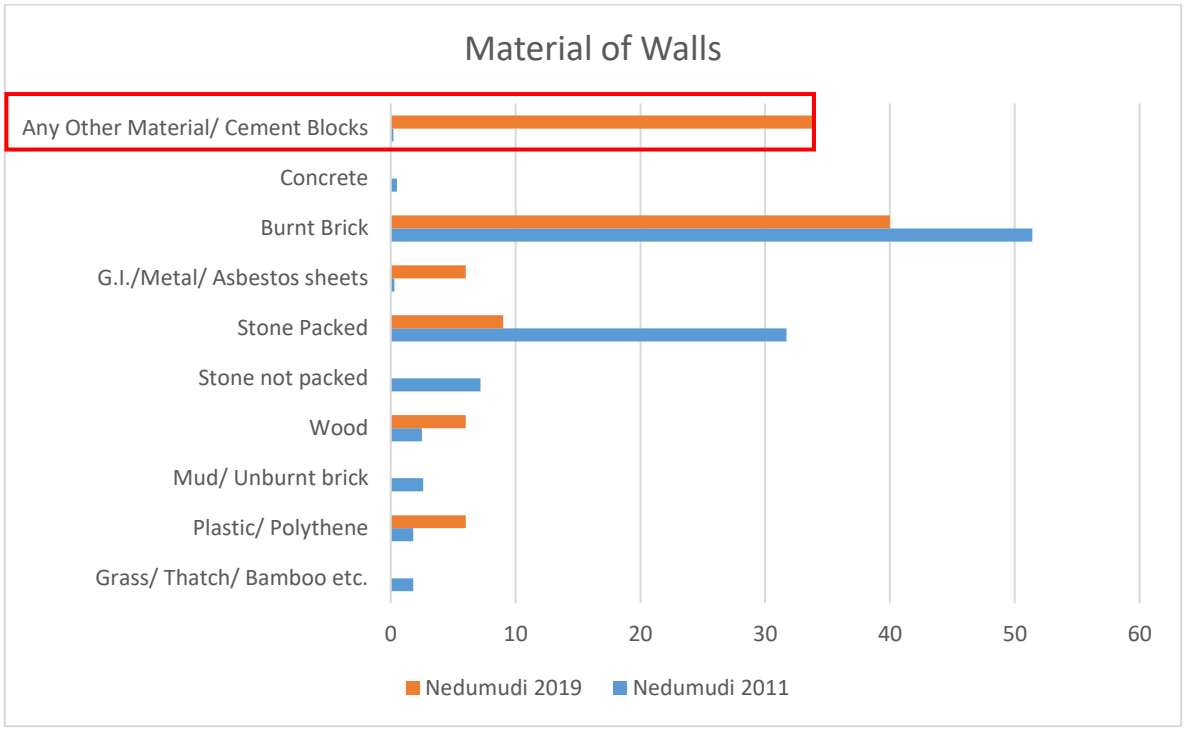


Figure 55 : Material of Walls in Nedumudi. Survey 2019

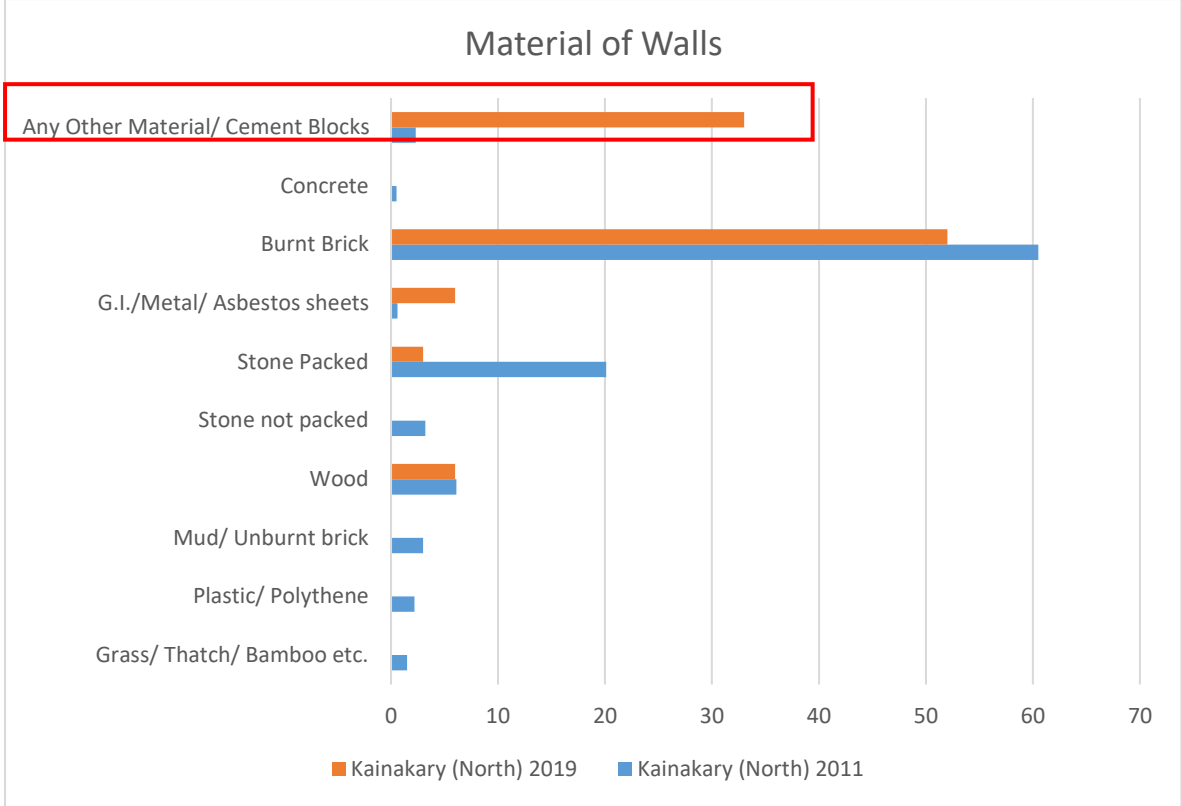


Figure 56: Material of Walls in Kainakary. Survey 2019

Foundations: Primarily foundations are made with salvaged laterite stones

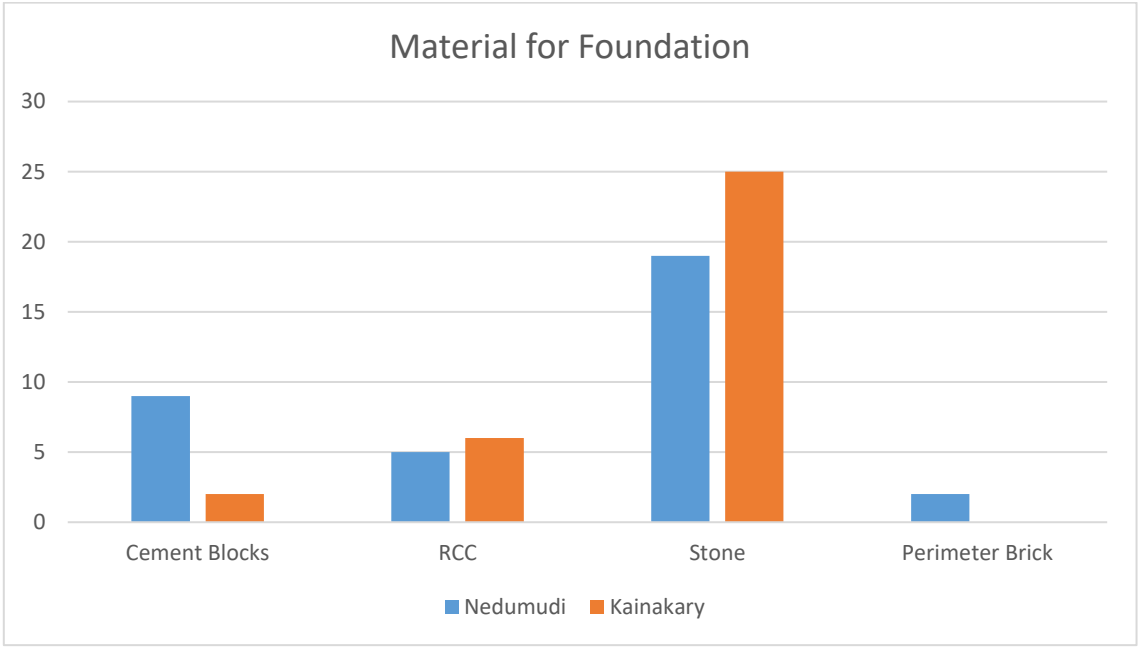
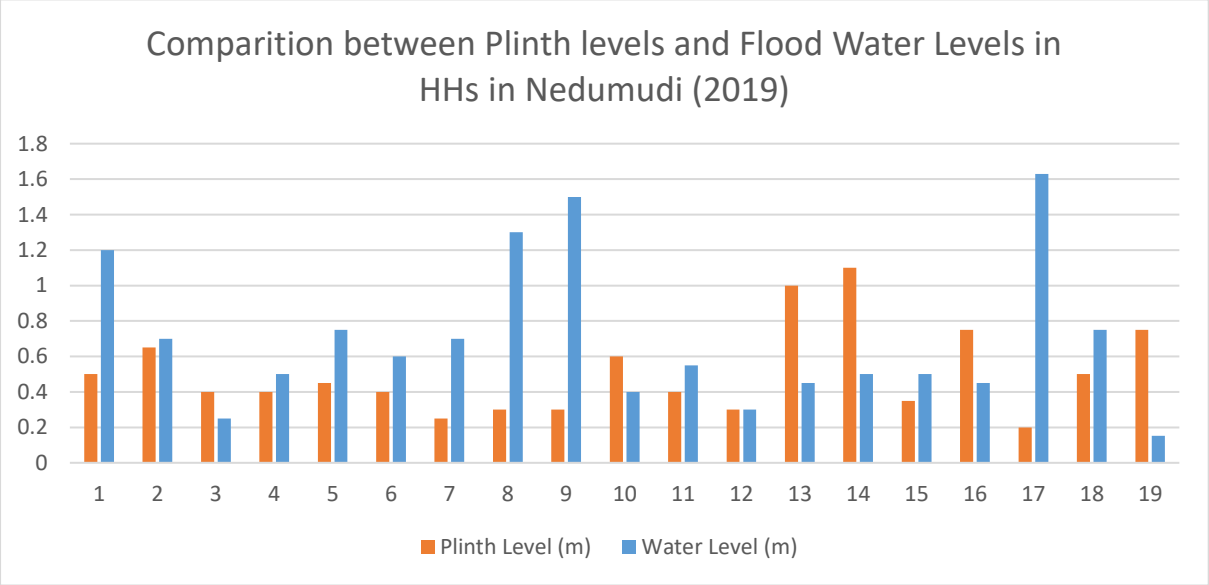


Figure 57: Materials used for Foundation. Survey 2019

3.2.3. Extent of Damage Due to Floods

3.2.3.1. Plinth Levels vs. Water Levels:

In Nedumudi, the average height of plinth was observed to be approximately 0.5 m, while the water levels reached approximately 0.69 m. Similarly, in Kainakary, plinth height was observed to 0.7 m (This data set varies considerably since some houses have completely sunk, while others have been raised on pillars), while water levels reached approximately 1.12 m.



Figre 58: Plinth Levels and Water Levels in Nedumudi. Survey 2019

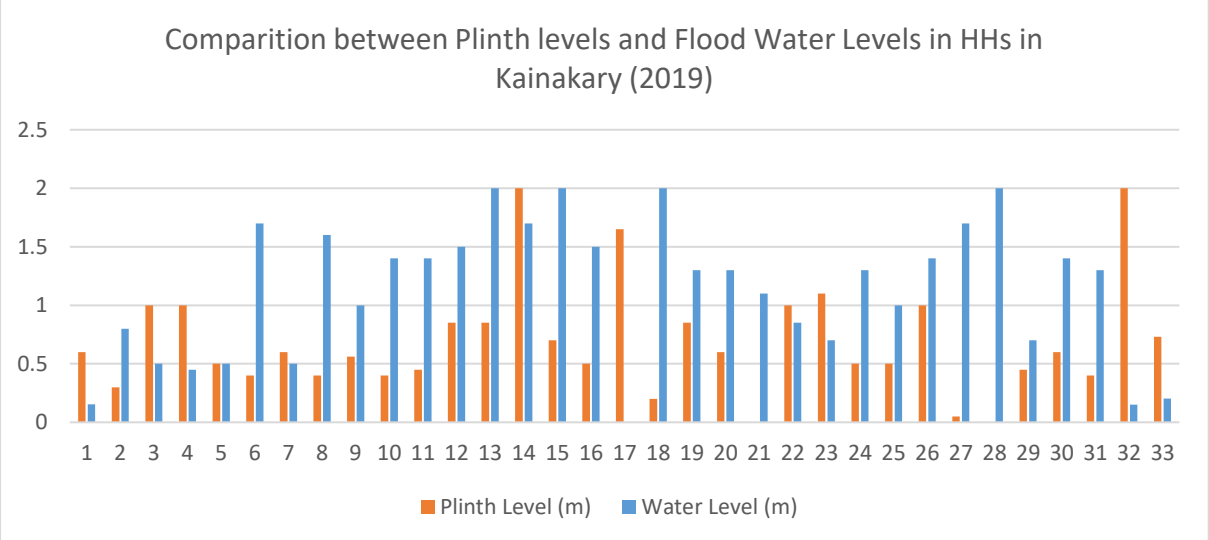


Figure 59: Plinth Levels and Water Levels in Kainakary. Survey 2019

4. FLOOD RISK ASSESSMENT IN THE REGION

The floods in the region can be classified under two categories. One is major flash floods which occur due to heavy rainfall and flooding of rivers. It affects the entire region with a high flood level. The second type is micro flooding, and it affects regionally due to the breach of bunds (due to tidal variations or rainfall) and the stagnation of rainwater. The variations between these two classifications according to the scale, causes and effects are high. Using the flood level data and rainfall pattern in the region the type and nature of floods were identified and categorized based on its causes and impact. The remote sensing-based analysis also conducted for temporal flood recession in flood inundation area. The recession rate is the time taken for the flood water to drain out. This prolonged stagnation of water influences the quality of life in a different way and the frequencies of such floods are increasing in the region. The important insight received from the comparison of these two classifications is that, the issues of flood vary according to the level and recession period.

Through the analysis it has been observed that, the 2018 flood itself was a combination of a dynamic flash flood with high flood level and persisting flood water pooling. The long persisting pooling part of the flood has separated as it is influenced by other factors. Depending on the rainfall intensity and the topography, these 30 cm to 1 m micro floods extend their pooling duration from 2 to 6 weeks. Unlike flash flood, these floods are least life-threatening. But its long persistence brings multidimensional effects to the normal life. Livelihood challenges and the increased chance of epidemics are the major corollaries of these floods. As the region's topography is divided into three segments, such as upper, low, and middle regions, the runoff from the upper and middle parts settle at the lower region. This makes the lower Kuttanad region most prone to micro flooding. Climate change has a huge impact on the flash flood events like the 2018 flood. But the flash floods are rarely occurring ones and micro floods are a frequent phenomenon in the region.

Table 3: Micro flood Vs Flash flood

Variables	**2018 Flood**	**Flash Floods**
Flood level	1 m to 3.5m	30 cm to 1 m
Flood occurrence	Rapid	Relatively slow
Duration	1 Week	2-8 weeks
Cause	Heavy rainfall and river runoff in a short period coincide with high tide	Congestion in drainages
Factors influencing	Climate change, dam management, siltation in dams and spillways, tidal variations	Congestion of drainage system, Siltation in the canal, reduction in water carrying capacity from encroachments
Scale	Basin level	Micro watershed level
Effects	• Sever damage to Buildings and contents, vehicles, livestock, crops, infrastructure • deaths, serious injuries and loss of property occur.	• Long term effects on structures due to prolonged contact with water and dampness • Epidemics & Sanitation issues • Mobility discomfort • Agriculture loss • Livelihood challenges • Disruption to normal life • Economic hardship due to a temporary decline in tourism, rebuilding costs, or food shortages leading to price increases is a common after-effect of severe flooding. • Inconveniences of recovery after flood increased vulnerability of survivors. • More gender issues
Occurrence	Rare	Common
Solutions	Large scale	Panchayat level

4.1. GIS FOR FLOOD RISK ASSESSMENT

Geographical information system (GIS) is a structured framework for gathering, managing and analyzing spatial data. It organizes the different layers of information into visualization using maps and 3D scenes which further can be used to obtain deeper insights. Performing forecasting, monitoring changes, understanding trends and identifying problems are some of the crucial uses of GIS. Exploring the potential of GIS in the project will help to create a base level understanding about various vulnerabilities in the region.

As per the AR5 Reports of the Inter-Governmental Panel on Climate Change (IPCC), the Earth has warmed more since 1,750 because of anthropogenic activities. The expected average rise in surface temperature is around 1 - 2.9degree Celsius by the next century (IPCC AR5, 2014). The rice in global temperature makes a huge impact on the overall ecosystem and human life. The impact of climate change varies regionally based on the physio-geographical characteristics. As the region lies below mean sea level, a large part of the area is waterlogged for most of the year and is subjected to flooding and inundation during the monsoons (CWC, 2018). The changing climate has made the region more vulnerable to the floods. The recent floods of 2018 and 2019 are one such example. The systematic evaluation of the natural and socioeconomic vulnerability of an area is an important starting point for the development of compensatory or adaptive measures (IPCC, 2001). The complex art, architecture of the region and nature of the vulnerability demands of a theoretical framework for quantitative vulnerability assessment using composite index in a GIS/remote sensing environment. The GIS and RS have a wide variety of applications in disaster management and planning. Due to it spatial capabilities, it provides a better analysis for vulnerabilities based on the topography, soil properties land use patter and hydrological parameters.

4.2. DEM & Modelling

Digital elevation model (DEM) is the digital representation of land surface elevation or topography. Hydrological applications in which flood mapping is one of them can be implemented through DEM. Estimation of elevation or slope and determining drainage networks or watershed are crucial components which will be used in our flood mapping technique. Shuttle radar topography mission (SRTM) provides the source for DEM data. Higher DEM resolution preserves the topographical terrain features which provide better

insights for floodplain, small streams, roads and other narrow conduits of flow which may have significant impact on overall analysis.

4.3. Developing a protocol for GIS based vulnerability analysis: Nedumudi

Flood is the major threat in the study region. As topography and flood level are highly associated, the topography is considered as a basic parameter to analyze the flood in a region. By using Digital Elevation Modeling (DEM) with the help of high-resolution satellite images, a very micro level topographic vulnerability evaluation can be performed. As the study area is a coastal wetland and reclaimed land, the architecture of the land is very different from other regions. The houses and settlements are constructed over the bunds (embankments) raging a width of 20 m to 30 m. Most of the regions are located in between the paddy fields and canals. The very narrow size of the clay bund limits the analysis due to the lack of a high-resolution DEM image. So, a 12.5m resolution DEM image was used to conduct the study in the region.

4.4. Physical Vulnerability of Nedumudi

Physical vulnerability assessment looked at the topography, hydrology and physical structures in the region. A comprehensive topography-based flood vulnerability assessment was performed with the help of the DEM model, correlating the land use patterns, building density, and the flood level. A pilot digital elevation modelling was conducted for the Nedumudi panchayath and ground-truthed the observations with the help of flood levels marked in the region from the 2018 and 2019 floods

4.4.1. Methodology

The methods for topographical vulnerability analysis include 3 steps. The primary step is the development of a base map. As the region's major land-use portion covers paddy fields and water bodies, the land area needed to be separated for better analysis. So, with the help of Kerala state Land Use Board's dataset, the region is classified into land, water bodies, and paddy fields. The land area was separated from the paddy and water bodies and maintained

as a base map for the analysis. Then, the high-resolution DEM raster from the Alaska Facility was used for the digital elevation modelling. The raster was clipped with the land use map created for better analysis of topographical varies over the land. The raster value is calculated for the sea level and the raster manipulated by correcting the mean sea level value as zero with the help of the raster calculator. Then the raster image converted into vector for better analysis with the attributes. Based on the flood events measured during the 2018 floods the topographical points were classified into high to low topography and developed as a heat map. The multispectral heat map provided a profile of high, medium and low topography regions. Overlying the vector layers of the buildings in the region provide the classification of high, medium and low-risk zones.

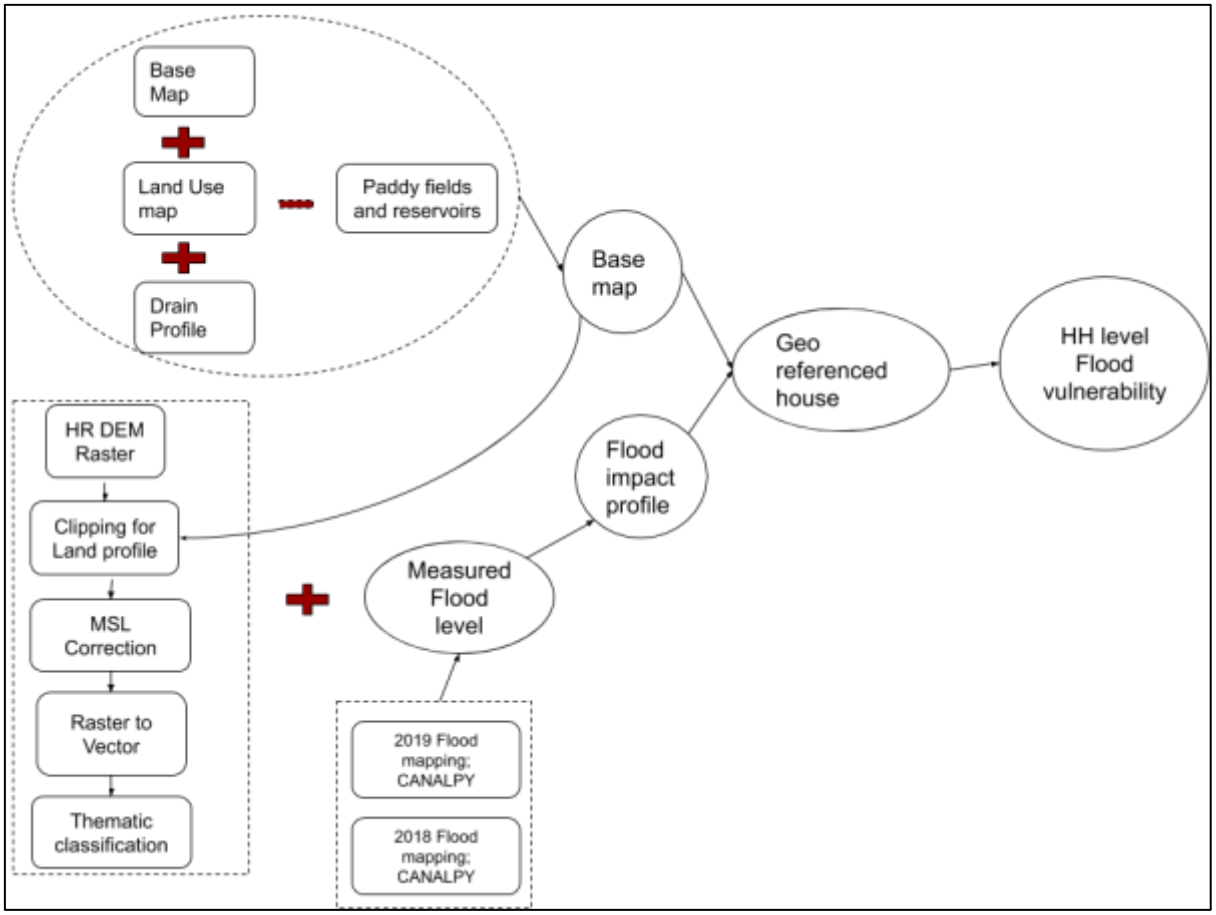


Fig 13-Methodology for Flood risk assessment using DEM

4.4.2. Base map

The base map is the foundation for the flood vulnerability assessment. About 81% of the region is covered by paddy fields and water bodies. The elevation is very low as compared to the land. This higher proportion of this low elevation region makes the multispectral analysis difficult. Also, the large variations of elevation from higher topography to lower topography annihilate the micro-level variation within the land. Hence the profile of the land has been developed prior to the digital elevation Analysis. The common method of extraction of the land area is the LULC classification using NDVI analysis using Landsat or Sential-2 imageries. Based on the differential spatial values of the images, the land, water bodies and paddy fields can be separated. The images from the crop harvesting months such as May or December are recommended as the colour of the paddy fields will move from the green to the yellow-orange spectrum This enables the configuration of the land as green and paddy fields as yellow. With the help of macro tool in classification plugin in QGIS, the classification and vectorization of the land were done. The land use vectors provided from the Kerala State Land Use Board also were used. There were 21 different categories in the land use were provided to form the KSLUB. The classifications were reclassified as Water bodes, Paddy field and Land. The final map obtained has shown in (fig 14).

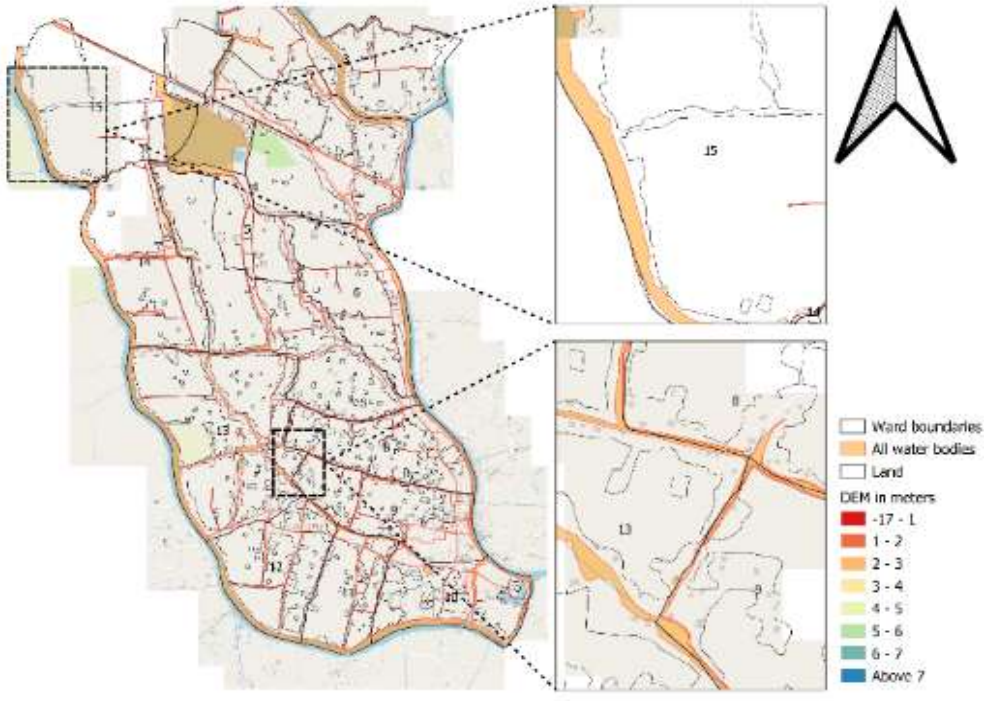


Fig 14: Base map prepared for vulnerability assessment

4.4.3. Flood level assessment

The IIT Bombay-KILA initiative in Alappuzha has conducted a flood level study in the region after the 2018 and 2019 floods. The local students in the region measured the height of watermarks in the houses and public building from the ground. The maximum flood level from the survey was 300 cm and the average flood levels were ranging from 100m to 50m in 2018 and 2019 floods. Based on the histogram, the predominantly affected flood range was identified as 31 to 70cm.

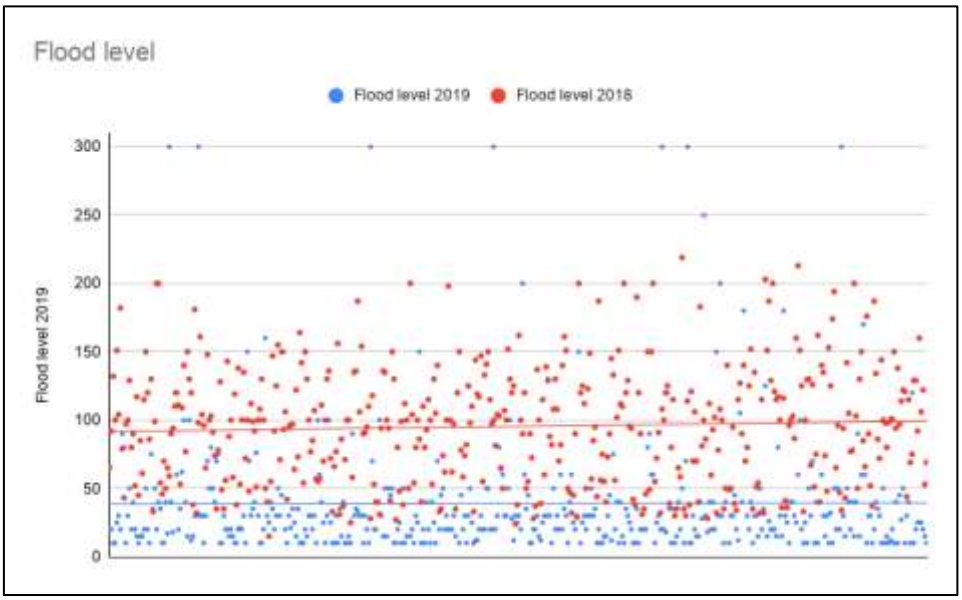


Figure 15: Maximum flood levels during 2018 and 2019 floods

4.4.4. Digital Elevation Modelling (DEM)

The 12.m resolution digital elevation data were obtained from the ALOS PALSAR- mission from the Alaska Satellite Facility. A horizontal strip from the raster was clipped that extend from the high elevation western ghats to the Arabian sea. The raster value of at the Arabian sea was measured a corrected it to zero using raster calculator. The profile of land in the base map was used to extract the raster image with the help of clip tool. The clopped raster image contained the vales of raster varies from -6m to 1.5m. The raster image was vectorized for conducting the spectral analysis using the attribute table. By correlating the topography value

with the maximum flood-affected houses, the attribute values of the vector were colour coded from red to blue.

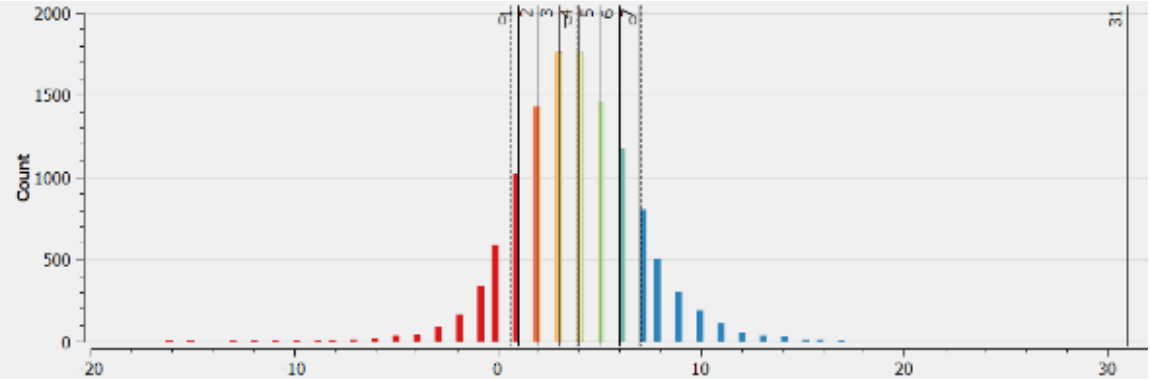


Fig 16: Histogram for topography-based classification

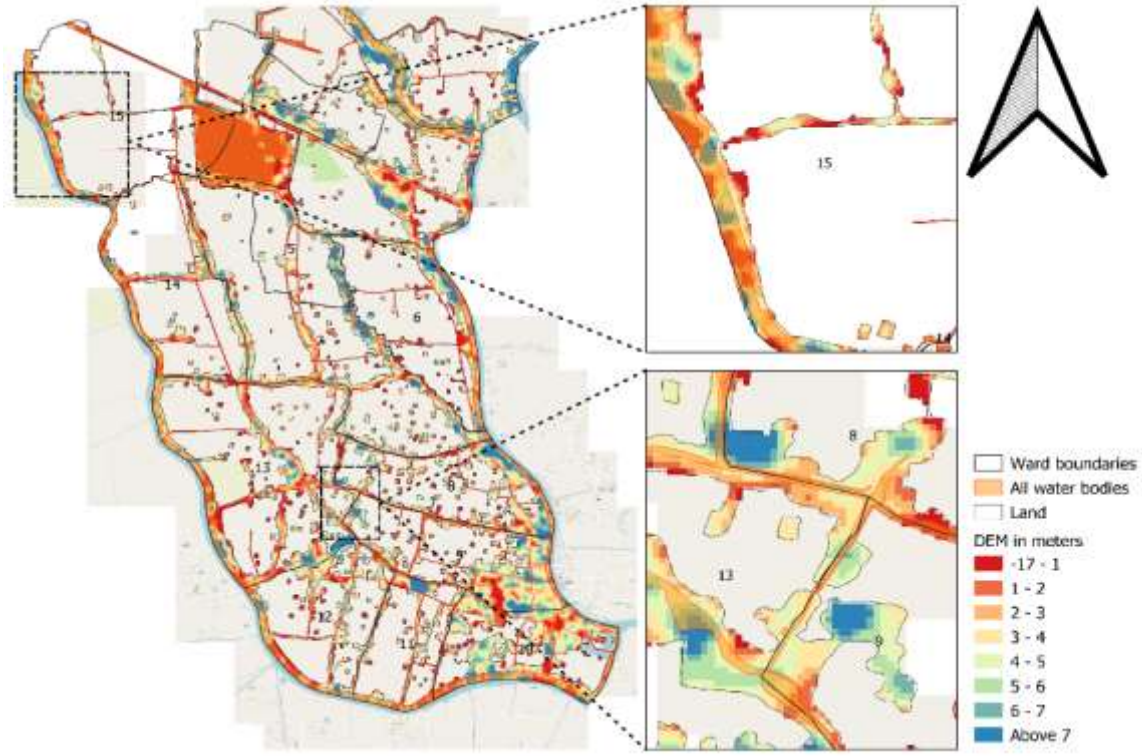


Fig 17: Heat map produced based on topography

4.4.5. Vulnerability assessment

The flood vulnerability of this region is a combination of low topography and the presence of buildings. The geo-tagged building information from the field survey has overlaid on the DEM model. The building shape files also can be extracted from the LULC classification with the help of semi-automatic classification plug-in available in QGIS. The regions with low elevation and high building density were marked as highly vulnerable and regions with less

number of houses and high elevation marked as no-vulnerability zones (Table 1). Four separate vector classes formed according to the elevation (less than 0m,1-2m,3-5m and above 5m) classification and extracted the houses within each polygon with the help of vector analysis tool. The household density hotspots were developed through extrapolation plug-in and the different vulnerability classes were developed through vector difference tool. The number of buildings on each elevation class was analysed and the house details were classified as four classes from high vulnerability to low.

Table 4: Vulnerability ranking strategy based on elevation and building density

Elevation		
No of buildings	**High**	**Low**
High	Low vulnerability	High Vulnerability
Low	No Vulnerability	Medium vulnerability

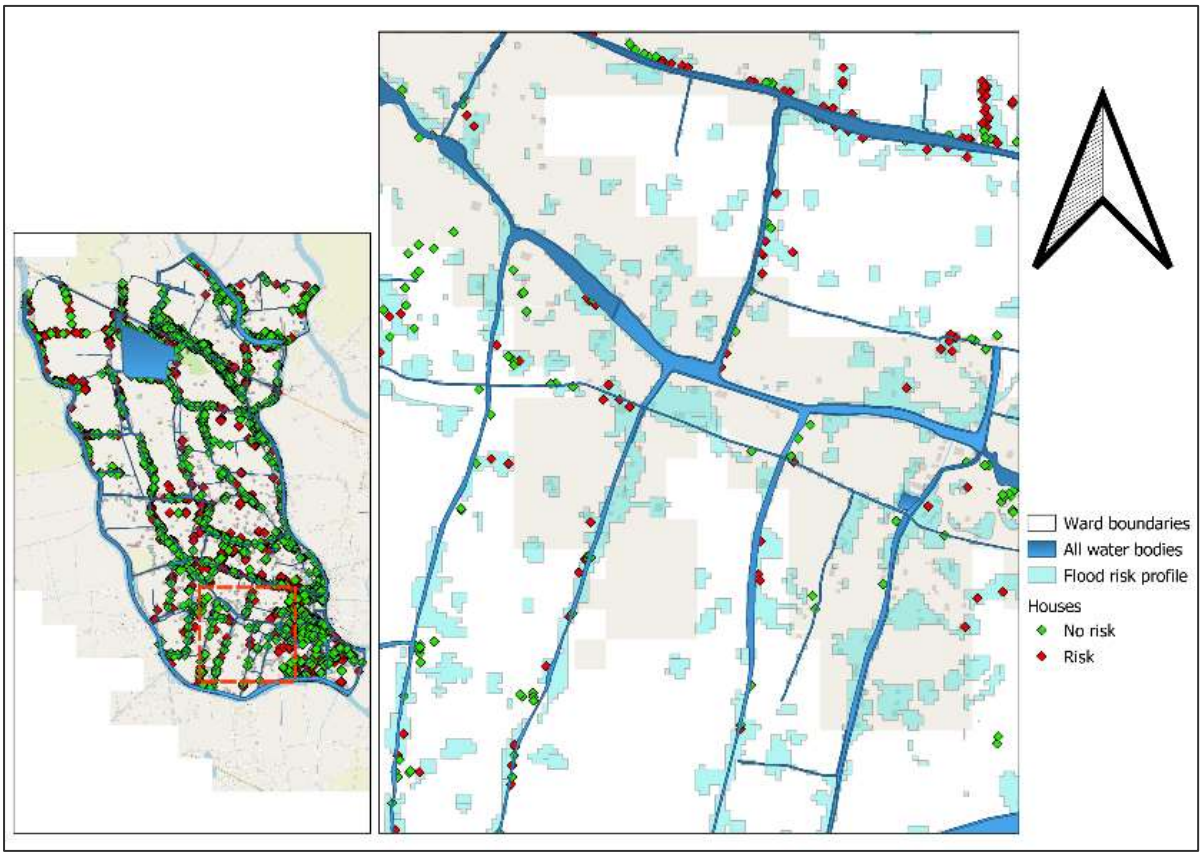
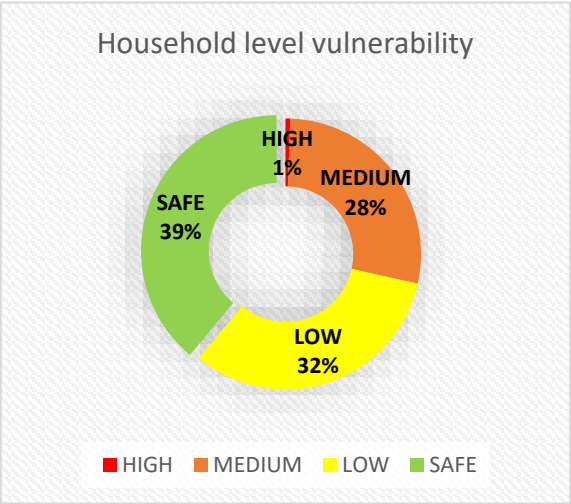


Fig 18- Classification of houses based on vulnerability

4.4.6. Results



As per the analysis around 29% of the houses in Nedumudi come under high and medium vulnerability zones. Only 1% of the houses were located in below sea level areas. About 32% of these houses come under low-risk zone and 39% under safe zones.

Figure 19: Percentage of hazard

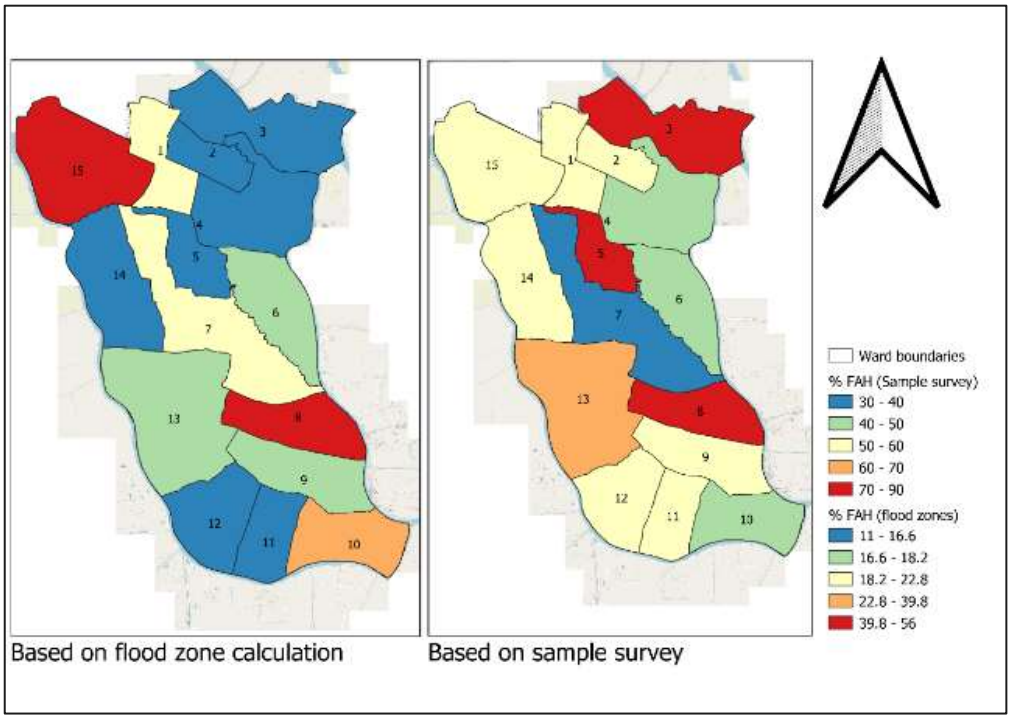


Figure 20 : Comparison of measured flood level Vs topography-based flood level

Even if the topography of the region has a high influence on floods, the other variables also influence the flood level in the houses. To understand the variation of flood level in accordance with the topography, the correlation between topography and flood level measured from the survey was conducted. The comparison between measured flood levels

and topography shows a non-liner relationship. At some regions it shows clear proportionality and varies in other regions. The occurrence of high flood level in some safe topography regions has been identified. Also, some low topography regions show fewer flood levels. This indicates the existence of other variables in the region which have a huge influence on the flood level other than topography.

The analysis has given various results in this region. The major analysis is the number of houses which are prone to flood. The wards such as 5,7,9,10,11,12,13,14 was showing high vulnerability to floods and recurring micro trends. But one important finding is the variation in flood level with the topography. The measured flood level forms the ground which shows serious variation with the topography. The major factor for this variation may be the smaller number of samples from most of the inner bund settlements that are more prone to floods and the bias in sample selection. But, a deep study on this issue has to be conducted to identify the role of other variables that influencing other than topography.

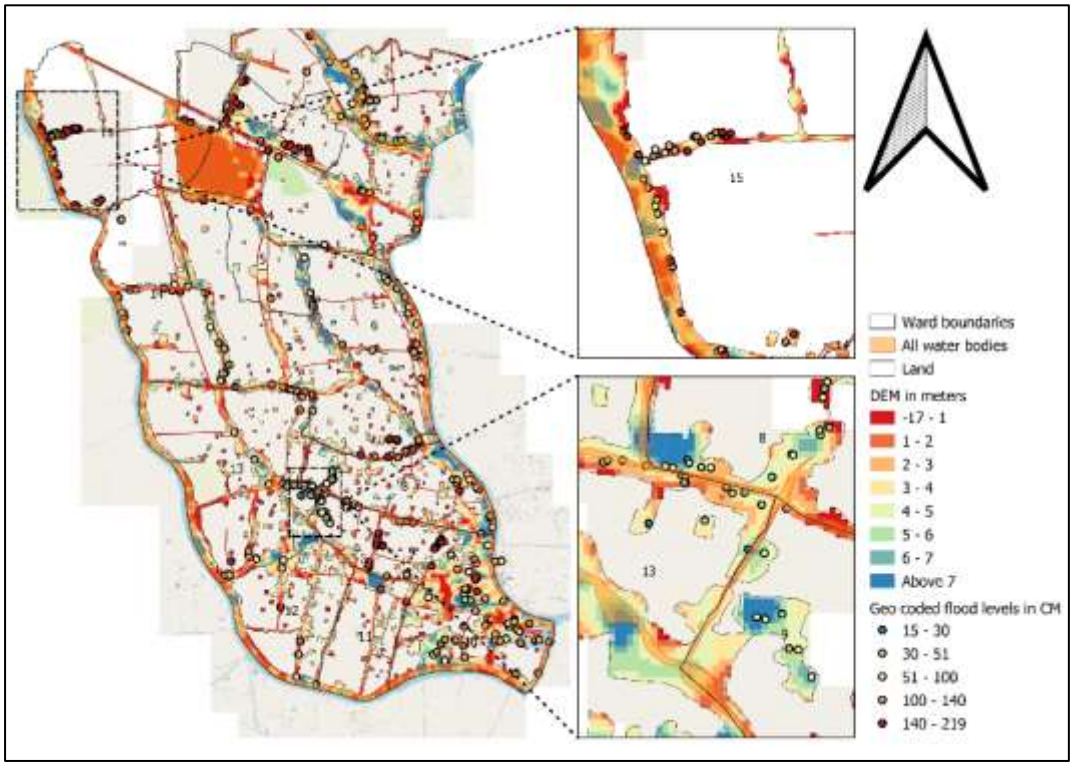


Figure 21: Topography based flood level vs measured flood level

4.5. Discussion

From the topography-based assessment, it is observed that the topography alone cannot determine the flood situation in the region. More micro level understanding is needed to understand why the flood level is not directly related to the topography. Other important factors decide the type of floods and issues arising from that. From the literatures, it is clear that 2018 flood event was an occasional phenomenon. But the micro flooding issues are predominant and frequent in the region. So, a deeper assessment of micro flooding is also required. The economic vulnerability assessment through literature and secondary data analysis of Nedumudi Panchayat were done with the help of Census 2011 data and Panchayath level development plan. The relation between frequent floods, livelihood, and economy were compared for the analysis. As per the Nedumudi panchayat 2017 annual report, 43% of its population is dependent on the agriculture sector and 31% is working as daily wages labourers. About 42% of the total population of this region is under below the poverty line and 9.4% are from Scheduled Castes. Within the agriculture sector, more than half of the population are marginal labourers. In Nedumudi panchayat, about 32 paddy fields and 10 farms were destroyed in the 2018 floods. It has been identified that the vulnerability of the agriculture sector from floods and the large proportion of marginal workers escalates the economic impact of floods. So, an in-depth assessment is required to know how the life and livelihoods are connected to the floods.

5. FIELD STUDY FOR HOUSING VULNERABILITY

Our preliminary study focused specifically on the housing and house conditions in the region and it revealed that physical vulnerability of houses needs to be considered as one of the major aspects related to living conditions in the region. But it is also understood that, for a detailed understanding of the vulnerabilities in the region, we need to consider social and economic vulnerabilities along with the physical vulnerabilities of 'housing' and geographical vulnerabilities of the region. So, for a detailed understanding and mapping of the vulnerability of the households, we need to consider the all three types of vulnerabilities acting on them. For actualizing this study plan, the vulnerability related themes and questionnaires were divided broadly into two – the bio-physical and socio-economic vulnerabilities. The study further intends to collect first-hand information related to the socio-economic backgrounds of the households that can also help in the second phase of the study.

The study was designed into different steps starting from the 'transect walk' through the Panchayat followed by the household survey and focus group discussions. The interviews of key informants and analysis of locally available documents were also carried out for gathering an in-depth understanding.

5.1. Research framework

The IPCC framework for risk assessment was adopted for this study. It identifies risk as a combination of three variables; i.e., Hazard, Exposure and Vulnerability. The study attempted to assess each variable individually and as combinations. For hazard assessment, two approaches were identified for carrying out the analysis. One was the 'block maximum approach' where one peak value is found out and then we look at the deviation from that. The second one is the threshold approach where we fix a threshold and then go to increase and decrease what is going above and below. These are very much helpful while considering floods. The other part mainly focused on the vulnerabilities in the region. Vulnerability depends directly on age, population, livelihood, healthcare etc. A detailed analysis on measuring vulnerability was planned through the survey, especially in terms of 'housing'. It is

basically the regions susceptible to damage from natural hazards and it comes under – 'exposure'.

The most useful indicators selected at the end were classified into four units;

- Physical
- Economic
- Infrastructure
- Social

By aggregating these variables as permutations and combinations, a clear picture of the compounding vulnerabilities in the regions can be observed (Fig.26) & (Fig.27). The field study attempted to collect these variables individually and the patterns of compounding vulnerabilities.

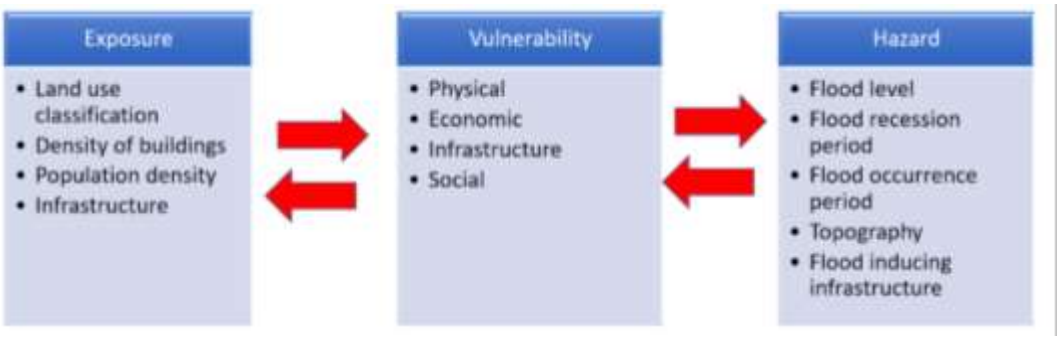


Figure 26 : Permutations and combinations of Hazard, Vulnerability and Exposure

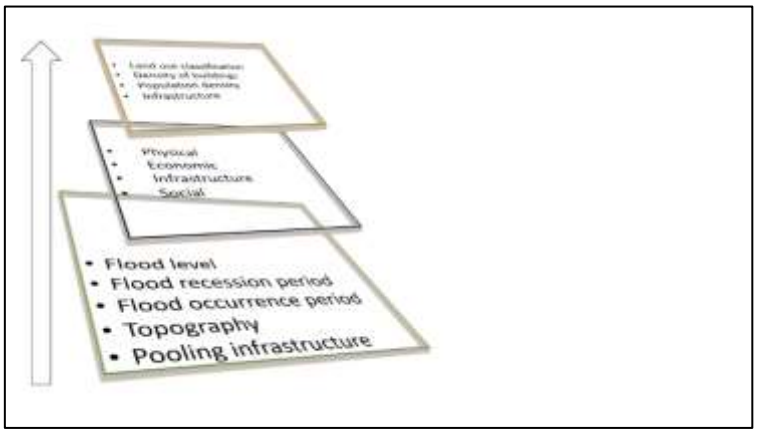


Figure 27: compounding effect of Hazard, Vulnerability and Exposure

5.2. Methodology

The methodology adopted was a participatory approach along with a focus on the mixed approach in data collection. Both quantitative and qualitative data were collected from the field. The major steps involved in the study are;

5.2.1. Document Analysis

After the completion of winter school sessions, the first step was to collect and understand the basic details about the Panchayat by accessing the different available reports and other data including maps. The set of documents included the Developmental Plan envisaged for Kainakary Panchayat which was released in the early 2000s. By referring to the documents available at the Panchayat level gave a brief idea about the Panchayat above which the further planning is carried out.

5.2.2. Consultation with major stakeholders

After the analysis of documents, the next step was to consult with the panchayat and letting them know the broader objective of the study. The consultation with panchayat committee members, Panchayat Secretary and few local people were carried out to get their opinion about the study which we are planning to carry out. The consultation with the stakeholders was carried out at different stages of the study. The consultation and getting inputs and suggestions from them to carry out the study made it more 'participatory' in nature.

5.2.3. Defining Objective and Purpose of the Survey

The broader objective of the study is to;

i) To understand the different aspects and characteristics of 'housing' in Kainakary Gram panchayat
ii) To understand the biophysical vulnerability of Kainakary panchayat
iii) To understand the socio-economic vulnerability of Kainakary Panchayat

The purpose of the study is to understand, explore and plan the possibilities of sustainable housing in the Kuttanad region with Kainakary as a case.

5.3. Field study

The household survey and Focus Group Discussions were conducted in order to understand the housing, livelihood and flood management in the region.

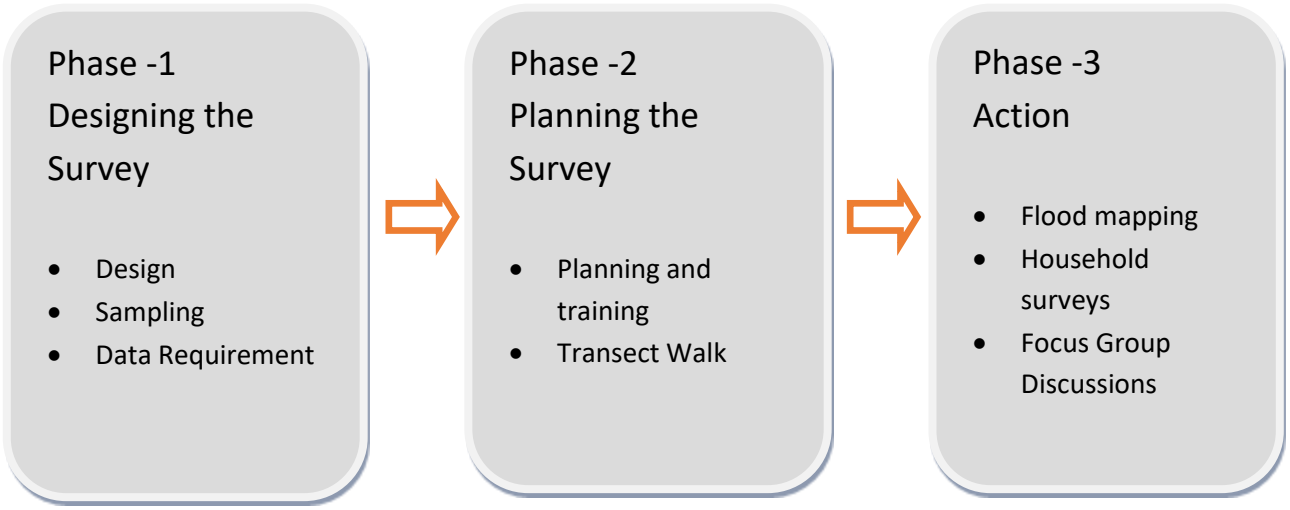


Figure 28 : Field study phases

5.3.1. Phase 1 - Study design

When conducting a survey, the first step is to determine the objective and purpose of the survey. This will provide the framework for the content and scope of the survey work and be used to help identify which kinds of stakeholders and communities are to be surveyed.

5.3.1.1. Data requirements and survey design

The data to be gathered through the survey process will reflect the purpose of the survey work. In developing the survey, other considerations are the length of the surveying time in each household and resources (both financial and human) needed to effectively conduct the survey and analyze the results.

Different tools such as surveys, discussions and interviews were used to obtain different kinds of data from different groups of informants. For example, the household survey was conducted to gather information on different biophysical and socio-economic details of the household. In contrast, the historical and current situations of the region and functioning of the panchayat, its activities and broader issues of transportation, healthy, development, etc. were obtained through Focus Group Discussions and interview with key informants.

The survey was planned in ODK mobile application and one member of the survey team is expected to ask questions to the respondent and other members will enter the details in the ODK mobile application.

5.3.1.2. Sampling method and sample size

The sample size for household survey was planned as 600 HH. The total number of households in the panchayat as per the recent statistics are 5689 (Census, 2011). As part of our HH survey, we have taken 604 samples, which is 11.5 % of total households.

Cluster sampling is adopted in 'two-stage' sampling plan. In cluster sampling, the total population is divided into groups or clusters and a simple random sample of the group is selected. The cluster sampling is called 'two-stage' if a simple random subsample of elements is selected within each of these clusters. As one of the common motivations for choosing cluster sampling is to reduce the total number of HH surveys and costs along with providing the desired accuracy.

Each cluster selected in this study is based on the polder (the area within which the group farming is performed). There are 21 polders drawn out of which some of the polders (clusters) were not sampled due to technical issues such as COVID-19 restrictions and transportation access issues.

5.3.2. Phase 2 - Planning

5.3.2.1. Planning and training the team

A well-trained team is necessary for the success of any household survey. Prior exposure to the field area is essential for the tea before they go to the field. This issue has been rectified with a 'transect walk' and the addition of local people to the survey team. The technical

knowledge of the team in measuring, understanding and assessing the 'housing' related aspect and other biophysical and socio-economic details has helped the survey. The team members were also given a combination of classroom and field-based training to best understand how to conduct the household survey. All members of the team were given a thorough understanding of the aims of the work and the meaning of every question asked with a daily review from day one.

5.3.2.2. Transect walk

The first step in the fieldwork of risk assessment was to conduct a transect walk. The transect walk is a space-related Participatory Rural Appraisal (PRA) method. PRA methods are those which facilitate local people to share, enhance and analyze their knowledge which is based around their life and surrounding conditions, and further to plan and act. A transect walk helps in understanding the spatial distribution in the region through multiple walks. In the case of disaster risk mapping, understanding the spatial aspects of a region is crucial. Therefore, the transect walk was considered the first approach for fieldwork. Transect walk involves the following:

i) Observing, asking, listening, discussing, identifying different zones, soils, land uses, vegetation, crops, livestock, local and introduced technologies, etc; seeking problems, solutions, and opportunities;

ii) Mapping and diagramming the zones, resources, and findings.

The transect walk was conducted for 3 days from 8th February 2021 to 10th February 2021. The entire panchayat was divided into four sectors for easier delineation of work with the help of the panchayat President and other members. The survey team was divided into five groups of two members each and two groups were sent to sectors with the larger geographical area. Each day the teams traversed each sector with the help of OSM Tracker (Open Street Map Tracker) android application and GPX viewer application. OSM Tracker allows tracking the journeys, mark the waypoints with tags, voice record, and click photos whereas GPX viewer is a GPS locator and GPS track viewer which will help in viewing the tracks traversed with the help of OSM Tracker.

At the end of each day, each survey team presented and discussed their finding along with the path they traversed.

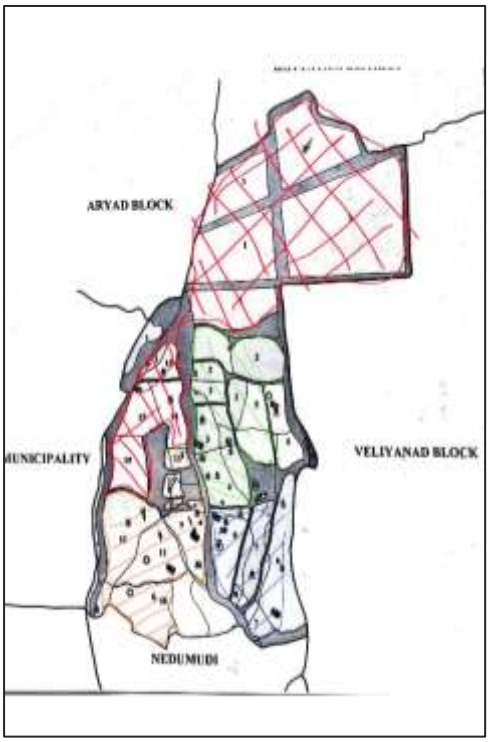


Fig 29: Rough division of Panchayat into 4 sectors (red,green,yellow,blue*)*

Fig 30: Division of Panchayat into different micro units

Figure 31: Pictures taken during the first day of transect walk

The major finding of the transect walk was the identification of land typologies into 7 different types based on their characteristics. These different land typologies and their characteristics are;

1. *Bund on the sides of Lake or River*

The houses under this typology are located facing the lake or river on the bund. The bunds of these kinds are susceptible to damages from tides caused by the movement of tourist boats and larger boats. These damages lead to the breakage of bunds, settling of the pathway, and houses on the bund. Therefore heavier bunds of stone or concrete are constructed in this typology.

2. *Bund on the sides of Canal*

The houses under this typology are located on the sides of canals. The water of these canals does not have the issue of tides as seen in the case of a river or lake. Therefore, the bunds made here are not uniform in nature and are mostly constructed in smaller lengths with varying materials based on the economic situation of the people living in the region. Some canals of the Panchayat are polluted by weeds and plastic and are therefore stagnant. Therefore, in such areas, the chances of infecting water-borne diseases are high.

3. *Reclaimed Paddy land*

The houses under this typology are constructed on reclaimed lands which were once part of paddy fields. This typology is mostly seen along tar roads and is therefore raised to reach the same level or higher level than the road.

4. *Isolated houses within a paddy field*

These are the houses that are located within the islands (T*huruth)* in the paddy field. These islands have less than 3 houses and are characterized by a lack of vehicular access. The access to the island was through a narrow path (V*aramb*) through the paddy field. During rainy seasons or bund breach events, the paddy fields tend to get flooded at the very first and therefore these houses get isolated if they do not have a boat facility.

Figure 32: Isolated house in a paddy field, the questions are marked

5. *Clustered houses within paddy field (more than 3 houses)*

These houses have similar characteristics as Isolated houses within paddy fields but are more than three in number.

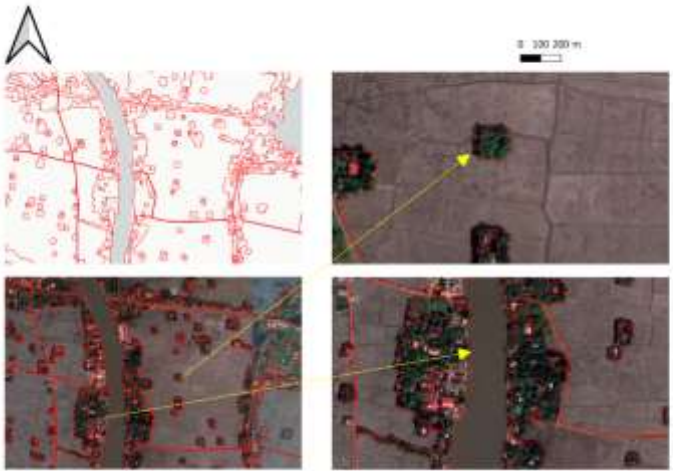


Figure 33: Various land typologies from Landsat images

6. *Isolated houses on islands in the lake*

These houses were located in the islands of the lake area and are therefore surrounded by water all year long. They are susceptible to excess runoff more frequently than the rest of the typologies.

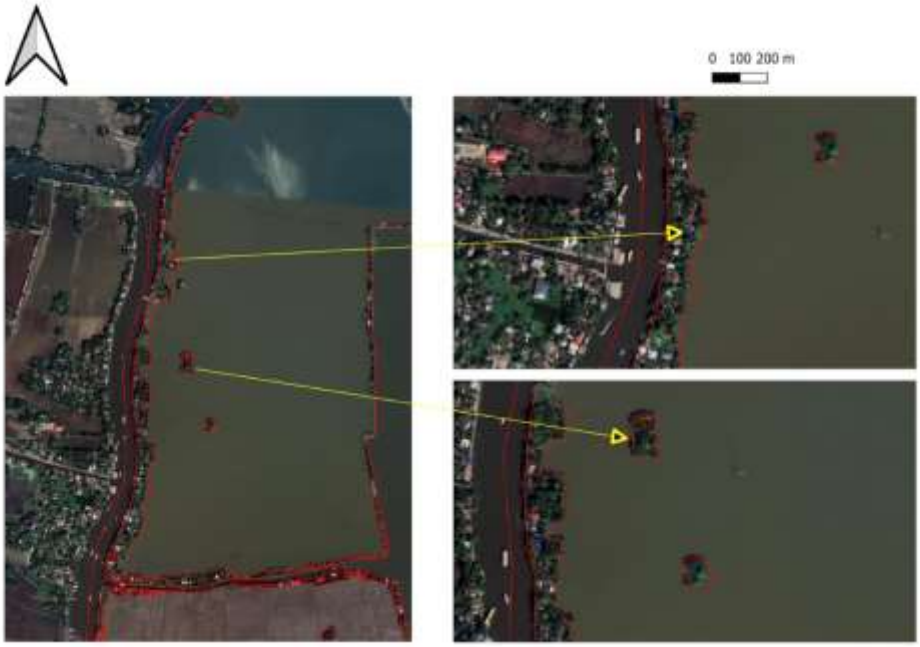


Figure 34: Isolated houses on islands

7. *Clustered houses on islands in the lake (more than 3 houses)*

These houses have similar characteristics as isolated houses on islands in the lake and have more than 3 houses. One such prominent area is Kuttamangalam with 80 houses on the island.

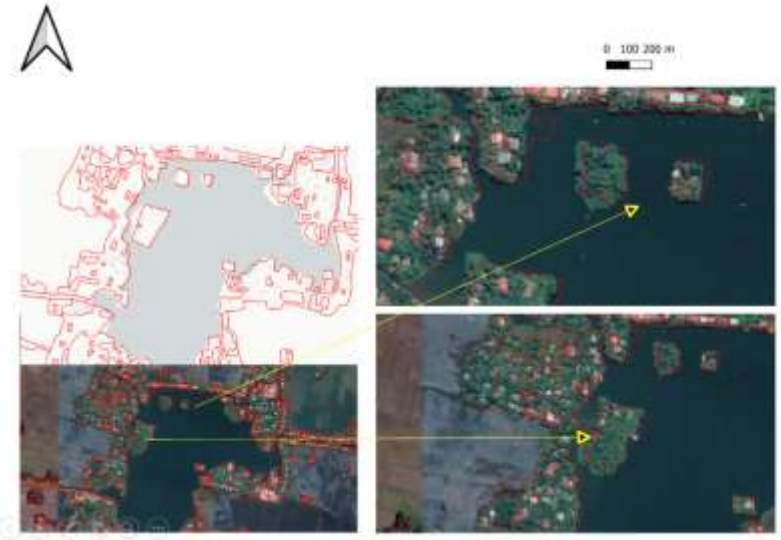


Figure 35: Clustered houses on islands in the lake

With the findings from the transect walk, a detailed discussion was conducted with the Panchayat members on 10th February 2021. The main aim of this meeting was to present our findings regarding the land typologies to get their suggestions and feedback. It was understood that two typologies were missing in our list and those need to be added. They are 'Kaayalnilam Isolated' and 'Kaayalnilam cluster' typologies.

5.3.3. Phase 3 - Action

5.3.3.1. Flood Mapping

With flood being a major issue in the region and as the study intends to come up with a detailed understanding around housing, development, livelihood, and other physical and socio-economic factors in the region, a pilot flood mapping is conducted with a small set of the questionnaire in ODK software. The flood mapping exercise planned to carry out a process to identify areas having the risk of flooding and can be used when drawing the flood-risk management plans, for preventing flood damages, in land use planning, planning of houses, for providing information on floods, in rescue operations and also in determining what the lowest allowable construction elevation should be to avoid flood risk.

One of the concluding remarks from the flood mapping exercise was that we can integrate it with the vulnerability survey. The second major outcome of the flood mapping exercise as a pilot survey was that our assessment based on 'wards' in Panchayat has changed to assessment based on 'polder'.

Figure 36: Picture taken during the flood mapping survey

5.3.3.2. Household Surveys

The survey was prepared based on a transect walk and flood mapping survey. The field survey component includes both quantitative and qualitative aspects. The quantitative data were mainly collected through the household survey and document analysis. The qualitative part of the field survey is conducted through focus group discussion, detailed notes about the daily observations by the survey team and interviews with key informants.

The Process Involved in the conduct of the field survey were ;

i) Division of the Kainakary panchayat into 21 polders

ii) Preparation of preliminary survey questionnaire and correction of the same by the entire team

iii) Covering one polder on each day of the survey

iv) Division of each polder into 5 sections and deployment of teams into those sections.

Data from the survey can be used for analyzing the hazard factors, socio-economic vulnerability, adaptive capacity, exposure analysis and biophysical vulnerability.

Figure 37: Pictures taken during the field survey

5.3.3.3. Focus Group Discussions

A focus group discussion aims to obtain an in-depth understanding of the concepts, perceptions and ideas of a group of 6–12 people. Ideally, a focus group discussion is an iterative process, whereby each discussion builds on previous discussions by developing a topic or emphasis on certain aspects.

In the context of a participatory study to understand the flood-risk in Kainakary, a focus group discussion with elected representatives of the Kainakary panchayat was of utmost importance. It included discussions on institutional arrangements, issues of the community, livelihood opportunities of the community and understanding how the people live today and what are the aspirations of the local self-government as well as the people of Kainakary. The focus group discussion revealed the different narratives, viewpoints, and insights among different issues in the panchayat by different elected representatives.

Another focus group discussion was conducted with the female farmers who are a part of the group farming committee. The idea of that FGD was to know about the issues around their life related to group farming and how the farming activities and frequent floods are understood by them.

Figure 38: Picture taken during the Focus Group Discussion with Panchayat members

6. ROLE OF HOUSING PROVIDERS IN POST-DISASTER HOUSING

6.1. India: Approaches to Reconstruction

Over the last three decades, the various central and state-led large scale social housing programs targeted at EWS and LIG sections of society and had a significant role in how post-disaster housing needs are met in the country (Iyengar, 2010). Iyengar (2010) further argues that while the overall framework of housing policies in the mid-nineties moved towards empowerment and ownership of prime beneficiaries of housing interventions, through strengthening of local institutions of self-governance (village Panchayats, and municipalities), post-disaster reconstruction on the other hand, moved along a different axis. Key Census terminology of "kachcha"[11] and "Pucca" housing was introduced with the Indira Awas Yojana in the mid-1980s, which saw the inception of 'contractor driven housing', as opposed to 'self-construction'. Because of the terminology of 'kachcha and pucca' in the social housing programs, locally available materials such as mud, bamboo, clay roof tiles, thatch etc. – which is traditionally associated with 'kachcha construction' was removed from social housing programs, along with local building skills and knowledge (J. D. Barenstein & Iyengar, 2010). (J. D. Barenstein & Iyengar, 2010) argues that this process led to a situation where the opportunity to upgrade local building materials and construction systems was completely lost.

Throughout the 80s and the 90s, not only were the local building systems lost, but since rural housing is primarily owner-driven, the social housing programs did not recognize the rights and abilities of the beneficiaries, largely poor, to control decisions regarding their house construction.(J. D. Barenstein & Iyengar, 2010) argues that this led to social rural housing programs being both contractor driven and agency[12] driven thus diluting the power from rural poor in home building processes.

[11] The Hindi words 'pucca' for strong or 'mature' houses, and 'kachcha' for weak or 'raw' houses were officially used by the Govt. of India to differentiate between houses built with industrially produced construction materials, on the one hand, and vernacular houses built with locally available construction materials, on the other. These terms are far from neutral – with kachcha being associated with poverty and backwardness and pucca with progress and modernity. Of particular importance for this classification are the roofing materials. All houses with thatched roofs are considered kachcha, those with tiled roofs as semi-kachcha and only those with concrete flat roofs as pucca.

[12] District Rural Development Agency

The failures of this approach gradually led to the reforms in 2004, which reinstated powers to home-owners, and state agencies eventually playing an enabling role, as discussed above.

6.1.1. Response to Disasters

Barenstein and Iyengar (2010) points out that disaster response in India has tended to view climatic calamities, such a floods and cyclones[13], which are more regular in nature as 'small' disasters, and by and large, these disasters have not evoked a long-term reconstruction response from states, despite the fact that these have been characterized by some very large-scale destruction, damage, and short-term displacement – such as the Orissa Super Cyclone of 1998, and the Bihar Floods of 2007. On the other hand, geophysical calamities, such as earthquakes, which are less frequent but larger in their regional impact, are viewed as 'large' disasters, and have had a prominent focus on reconstruction such as in Latur, Gujarat, and Jammu and Kashmir. These disasters attracted funds, strategies and higher media attention nationally and internationally, in comparison to the smaller, recurrent disasters.

In the case of climatic disasters, particularly housing losses caused by floods, people affected by the disaster are compensated with a one-off cash assistance which is governed by the relief code14 (Barenstein & Iyengar, 2010). This cash-assistance within the framework of the relief fund enables the victims to restore the damaged house to 'pre-disaster housing condition' with its structural vulnerabilities, and they are not expected to 'build better houses', but are instead, expected to 'build themselves' (Barenstein & Iyengar, 2010).

For geographical calamities such as earthquakes on the other hand, the State has often gone beyond the relief code, developed long-term reconstruction packages and provided 'better' houses, through different approaches, as detailed below:

(Barenstein & Iyengar, 2010; Government of Maharashtra,2005; Jigyasu, 2001; Salazar, 2002)

[13] With the exception of the 2004 tsunami in Tamil Nadu, Kerala, Andhra Pradesh, and the Andaman and Nicobar islands, which were part of an international disaster and hence received very high media coverage

[14] Relief assistance is regulated as per the norms approved vide GO (Ms) No. 194/2015/DMD dated 20-05-2015. Pg 146- Kerala State Disaster Management Plan 2016

6.1.2. Contractor Driven Approach: Latur Earthquake (1993)

The districts of Latur and Osmanabad in Maharashtra's historical Marathwada region were hit by a massive earthquake of the magnitude of 6.4 on the Richter scale on 30 September 1993. The earthquake killed nearly 9,000 people and over 16,000 reported injuries. It affected over 2,500 villages. Fifty-two villages consisting of a total of 27,000 houses were completely destroyed. GoM announced that all devastated villages would be rebuilt on safer sites and resettlement was emphasized.

The quake-affected villages were divided in three damage categories: relocation and full reconstruction of about 28,000 houses was suggested for the 52 most heavily damaged 'category A' villages; reconstruction in-situ through financial assistance in 'category B' villages; and repair and seismic retrofitting of about 190,000 damaged houses in 'category C' villages. The new houses to be provided were again divided into three categories: landless and marginal landholders (owning up to one hectare of land) would be given houses with a carpet area of 250 sqft; households owning between one and seven hectares of land would get houses of 400 sqft, whereas large farmers (owning more than seven hectares of land) would get houses of 750 sqft. This policy implied that wealthier people would benefit significantly more than poor households regardless of their individual requirements.

While 'resettlement' was not advised by social scientists[15], the 22 less severely damaged category B villages refused housing assistance in-situ demanding to be relocated, as they had lost faith in their traditional building capacity and thus preferred to move to modern and seismically safe villages.

(J. D. Barenstein & Iyengar, 2010) put forth 2 reasons for the decision of the victims to relocate:

- People's preference for relocation and modern houses was influenced by the negative attitude towards traditional housing by the junior engineers who surveyed the earthquake damaged villages.
- International NGOs were more interested in building new villages in relocated sites than in supporting communities to rebuild their own houses by themselves. By

offering modern 'ready-made' houses to people who, according to the government policy, were entitled to a financial compensation of only Rs62,000 to rebuild their houses in-situ, NGOs created an artificial demand for relocation.

Outcomes: No agency involved in the Latur relied upon local technologies by promoting and upgrading the use of locally available materials such as stone, and by integrating the local building industry. Community participation, if such participation took place at all, was limited to a few village meetings aimed at communities approving the house designs and settlement layouts. The fact that reinforced concrete was the only building technology that was largely adopted, is an indication of the extent to which local masons and artisans were marginalized from the reconstruction process (Salazar, 2002).

Resettlement proved to be unsustainable. Due to the villagers' inability to pursue their livelihoods and to adjust their lifestyles to the urban-like settlements and house designs (Salazar, 2002) many people abandoned the relocated villages and moved back to their old villages. There, they started to rebuild their old houses following their traditional building technologies, without employing any earthquake resistant features. Not only was the opportunity missed to improve resilience by enhancing local building capacity, but the excessive reliance on industrial building materials led to a tremendous waste of financial and material resources; the approach led to a high environmental impact and the loss of valuable agricultural land.

6.1.3. Owner Driven Approach: Gujarat Earthquake, 2001

On 26 January 2001 Gujarat was hit by a devastating earthquake of the magnitude 7.6 on the Richter scale. Nearly 20,000 people lost their lives, 167,000 were injured, and over 1 million were rendered homeless. The earthquake affected 21 of Gujarat's 25 districts and 7,633 out of 18,356 villages. In total 450 villages were completely flattened, 344,000 houses were destroyed and there were 888,000 reported damages ((UNDP), 2001).

With the Maharashtra Experience still fresh, the state government adopted an 'owner-driven' reconstruction approach (ODR16) Thus, under this approach, a systematic

[16] Aided self-help approach- reconstruction approach that enables home owners to rebuild their houses themselves (by hiring the necessary skilled labour), through a guided combination of financial and technical assistance, and a regulatory framework that would ensure access to good quality and affordable construction materials. Owner-driven reconstruction may be considered the most natural, empowering and dignifying

public consultation carried out in 468 villages by the NGO network Kutch Nav Nirman Abhiyan (KNNA), to gauge requirements. This reconstruction policy consisted of offering financial assistance (INR 40,000–90,000 depending on the extent of damage and size of the previous house), technical assistance and subsidized construction materials to all those who preferred to undertake reconstruction on their own, with state support.

(J. D. Barenstein & Iyengar, 2010) also mention that ODR approach in itself does not lead to a sustainable built environment or to resilient communities as the application of local knowledge and building technologies may be constrained by a number of factors such as inadequate building capacity, lack of information, and access to building codes and guidelines. In the case of the Gujarat reconstruction policy, the KNNA set up a unique mechanism called Setus ('the bridge'), which served as a chain of information/knowledge facilitation hubs in clusters of affected villages. It also collaborated with the government in organizing training campaigns for masons and homeowners. Further, it trained retired masons as 'advocates' for safety, and posted them in villages to supervise reconstruction at community level. It also organized demonstration camps to inform people about different technological options, including upgraded stabilized earth building technologies, which were low cost, eco-friendly, and above all built upon indigenous knowledge, which as a first, the use of alternative building materials was regulated through guidelines that were endorsed by the government (GSDMA, 2005)

Gujarat's reconstruction experience proved that people have the capacity to build houses that are more likely to respond to their needs than houses provided by external agencies if adequate financial and technical support and other enabling conditions (e.g. good supervision, massive training of local masons and access to subsidized construction materials) are provided(Abhiyan, 2005). However, as reported by (Abhiyan, 2005), in the aftermath of the reconstruction experience, it was found that while self-built houses often made extensive use of salvaged and locally available construction materials, most agency[17]-led, contractor-managed reconstruction promoted the use of reinforced concrete, a construction material

approach towards reconstruction. **Cash provision has to be accompanied by the state regulating and/or subsidizing prices of key building materials, strengthening access to good quality construction materials, ensuring support to the most vulnerable, mitigating hazard risks by developing relevant technical guidelines and facilitating technical support and training**. While being an extremely decentralized and citizen-centric approach to mass-scale reconstruction, it demands firm post-disaster governance by the state.

[17] NGOs and private companies

with a high ecological footprint. NGOs and private agencies, by and large, showed little or no interest in proactively, supporting the repair of partially damaged houses. It is estimated that over 38 per cent of the houses built by NGOs replaced houses that would have been reparable (Abhiyan, 2005).

6.1.4. Agency-Driven Approach: Tamil Nadu, 2004

On 26 December 2004 a severe earthquake measuring 8.9 on the Richter scale hit northern Sumatra. The quake resulted in one of the most powerful tsunamis of recorded history. In India the tsunami killed over 12,000 people, and approximately 5,800 persons remain missing. Nearly 80 per cent of the human and material losses were concentrated in the State of Tamil Nadu. The vast majority of the tsunami victims belong to the coastal fishing communities (Government of Tamil Nadu, 2005).

While the state govt. estimated that over 130,000 new houses were needed for people made homeless by the tsunami, the first reconstruction policy issued by the government in January 2005 envisaged permanent relocation of all coastal communities, which implied the need for new houses for all affected people (Asian Development Bank (ADB), 2005). Another factor that contributed to giving little importance to a housing damage assessment was the assumption that 87% of the coastal people were living in kachcha housing[18] and that reconstruction would be an opportunity to upgrade these people's housing condition (J. D. Barenstein & Iyengar, 2010).

(J. Barenstein, 2006) in the post-reconstruction survey points out that pejorative attitudes towards vernacular housing and explains why, immediately after the tsunami, the Government of Tamil Nadu announced that it would replace all damaged kachcha houses with pucca houses, explaining that kachcha is erroneously translated to mean living in 'temporary shelters', when in fact a "significant proportion of households had owned comfortable and beautiful houses, which were well adapted to the local climatic conditions and were environmentally sustainable"(Asian Development Bank, 2005). It further reports that the problem is with the understanding that all kachcha or vernacular houses are vulnerable and structurally unsafe, while all 'engineered' pucca structures, which cost approximately 30 times higher than the cost of a kachcha house are safe and appropriate.

18

GOTN initiated a fully agency-driven reconstruction programme by inviting NGOs, voluntary organizations, public and private sector enterprises, national and international charity organizations to adopt particular villages for their reconstruction programme, wherein, while the the government issued detailed guidelines and building codes, the organizations were free in choosing their own architects and reconstruction approach (Government of Tamil Nadu, 2005)

Outcomes: Barenstein and Iyengar (2010) points out that due to the unprecedented scale of private donations, all tsunami affected villages in Tamil Nadu ended-up being 'put up for adoption' by NGOs and private corporations. In December 2005, the government reported that 43 agencies were in charge of the construction of 17,461 houses in 80 villages (Government of Tamil Nadu, 2005). All of them opted for contractor-driven reconstruction and in most cases community participation was minimal.

Barenstein and Iyengar (2010) argue that "preserving as much as possible of the pre-disaster-built environment is important from a psychological, socio-cultural, economic, and environmental point of view", however, reconstruction in Tamil Nadu led to a massive demolition of undamaged houses.

Subsequent surveys conducted by (Barenstein, 2006) presents a dismal situation post-reconstruction, pointing out how while agencies eager to spend their funds on building new houses, when unable to find land for relocation, started pushing for reconstruction in-situ leading to demolition of good quality, undamaged vernacular houses.

This Tamil Nadu model of House Reconstruction post-disaster, has been adopted by the state government of Kerala as detailed ahead.

6.2. Housing Reconstruction: Kerala Approach

(Anilkumar & Banerji, 2021) argues that much of Kerala state government's disaster response was shaped by the 2004 Indian Ocean Tsunami triggered significant destruction to housing and related infrastructures across various coastal districts of south India. In Kerala, 219 villages in nine districts (out of 14) were affected, however, tsunami-related damages were severely felt in 187 villages along the coast in three southern districts—Ernakulam, Alappuzha, and Kollam (Anilkumar & Banerji, 2021).

In an approach similar to that adopted by GOTM, two strategies were adopted for providing permanent housing for the tsunami-affected communities:

- Relocating the communities within 200 m of the shore to new settlements inland;
- Rebuilding on the original land that is 200 m beyond the coastline.

Subsequently, new houses were constructed in situ or communities were relocated to new settlements inland following owner-driven as well as agency-driven approaches. The state government of Kerala functioned as the lead agency for managing the long-term recovery programs post tsunami. The district administration was entrusted with the planning and implementation of reconstruction activities in each district. The district administration acquired suitable land for relocation of tsunami-affected communities to safer areas. They identified the beneficiaries for permanent houses at various locations and reconstruction was carried out by nongovernmental organizations (NGOs). A total of 22 NGOs, national as well as international, were involved in the rebuilding process.
More than 50% of the disaster-affected families possessed land within 20 m of the coastline pre-tsunami. Subsequently, new houses were constructed in the relocated settlements in three panchayats inland, 3–5 km away from the original settlements. Over 5000 houses were constructed in 60 new settlements following a donor-driven approach (Kerala., 2011).

A typical design was followed for the dwelling units in various settlements, maintaining equity in housing facilities. Each house had a plinth area of 40 m^2 with two bedrooms, a small hall, an open verandah, a kitchen, one toilet cum bathroom, and an external staircase. After the completion of the project within the stipulated period (2006–2010), the NGOs handed over the housing units to the government. There was no involvement of the affected communities or their representatives in the planning and design of new settlements for relocation. The housing units were distributed to the eligible beneficiaries through random allotment without seeking the community preferences on the location of new neighborhood as well as housing unit (Anilkumar & Banerji, 2021).

The governance structure and process for implementing TRP19 special package are as follows (Kerala., 2011). District Planning Officer held discussions with the president of Panchayat along with three members selected by the president and made a draft plan for R&R activities. The three members were chosen by the Panchayat president from among three ward members. This plan was discussed in the Panchayat Samiti, and based on the discussion, it was modified. Projects were allotted to wards. The projects were placed in the respective Grama Sabhas and their suggestions were incorporated. The modified projects were discussed in the Panchayat Samiti in the presence of the District Collector. The Grama Panchayat was the nodal agency entrusted with the task of prioritisation and fund allocation across different projects. Some projects were implemented directly by the Panchayat, while others were implemented through the ten government departments/agencies. Under a TRP special package, 724 houses were constructed at *Alappad*. People were given Rs 3 lakhs each to construct houses on their own land in *Alappad* Panchayat itself.

(Joseph, 2015) argues that existing decentralized system of governance was not utilised systematically for reconstruction programs and that they were conceived and implemented through the hierarchical bureaucratic system of governance. Consequently, tsunami relocated communities were found to be dissatisfied with the living environment in terms of quality of housing and other infrastructures, sociocultural and economic sustainability (Joseph, 2015).

6.3. Post Tsunami: Kerala Disaster Management Plan, 2016 (Focus on Floods)

(Kerala State Disaster Management Authority, 2016) has classified 'Floods' (Riverine, Urban and Flash Floods) as 'Natural' Hazards, while Dam spillway operation related floods & accidents are classified as 'Anthropogenic Hazards'. KSDMP notes that floods are the most common of natural hazards that affect people, infrastructure and natural environment in Kerala and identifies reclamation and settlement in floodplain areas is a major cause of flood damage in Kerala. According to the Natural Hazard and Vulnerability Assessment mapping in Alappuzha district more than 50% percentage of area is identified as flood prone. Of this,

[19] Tsunami Rehabilitation Programme

floods are mostly confined to the Kuttanad region that host seasonally waterlogged flat lands with linking waterways connected to Vembanad lake.

While the KSDMP as well as the Alappuzha District Disaster Management Plan (2015) note that Alappuzha has been traditionally vulnerable to natural disasters, particular floods which have been a recurrent phenomenon on account of its unique geo-climatic conditions & vast coastline, the standard management procedure is in accordance with the National Disaster Management Guidelines: Management of Flood, 2008.

While, the document notes that the frequency and magnitude of floods in the state seems to be on the rise due to reclamation of wetlands and water bodies, increase in impermeable built-up area, increase in roads with impervious surfaces, deforestation in the upper catchments, population pressure and encroachment of river banks and infilling of paddy lands and wetlands, etc. the document has stated that "it is assumed that the hazard footprint may not increase beyond the worst case scenarios mapped20 and hence separate hazard foot print assessment in light of climate change scenarios was not conducted."

This attitude of considering 'small, reoccurring' disasters as part and parcel of business-as-usual, and offering one-time cash-compensations for repair of houses, instead of focusing on "Build Back Better" in recovery, rehabilitation and reconstruction-a statement objective of the KSDMP, 2016 is a glaring lacuna in the entire disaster cycle in the state. According to the Alappuzha District Disaster Management Plan (2015) Matrix of 'Past Disasters', 34 villages in Kuttanad and more than 3 lakh people have been affected by floods causing an estimated house damage of INR 14.7[21] Billion.

The Comptroller and Auditor General (CAG) report for the year 2016 criticised the functioning of disaster management system in Kerala stating that it was continuing a "relief-centric approach" in disaster management activities rather than a "pro-active prevention, mitigation and preparedness drive approach". It further stated that Provisions of National Disaster Management Authority guidelines were not included in the municipal and panchayat building rules dealing with the construction of buildings in the state (PTI, 2017).

[21] 14766200

6.4. ‘Rebuild Kerala’ & Housing Reconstruction Post 2018 Floods

Rebuild Kerala initiative was launched by Chief Minister of Kerala on Oct 16, 2018 to aid in the reconstruction, rehabilitation and overall recovery of the State of Kerala after devastating floods in 2018. According to data released by the Govt. of Kerala, a total of 57597 houses were damaged by floods in Alappuzha district of which an estimated 56070 houses were partially affected by floods, while 1527 were completely affected by floods (Local Self Government Department, Government of Kerala., 2018).

While a compensation of INR 10,000 was handed out to every household affected by floods, the housing damages were assessed based on degree of structural damage. The houses were divided into houses with concrete roofs and non-concrete roofs, and 5 categories were established by the authorities to assess housing damage namely:

(i) Up to 15% damage for houses that were submerged under ‘knee deep’ water with no visible damage

(ii) 16%–29%;

(iii) 30%–59%;

(iv) 60%–74%;

(v) Greater than 75% where there was structural damage to roof and walls.

These houses were to be rebuilt entirely. There was also a category for ‘complete loss of land and house’. However, under the last category for which there was a fixed compensation of up to INR 4 lakh, there were no houses in Alappuzha district as per data.

Between INR 10,000 and 1 Lakh (Survey, 2019) for partially damaged houses with no broad framework or follow-up with the households on the house repair process. There is no training for masons and local contractors and the building activity is heavily unregulated. Currently for flood victims under the LIFE Mission, state commissions are giving 4 Lakh rupees for construction of Rs 420 sq. Ft. house. However, labour charges and transportation charges in Kuttanad are high, and foundation construction itself takes up to 2.5 Lakhs to construct, making it impossible for inhabitants to construct a house within INR 4 Lakh

According to the (Local Self Government Department, Government of Kerala., 2018) ‘Rebuild Kerala’ report, the Central Govt. announced that villages with destroyed mud brick houses

would be provided houses under the Pradhan Mantri Awas Yojana (PMAY). While the report both understood and acknowledged that Kerala requires a multi-pronged approach to reconstruction, in that the needs for housing reconstruction in the Kuttanad area will be different from the house type of the high lands. It also proposed that there must be region specific menu of options including design, implementation arrangements, enabling mechanisms. Further, the report recommended specific Planning studies for Kuttanad region in the wake of climate change implications.

However, as observed[22] after post-tsunami reconstruction in the state, the reconstruction is primary occurring under 2 modes:

6.4.1. Agency-Driven: Sponsorship housing through NGOs

Some NGOs have sponsored housing for fully damaged houses in the area as tabulated below:

Table : Sponsorship Housing in Alappuzha District. Source: District Collectorate

Sl.No	Name of the Local Sponspor	No of houses to be constructed by the sponsor	Taluks where the sponsor is building the houses	No of house construction started by the sponsor	No of houses completed by the sponsor
1	Abhaya Foundation	4	Ambalappuzha	4	
2	Sathya Sai Seva Samithi	65	Ambalappuzha	20	
3	Aster Medicity	10	Ambalappuzha	5	
			Kuttanad	5	
4	Ramoji Film City	116	All Taluks	40	

[22] As Observed in Primary Survey of 2 Villages- Nedumudi and Kainakary

5	Sathya Sai Orphanage Trust	3	Ambalappuzha	3	
6	Peoples Foundation	40	All Taluks		
7	Bahubali Film Team	5	Ambalappuzha	5	
8	World Vision	115	Kuttanad	75	
9	Flood Volunteers Foundation	5	Kuttanad	5	5
10	Joy Alukkas	47	All Taluks	23	
	Total	410		185	5

6.4.2. Contractor Driven under the LIFE Mission

"Livelihood Inclusion and Financial Empowerment (LIFE) mission" undertaken by the Government of Kerala aims at providing 'Affordable Housing for All by 2022'. The mission aims at providing shelter for homeless and landless people and also to enhance the livelihood of poorer sections across the State of Kerala. The beneficiaries under the mission were selected through proper surveys conducted using the government missionaries and system (Vijayan, 2019).

According to information available on the Life Mission website (Kerala, n.d.), landless homeless, poor sections living in uninhabitable housing, and people living in temporary shelters in coastal regions, are the beneficiaries of the Life Project, while the priority beneficiaries as listed as:

Mentally challenged / blind / physically challenged/ People with disabilities, transgenders, Destitute, People with serious/fatal illnesses/ unemployed due to serious illnesses, Unmarried mothers and widows.

The Mission aims to build 759,523 houses for people in the State (Nair et al., n.d.) .Post 2018 floods, the government has decided to provide assistance to build and repair the damaged houses under its Life Mission Projects. Further, the government is also planning to identify

the flood prone areas in the state and permanent rehabilitation measures for the residents of such areas (State & Board, 2019).

The Mission is structured into 2 Phases:

- **Home Construction for Beneficiaries 'without' land:** Life Mission has decided to rehabilitate landless by constructing housing complexes for the landless and homeless. Procedures are in progress to construct 14 housing complexes for landless and homeless in Phase 3. While this is an important discussion, particularly with regards to the contractor-driven approach to housing and the issues with rehabilitation in urban-complexes as seen prior with the Latur example, among others, this discourse including discussions on adaptability and design of complexes is out of the scope of this research.

- **Home Construction for Beneficiaries 'with' land:** For these beneficiaries, under general category, an amount of 3.5 L will be given, while for SC/ST category, 4 L will be given. Actual construction cost will be split between PMAY and LIFE Mission.

Progress Report for Life Mission in Different Districts (General)

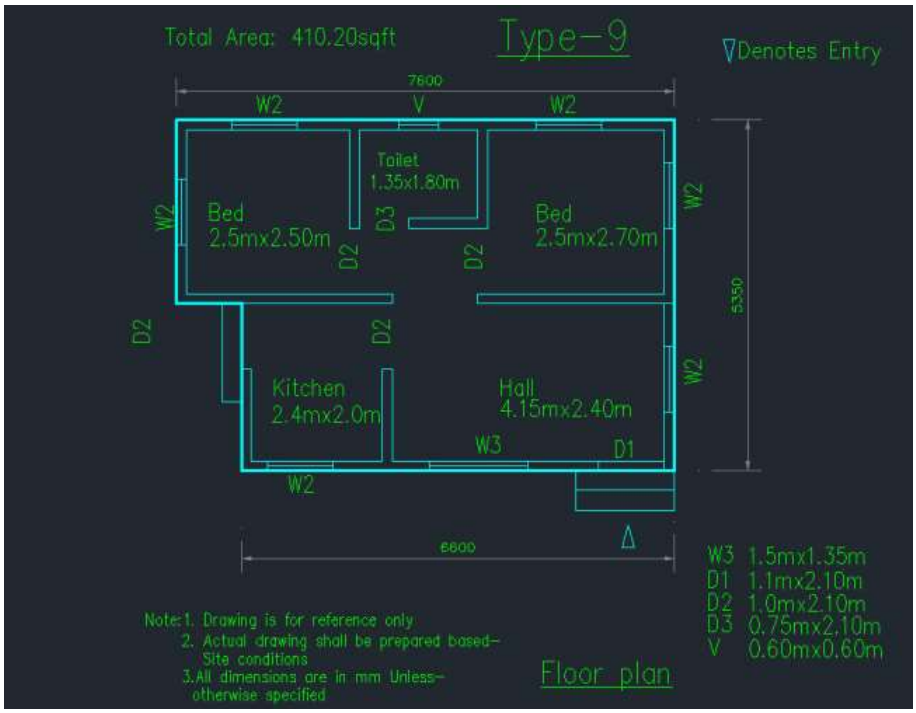
LIFE Mission - Physical Progress Report of Phase-2(GENERAL- As on 10.02.2020)

Sl No	DISTRICT	Approved Beneficiaries	Eligible Beneficiaries	Agreement executed	Physical Progress - Stages of Completion						% of Completion
					Not started	Started	Basement	Lintel	Roof	Completed	
1	THIRUVANATHAPURAM	26195	13283	13103	43	0	483	575	1413	10579	**80.94%**
2	KOLLAM	12493	7286	6606	82	0	180	321	398	5625	**85.09%**
3	PATHANAMTHITTA	3337	1802	1717	28	0	98	103	83	1407	**81.95%**
4	ALAPUZHA	12291	8764	7868	88	79	99	259	380	6970	**88.59%**
5	KOTTAYAM	8500	5890	3563	53	26	89	107	98	3189	**89.50%**
6	IDUKKI	13528	8916	8109	290	0	718	792	722	5587	**68.90%**
7	ERNAKULAM	7990	4655	4655	28	30	60	97	124	4291	**92.18%**
8	THRISSUR	9402	4716	3947	94	0	106	123	360	3262	**82.66%**
9	PALAKKAD	19859	12545	11325	206	0	529	1065	1116	8409	**74.25%**
10	MALAPPURAM	12403	5606	5436	126	0	183	191	272	4666	**85.86%**
11	KOZHIKODU	7606	4360	4356	25	0	83	246	303	3697	**84.87%**
12	WAYANAD	5776	3216	3216	98	0	213	279	538	2091	**65.02%**
13	KANNUR	4265	2321	2257	9	0	11	37	138	2064	**91.45%**
14	KASARKODU	6807	2780	2551	38	0	49	132	522	1810	**70.96%**
	TOTAL	147728	84462	79001	1203	155	2907	4323	6468	63947	**80.94%**

6.5. Typical House Types under Life Mission

Life Mission has 12 Typical House Designs between 399 -418 Sqft (Carpet), as shown below:

Life Mission House Type 9 : Area 410.20 Sqft



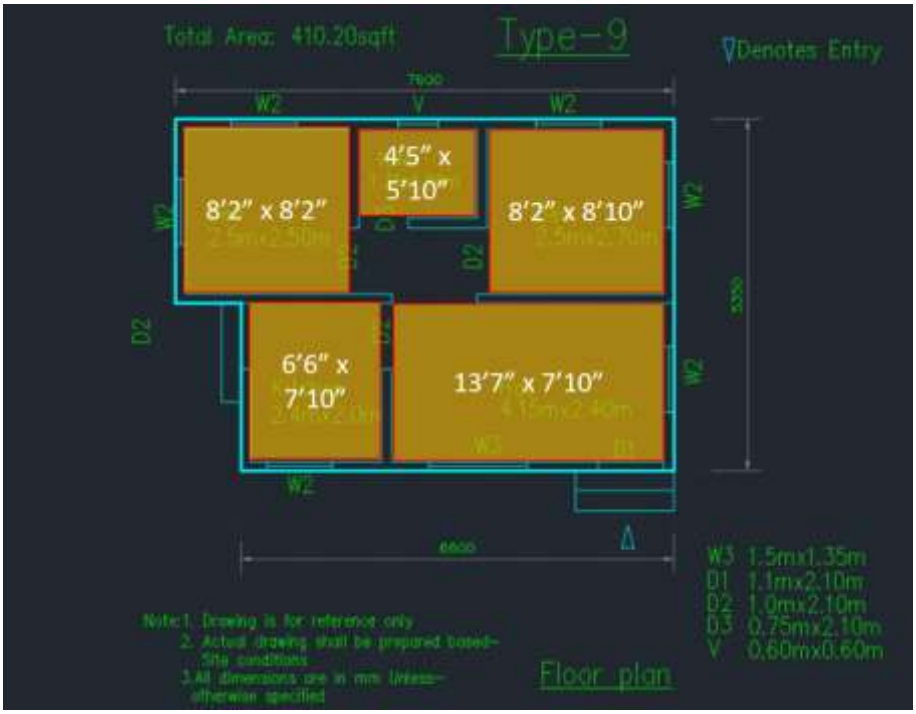
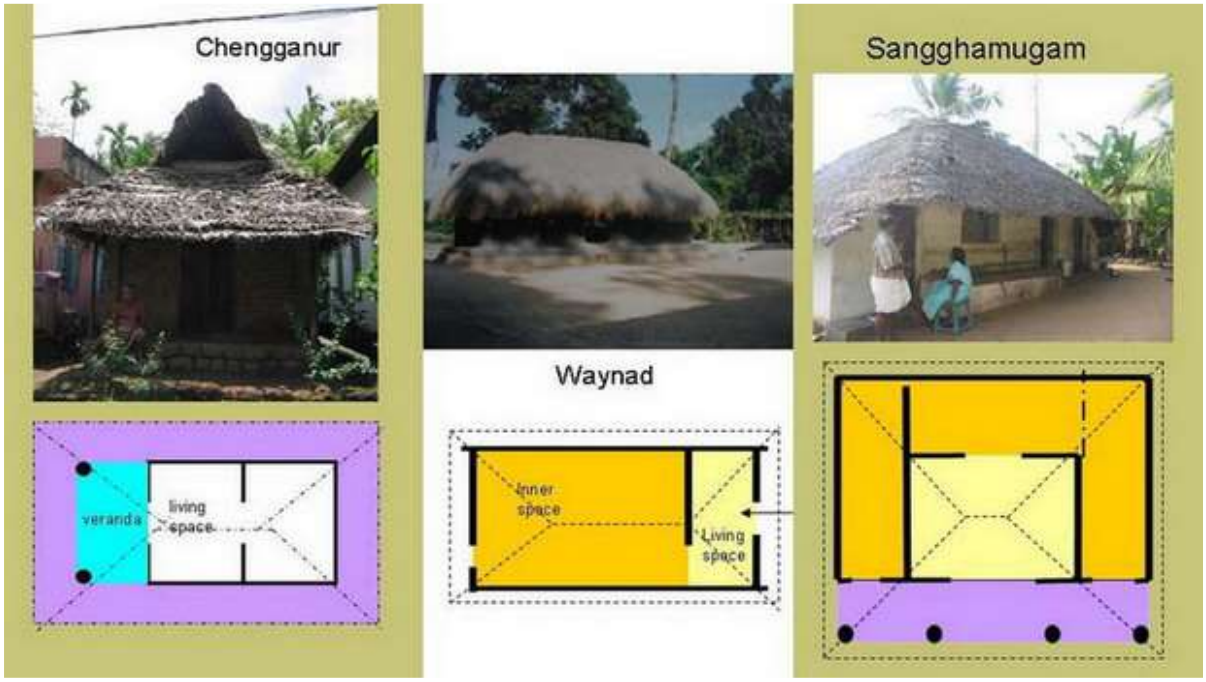


Figure 60: Typical Houses constructed in Nedumudi and Kainakary under LIFE

6.6. Key Issues

- Plan states that total area is “410.20 sq. ft.” however “Unusable” Carpet Area is only 325 sqft.
- One of the major issues with a plan like this, is the rigid division of spaces. While “traditional”/vernacular homes” by weaker sections of society were also ‘Adaptable spaces. Multifunctional Spaces are important to smaller units, because it allows the inhabitants to engage in a variety of uses. As times change, and the aspirations of families change, the “western” architectural ideas of formal division of spaces have been introduced.



One advantage of “Adaptable” design is the ability of the owner to “add” rooms incrementally as the needs of his family changes.

- Issues of Light/Ventilation cannot be determined in the absence of “north” point on drawing
- One clear “problem” in the context of Kuttanad with such a plan is the “Plinth Height”. In the Plan, the plinth is approximately 0.45-0.6 mm. While this is the common plinth height seen during survey, the current Houses being built in the region under Life

Mission are being built on Stilts. This in turn, brings the idea of “Inside” space vs “Outside” space to the fore.

- As traditional/vernacular “compact” homes were also homes with a lot of “spill out” area. When these homes are elevated, and that connection is severed, there is more detachment from a way-of-life. Such disruption, while seemingly minor, adds on to the general apathy that one experiences in city dwellings.

Table 7: Estimation for 400 Sqft House under Life Mission (Detailed Sheets Attached as Annexure)

Sl.no	**Particulars**	**INR**
1	Foundation (1.5 M depth) up to Plinth Level	100,795
2	Plinth to Sill Level (Cement Blocks)	22,890
3	Sill Level To Lintel Bottom	20,279
4	Up to Slab Bottom	59,255
5	RCC Roof	91,697
6	Interiors (Inc. Doors & Windows) (Anjali/Jack wood for doors & windows)	232,264
7	Plumbing & Sanitary Fixtures (inc. STP)	32,355
8	Electrical	30,000
9	Contingency	10,000
	TOTAL COST	**599,534**
		~ 6 Lakhs

Issues:

- Does not Include “Labour Costs”, and “Material Transport Costs”. Assuming 20% Labour and Nominal (5%) Transport Costs, Cost of house goes up to: approx. 7.5 Lakhs.

- Does not include “additional Cost of Raising Foundation”. Assuming an increase in Pillar height up to 1.5m, without increasing depth- there will be an increase of up to 50,000/-
- Thus, cost of house would be approximately INR 8 Lakhs, which is approximately twice as much as the current funding.

Additional Issues:

Low Bearing Capacity of Soil and Additional Load of House: One major problem that remains in such housing that is being promoted and currently constructed is the low bearing capacity of Kuttanad “Clay”. To reach optimal depth for pillar (~ 5 m), the cost of constructing pillars for a house with area less than 500 sqft, is not only a waste of resources, but also unjustifiable economic burden on the already disadvantaged end-user.

Thus 2 Solutions:

1. Reduce “Load of House”: Ferro-Cement and other light-weight materials such as Bamboo.
2. Increase the Depth of Foundation by “Sharing Costs” through ‘Cost-Effective’ Group Housing. This Solution is the most pragmatic.

However, both solutions will be explored in the project in collaboration with partner organizations.

7. Objectives for Phase 2

Various aspects of sustainability have been addressed from the literature review. The initial field study showed other variables contributing to the sustainability of housing. As the vulnerability to the flood is identified as a highly influential variable, a more detailed analysis is required to evaluate current housing practices' appropriateness with the compounding vulnerabilities. Evaluating the current patterns and transitions in housing in terms of sustainability and flood resilience may develop effective recommendations for owner-driven and mission-driven housing strategies. So, the next phase of the study aims to evaluate sustainability in terms of various aspects addressed in the above chapters and develop an alternate housing design and strategy. Understanding the gaps within current the LIFE housing program in terms of the sustainability assessment can deliver effective recommendations to the program. It may also bring more practical results at the ground level. The detailed objectives are as follows,

Objective 1: Suitability

- Analyzing the transition in building techniques and its impact on the ecology of Kuttand
- Evaluating the sustainability in building techniques/strategies in terms of compounding vulnerabilites
- Analyzing the suitability of 'new, emerging materials' and research conducted on modern construction techniques: light-weight fly-ash blocks, coir-stabilized and lime-stabilized Kuttanad clay bricks, use of bamboo mats for walling, use of bamboo to stabilize clay foundations
    - **Methods:** Document surveys, Flood and Hazard Maps, Settlement Plans (GIS based mapping of Kainakary and Nedumudi) and primary surveys (field surveys), Interviews with Experts (COSTFORD (Bamboo) IST, Trivandrum (Coir-stabilized Kuttanad Clay), CUSEK (stabilized Kuttanad Clay), and Field Tests for materials and technology

Objective 2: Understanding Interdependence: Interlinkages between people and habitat

- Understanding the human geography of Kuttanad- cultural practices, links with the environment (canals), changing patterns of living and occupations, coping with annual flooding (damages both monetary, physical and mental well-being)
- Understanding the impacts of 2018 flooding and the changes in associating with the built environment
- Analysing and documenting the affordability and social vulnerabilities of people and understanding decision-making process in house building
- Analysing and documenting physical infrastructure with a focus on sewage and drainage and documenting people's experience w.r.t. services in times of flooding
- Understanding the 'acceptability' and cultural suitability of introducing new materials and building techniques Methods: Document survey (District Census Handbook, Census of India), Interview with residents of Kainakary and Nedumudi villages, Interview with Panchayat officials, Interview with Experts

Objective 3: Measuring Impacts: Understanding and Framework existing coping Mechanisms

- Understand how the hosing conditions and current housing trends contributing to the coping mechanisms

Objective 4: Develop a new design from the existing understanding which satisfy the appropriateness (economically, environmentally and socially), affordability and flood resilience.

- Understanding the gaps within the owner driven housing initiatives in terms of sustainability and flood resilience.
- Understanding the gaps within the mission driven housing initiatives like 'LIFE' in terms of sustainability and flood resilience.
- New design and construction strategies for individual and mission driven housing initiatives

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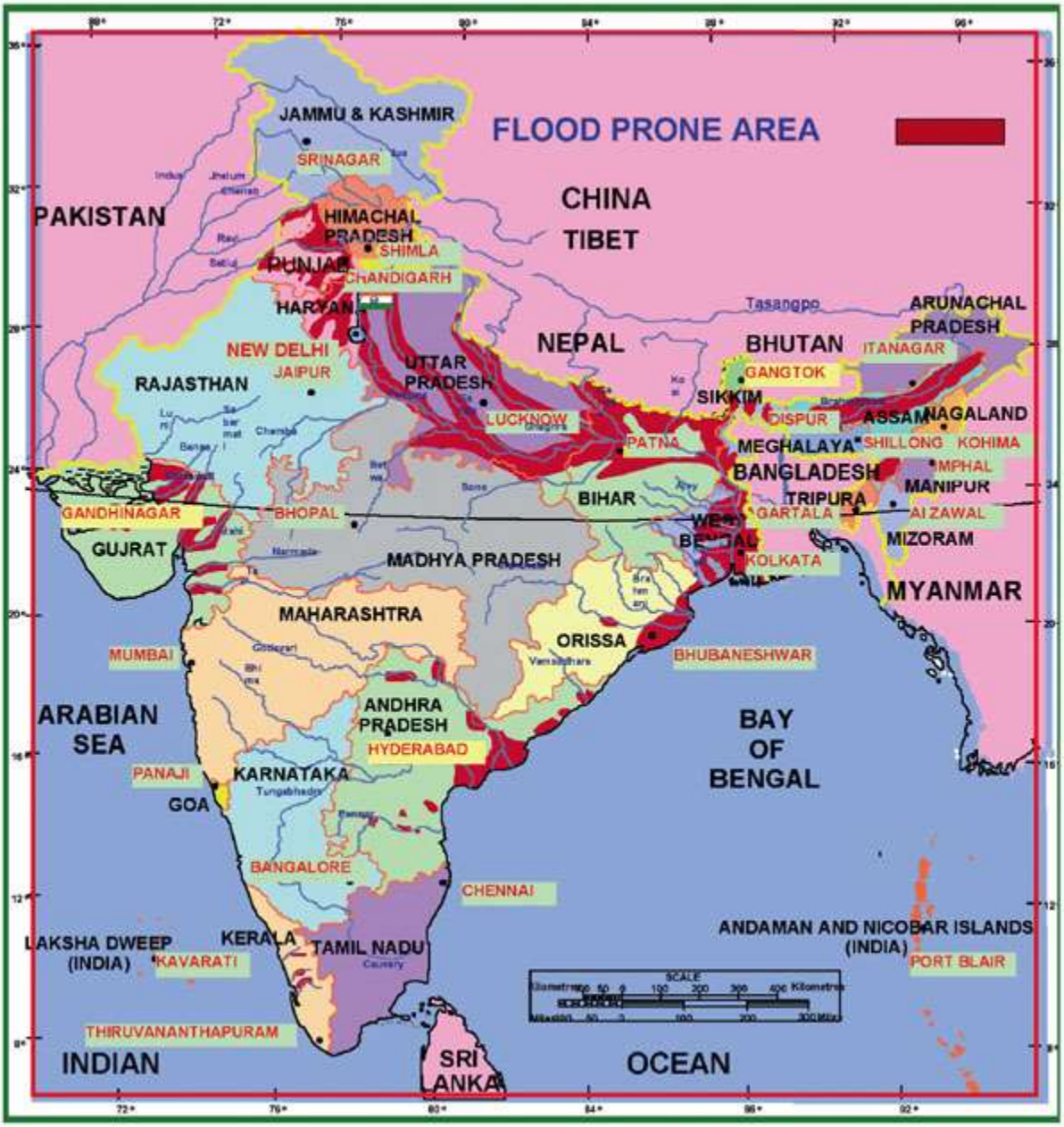
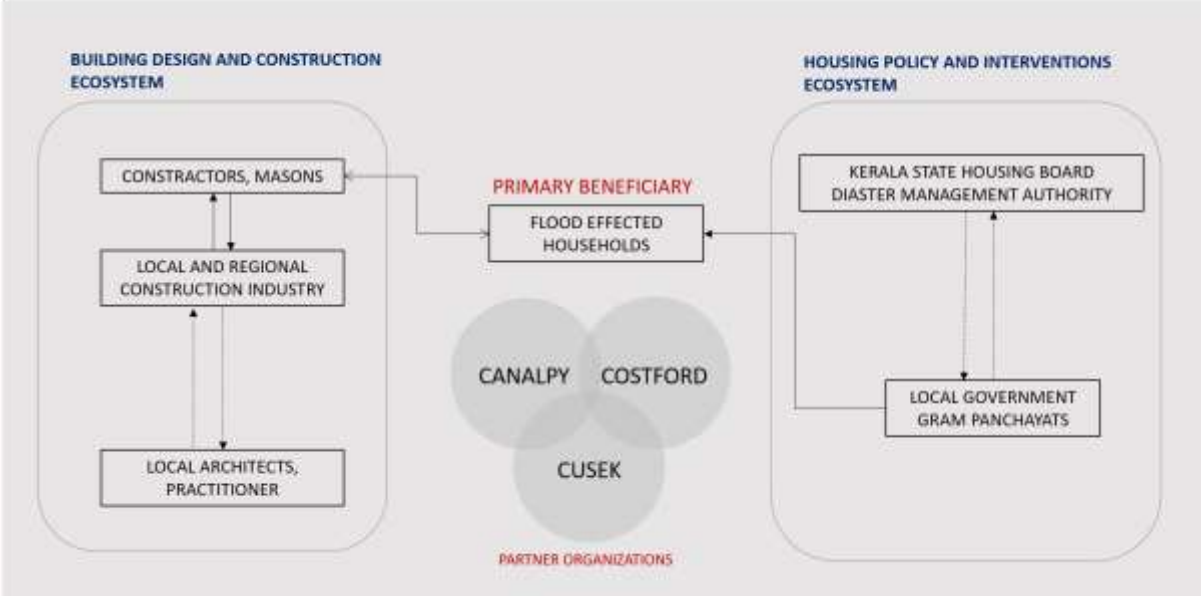
ANNEXURE 1- MAP OF FLOOD PRONE AREAS OF INDIA. (NATIONAL COMMISSION ON FLOODS)



ANNEXURE 2-STAKE HOLDER MAP

STAKEHOLDER MAP



ANNEXURE 3-TEAM

Sl.No	Name	Qualification	Role
1	Hari prasad V M	PhD scholar, IITB	Research assistant
2	Rohit Joseph	MTech scholar, IITB	Research assistant
3	Reshma Remesh	BTech Fresh graduate	Engineering intern
4	Vishnu Suresh	BTech Fresh graduate	Engineering intern
5	Abhiram D	BTech Fresh graduate	Engineering intern
6	Vrindhamol K S	BTech Fresh graduate	Engineering intern
7	Devika Jayakumar	BTech Fresh graduate	Engineering intern
8	Alfiya A	BTech Fresh graduate	Engineering intern
9	Prathibha P	BTech Fresh graduate	Engineering intern
10	Nethaji N R	BTech Fresh graduate	Engineering intern
11	Nethaji N R	BTech Fresh graduate	Engineering intern

ANNEXURE 4-FIELD STUDY PHOTO GALLERY

- **Initial meeting with panchayat**

- **Transect walk**






- **FGD1 (10-2-2021)**



- **Flood Mapping**



- **Quantitative Survey**


- **FGD2 (18-2-2021)**


- **Qualitative Survey**