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Landslide Susceptibility Map and Housing: A Case of Kerala

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Abstract:

One of the nation's most susceptible to natural disasters is India. It has had some of the deadliest cyclones, earthquakes, chemical accidents, landslides, head-on air collisions in mid-air, rail catastrophes, and traffic accidents in the history of the planet. The 2010–2020 decade is expected to experience an increase in the frequency of landslides compared to earlier decades. In several areas of India, particularly in the Himalaya, the north-eastern hill ranges, the Western Ghats, the Nilgiris, the Eastern Ghats, and the Vindhya, landslides are among the most dangerous hydro-geological dangers. Up until September 2022, 10 Indian states reported 182 landslide-related fatalities in various locations, according to data from the National Emergency Response Centre of the Ministry of Home Affairs. Kerala is one of the most densely populated states in India, with 860 people per square kilometre, making it more vulnerable to landslide losses and damages due to its heavy rainfall pattern and the presence of the Western Ghats. This paper aims to develop a clear understanding of landslides, their occurrence mapping, their effects on housing, and how early detection of landslide helps in displacing and evacuation of public. The review addresses the exigency of Landslide Susceptibility Maps in the field of Housing planning with context to state of Kerala in India.

Key words: Landslide Susceptibility Maps; Housing; Evacuation and Displacement; Kerala

Introduction:

A landslide is an occurrence or set of events in which a mass of rocks, soil, or debris slips down a hill. Landslide mechanisms involve material sliding, dropping, or flowing down a slope as a result of gravitational pull. Various factors can influence a landslide, including slope conditions and slope angle, lithology, soil type, and hydrological or climatic conditions (Silalahi et al., 2019). Landslides are frequently associated with triggering events such as heavy rainfall. Rainfall-induced landslides occur as a result of water's combined action on topography, geology, soil, and vegetation (Jain et al., 2021). Every year, landslides cause massive environmental damage, such as an increase in sediment discharge due to soil erosion and the loss of human lives (Wadhawan et al., 2020).

The landslides change according to the topography of the areas. Landslides are a common occurrence in Ethiopia, causing significant damage to people and property. The highlands are home to nearly 60% of Ethiopia's total population (Mersha & Meten, 2020). There are over 230,000 potential geological hazards in China due to complex terrain, tectonic development, and human activities, with landslides accounting for 53.50% of them. As a result, preventing landslide development in China is critical (Zhang et al., 2022) . According to P G Fookes etal in Engineering Geomorphology, an exceptional land storm in Washington, USA, caused several hundred landslides in 1996 which is over 50 cm in 7 (Srinivasaperumal et al., 2011). According to an approximate estimate of landslide losses in India, 500 lives are lost yearly and up to 4 billion INR in economic losses (Parkash et al., n.d.). These indicates the requirement of immediate study and need for urgent action in case of landslide disaster.

Purpose of paper:

The main purpose of this review paper is the understanding the exigency of Landslide Susceptibility maps in field of Planning of Housing with context of Kerala. For this, different papers are studied and reviewed to get the basic idea. The entire work is a review paper that focuses on data collection from internet and student-written sources. All of the studies were originally appraised using the abstract of the source publication and based on how well they linked to the subject being examined. The key findings from each selected paper were then examined and incorporated to this. The articles from different publications are not cross examined or compared because the study focuses on a review of the need for Landslide mapping in the housing field.

Landslides - A General Understanding:

One of the many natural processes that sculpts the surface of the earth is land sliding. Landslides are only a menace to humanity when they do so. The term "mass movement" refers to a much bigger group of slope processes than just landslides. All procedures involving the outward or downward motion of slope-forming materials caused by gravity are collectively referred to as "mass movement." While some mass movement processes, like soil creep, are fast, discrete, and have a high velocity, others, like landslides, are almost imperceptibly slow and diffuse (Sahoo, 2009).

The major causes of this disaster are weathering processes such as physical, chemical, and biological. Human intervention, such as excavation at the slope's base, causes devastating landslides. (Srinivasaperumal et al., 2011). Human activities like as deforestation, changes caused by the construction of structures on the slope, undercutting the toe of the slope for road construction, and so on all contribute to the potential component for the occurrence of landslide. Changes to the slope caused by humans can make it less stable. Landslides have a negative influence on infrastructure (housing, buildings, roads, bridges, irrigation, canals, etc.), geological and environmental damage (fractures, creeping, and slumping), and significant injuries and loss of human life (Silalahi et al., 2019).

Low – Moderate vulnerable Landslide zone	**Highly vulnerable zone**	**Very highly vulnerable zone**
• Trans Himalayan region • Spiti of Himachal Pradesh • Aravalli mountains • Deccan Plateau • Chhattisgarh • Jharkhand • Odisha	• North-eastern region • Eastern Ghats • Konkan Hills • Nilgiris	• Andaman and Nicobar Island • Western Ghats • Darjeeling • Sikkim • Uttarakhand

Table 1: Landslide vulnerable areas in India (https://www.godigit.com/guides/natural-disasters/landslides-in-india)

In huge sections of India, particularly in the Himalaya, the north-eastern hill ranges, the Western Ghats, the Nilgiris, the Eastern Ghats and the Vindhya, landslides are among the most significant hydro-geological dangers (Table 1). In India, there are four main areas that are prone to landslides, according to Rao (1989).

- Western Himalayas (Jammu & Kashmir, Himachal Pradesh and Uttar Pradesh).
- East and North Eastern Himalayas (Arunachal Pradesh, Sikkim and West Bengal).
- Mount Naga-Arakkan Range (Nagaland, Manipur, Mizoram, Tripura).
- Northeast India's Meghalaya and Peninsular India's Plateau Margins (Sahoo, 2009).

In India, about 12% of the territory is under the landslide prone zones on an average killing 300 people every year. It is the third most fatal disaster after flood and famine. This also adds about $400 billion per year just for the disaster management. Fig.1. depicts the landslide prone areas in India, given by the Geological Survey of India.

The biggest number of landslides, 2239, were reported in Kerala out of a total of 3,782 landslides that occurred in India between 2015 and 2022. The remaining were in Jammu and Kashmir (204), Tamil Nadu (196), West Bengal (376) and Karnataka (194). The ministry also disclosed that the Geological Survey of India (GSI) had conducted the National Landslide Susceptibility Mapping (NLSM), which covered a total area of 4.3 lakh square kilometres (13% of the country's total geographical land), in various landslide-prone states and union territories. The largest 71,228 sq. km of vulnerable areas are located in Arunachal Pradesh, followed by 42,108 sq. km in Himachal Pradesh, 40,065 sq.km in Ladakh, 39,009 sq.km in Uttarakhand and 31,323 sq. km in Karnataka.

According to the National Landslide Susceptibility Mapping (NLSM) statistics, the Western Ghat regions and the North-Eastern states are most susceptible to landslides.

- Due to a wave of landslides caused by the Darjeeling floods of 1968, large portions of Sikkim and West Bengal were damaged, resulting in significant loss of life.
- In the Nilgiris, landslides claimed the lives of 90 persons between October and November 1978.
- The Malpas rock avalanche catastrophe of August 18, 1998, in the Kumaun Himalaya, Uttarakhand, claimed the lives of 220 people and completely destroyed the Malpa village.
- In the state of Kerala, 40 people were killed in the Amboori landslide on November 9, 2001
- The Uttarkashi township was in risk because to the Varunavat landslide, which began on September 23, 2013 and continued for 15 days.
- Around 190 persons were killed in the 2005 Konkan landslide in Maharashtra's Konkan Plain.

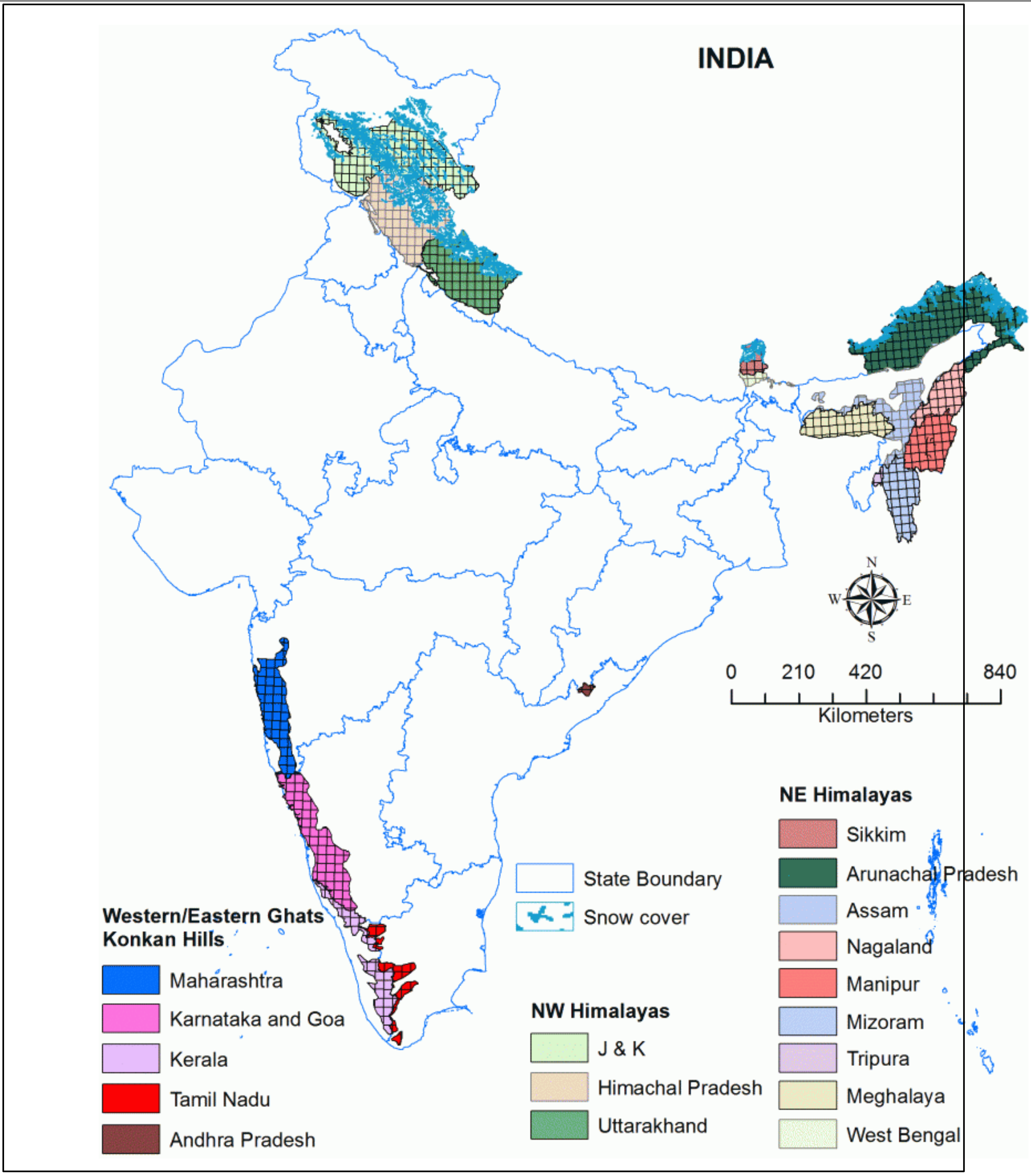


Figure 1:Major Landslide Prone areas in India (Source: Geological Survey of India)

Landslide Scenario in Kerala:

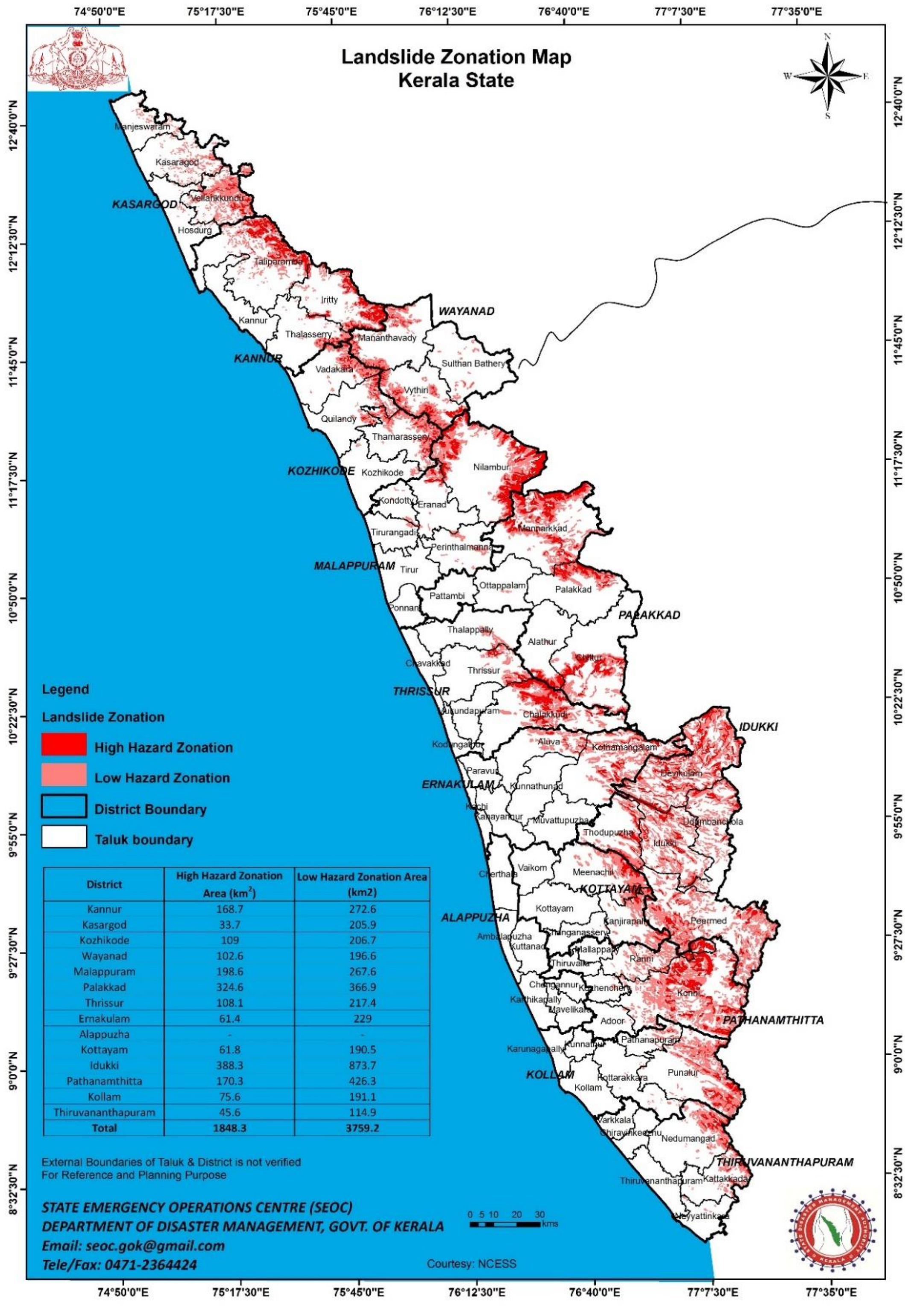
Kerala is a multi-hazard prone state in the country. Kerala, located in the Western Ghats, is highly vulnerable to mass movements due to its hilly terrain and heavy rainfall (Jain et al., 2021). The Western Ghats are characterized by thick soil cover that has been altered by anthropogenic activity, making them vulnerable to debris flows during the monsoon season. Kerala's highlands receive heavy rainfall from the south-west, north-east, and pre-monsoon rains (Jain et al., 2021). The Fig. 2. shows the major landslide zones in Kerala.

Landslide research in India received a lot of attention in 1994, thanks to a report presented by the Ministry of Agriculture, Government of India, to the world conference on IDNDR held in Japan. Kerala is one of India's most often hit regions by landslides. The state's diverse climate, high population density, and changes in land use are the main contributors. Between 1961 and 2013, 67 significant landslide disasters and hundreds of smaller ones resulted in the loss of more than 270 precious lives. 2,239 (59.2%) of these landslides between 2015 and 2022 were reported in Kerala. In the districts of Idukki and Wayanad, there were 3000 major-minor landslides in 2018, and 155 people died as a result (Premlet B, 2019).

As per Kerala State Geological Programming Board, between 1961 and 2013, 67 major landslides and hundreds of minor events claimed the lives of over 270 people. In 2018 and 2019, Kerala had the most destructive sequence of landslides, which affected millions of people, resulted in a large number of fatalities, and caused significant economic, social, and infrastructure damage. The state of Kerala saw excessive rain in October 2021, which resulted in flooding and a number of landslides (Jones et al., n.d.). Kerala experienced disastrous landslides and floods in 2018, killing nearly 500 people. In 2019, the Puthumala and Kavalappara landslides killed 81 people, and the Pettimudi landslide killed 66 tea estate workers in 2020 (Jain et al., 2021). Almost all of Kerala's major landslides have been debris flows (locally know as 'Urul Pottal'). In mountainous terrain, steep channels experience rapid flows with extensive runout distances. These traits put people's lives, livelihoods, and housing units in peril, and they also significantly harm the economy. (Wadhawan et al., 2020).

The Geological Survey of India places a strong focus on zoning laws and land use planning as a means of reducing landslide damage and improving disaster preparedness. One of the main causes of concern in rain-related calamities is the failure of hill slope modifications (cut slopes) carried out for development operations and plantings in disaster-prone locations *(Sahana Ghosh, Mongabay Series: Flood and drought,2018;*Jacinth Jennifer & Saravanan, 2022).

Based on a Geological Survey of India assessment, 43% of Kerala's total area is situated in landslip or landslide prone areas. In accordance with the report, 74% of Idukki and 51% of Wayanad are located on mountainous slopes prone to landslides. According to the National Centre for Earth Science Studies' evaluation of natural hazard proneness, 1848 sq. m. in Kerala, which extends along the Western Ghats, is very vulnerable to this natural calamity.



District	High Hazard Zonation Area (km^2)	Low Hazard Zonation Area (km2)
Kannur	168.7	272.6
Kasargod	33.7	205.9
Kozhikode	109	206.7
Wayanad	102.6	196.6
Malappuram	198.6	267.6
Palakkad	324.6	366.9
Thrissur	108.1	217.4
Ernakulam	61.4	229
Alappuzha	-	-
Kottayam	61.8	190.5
Idukki	388.3	873.7
Pathanamthitta	170.3	426.3
Kollam	75.6	191.1
Thiruvananthapuram	45.6	114.9
Total	**1848.3**	**3759.2**

Figure 2: Overall Landslide Hazard Zones of Kerala (Source: State Disaster Management Authority of Kerala (SDMA))

Landslide Susceptibility Map (LSM):

According to Brardinoni (et. Al. 2003), it is extremely difficult to identify tiny landslides to a significant extent and to detect all landslide features from photographs in mountainous forest watersheds with canopy cover. Any landslide-related research must start with an accurate mapping of a landslide's magnitude, notwithstanding the difficulty of this task. Governmental documents, newspapers, archival records, historical travel guides, and citizen accounts are a few of the typical sources of information on landslide occurrence. Although certain exaggerations can be found in these records, they nonetheless offer a good deal of information about the actual occurrences (Azemeraw Wubalem, 2021; Sahoo, 2009). Mapping the characteristics and surface aspects of landslide complexes is a crucial part of the database used to keep track of landslides. That's where Landslide Inventory Map, Landslide Hazard Map, Landslide Susceptibility Map, Landslide Risk and Zonation Maps come into picture. These are necessary to categorise landslides and track their progression.

The possibility of future land sliding is depicted on maps of Landslide Susceptibility based purely on the inherent characteristics of an area or site. Three site parameters have the most impact on susceptibility: rock or soil strength, previous failure (as verified by a landslide inventory), and slope steepness. Such maps are referred to as "landslide potential maps" by some organisations. Three of the key site characteristics that affect vulnerability are rock or soil strength, slope steepness, and prior failure (as established by a landslide inventory) (US Geological Survey; Khanh, n.d.).

Housing Scenario in Mountainous Terrain of Kerala:

One of the most basic requirements is shelter, and housing is a human right. It is a civic responsibility to provide suitable housing. Habitat is no longer regarded as merely a roof over the residents' heads to shelter them from the whims of nature. It has expanded in terms of efficiency, safety, and utility (Government of Kerala State Planning Board, n.d.). Many of these "Land Slide Prone Areas" may not have been susceptible to landslides before human-caused climate change enhanced torrential rain events all over the world. Kerala's public housing plans began in the early 1950s with the village housing scheme, which was funded by the Government of India's Community Development Programme. Local self-governments (LSGs) have been actively engaged in housing support since the implementation of democratic decentralized planning (DDP) in the State in 1996 (Government of Kerala State Planning Board, n.d.) In hilly areas the construction of houses and living in them is more vulnerable. Some of the major reasons why people tend to have construction in hilly areas are:

- Typically, people choose to live in landslide-prone areas because of the abundant water and fertile land.
- Slopes are preferred because they are less expensive by many poor communities in these vulnerable places.
- In addition, cliffs, mountains and hills offer stunning scenic views.
- Public perception is the key factor in the scientific and political debate surrounding risk reduction. The majority of people, including politicians, are unwilling to engage in mitigation and preparation for such uncommon catastrophes because a terrible disaster might only happen once every ten, fifty, or one hundred years.
- Cultural and emotional costs might also be associated with risk reduction. Their families have lived in a disaster-prone area for generations and leaving the spot where they were raised would uproot them.

When landslides happen, a great number of lives are lost, and infrastructure is harmed. The populace may occasionally be ignorant of the risks or unable to pay to go to safer areas. Hence the housing construction in those areas increase over time without proper planning and government rules violation. Kerala government has taken various schemes into consideration for better housing and safety of the public.

The Central Government Schemes like JNNURM (Jawaharlal Nehru National Urban Renewal Mission), BSUP (Basic Services for Urban Poor), IHSDP (Integrated Housing and Slum Development), IAY (Indira Awas Yojana) and the State Government Schemes like Housing schemes of Kudumbasree, NFWF Housing Scheme and other housing schemes by Fisheries department, Housing Schemes of Housing Department for the Poor implemented by Housing Board, Innovative Housing Scheme for urban poor, Saphalyam Housing Scheme (Flats) for landless and houseless, Grihasree Housing Scheme, One Lakh Housing Reconstruction Scheme, House Building Grant helps in better housing planning. Along with these schemes, Under the following two programs the government of Kerala are trying to incorporate all the ones in need for housing especially the ones who are affected by natural calamities.

- Project LIFE- Livelihood, Inclusion, and Financial Empowerment (LIFE) is a state-level housing development project that envisions a complete rehabilitation programme for the state's landless-homeless population, including programmes for nourishment, social and financial security, and skill development aimed at improving their livelihood. This mission would provide housing for 4.32 lakh families. There are 1.58 lakhs of landless homeless people, 2.3 lakhs of landless people, and 44,000 incomplete dwellings and families from coastal and plantation areas (Government of Kerala State Planning Board, n.d.).

- Rebuild Kerala - Rebuild Kerala is a State Government programme aiming at improving road infrastructure following the floods. High-quality, long-lasting road infrastructure is a prerequisite for any state's social, economic, and industrial development. The government established the Project Management Unit (PMU) for the rehabilitation of damaged road assets as part of the Rebuild Kerala Initiative (https://rki.lsgkerala.gov.in/).

Many landslide, mudflow, and debris flow issues can be reduced with correct design, land-use zoning, and professional inspections. For this, the understanding of different approaches towards residential structures and other structures, construction rules and guidelines, major mitigation methods etc. is a necessity and should be taken into consideration before any construction.

Common Gaps of Housing in Hilly Areas:

All of the homes destroyed by landslides were situated on precarious mountain slopes. Houses in several locations suffered from foundation settlement and were subject to subsidence. Areas covered in a thick layer of mud, possibly on the site of previous landslides, experienced subsidence. The majority of house damage in hilly areas of Kerala was brought on by "Shallow Landslides." They happen when heavy rains cause the soil on the hillside to become saturated. Constructions on hillsides differ greatly from those on the plains, so different rules must be followed in hilly areas. It is important to create instructions for hillside buildings (Developing Appropriate Strategies for Housing in Kuttanadu, 2018). The following are typical housing gaps that prompt people to purchase land in mountainous places.

a) Shortage of land

The first and most significant barrier is a lack of available excess land in Kerala. The second barrier is that this land must be located in areas where the recipients can find work that matches their ability. Furthermore, market forces have permeated all aspects of house construction activities. The poor do not have access to common natural resources used in construction. They are unable to afford modern technology and consulting services. Land prices are currently much above the means of the middle class, let alone the impoverished. These reasons eventually lead people in search of land in Hilly terrains (Government of Kerala State Planning Board, n.d.).

b) Lack of Planning in Housing

At the moment, planned habitat development receives the least attention. Houses are being built in areas where there are insufficient community services and infrastructure amenities. Local governments should be reinforced in order to implement a planned neighbourhood development that includes all infrastructure required for comfortable and quiet living. Environmental concerns, genuine beneficiary needs, capability and potential, and so on were not prioritised in the current housing programme and schemes (Government of Kerala State Planning Board, n.d.).

c) Lack of Financial Support

The legal framework, building codes, and PWD codes are incompatible with the standards for encouraging cost-effective, energy-efficient, and environmentally friendly technology and approaches for sustainable housing programmes. Due to the ever-increasing cost of inputs and construction, any financial aid granted by government agencies has shown to be totally inadequate for finishing house construction on time (Government of Kerala State Planning Board, n.d.).

Role of Landslide Susceptibility Mapping in effective relocation of people:

The landslide susceptibility map plays a very crucial role in the prediction and identification of landslides. Though the accuracy of prediction remains questioning, the constant monitoring and studies of the area helps in easy and efficient evacuation of people from those vulnerable areas.

The main causes of landslides in mountainous terrains include removal of vegetation (deforestation) of the hill, change of slopes (base cutting for construction of houses and infrastructure), and large-scale removal/excavation of soil at the toe of the hill (for developmental works in the region). The cumulative rains over many days preceding the landslide totally saturated the soil mass and raised pore water pressure, which, combined with increased own weight owing to saturation, increased the driving power for the slide, resulting in landslides and property destruction (Sooraj & Kumara, 2020).

The Landslide Susceptibility Map is created with proper analysis of certain parameters/conditioning factors. These parameters, like elevation, slope aspect, profile curvature, drainage density and road density, land use and land cover, rainfall, soil type, weathering and erosion, platonic movements, seismic intensity, affect the occurrence of landslide over a great extent.

With the creation of LSM, all these parameters or conditioning factors responsible for landslide occurrence could be identified prior. This prior identification helps in early detection of calamity and easy evacuation and displacement of residents in these regions. The development of LSM also aids in the identification of environmental changes over time and in identifying the immediate disaster-prone locations where actions to be done.

Urgent Need for Landslide Susceptibility Mapping in Kerala:

A landslide susceptibility map can benefit in land use planning in landslide-prone areas. Landslide susceptibility maps indicate the possibility of future landslides based purely on the intrinsic characteristics of a location or place. Prior failure (as determined by a landslide inventory maps), rock or soil strength, and slope steepness are three of the more critical site variables that influence susceptibility. The locations are identified by comparing the current distribution of landslides with some of the major causes of land sliding, such as steep slopes, weak geologic units that weaken when wet or disturbed, and poorly drained rock or soil. These maps do not offer absolute forecasts; they merely show the relative stability of slopes (Wadhawan et al., 2020).

In Kerala, Idukki district has the greatest percentage of landslides at 49.04%, followed by Malappuram (12.82%) and Wayanad (11.04%) districts (Jones et al., n.d.). When studying the landslides, it was discovered that plantations, which include those for tea, coffee, rubber, cardamom, and other commodities, accounted for 59.38% of the total number of landslides. The second most common land use is forest, which accounts for 21.85% of all landslides (including all types of forests, including evergreen, deciduous, fragmented, etc.). Other human-modified land use techniques had landslide occurrences of 0.37%, 2.20%, 2.39%, and 0.42%, respectively. These include built-up, farmland, forest plantations (teak, pine, etc., planted forest) and quarry (Jones et al., 2021).

A study used the variety of models to examine the part played by anthropogenic conditioning factors in initiating landslides. The outcome suggests that, in addition to natural factors, human-modified landscapes play a crucial part in landslide occurrences (Srinivasaperumal et al., 2011); which needs to be identified and studied.

Conclusion:

A map offers a clear visual representation of a region and all of its distinctive features, including roads, municipal boundaries, land use, zoning, and other aspects. Also, maps make it possible to summaries key elements of the area, including its population, terrain, resources, and infrastructure. The requirement of maps is highly desirable when it comes to the locating and demarcating the area of disasters. It is shown that landslides are significantly influenced by natural elements like slope and rainfall. The primary gap found in the aforementioned review is the limited number of studies and research on house planning in landslide-affected areas. A focus of research should be on how to improve housing planning in landslide-prone areas and what precautions should be taken for the evacuation and resettlement of the populace. Therefore, the need for a well-factor-analysed landslide susceptibility map in the area of landslide recurrence to predict the future occurrence is highlighted by references from other works.

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