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Changing Land Use, Land Cover and Climate: The Significance of Social Capital in Disaster Resilience in Kerala

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Abstract

Objectives: It aims to identify the land use and land cover effect on climate change in cyclone affected areas in Thiruvananthapuram District. It aims to demonstrate the significance of examining social capital at the community or spatial level to achieve resilience more rapidly. **Method:** Several satellite imageries were utilized in order to evaluate the changes in land use land cover (LULC) that occurred within the research area. In order to comprehend the spatial distribution of social capital among households in the district's coastal and inland villages, which is essential for achieving disaster resilience, a primary survey was also carried out among 200 households in two Ockhi-affected villages, Karumkulam and Venganoor. **Findings:** The study shows that the studied area has seen substantial changes during the period 2018 and 2025. The period was characterized by the continuous decrease in vegetation cover and the doubling of the built-up area of two villages. Furthermore, it shows that inland villages immediately became resilient after the disaster, whereas coastal villages took almost two years to do so due to a lack of social networks. **Novelty:** Satellite images used in remote sensing have been used to classify and map changes in LULC by finding different parts of the landscape. More than 70 training samples were gathered from all LULC classes to ensure precise classification, with over 15 samples obtained for each class. Variations in four classes, such as built-up areas, agriculture, mixed trees, and water bodies in two villages, have been identified for three periods 2000, 2018 & 2025.

Keywords: Climate Change; Cyclone; Disaster Resilience; LULC; Social Capital

1 Introduction

Kerala is a highly urbanized society, with nearly half of the population (48%) now residing in urban centres, the conversion of land utilized for uses other than agriculture continues to worsen in the state of Kerala. Escalating the changes in land usage can have a negative impact on the state's ability to maintain ecological sustainability [(1)]. After taking into account the most recent demographic predictions of Annual Vital Statistics Report 2021, it is predicted that the population density of Kerala has reached 904.61 per square kilometre, making it the highest in the country at 860 per square kilometre and

is highly vulnerable to natural disasters and changing climatic dynamics[2]. From the past seven years, the State has witnessed severe changes in climatic dynamics which caused natural calamities such as cyclone, floods and landslides, seasonal drought, lightening, forest fire, coastal erosion and high wind speed in many parts of the State. On November 30, 2017, a powerful tropical storm known as Ockhi made landfall along the coast of Kerala and Tamil Nadu, causing extensive damage in the coastal region of the Thiruvananthapuram district[3]. The storm was responsible for the deaths of 75 people and left 141 others missing. Following the devastation caused by Cyclone Ockhi, the government of Kerala undertook several types of relief programs for the families of fishermen who had lost their lives. Despite of this, six years after Cyclone Ockhi, the families of fishermen in Kerala are working very hard to reconstruct their life and the coastal villages are still in the process of recovering from its effects[4]. This means that the community that was impacted by the disaster has not been able to obtain the assistance that is needed for rehabilitation and relief. In this context, natural disasters namely cyclone Ockhi in 2017 and severe floods and landslides in 2018 and 2019, it is reported that the cyclone affected fishermen community struggled a lot to attain resilience in the State whereas the flood affected communities have coped well and recovered from the disaster impact. According to social capital theory, an increase in a community's social capital will directly enhance its resilience to natural disasters[5]. A preliminary observation suggests that the stock of social capital among cyclone affected fisher community is too week to access resources and probably that is the reason they are struggling hard to recover whereas the stock of social capital among the flood affected mainstream population is larger enough and that has, undoubtedly, helped them to attain resilience faster.

Furthermore, the literature demonstrates that the growing urban population and human actions in conjunction with it have generated a great deal of challenging circumstances[6]. The recent climatic dynamics in Kerala reveals the same. The key drivers that are driving climate change on a regional and global scale are changes in land use and land cover, which are commonly referred to as LULCC[7]. It is anticipated that the combination of climate change and land use land cover change (LULC) could result in an increase in the frequency of drought and flood events[8]. The implications of climate risk are highlighted by the community's low adaptive ability and significant exposure to the environment[9]. There have been studies that have looked into the changes that have occurred in LULC in India concurrently with the incidence of climate change[10]. The acquisition of an extensive understanding of LULC is a critical component of the preservation of a sustainable, benign, and healthy environment[11]. The LULC change that has occurred over southern India which includes the states of Kerala, Telangana, and Tamil Nadu has resulted in a rise of 20–25 per cent in the frequency of heavy rainfall events taking place[12]. The researchers reported that the change in LULC is producing an increase in the convective available potential energy. This is due to the fact that the surface temperature and sensible heat fluxes are expanding. Along with this, an analysis of land use in the Bagalkot district of India and determined the various land use classifications that are present in the district[13]. Research conducted in Kerala demonstrates evidence of land-cover transformations that are linked to urbanization[14]. It is also explored how the floods that occurred in Kerala in 2018 were affected by uncontrolled urbanization and built-up construction throughout the course of the years[15]. These transformations have led to a decrease in the amount of greenness, as well as an amplification of urban heat island effects[16],[17]. Alterations in land use patterns over time and the extent to which they impact the human population and the natural habitat are highlighted by advanced technologies such as remote sensing and geographic information systems[11]. Investigations continue to be fragmented and district-specific, despite the fact that research conducted in districts such as Wayanad and Kottayam demonstrates the importance of RS–GIS in monitoring vegetation and surface temperatures[18],[19]. In another study, in the regions of Thiruvananthapuram district that were impacted by the cyclone Ockhi, homes and business establishments have taken up residence in the coastal belt that was formerly used for the cultivation of coconuts[20]. The study reveals that nearly the whole geographical area of the coastal village has been characterized by a pattern of land use that has resulted in the transformation of agricultural land into built-up land. This transformation has occurred as a result of the transformation of land use. Nevertheless, it did not describe the rate at which the land cover was changing. It is found that there has been very few research carried out on the subject in India and in Kerala. In spite of this, investigations at the regional and local levels are necessary in order to arrive at more informed conclusions regarding the interplay of LULC with climate change. Therefore, the present study tries to identify the land use and land cover effect on climate change specifically in cyclone affected areas in the State.

In the aftermath of a catastrophe, social capital is an extremely important factor in the reconstruction process. Social capital that is formed through bonding is inwardly focused, with the goal of building close ties (such as those with family and friends) for the purpose of mutual support and belonging. The act of bridging involves looking outward with the intention of connecting individuals who come from different social, economic, or cultural origins. When put in a more straightforward manner, social capital can be described as the adhesive that binds individuals together[21]. Research has shown that communities that have a bigger pool of social capital tend to be more effective in post-disaster rescue and recovery efforts[5]. When it comes to recovery, the speed and ease of recovery are dictated by the magnitude of the incident as well as the resistance of the social system to absorb the repercussions of the event[21]. In this context, the rescue and relief activities that took place in Kerala after the disasters

revealed that there is probably a discrepancy in the allocation of social capital among the various demographic categories and spatial/regional groups. This inequality had a negative impact on the distribution of post-disaster items to the victims[20]. It has been observed that no study investigates the relationship between LULC change and social capital in the context of post-cyclone resilience at the village level. As a result, the purpose of this paper is to concentrate on explaining why it is important to investigate the many aspects of social capital in the context of disaster resilience in Kerala, particularly in light of climate change. Thus, it aims to demonstrate the significance of examining social capital at the community or spatial level to achieve resilience more rapidly.

2 Methodology

Global warming is expected to increase the frequency of cyclones like Ockhi[3]. Since the country has experienced disasters like cyclones in Odisha, floods in Mumbai and Assam, drought in Chennai, and others, this study helps policymakers strengthen social capital's role in community disaster preparedness and recovery at the local and national levels. Kerala has high human development compared to other states. Coastal populations cannot obtain resources due to low social capital[20]. Hence, studying social capital determinants among communities and spatial forms benefits other states.

Tropical Ockhi has a significant impact on the coastal regions of the Thiruvananthapuram district in the state of Kerala. Therefore, for the purpose of this study, two villages, one from the coastal area Karumkulam and one from the inland area (Venganoor), that are impacted by Ockhi and are located within a single block panchayat in the Thiruvananthapuram district have been chosen. The location map is given in Figure 1.

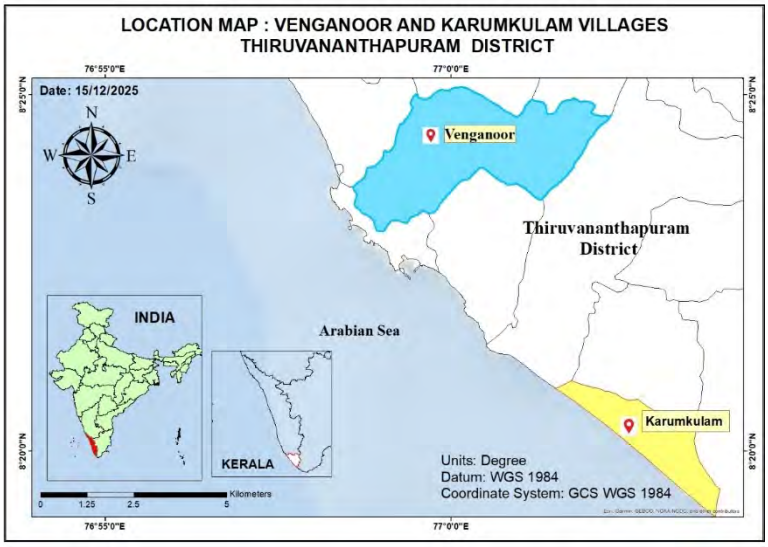

Fig 1. Location Map of Study area. Source: Compiled by the researcher, 2025

Different satellite images assessed LULC changes in the research area for the year 2000, 2018 & 2025. Image resolution was 10 m and 30 m which is given in Table 1. United States Geological Survey (USGS) platforms, https://earthexplorer.usgs.gov/ and https://earthengine.google.com/ provided all Landsat images. Land Use Land Cover change assessments use these datasets widely. The images exhibited great spatial resolution and less than 10 per cent cloud cover. The research area shapefile came from Open Street Map. All data were translated into WGS84-UTM Zone 43N coordinates to study Karumkulam and Venganoor Village LULC changes. QGIS 3.40 assessed LULC changes and processed images, whereas ArcGIS 10.4 (Esri, Redlands, CA, USA) performed spatial analysis.

The research area was defined, and false colour composite (FCC) images were produced by merging spectral bands to enhance visual perception and increase classification precision. Visual interpretation offers significant insights regarding temporal land cover alterations. Techniques for image augmentation have enhanced the interpretability of satellite imagery. Satellite imagery-based remote sensing techniques have been utilized to classify and map land use and land cover changes by recognizing unique landscape features[22]. Over 70 training samples were gathered across all land use and land cover classes to achieve precise classification, with more than 15 samples obtained for each class.

Table 1. Datasets and Sources Utilized for the Study

Sl.No	Satellite/Sensor	Acquisition Date / Year	Spatial Resolution of Spectral Bands (m)	Source
1	Survey of India Topographical Map	1970	1: 50,000	Survey of India
2	Landsat 7	2000	30 Meter	www.earthexplorer.com
3	Landsat 8	2018	30 Meter	https://earthengine.google.com/
4	Landsat 8	2025	30 Meter	https://earthengine.google.com/
5	Sentinel-2 (MSI, L2A)	2025	10 Meter	https://browser.dataspace.copernicus.eu

Source: Compiled by the researcher, 2026

For this study, SOCAT method of World Bank with certain modifications will be more applicable because it covers household and community social capital [23]. The study has analyzed three dimensions of social capital. a) Membership in Associations and Networks (Structural Social Capital); b) Trust and adherence to norms (Cognitive Social Capital); and c) Collective Action (an output metric). Each dimension is operationalized with numerous indicators deemed significant in the Kerala setting, quantified through multiple latent variables. The study indicators are diversity of membership, participation in decision making, extent of mutual support, solidarity, trust, extent of conflict avoidance, collective action to provide services. The present study demonstrated that the Social Capital measures had strong reliability, with Cronbach's alpha coefficients often between 0.70 and 0.90. The study utilized a three-stage stratified random sampling procedure, including block, village, and home levels, to select the households. Approximately 200 houses from the cyclone-affected regions are surveyed, with participants randomly selected from the village assessment record. A standardized questionnaire is employed to gather data regarding their demographic profile and socioeconomic status. Additionally, inquiries are made to evaluate the extent of social capital among the victims. The collected data have been analysed with the help of IBM SPSS Statistics (Version 22.0). The statistical techniques used in the study are mean scores with standard deviation, independent samples t test and Mann-Whitney U Test (Non-Parametric Test).

3 Results and Discussion

Four major LULC types such as built-up area, agriculture, mixed trees and water bodies were classified for the years 2000, 2018 & 2025. A detailed description of LULC classes is given in Table 2.

Table 2. Land Use Land Cover Classification

LULC Class	Details of the LULC Class
Built-Up Area	Includes all residential, business, and industrial areas, settlements, villages, and infrastructure related to transportation.
Mixed Trees	Comprises trees, shrubs, and all types of vegetation (excluding standing crops).
Agriculture	Encompasses cropland, including both large and small farms, as well as mechanized farms.
Water Bodies	Refers to anybody of open water, such as ponds, rivers, and lakes.

Source: Compiled by the researcher, 2026

This study adhered to the Kerala State Land Use Board classification for the generation of land use and land cover data. The extraction of Land Use/Land Cover (LULC) and the analysis of changes in urban landscapes are essential for comprehending urbanization trends and their environmental consequences [22]. Several studies have utilized remote sensing and GIS methodologies to observe land use and land cover changes, indicating substantial alterations in metropolitan regions over time [24], [25]. This study utilized the widely adopted Segmentation and Classification based Train Support vector machine classifier within ArcGIS 10.4 program for LULC classification implementation. Venganoor and Karumkulam Village were categorized into four primary land use and land cover classes: built-up area, mixed trees, agriculture, and water bodies (Figure 2 & Figure 3). Various spectral signatures from distinct satellite pictures were detected and corroborated using Google Earth images from the corresponding timeframe. Prior to the assignment of LULC categories, band composition was utilized on the satellite images.

The LULC analysis reveals that the built-up area has increased largely about 60 per cent over a period of 25 years from 2000. This is mainly due to the construction of coastal highway and outer ring road development as a part of Capital Region Development Programme (CRDP). It also shows that area under all types of vegetation, open land and cultivation have come down during this period. This in turn destroys natural carbon sinks, release more stored greenhouse gases, and disrupting the

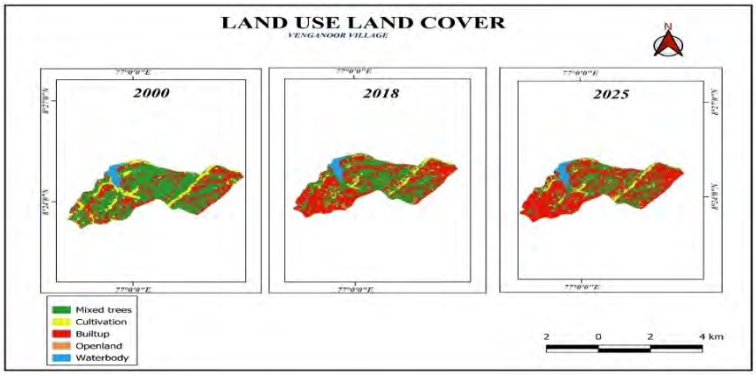

Fig 2. LULC in Venganoor Village in the Years 2000, 2018 & 2025. Source: Compiled by the researcher, 2026

Earth's energy balance. Increased urbanisation is considered as a major factor for this drastic change in land use and land cover in this region. It is observed that construction of buildings and roads are increased during this period. In another study with LULC, the most dynamic land uses in Thiruvananthapuram are agricultural land and the barren land[20]. This significant drop in these land use groups is the result of the rapid urbanization and related land reclamation that has taken place in the area under consideration[26].

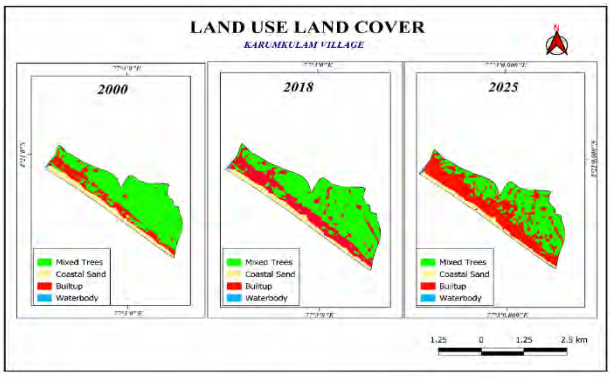

Fig 3. LULC in Karumkulam Village in the Years 2000, 2018 & 2025. Source: Compiled by the researcher, 2026

The LULC analysis in coastal village shows that drastic increase in built up area (from 20 per cent to 55 per cent) over a period of 25 years from 2000 as a result of development of coastal highway and associated development of commercial activities in this area. All type of LULC classification indicates that urbanisation and development of Vizhinjam Harbour causes considerable changes in the region. Such changes suggest that the climatic dynamics may be altered as a result of the high temperature increase following the decrease in vegetation cover.

It is observed that the impact of cyclone Ockhi was high due to decline in natural vegetation in the area. More than 97 percent of the coastal dwellings in Karumkulam are below the poverty line, whereas it is only 21 percent in Venganoor village. It is found that almost 96 per cent of homes in Karumkulam village have children who have not completed high school. This highlights the disparities in social and economic conditions between coastal communities and inland locations. Fishing is the primary source of income for coastal communities. Public restrooms, which may charge from three to five rupees, serve as their sole means of sanitation. First and foremost, it has been established that they are members of one of the groups. Residents of inland areas have significantly higher standards of living. 40 percent of the homes in the inland village have at least one member of the family working in a Gulf country. 30 percent of those who participated in the survey from Venganoor reveals that at least one member of their family who has employed in the government service. Hence, the results from socio economic analysis itself shows large variations between the two communities residing in coastal and inland villages. To understand the disparities in the stock of social capital between two spatial units or two communities, mean scores and standard deviations for different indicators are calculated and given in Table 3.

Table 3. Scores of Independent Variables among Fisher Community and Other Communities

Independent Variables	Fisher Community/ Coastal Village		Other Community/ Inland Village	
	Mean Score	SD	Mean Score	SD
Diversity Score	52.768	24.826	84.395	13.076
Democratic Function Score	34.929	8.219	76.587	4.409
Mutual Support Score	88.537	15.08	58.971	15.237
Exclusion Score	85.303	7.114	74.213	1.928
Solidarity Score	55.144	13.186	57.99	3.802
Trust Score	44.242	9.565	59.834	2.053
Conflict Avoidance Score	34.857	19.425	65.928	21.353
Collective Action Score	87.488	3.275	94.559	14.901

Source: Calculated from primary data collected, 2025

The diversity score of fisherfolks indicates a moderate level of diversity with high levels of variation. The primary survey indicates that the coastal communities are not interested in participating in various organizations that are comprised of individuals from a variety of occupations. Additionally, the majority of them are not engaged in any networking activities that would establish connections with other mainstream communities in other regions. On the other hand, the diversity score of people in inland village reveals higher levels of diversity with low levels of variation [20]. Among the major eights scores which represents various dimensions of social capital in which Cognitive social capital among the coastal people are very high. It refers to the shared resources within a network that facilitate a shared understanding, including shared language, values, beliefs, and attitudes. It promotes collective action and cooperation by encouraging shared interpretations and decreasing opportunistic behaviour. This intangible asset facilitates the efficient exchange of knowledge and communication among individuals.

Fig 4. House of Fisherfolk in Coastal Village in Thiruvananthapuram. Source: Photograph taken by the researcher in October, 2019

In short, with regard to the coastal communities in the study area, structural social capital is low in comparison to cognitive social capital. This indicates that a community or organization possesses high levels of trust, shared values, and solidarity; however, it does not possess the formal networks, associations, or rules (structural) necessary to effectively act on these qualities. Despite having a similarly optimistic frame of mind, this results in missed possibilities for collaboration, low levels of collective effort, and decreased economic progress[21]. This is true for the fisherfolk in cyclone affected area as it is revealed from the Figure 4 which shows the pathetic housing condition of fisherfolk in cyclone affected area exactly after one year and eleven months. In accordance with previous research, this study demonstrates that the community's access to relief aid is limited because they have relatively few structural social capital[27].

Table 4. Two Sample Independent Tests

Independent Variable	T-Test (Parametric Test)			Mann-Whitney U Test (Non-Parametric Test)
	t-Statistic	DF	P-Value	P-Value
Diversity Score	-4.5691	27	0.000	0.000
Democratic Function Score	-18.058	27	0.000	0.000
Mutual Support Score	5.057	27	0.000	0.000
Exclusion Score	6.509	27	0.000	0.000
Solidarity Score	-0.894	27	0.384	0.659
Trust Score	-6.976	27	0.000	0.000
Conflict Avoidance Score	-3.909	27	0.001	0.001
Collective Action Score	-1.488	27	0.172	0.106

DF= Degrees of Freedom associated with t-statistic

Source: Calculated from primary data collected, 2025

The results from the t-test and Mann-Whitney U Test are given in Table 4, reveals that all the indicators except solidarity and collective are statistically significant and shows difference in two communities. It again substantiates the mean score and standard deviation results. Consequently, the analysis indicates that the coastal communities are inadequately equipped to receive relief aid and other resources during disasters, which necessitated a lengthy recovery process. The results signify the need to enhance bridging and linking social capital among the coastal communities for faster resilience. This finding is consistent with the findings of the earlier study which reveals that the detrimental effects of Cyclone Ockhi were found to be more severe on people who lived in coastal areas as opposed to those who lived in interior areas[20]. This is in line with the findings of Balakrishnan et al.[28] who revealed that the native fish farmers in the lowlands of Alappuzha have experienced significant losses as a result of the floods in 2018. The studies highlight the engagement and participation of the community are essential components in the process of designing effective resilience plans[29].There was a clear demonstration of the high focus placed on community involvement in attaining resilience[30].

4 Conclusion

The LULC analysis in cyclone Ockhi affected areas in Thiruvananthapuram district for the years 2000, 2018, and 2025 demonstrates that the patterns of land use in the area that was examined have undergone significant changes. In 2000, the built-up territory of the inland village Venganoor accounted for only 30 percent of the total land area. However, it has increased by twofold in 2025. This is also true for the coastal village Karumkulam as well. The substantiation of the ground truth indicates that a linear pattern of settlement type has emerged along the highways due to urbanisation. There has been a significant increase in the number of commercial structures and the conversion of agricultural land into built-up areas in both villages, which are considered significant contributors to climate change. All of these factors shed light on the fact that there is microclimatic change as a result of unplanned development and the loss of vegetation. This change can come about as a consequence of the creation of small heat islands, which can interact with tropical cyclones that are approaching and intensify the consequences of storms.

Therefore, the study provides a clear depiction of the interaction between changes in land use, changes in land cover, and changes in climate. The disaster resilience is positively associated with bridging and linking social capital. In the study area, it is viewed that the inefficient distribution of relief and the limited structural social capital have enabled the residents of coastal regions to resume their daily routines one year and a half after the disaster. Conversely, residents of the interior who possess a higher level of cognitive social capital and structural social capital are capable of requesting additional resources from the

government during the post-disaster period. As a result, the communities located inland gained resilience at a more rapid pace than the villages located along the coast.

This assertion is also corroborated by the statistical analysis. The Mann-Whitney U Test reveals that the two communities have significant differences in terms of bridging social capital. This is demonstrated by the fact that the p value of diversity score, democratic function score, and mutual support score for the two communities is significant. It is clear that inland communities have a higher level of bridging social capital than coastal communities do because the mean scores for diversity score and democratic function score are significantly higher (84.395 and 76.587 respectively) for inland communities than they are for coastal communities. The collective action score is also high among the inland communities. As a result of the findings, it is clear that the mobilization of bridging and linking social capital is equally important for connecting with external, powerful resources. This suggests that effective management of collective action involves both of these types of social capital. Therefore, the study underscores the significance of social capital in the attainment of resilience at community and spatial level by pointing out the resilience story of inland communities in the cyclone Ockhi affected areas of Thiruvananthapuram district of Kerala. The findings of this study contribute to the existing body of knowledge, which can assist in the development of more efficient methods for incorporating social capital into climate resilience strategies that are sensitive to the context of a variety of geographical and cultural environments.

Social capital is a critical component of resilience building in the disaster management endeavor, which is a collaborative effort between the local community and local government. This study is confined to examining the importance of social capital in disaster resilience. Further investigation into the nature, sources, and impacts of social capital is necessary but exceeds the scope of this work. Investigating the interplay of bonding, bridging, and linking social capital in relation to climate change provides a conceptual framework applicable to various marginalized or ecologically vulnerable contexts, such as forest-adjacent communities or politically underserved countryside regions. It will be beneficial to policymakers in the promotion of disaster preparedness at the community and spatial levels. The errors in the criteria for aid targeting can also be rectified in the context of social capital research.

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