

Integrating Social Innovation and Geoinformatics for Community-Based Disaster Risk Reduction: A Sandbox Approach in Mueang Tak District, Thailand

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ABSTRACT

Background and Objectives: Natural disasters, particularly landslides, floods, and droughts, pose increasing threats to the socio-economic stability and environmental security of communities in Mueang Tak District, Tak Province, Thailand. Conventional top-down disaster management strategies often suffer from a critical data-action gap in which advanced spatial technologies and risk information are not effectively translated into locally actionable practices. To address this challenge, this study aimed to integrate social innovation with geoinformatics technology to strengthen community-based disaster risk reduction. The specific objectives were to analyze natural disaster risk areas using Geographic Information Systems (GIS) and Remote Sensing (RS), investigate community-based social innovation needs, and develop and evaluate “Sandbox Innovation Areas” for landslide, flood, and drought management.

Methodology: The study employed an integrated research design structured into four phases: spatial risk assessment, community survey, participatory sandbox development, and evaluation. Spatial data were processed using Google Earth Engine (GEE) and GIS to identify priority risk areas. Social data were collected from 462 residents using stratified multistage cluster random sampling across landslide-prone, flood-prone, and drought-prone areas to assess existing practices and innovation needs. Spatial and social findings were integrated to guide the selection of three pilot sandbox areas and the design of capacity-building activities for Community Innovators. The sandbox process included participatory GIS, field validation, co-creation of community risk maps, and evaluation of perceived knowledge gain and stakeholder opinions.

Results: The spatial analysis identified critical risk areas, revealing that 40.13% of Mae Tho Subdistrict was classified as high to very high landslide risk, 16.98% of Wang Hin Subdistrict faced high to very high flood risk, and 22.05% of Pa Mamuang Subdistrict was exposed to high to very high agricultural drought risk. The social survey indicated strong demand for practical and

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participatory innovations, particularly nature-based solutions, village-based response teams, and community drills. The sandbox intervention developed 32 Community Innovators who applied GPS and geospatial tools to validate risk locations. Post-training self-assessment indicated a high level of perceived knowledge gain ($\bar{x} = 3.86$), while stakeholder opinions toward the sandbox model were also rated at a high level ($\bar{x} = 4.16$), reflecting favorable perceptions of the approach.

Discussions: The findings show that the sandbox mechanism can help bridge the gap between academic spatial technology and local disaster-management practice. By integrating scientific risk information with community knowledge and participatory learning, the approach enabled local actors to verify risk conditions, interpret spatial information, and co-create context-specific responses. This process supported a “Hybrid Knowledge Model” in which geoinformatics complements rather than replaces local wisdom, thereby strengthening participation, ownership, and local decision-making.

Conclusions: Integrating social innovation with geoinformatics can strengthen community preparedness and support locally responsive disaster risk reduction. Sustainable implementation requires local administrative organizations to invest in community-level spatial information, participatory risk-management processes, and continued development of community innovators. The sandbox approach provides a practical mechanism for translating risk evidence into local action, while future applications in other disaster-prone areas are recommended to assess its transferability and scalability.

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Introduction

Natural disasters, particularly landslides, floods, and droughts, pose continuing challenges to socio-economic stability, environmental sustainability, and community well-being. Mueang Tak District, Tak Province, Thailand, represents a complex multihazard setting characterized by steep mountainous terrain in the west, low-lying communities along the Ping River, and rain-fed agricultural areas vulnerable to seasonal drought. Such contrasting environmental and socioeconomic conditions require disaster risk management approaches that can respond to different local contexts.

Although geoinformatics technologies provide increasingly detailed information for identifying and assessing disaster risk, a persistent challenge lies in translating technical spatial information into practical knowledge that can be understood and used by communities. Disaster management remains ineffective when risk maps and scientific information are disconnected

from local experience, community priorities, and operational decision-making. Consequently, effective disaster risk reduction requires not only accurate spatial evidence but also mechanisms that enable local actors to participate in interpreting, validating, and applying such information.

This study addresses this challenge by integrating geoinformatics with social innovation through the development of “Sandbox Innovation Areas.” The sandbox approach provides a participatory setting in which spatial risk information, community knowledge, and locally appropriate innovations can be brought together through learning, field validation, and co-creation. Rather than treating communities merely as recipients of technical information, the approach emphasizes their role as active participants and Community Innovators in local disaster risk management.

Therefore, this study aimed to integrate social innovation with geoinformatics technology to enhance community-based disaster risk reduction in Mueang Tak District. The specific objectives were to: (1) analyze and assess landslide, flood, and drought risk areas using geoinformatics; (2) investigate existing community practices and social innovation needs for disaster management; and (3) develop and evaluate prototype Sandbox Innovation Areas in Mae Tho, Wang Hin, and Pa Mamuang Subdistricts through the development of Community Innovators. The study seeks to demonstrate how spatial evidence can be translated into locally relevant action and contribute to more participatory and sustainable disaster risk management.

Review of Literature

Geoinformatics for Multi-Hazard Risk Assessment

Geoinformatics technologies, particularly Geographic Information Systems (GIS) and Remote Sensing (RS), have become important tools for disaster risk assessment because they enable environmental, physical, and socioeconomic information to be analyzed within a spatial framework. Previous studies have demonstrated their applicability across different hazards. Patil and Panhalkar (2023) applied the Landslide Numerical Risk Factor (LNRNF) method for landslide susceptibility mapping, while Abay et al. (2025) demonstrated the application of GIS-based frequency ratio analysis. Alamrew et al. (2024) further combined GIS, frequency ratio, and the Analytical Hierarchy Process (AHP) for landslide susceptibility and risk zonation. For flood assessment, Gacul et al. (2024) applied a GIS-based Fuzzy Analytical Hierarchy Process (FAHP), whereas Bostani et al. (2024) emphasized the importance of multidimensional assessment in drought risk analysis. Collectively, these studies demonstrate the value of integrating multiple spatial criteria for identifying priority risk areas and supporting evidence-based disaster planning.

However, spatial risk assessment alone does not ensure that the resulting information will be understood or applied by local stakeholders. Disaster risk involves interactions among hazard, vulnerability, and exposure, while practical risk reduction additionally depends on local capacity to interpret and act upon spatial information. This creates a need to connect technically derived risk evidence with community knowledge, priorities, and decision-making processes.

Social Innovation and Community-Based Disaster Risk Reduction

Community-based disaster risk reduction emphasizes the participation of local people in identifying risks, developing responses, and strengthening local capacity. Social innovation complements this perspective by focusing on new or improved social processes, relationships,

and collaborative practices designed to address unmet societal needs (National Innovation Agency, 2024). In the context of disaster management, social innovation may include community warning systems, local response teams, participatory risk mapping, knowledge-sharing mechanisms, and collaborative arrangements among communities, local authorities, and academic institutions.

Participation is particularly important when scientific information must be translated into locally meaningful action. Vukomanovic et al. (2019) demonstrated that participatory geospatial approaches can enhance stakeholder understanding and involvement in spatial planning, while Matharage et al. (2025) emphasized the role of bottom-up engagement in strengthening community capacity for disaster risk reduction. In Thailand, Klomklumnum et al. (2023) highlighted the integration of community knowledge and geoinformatics in the development of Community Innovators. These studies suggest that the effectiveness of spatial technologies depends not only on the quality of the information produced but also on the capacity of communities to understand, adapt, and apply that information within their own contexts.

Sandbox Innovation Areas as an Integration Mechanism

The sandbox approach provides an environment for testing, adapting, and co-developing innovations under real-world conditions. Its principles are closely related to living labs and innovation testbeds, which emphasize experimentation, collaboration, iterative learning, and stakeholder participation before wider implementation (Rosemberg et al., 2020; Schuurman et al., 2024). Such approaches allow technologies and management practices to be adapted to local conditions rather than transferred directly from technical or institutional settings.

Within disaster risk reduction, a Sandbox can serve as an interface between scientific evidence and community action. Geoinformatics provides spatial information for identifying and understanding risk, while social innovation provides the participatory processes through which that information can be interpreted, validated, and transformed into locally relevant practices. This orientation is consistent with contemporary disaster risk reduction approaches that emphasize locally appropriate, participatory, and adaptive solutions (UNDRR, 2021).

Despite increasing applications of geoinformatics and participatory disaster management, these two domains are often implemented separately. Relatively limited attention has been given to their systematic integration through a Sandbox process across multiple disaster contexts within the same administrative area. The present study addresses this gap by linking geoinformatics-based risk assessment with community social innovation needs, participatory learning, field validation, and Community Innovator development for landslide, flood, and drought management in Mueang Tak District.

Research Methods

Research Design and Study Area

This study employed an integrated research design combining quantitative spatial analysis using GIS and RS with a community survey and participatory social innovation processes. The study area was Mueang Tak District, Tak Province, Thailand. Administratively, the district is divided into 11 local administrative units, comprising Tak Municipality (TM) and 10 sub-districts: Nong Bua Nuea (NBN), Mai Ngam (MNG), Pong Daeng (PD), Nam Ruem (RM), Wang Hin (WH), Mae Tho (MT), Pa Mamuang (PMM), Nong Bua Tai (NBT), Wang Prachop (WPC), and Taluk

Klang Thung (TKT). Geographically, the district is situated along the Ping River, which serves as the main water resource and flows from north to south through the area. Regarding land use and land cover (LULC), more than 60.93% of the district is covered by forest areas, primarily in the highlands. Agricultural land represents the second-largest category, in which cassava and rice are the dominant economic crops (Figure 1).

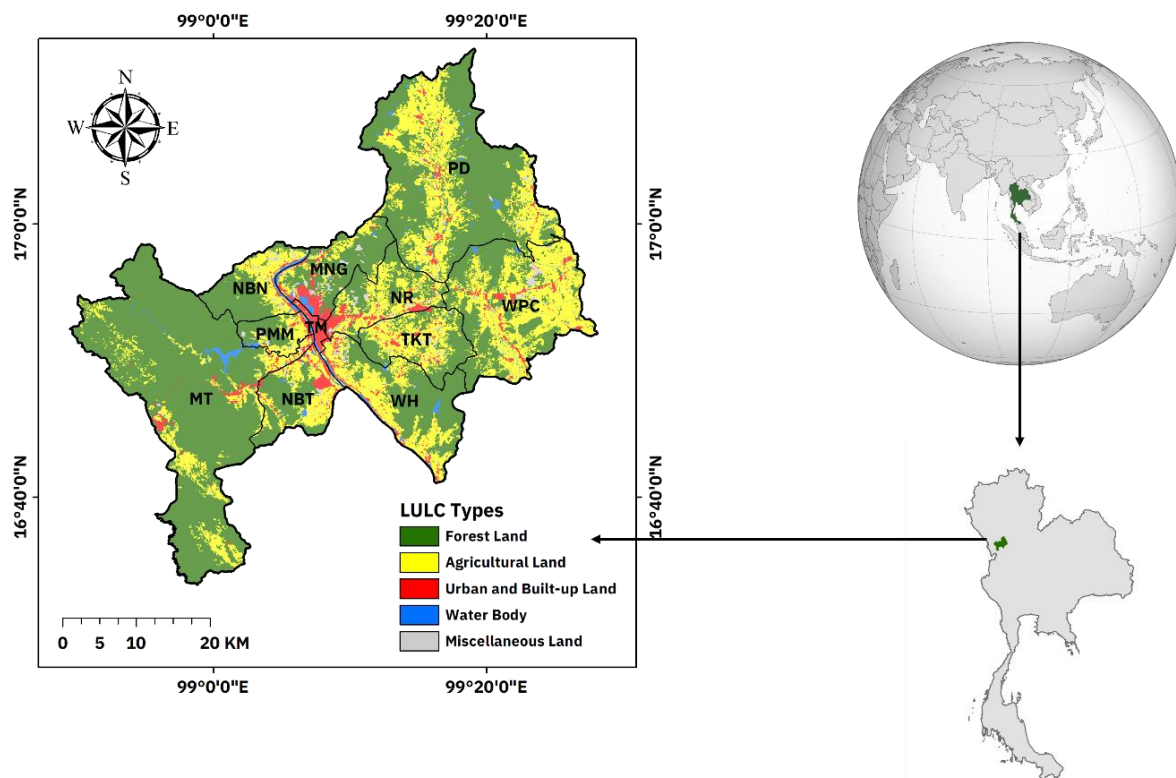
Mueang Tak District was selected as the case study because it represents a geographically diverse multihazard setting within a single administrative area. The western mountainous zone is susceptible to landslides, the low-lying communities along the Ping River are exposed to recurrent flooding, and the rain-fed agricultural areas experience seasonal drought. This combination of contrasting hazard contexts provides an appropriate setting for examining how geoinformatics-based risk information can be integrated with community knowledge and social innovation to support locally differentiated disaster risk reduction strategies.

To implement the “Sandbox Innovation Area,” the research specifically targeted three pilot subdistricts representing distinct disaster contexts:

- 1) Mae Tho Subdistrict: Selected as a high-risk area for landslides due to its mountainous terrain and steep slopes.
- 2) Wang Hin Subdistrict: Selected as a high-risk area for floods, being located in the low-lying basin of the Ping River.
- 3) Pa Mamuang Subdistrict: Selected as a high-risk area for droughts, characterized by agricultural zones with insufficient water management systems.

Figure 1

Map of Research Locations



Participants

The participants were categorized into two main groups:

1) Survey Respondents: A total of 462 residents from the disaster-prone areas in Mueang Tak District were selected using stratified multistage cluster random sampling (Cochran, 1977). The sample was distributed across the three risk strata: landslides ($n = 154$), floods ($n = 154$), and droughts ($n = 154$). These respondents provided information on existing social innovations and community needs for disaster management.

2) Sandbox Participants and Stakeholders: The participants consisted of 32 Community Innovators and 9 organizational executives and relevant personnel (total $n = 41$). The community innovators, representing the three target subdistricts (Mae Tho, Wang Hin, and Pa Mamuang), were selected using purposive sampling from voluntary applicants. This group comprised local volunteers and Sub-district Administrative Organization (SAO) officers engaged in disaster management at operational and policy levels, with inclusion criteria requiring basic proficiency in map reading and computer usage. While the innovators' knowledge acquisition was measured via self-assessment, the entire cohort of 41 participants provided feedback to evaluate the development of the Sandbox Innovation Areas.

Ethical Considerations

The study involving human participants was reviewed and approved by the Kamphaeng Phet Rajabhat University Research Ethics Committee (REC No. 019/67; COA No. 019/2024) through an expedited review process. Ethical approval was granted on November 7, 2024, prior to the collection of data from the study participants. The approved protocol covered the questionnaire survey and other research activities involving participants conducted as part of the Sandbox Innovation Area project. In addition, all members of the research team had completed Research Integrity training provided by the National Research Council of Thailand (NRCT) in collaboration with Mae Fah Luang University. Only non-identifiable photographs are presented in the manuscript to protect participant privacy.

Instruments

The research employed three groups of instruments: (1) geoinformatics tools, including Landsat-9 and Sentinel-2 imagery, DEM, CHIRPS precipitation data, GEE, and QGIS; (2) AHP pairwise-comparison forms used by experts to weight spatial risk factors; and (3) social research instruments, comprising community questionnaires on existing disaster management practices, social innovations and innovation needs, together with evaluation forms assessing perceived knowledge gain and stakeholder opinions toward the Sandbox model.

Procedures

The research methodology was structured into four systematic phases designed to integrate quantitative spatial analysis with community survey and participatory social innovation processes.

1) Phase 1: Data Acquisition and Preparation

The initial phase focused on gathering the fundamental datasets required for both spatial modeling and social assessment.

- Spatial Data Acquisition: The spatial risk information was derived from the geospatial component of the broader research project. Landsat 9 imagery acquired in February 2025 and

Sentinel-2 Surface Reflectance time-series data for 2020–2024 were used together with CHIRPS precipitation data (2000–2024) and SRTM DEM data at 30-m spatial resolution. Satellite data were processed in Google Earth Engine (GEE). Sentinel-2 Surface Reflectance data had undergone atmospheric correction at the product level, and cloud, cloud-shadow, and other low-quality pixels were excluded using the Scene Classification Layer (SCL). Cloud-free observations were subsequently used to derive vegetation and drought-related indices. All spatial datasets were projected to WGS 1984 UTM Zone 47N (EPSG:32647) and harmonized to a common 20-m spatial resolution. Detailed dataset specifications and geospatial modeling procedures are reported in Ruthamnong (2026). In the present study, the resulting spatial information served as an evidence base for Sandbox selection and development.

- Social Data Collection: The community survey employed stratified multistage cluster random sampling with proportional allocation across three disaster strata: landslide, flood, and drought. The initial sample size was calculated using Cochran's formula at a 95% confidence level and 5% margin of error and adjusted using a design effect of 1.2, yielding 462 respondents ($n = 154$ per disaster stratum). Within each stratum, respondents were proportionally allocated according to the population of the selected subdistricts. The survey examined existing disaster management practices, locally used social innovations, innovation needs, and suggestions for community-based disaster risk reduction.

2) Phase 2: Data Analysis and Strategic Zoning

This phase involved parallel processing of spatial and social data to identify critical targets.

- Geoinformatics Analysis (The Scientific Track): The selection of spatial indicators followed the Hazard–Vulnerability–Exposure (H–V–E) framework, in which hazard represents the physical conditions contributing to the occurrence or intensity of a disaster, vulnerability reflects the susceptibility of communities and their environments to adverse impacts, and exposure represents the presence of people, livelihoods, infrastructure, and other assets within potentially affected areas. Accordingly, the indicators incorporated physical, environmental, socioeconomic, and infrastructure-related characteristics relevant to landslide, flood, and drought risk. Their selection was based on previous disaster-risk studies, expert consultation, and the local environmental and socioeconomic context of Mueang Tak District. The detailed theoretical justification, indicator definitions, and factor-specific applications have been reported in the accompanying geospatial assessment (Ruthamnong, 2026). In the present study, these indicators provided the spatial evidence used to identify priority areas for subsequent community-based intervention.

The AHP weighting process was conducted by a panel of five experts with expertise in geoinformatics, spatial risk assessment, and disaster prevention and mitigation. Pairwise comparisons were used to determine the relative importance of the conditioning factors within the hazard, vulnerability, and exposure components. The consistency of expert judgments was evaluated using the Consistency Ratio (CR), with $CR \leq 0.10$ considered acceptable; all final AHP assessments satisfied this criterion. The detailed weighting procedure and factor-specific weights are reported in Ruthamnong (2026).

- Social Context Analysis (The Social Track): The social assessment examined existing disaster management practices, social innovations already present in the communities, and the need for further innovation. Differences between existing and needed innovations were used to identify practical innovation gaps for each disaster context. These findings were integrated with

spatial risk evidence to inform Sandbox development and area-specific capacity-building activities.

- Target Selection: Based on the spatial risk evidence together with local organizational readiness, three subdistricts were selected as Sandbox Innovation Areas: Mae Tho (landslide), Wang Hin (flood), and Pa Mamuang (drought).

3) Phase 3: Sandbox Innovation Area Development (The Integration)

- Step 1: Curriculum Co-Design and Community Innovator Development: Spatial risk evidence and findings from the social innovation assessment were jointly used to develop a 10-module capacity-building curriculum combining disaster risk management, social innovation, geoinformatics, and area-specific applications. The program was delivered to 32 Community Innovators from the three target local administrative organizations.

- Step 2: Field Action (Participatory GIS): Innovators applied their skills in real-world settings. This involved using GPS applications to validate risk locations, verifying satellite data against ground reality, and conducting field surveys to identify local hazard points.

- Step 3: Co-creation of Risk Maps: The scientific data and local field observations were synthesized. Innovators and researchers collaborated to co-create community-specific risk maps by integrating scientific data with local field observations, with the aim of producing outputs that were understandable and relevant for community use.

4) Phase 4: Evaluation and Knowledge Transfer

The final phase assessed participant learning, stakeholder perceptions of the model, and its potential for sustainability.

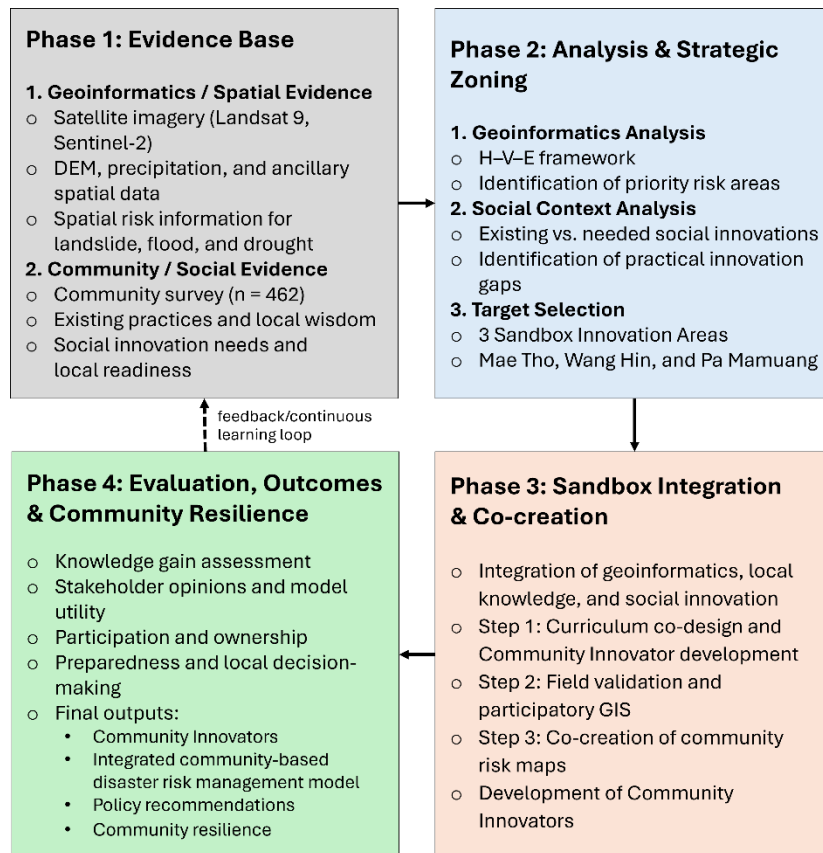
- Performance Evaluation: The Sandbox development process was evaluated using structured self-assessment and opinion forms. The 32 Community Innovators assessed their perceived knowledge gain across 10 learning domains following participation in the capacity-building activities. In addition, the overall Sandbox model was evaluated by the Community Innovators together with relevant local executives and personnel involved in the development process. All items were rated using a five-point Likert scale (Likert, 1932), and the results were summarized using mean scores and standard deviations.

- Model Synthesis & Policy Recommendation: The outcomes—verified risk maps, trained personnel, and established protocols—were synthesized into an “Integrated Community-Based Disaster Risk Management Model,” ready for policy submission to local administrative organizations.

Figure 2 summarizes the integrated conceptual and research framework. Spatial risk evidence and community-based social evidence are integrated through the Sandbox process to support co-creation, capacity building, local decision-making, and community resilience.

Figure 2

Integrated Conceptual and Research Framework Linking Geoinformatics, Social Innovation, Sandbox Development, and Community Resilience



Data Analysis

Data analysis involved both spatial and statistical methods:

1) Spatial Analysis

Spatial risk indices for landslide, flood, and drought were generated using the H-V-E-based MCDA framework described above. Standardized criteria were integrated using AHP-derived weights and WLC and classified into five risk levels using the Quantile method. Detailed model development and validation procedures are reported in Ruthamnong (2026).

2) Social and Statistical Analysis

Social survey and evaluation data were analyzed using descriptive statistics. Frequencies and percentages were used to summarize respondent characteristics, existing disaster management practices, and social innovations currently present in the communities. Mean scores and standard deviations were used to assess the level of need for social innovations, Community Innovators' perceived knowledge gain, and stakeholder opinions toward the Sandbox model. Five-point rating-scale responses were interpreted as follows: 4.51–5.00 = highest, 3.51–4.50 = high, 2.51–3.50 = moderate, 1.51–2.50 = low, and 1.00–1.50 = lowest (Srisa-ard, 2010). The social findings were subsequently interpreted in relation to the spatial risk evidence to identify innovation gaps and inform the development of context-specific Sandbox activities.

Findings

Natural Disaster Risk Assessment and Selection of Sandbox Innovation Areas

The assessment of natural disaster risks in Mueang Tak District was conducted through a spatial analysis integrating Hazard, Vulnerability, and Exposure factors using GIS. The results not only reveal the district-wide risk distribution but also provide the scientific basis for selecting the pilot Sandbox Innovation Areas.

District-Wide Risk Distribution

The analysis classified the disaster risks into three main categories, revealing distinct spatial patterns dictated by the district's diverse topography and land use characteristics (Figure 3).

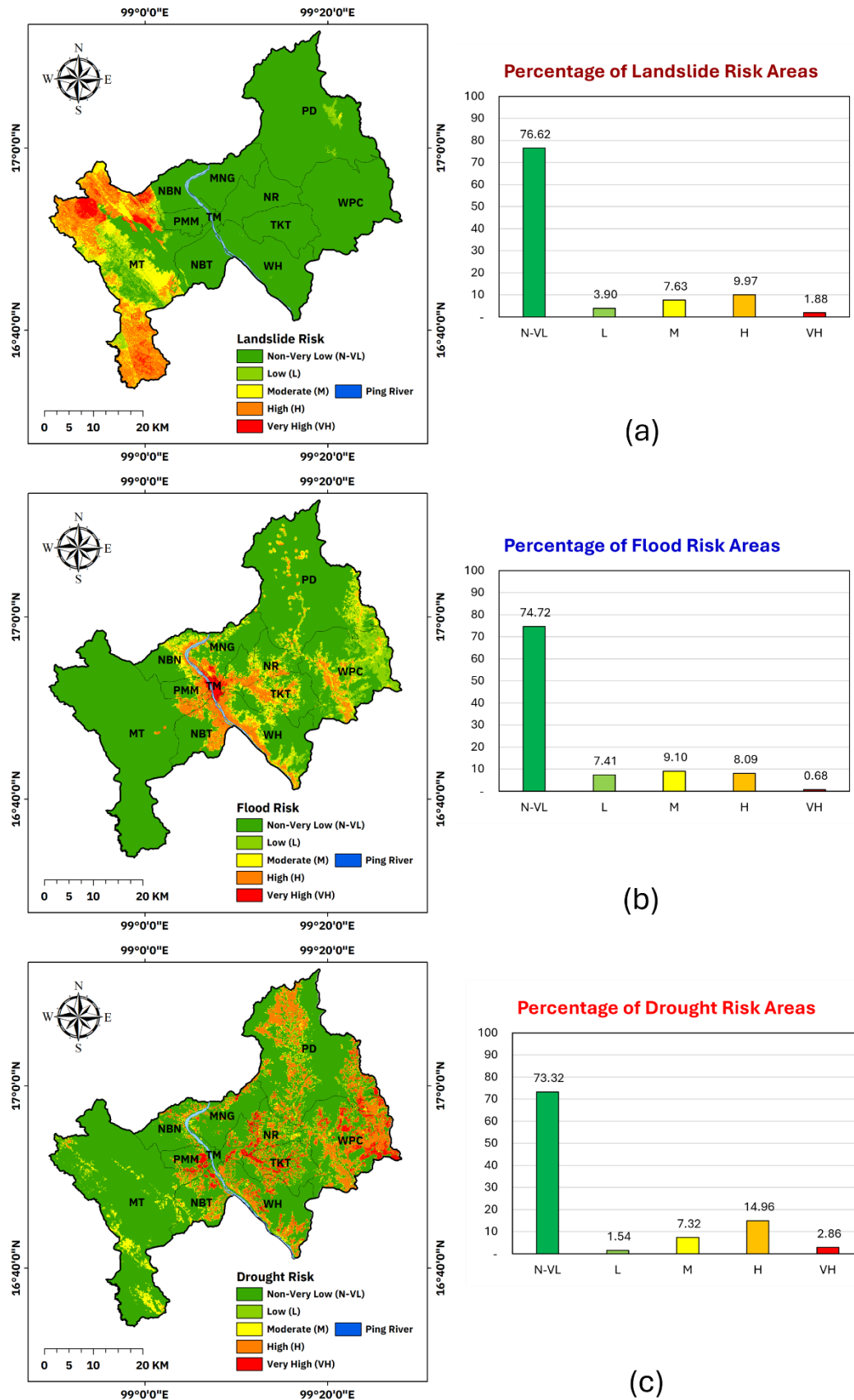
- **Landslide Risk:** The assessment identified that 11.85% of the district's total area is under “High” to “Very High” risk. These areas are predominantly located in the western and southwestern highlands, particularly along the Thanon Thong Chai mountain range, where slopes exceed 35 degrees and geological structures are fragile.

- **Flood Risk:** Approximately 8.77% of the district falls into the critical risk categories. The high-risk zones are concentrated in the central basin along the Ping River and the low-lying eastern plains. Urbanization and dense infrastructure in these areas act as barriers to natural drainage, exacerbating the impact of seasonal river overflow.

- **Drought Risk:** Drought poses a significant threat to agricultural stability, with 17.82% of the district classified as having “High” to “Very High” risk. The vulnerable areas are scattered across the rain-fed agricultural zones on both the eastern and western banks, driven by sandy soil conditions and a lack of access to main irrigation networks.

Figure 3

Spatial Distribution and Proportion of Risk Areas in Mueang Tak District: (a) Landslide, (b) Flood, and (c) Drought



Selection of Sandbox Innovation Areas

Based on the “critical risk area” analysis derived from the risk maps, three sub-districts were strategically selected as Sandbox Innovation Areas. The selection criteria prioritized areas with the highest specific risk intensity combined with the readiness of the local administrative organizations to adopt community-based innovations.

- Mae Tho Subdistrict (Landslide Sandbox): Mae Tho was identified as the critical area for landslide management. The spatial analysis revealed that 40.13% of its territory is at “High” to “Very High” risk (High: 34.04%, Very High: 6.09%), the highest proportion among all sub-districts. The key driving factors are the steep mountainous terrain, heavy rainfall intensity, and soil texture. Consequently, Mae Tho was designated as the prototype area for developing social innovations related to slope monitoring and community-based landslide warning systems (Figure 4).

- Wang Hin Subdistrict (Flood Sandbox): Although Tak Municipality showed the highest flood risk density, Wang Hin Subdistrict was selected to represent the “Peri-urban Community Model.” Located adjacent to the Ping River, Wang Hin faces recurrent riverine floods with 16.98% of its area classified as critical risk (High: 16.51%, Very High: 0.47%). The area's vulnerability is compounded by the density of settlements and agricultural lands in low-lying zones. The Wang Hin Sandbox focuses on integrating flood risk maps with local drainage management and community emergency response plans (Figure 5).

- Pa Mamuang Subdistrict (Drought Sandbox): Pa Mamuang Subdistrict was selected as the representative area for agricultural drought management. The analysis highlighted that 22.05% of the sub-district faces critical drought risk (High: 11.98%, Very High: 10.07%). Despite its proximity to the river, the area suffers from water scarcity due to sandy loam soil properties and high water demand from monoculture farming (Figure 6).

Figure 4

Spatial Distribution and Proportion of Landslide Risk Areas in Mae Tho Subdistrict

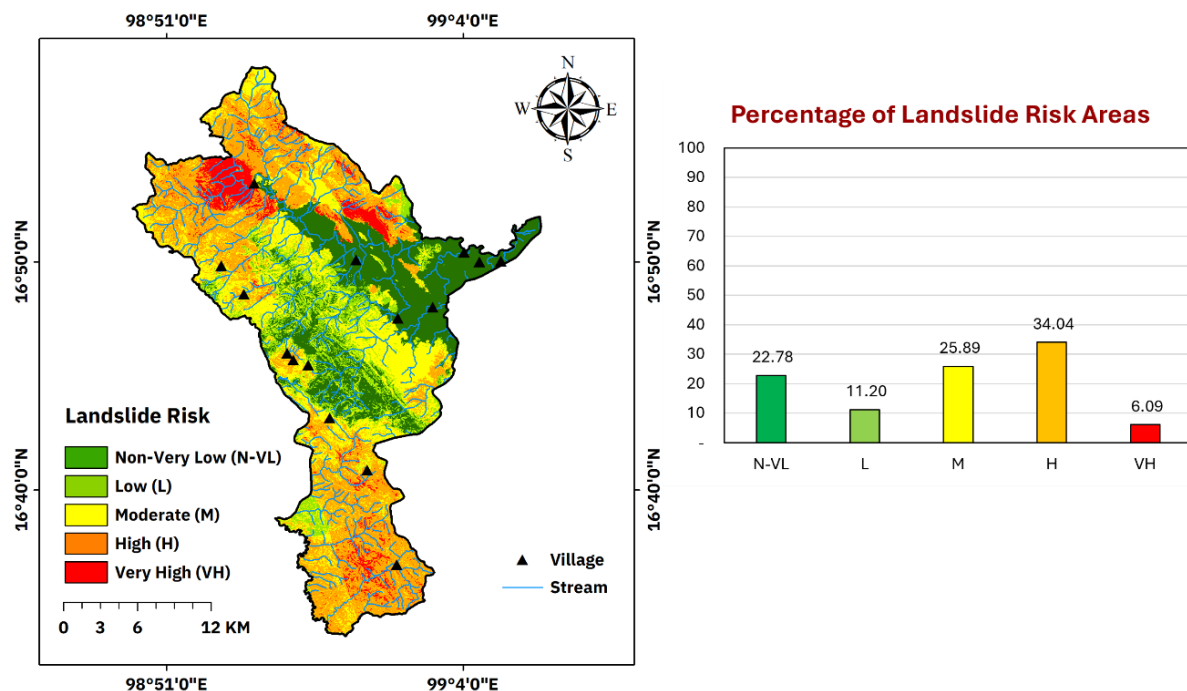


Figure 5

Spatial Distribution and Proportion of Flood Risk Areas in Wang Hin Subdistrict

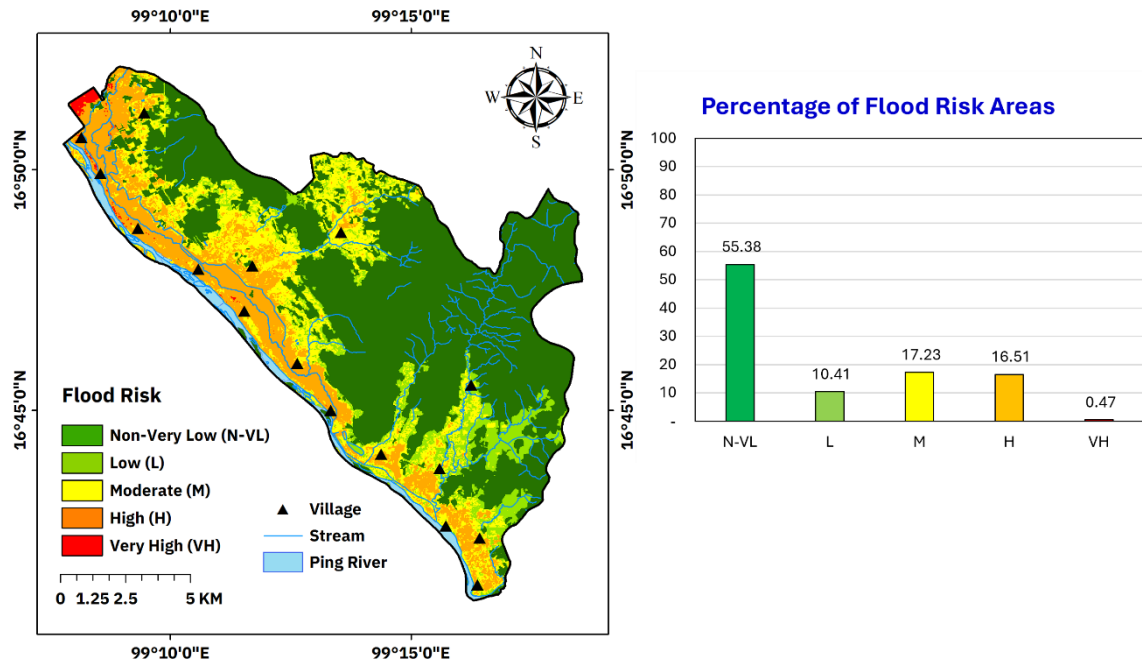
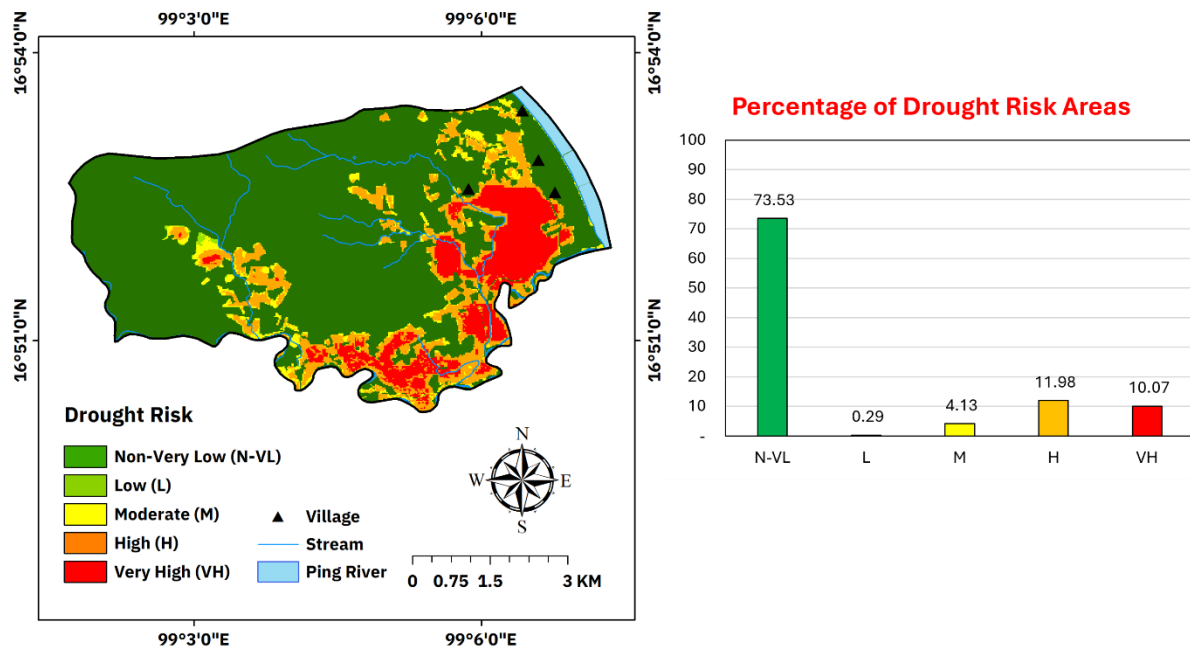


Figure 6

Spatial Distribution and Proportion of Drought Risk Areas in Pa Mamuang Subdistrict



Social Innovation and Community Readiness

To understand the community's capacity and requirements for disaster management, this study conducted a comprehensive survey of 25 potential social innovations across three disaster contexts: landslides, floods, and droughts. The survey evaluated both the “Existing Usage” (Current Practice) and the “Level of Need” (Community Demand) among 462 respondents in the risk areas.

Existing Social Innovations

The field survey revealed a clear distinction between “Local Wisdom-based” and “Technology-based” innovations. Innovations that are currently present and actively used in the communities are predominantly practical, low-cost, and rely on local resources. These include Community-based Risk Mapping, Village-based Response Teams, Community Warning Systems, and Check Dams. In contrast, high-technology innovations such as Landslide Tilt Sensors, Smart Broadcast Towers, or Disaster Alert Applications were rarely found or were not used at all, indicating a gap in technological access and infrastructure.

Community Needs Assessment

The quantitative assessment of community needs highlighted a strong preference for innovations that are actionable and participatory. The results, analyzed by disaster type, are as follows (Figure 7):

- Landslide Management Needs: The highest demand was for “Slope Stabilization through Local Plants” ($\bar{x} = 4.88$, $SD = 0.61$), reflecting the community's desire for nature-based solutions. This was followed by “Village-based Response Teams” ($\bar{x} = 4.80$, $SD = 0.85$) and “Temporary Sediment Traps” ($\bar{x} = 4.76$, $SD = 0.86$), emphasizing readiness and physical prevention.

- Flood Management Needs: The community prioritized preparedness activities. The most needed innovation was “Community Drill & Simulation” ($\bar{x} = 4.97$, $SD = 0.33$), indicating strong demand for practical preparedness activities. “Village-based Response Teams” ($\bar{x} = 4.64$, $SD = 1.01$) and “Community-based Early Warning Systems” ($\bar{x} = 4.26$, $SD = 1.17$) were also highly ranked.

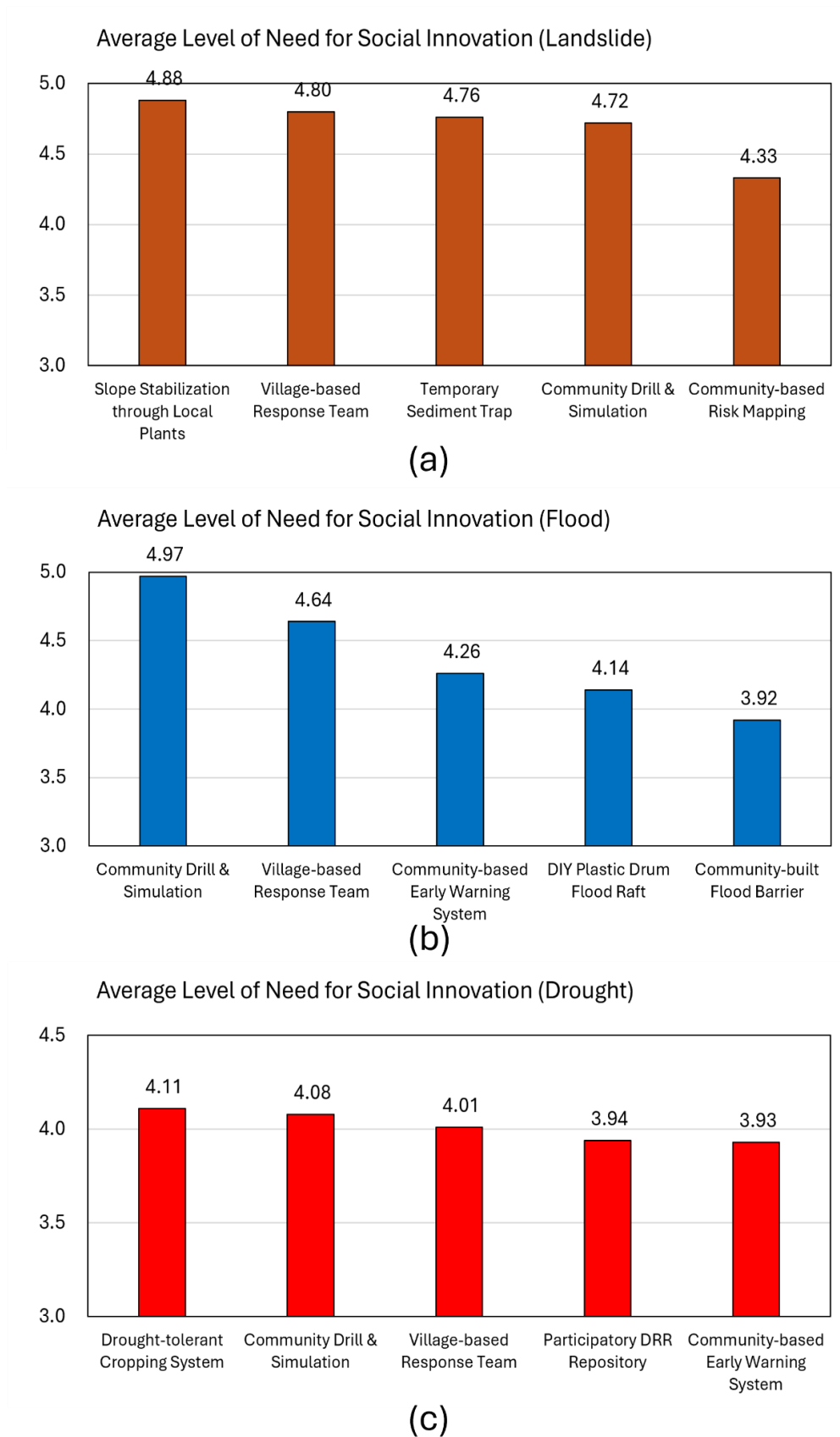
- Drought Management Needs: The focus was on agricultural adaptation. The highest need was for “Drought-tolerant Cropping Systems” ($\bar{x} = 4.11$, $SD = 1.10$), followed by “Community Drills” ($\bar{x} = 4.08$, $SD = 1.02$) and “Village-based Response Teams” ($\bar{x} = 4.01$, $SD = 0.78$).

Implication for Knowledge Development

The gap between existing practices and desired innovations indicated a need for targeted capacity building. These findings, together with the spatial risk evidence, provided the basis for designing the Community Innovator curriculum and area-specific Sandbox activities.

Figure 7

Top 5 Social Innovation Needs for Natural Disaster Management: (a) Landslide, (b) Flood, and (c) Drought



Development of Sandbox Innovation Areas

The development of the Sandbox Innovation Areas was not a standalone process but a strategic response to the findings from the Natural Disaster Risk Assessment and the Social Innovation Survey. These two foundational parts directly shaped the design of the training curriculum and the selection of community innovators.

The Community Innovator Development Curriculum

The training program comprised 10 modules, structured into two main categories to ensure both breadth and depth of knowledge:

(1) Core Competency Modules (Shared Learning): These modules were designed for all 32 innovators to build a common foundation. Topics included:

- Disaster Management Fundamentals: Understanding Hazard, Vulnerability, and Exposure (H–V–E) in the local context.
- Geoinformatics & Space Technology: Basic application of GPS for field surveys and introduction to satellite imagery.
- Social Innovation: Processes for community participation and designing local solutions, incorporating specific knowledge on social innovation for disaster risk reduction based on the needs identified from the survey.

- GIS for Beginners: Using QGIS software to visualize and interpret risk data.

(2) Area-Specific Modules (Contextual Learning): Tailored to the specific sandbox contexts:

- Landslide Sandbox (Mae Tho): Analysis of DEM and slope stability monitoring.
- Flood Sandbox (Wang Hin): Interpretation of historical flood satellite imagery and identification of water flow accumulation.
- Drought Sandbox (Pa Mamuang): Utilization of drought indices (Normalized Difference Vegetation Index: NDVI, Normalized Difference Drought Index: NDDI) to assess crop health and water stress.

Characteristics of Community Innovators

The 32 Community Innovators included local officers and volunteers involved in disaster management. Their roles combined local operational authority, adoption of GIS and smartphone-based tools, and communication between academic risk information and community practice, enabling them to function as local change agents.

Evaluation of Sandbox Development

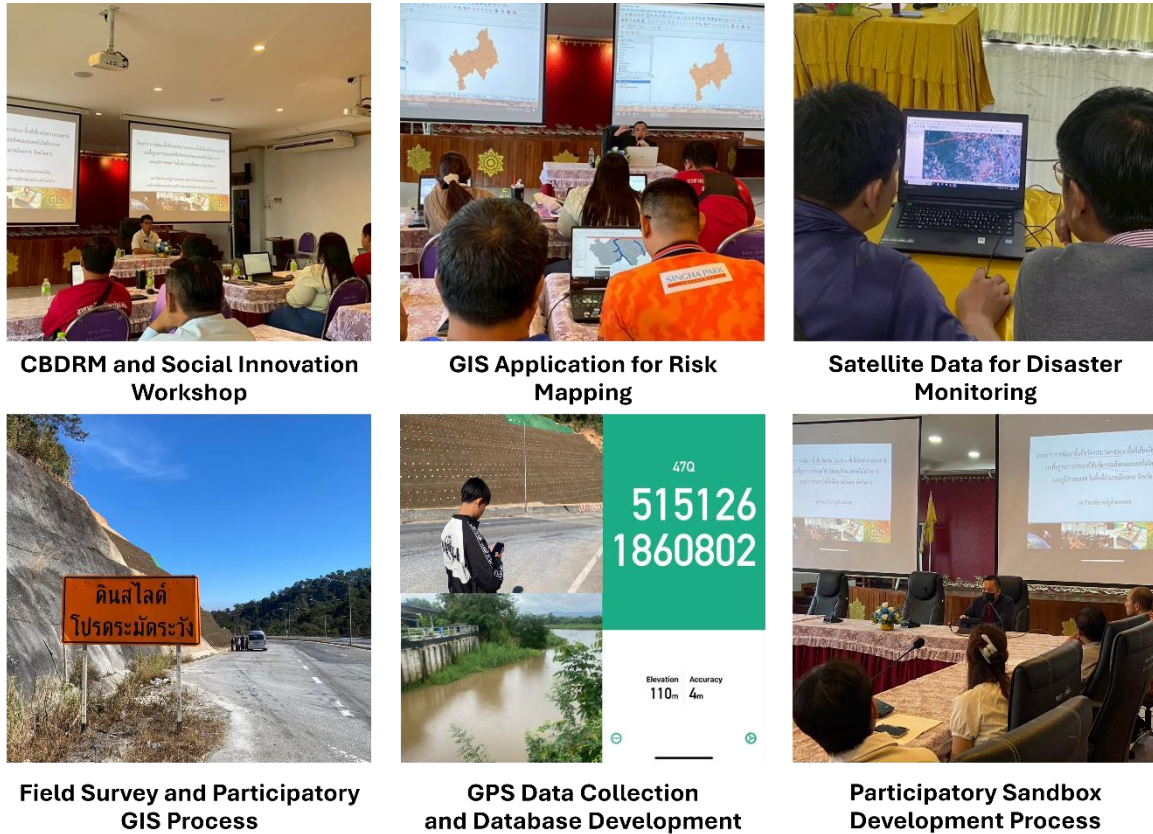
The evaluation of the Sandbox Innovation Areas indicated favorable results in terms of perceived knowledge gain and stakeholder opinions:

- Knowledge Gain: The post-training self-assessment indicated a “High” level of perceived knowledge gain regarding geoinformatics and social innovation for disaster management ($\bar{x} = 3.86$, $SD = 0.75$) (Table 1).

- Stakeholder Opinions toward the Sandbox Model: The assessment showed that Community Innovators and stakeholders viewed the Sandbox model favorably, with an overall rating at a “High” level ($\bar{x} = 4.16$, $SD = 0.75$) (Table 2).

Figure 8

Project Activities Driving the Development of Community Innovators and Sandbox Implementation


Table 1

Self-Assessment of Community Innovators' Knowledge Gain Compared to Prior Knowledge (n = 32)

Assessment Item	$\bar{x}$	SD	Level	Rank
1. Fundamentals of disaster management, risk area management, and subdistrict context	4.00	0.95	High	4
2. Fundamentals of space technology and geoinformatics and their applications	3.88	0.71	High	6
3. Social innovation and community participation processes in disaster management	3.94	1.01	High	5
4. Utilization of satellite data and spatial data sources	3.54	0.48	High	9
5. Field survey and spatial data recording using GPS applications	4.09	0.82	High	3
6. Analysis and utilization of H-V-E-based risk maps	4.19	0.78	High	1
7. Basic GIS software application for community innovators	4.13	0.75	High	2
8. Creation of risk areas and spatial data layers using GIS software	3.56	0.67	High	8
9. Presentation of risk maps (Landslide/Flood/Drought) and data application	3.78	0.79	High	7
10. Analysis of GIS and satellite data to generate knowledge sets for each Sandbox Innovation Area	3.52	0.50	High	10
Total Average	3.86	0.75	High	

Table 2*Opinions toward the Development of the Sandbox Innovation Area (n = 41)*

Assessment Item	$\bar{x}$	SD	Level	Rank
1. Clarity of objectives and goals in establishing the Sandbox	3.82	0.56	High	9
2. Consistency of content with social innovation concepts	4.28	0.95	High	5
3. Comprehensibility of applying space technology and geoinformatics	4.24	0.77	High	6
4. Suitability and usability of GIS tools and digital platforms	4.32	0.96	High	4
5. Quality and reliability of the prepared spatial data	4.52	0.58	Very High	1
6. Preparedness and effectiveness of instructors in providing guidance	4.38	0.85	High	2
7. Opportunities for opinion exchange among participants	4.04	0.67	High	7
8. Appropriateness of the duration and activity schedule structure	3.80	0.78	High	10
9. Potential for practical application of outcomes in the community	4.38	0.78	High	3
10. Completeness and systematic organization of instructional materials	3.82	0.63	High	8
Total Average	4.16	0.75	High	

Discussions

Geoinformatics as an Evidence Base for Community Action

Spatial risk information differentiated the three local disaster contexts and provided an evidence base for selecting and tailoring the Sandbox interventions. The H–V–E framework allowed physical, environmental, and socioeconomic conditions to be considered jointly, consistent with previous multidimensional and GIS-based disaster-risk studies (Bostani et al., 2024; Gacul et al., 2024; Patil & Panhalkar, 2023). The use of AHP for integrating multiple spatial criteria is also consistent with Alamrew et al. (2024), who combined GIS, frequency ratio, and AHP approaches for landslide susceptibility and risk zonation. However, the contribution of the present study extends beyond spatial zoning: the risk information was translated into locally relevant action through community assessment, participatory learning, and the development of Community Innovators. This evidence-to-action process is consistent with Ruthamnong and Chotiwan (2021), who demonstrated the value of transferring geoinformatics-based knowledge to local actors for resource and risk management.

The Sandbox Mechanism as a Tool for Acceptance and Empowerment

The findings demonstrate that geoinformatics technology alone is insufficient to address complex local disaster challenges. Instead, success in the study area reflects that social innovation acts as a crucial catalyst, transforming community members from passive recipients into active agents. The sandbox mechanism serves as the primary vehicle for this transformation, functioning as a “Spatial Living Lab” that provides a flexible, supported environment for communities to experiment with risk analysis. This approach aligns with Lounkaew et al. (2025),

who proposed Climate Adaptive Governance, emphasizing that governance innovation—characterized by openness and collaborative learning between the state and the public—is key to handling environmental complexity. The findings suggest that the participatory sandbox process can help reduce barriers to technology adoption and strengthen community confidence in using digital tools for local risk management.

Furthermore, the Sandbox Innovation Area supported a shift in disaster management from a centralized top-down approach toward a more community-driven approach. This transition supports the findings of Ruthamnong (2023), who observed that a Learning and Innovation Platform (LIP) empowers youth and communities to generate their own risk datasets and propose tangible local solutions. Similarly, it corroborates Vukomanovic et al. (2019), who noted that participatory integrated modeling significantly enhances stakeholder understanding and spatial planning capabilities.

Co-creation also fostered local ownership by enabling participants to produce and interpret their own risk maps and response plans. This process strengthens knowledge-management capability, an important foundation for organizational innovation (Naowakhoaksorn et al., 2022). Thus, the transfer of knowledge to Community Innovators supports the development of local capacity to maintain and use risk information sustainably.

Synergy between Local Wisdom and Modern Technology

The findings suggest that disaster risk management can benefit from integrating local context with scientific data, forming what may be described as hybrid knowledge. Surveys revealed that while communities possess traditional wisdom, such as observing water flow patterns and using community warning systems, they often lack scientific verification tools. Here, geoinformatics serves not to replace but to validate and enhance existing knowledge. A clear example is the Wang Hin Subdistrict, where local knowledge regarding flood pathways was scientifically corroborated by the DEM. This validation helped strengthen community confidence, enabling more informed water management planning within the Sandbox Innovation Area.

This integration aligns with Klomklumnum et al. (2023), who argue that effective risk reduction requires merging community insights with geoinformatics to create actionable datasets. It also supports Ruthamnong (2018), who proposed incorporating natural resource management wisdom into GIS layers to support decision-making.

Ultimately, this synergy transforms raw data into tangible wisdom, bridging the divide between academic technicality and local reality. This approach resonates with the concept of Community-Based Disaster Management described by Matharage et al. (2025), where bottom-up engagement enhances adaptive capacity. The resulting Hybrid Knowledge Model ensures that risk maps are not merely academic documents, but practical life-saving tools understood and utilized by the community.

Challenges and Limitations

The implementation of the Sandbox model encountered specific challenges, primarily concerning the technological learning curve. Since most community innovators lacked a background in GIS and RS, the capacity-building process required an extended duration and flexible scheduling to accommodate their primary official duties. Furthermore, while the proposed social innovations were theoretically sound, their practical implementation may face

constraints regarding budget allocation and inter-agency collaboration. Acknowledging these limitations is crucial, as it highlights the necessity for sustained policy support and resource commitment to ensure the long-term scalability of the model.

Conclusions

This study demonstrates how geoinformatics-based risk evidence can be combined with community knowledge and social innovation to support community-based disaster risk reduction. The three Sandbox Innovation Areas provided context-specific settings in which spatial risk information was translated into participatory learning, field validation, and locally relevant risk-management practices. The development of 32 Community Innovators served as the key mechanism linking technical information with local implementation, while the high level of perceived knowledge gain and favorable stakeholder evaluations indicated the practical value of the approach.

The findings suggest that sustainable local disaster risk reduction depends not only on the availability of spatial information but also on the capacity of communities and local organizations to understand, adapt, and apply that information. Local administrative organizations should therefore support community-level spatial information, participatory risk-management processes, and continued development of Community Innovators. Further application in other disaster-prone areas is recommended to assess the transferability of the Sandbox approach.

Author Contributions

S.R.: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing, Supervision, Project Administration, Funding Acquisition, and Correspondence Management. I.K.: Coordination of Stakeholder Meetings and Participatory Activities, Data Curation, and Writing – Review & Editing. P.P.: Investigation, Field Data Collection, Data Curation, and Writing – Review & Editing. All authors have read and approved the final version of the manuscript.

Declaration of the Use of Generative AI

During the preparation and revision of this manuscript, the authors used ChatGPT (OpenAI; GPT-5.6 Sol) as a supporting tool for language refinement and improvement of the manuscript's readability. Its use was limited to enhancing clarity, grammatical accuracy, and overall presentation of the text. All AI-assisted outputs were reviewed and revised by the authors, who retain full responsibility for the final content of the manuscript.

Ethics

This study was approved by the Kamphaeng Phet Rajabhat University Research Ethics Committee (REC No. 019/67; COA No. 019/2024). Further details regarding ethical considerations are provided in the Methodology section.

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