



Original paper

Consensus of Local Knowledge on landslide Hazard in Depopulated Mountain Communities in Japan – A Case Study on Matsunoyama Village

Uditha Dasanayaka^{1*} and Yoko Matsuda²

Received: 17/02/2022 / Accepted: 06/09/2022 / Published online: 14/11/2022

Abstract Rural depopulation in mountain communities is now well acknowledged as one of the salient challenges faced by Japan which made them more susceptible to landslide disasters with intense weather conditions. The degradation of the traditional culture due to the rapid depopulation in mountainous areas leads to the permanent disappearance of the best local knowledge for landslide disasters. This study attempts to investigate the community's landslide hazard knowledge. The research applied structural questionnaires and informal interviews for data collection. Firstly, the analysis has been conducted for identifying the main components in local knowledge on landslide disasters. Based on the component's results, the questionnaire was developed to measure awareness on those components within the community. Finally, the cultural consensus modelling was utilized in discovering the cultural truths not in individual responses but the degree of sharing of these responses. The research outcomes suggest how the local knowledge-based practices and the consensus of local knowledge had improved the level of disaster adaptation among the community members. Moreover, the findings revealed the impact of depopulation and aging on the sustainability of the mountain community in a landslide disaster environment.

Keywords: Landslide, Local Knowledge, Adaptation, Depopulation, Cultural Consensus Modelling

¹ Department of Energy and Environmental Engineering, Nagaoka University of Technology, Japan

* Corresponding author email: uditha05@gmail.com

² Department of Civil & Environmental Engineering, Nagaoka University of Technology, Japan

1. INTRODUCTION

Landslides recently became one of the most threatening natural disasters, especially in mountainous areas in Japan. Around 70% of Japan is a mountainous area, and therefore, the country often poses mudslides, landslides, slope failures, and other sediment disasters following heavy rains and earthquakes (Fujita *et al.* 2012; TSUNAKI 2000). In addition to the natural disturbance, social factors such as depopulation and the increased rate of aging in rural areas lead to additional natural vulnerability. The depopulation of rural regions in Japan started from the late 1950s due to the demographic changes and largescale rural-urban migration in post-war Japan (de Oliveira & Paleo 2016; Okubo *et al.* 2016). As the amount of population in rural mountain areas decreases, their inhabitants age rapidly. The rate of the aging population in Japan (people older than 65) became mid-level among developed countries in 1980s. At present, Japan reaches the top among the charts (Feldhoff 2013; Li *et al.* 2021; Tinker 2002). These social issues continuously increase the natural disaster risk specially in mountain communities. Due to this negative trend, the Japanese government established various structural and non-structural actions to prevent disaster risks. Research concerned with landslides and their related impacts has been carried out for more than 50 years. The “Landslide Prevention Law” was established and enacted in 1958 for landslide prevention and mitigation as the first of its kind in the world (TSUNAKI 2002). This law stands as the foundation to improve the technologies for controlling landslide risks in Japan. Since then, landslide investigation methods and several mitigation measures have been developed and continuously advanced (Fujita *et al.* 2012; TSUNAKI 2002).

The strategies and approaches for the preparation of disaster prevention, mitigation, and rehabilitation in developed countries by public or non-governmental agencies are unsuccessful to reduce the vulnerability effectively (Malla *et al.* 2020; Murti & Mathez-Stiefel 2019). The proper establishment and implementation of disaster management need a high degree of adaptability to the local situations. Culture, traditions, and customs play a crucial role in the success or failure of disaster management (Kelman *et al.* 2012). On the other hand, it is necessary to take into account the cultural context in affected localities and areas. In order to develop a suitable user-friendly package, the customs, traditions, local practices, and ethnic compositions in an area should all be considered (Giles *et al.* 2008; Kelman *et al.* 2012; Meyers & Watson 2005). In this situation, there are gaps between the technical information generated from the specialists and the information received from the local communities in the form of risk-based knowledge resulting from the previous disasters and familiarity with the environment, which can be vital for locally appropriated solutions (Fischer 2000). Local knowledge can be defined as beliefs, a set of information, mental abilities, and practices, developed from the adaption practiced through generations by personal interactions (Berkes 1999) and locally “generated through observations of the local environment” (Berkes 2002). It becomes the foundation of all environmental solutions for problems related to agriculture, the health care sector, food preparation, natural resource management, education, *etc* (Berkes 2009; Hiwasaki *et al.* 2014; Islam *et al.* 2018; Lin & Chang 2020). In addition, local knowledge

plays an essential role in contributing the basic techniques and strategies by providing early warning systems and weather forecasting management for disaster risk reduction (Dasanayaka & Matsuda 2019; Hiwasaki *et al.* 2014).

In Japan, the significance of indigenous/local knowledge in disaster risk reduction was emphasized by scholars related to different disaster events during past decades. For example, a story is told and believed to have been handed down by an ancestor who lived in the Sanriku region of Japan, a tsunami-prone area that saved many lives in the Great East Japan Earthquake in March 2011 (Zulfadrim *et al.* 2019). These phenomena describe how local knowledge is vital in disaster risk reduction among communities applying local knowledge to prevent disastrous events. In addition, many researchers have proved local knowledge as a vital factor of community resilience in the process of disaster risk reduction (Aldrich 2011, 2014; Aldrich & Meyer 2015; Mayer 2019; Norris *et al.* 2008). Furthermore, past studies have emphasized the function of local knowledge in disaster recovery (Lippi-Green, 1989) and the need for context-specific cultural understanding of disaster response (Aldrich 2014; Ganapati 2013). Nevertheless, the importance of local knowledge in disaster management was discussed and documented (Ragin & Becker 1992; Zanotti *et al.* 2010), but the effect of the consensus of the landslide-related local knowledge in a depopulating community is still not correctly identified, especially in the population-depleted mountain communities in Japan. Hence, the lack of theoretical research over the critical concepts related to landslide disasters with local knowledge motivated the present research.

Subsequently, this study observes local knowledge in landslide disaster adaptations and investigates whether a shared, local vision of community sustainability and consensus about risk priorities can be identified. This study engages the case study method (Weller 2007) to investigate how the community members identify and take action to risks and how different adaptation decisions are made. This method is suitable to explain complicated problems where research and data are abundant, but the diverse situations is challenging to explain with standalone quantitative analysis. Despite this, Cultural consensus analysis was occupied in finding the cultural answer key in the analysis process. Cultural consensus analysis is a method developed in the 1980s by intellectual anthropologists (Gollin *et al.* 2004). The consensus approach, one of the investigative techniques in cultural domain study, assesses the culturally best responses establishing shared cultural ideas and the informant's reliability in a cultural domain (Nekaris *et al.* 2018). This critical procedure has been frequently applied in ethnobotanical/ecological analyses, for example, to provoke local beliefs of flora and fauna for conservation and management (Carothers *et al.* 2014; Ruzol *et al.* 2021; Van Holt *et al.* 2010). Nevertheless, there is no proper research based on the consensus of local understandings in disaster management by applying cultural consensus analysis (U. Dasanayaka & Matsuda 2022; Morris *et al.* 2010). Therefore, the study described in this paper was focused on uncovering local knowledge through fieldwork with local cultural informants (participants) and relating cultural consensus theory to examine the field data and produce a clear, consistent consensus-based model using cultural consensus analysis for a geologically and culturally important regions of Matsunoyama, Japan.

1.1 Local knowledge

Indigenous knowledge/traditional knowledge or local ecological knowledge can sometimes be defined as local knowledge (Traditional Knowledge, n.d.; Wannous & Velasquez 2017). “Traditional knowledge” can be defined as the practices, skills, and knowledge established, maintained, and adapted from generation to generation within a community, commonly forming part of its cultural or spiritual identity (Beilin & Reid 2014). On the other hand, “local knowledge” can be referred to as the knowledge developed by individuals in each community over time and continued to grow. It is developed from repeatedly tested experiences over centuries, adapted to the local culture and natural environment, and embedded in community practices, relationships, and rituals (Hilhorst 2003). Local knowledge is frequently described as distinct from the expert or scientific knowledge, often seen as formalized, explicit, rational, systematized, placeless, non-contextual, and transferable (Lejano & Stokols 2021; McEwen *et al.* 2017). Instead of recognizing the local knowledge as an essential approach to scientific knowledge, the two types of knowledge are often placed against each other and occasionally in normative practices that indicate a point of weakness on the section of local knowledge (Lejano & Stokols 2021).

Moreover, local knowledge is primarily tacit and is often expressed through particular and created stories for better understanding, explanation, and making events in everyday life meaningful (Indian 2007; Leith & Vanclay 2017; Miller *et al.* 2004; Raymond *et al.* 2010; Romney *et al.* 1986). In summary, and for this article, local knowledge refers to the knowledge that individuals in each community have developed over time to reduce the risk embedded in the environment that they live, mainly because of natural disasters like landslides.

1.2 Cultural consensus analysis

Cultural consensus theory was established by Romney *et al.* (Paolisso 2007) for researchers to analyze the variation among groups and clarify what they term cultural ‘truths’ and the extent to which these ‘truths’ are shared in a statistically significant, able, and replicable manner. Cultural consensus analysis is a valuable tool for verifying intracultural difference and agreement patterns in specific areas or domains of knowledge (U. Dasanayaka & Matsuda 2022; Gatewood 2012; Johnson & Griffith 2010; Tokamachi central government office 2005). Cultural consensus theory pursues cultural truths not in individual responses, although the degree of sharing of these responses by accepting informants’ given answers is probabilistic rather than fundamentally true. As a result, it increases the objectivity of ethnographic results, even though these always continue contextually dependent. Romney *et al.* (Paolisso 2007) built a formal mathematical model known as Cultural consensus analysis to achieve this in a replicable approach. Its original method includes planning and administering a survey on a particular cultural domain and subsequent analysis of the degree of sharing of respondent answers. Cultural consensus analysis possesses three key ideas, including that all respondents contribute to a common truth and live within the same cultural life. When appropriately applied, cultural consensus analysis makes us decide whether a cohesive cultural domain exists, the

cultural experience of each respondent, and the culturally ‘correct’ answer key to the study. Though this practice agrees for an additional organized investigation of a culture generating more strong and generalizable outcomes inside the group under study, the application of cultural consensus analysis results in a list of knowledge and beliefs linked in some unknown means to form a domain of cultural knowledge (Matsunoyama Onsen Tourist Information Center, n.d.).

2. MATERIALS AND METHODS

2.1 Study area

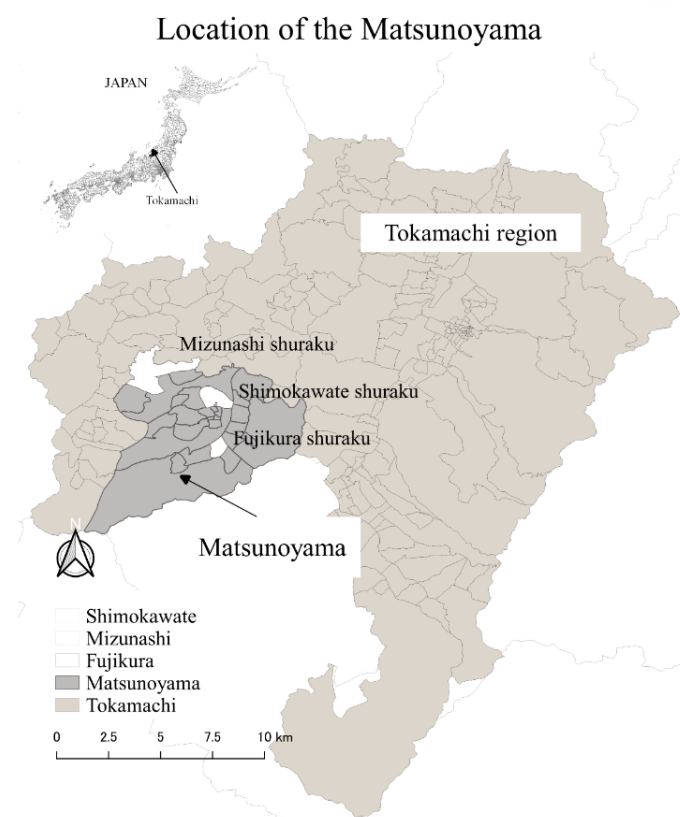


Figure 1. Location map of the selected three Shuraku divisions

The study was conducted in and with the community of the one mountain village named Matsunoyama, located in Tokamachi City, in Niigata Prefecture (Figure 1). Matsunoyama was an independent municipality until 2005, then merged into Tokamachi City and another two towns, Kawanishi, Matsudai, including Nakasato village (CITY POPULATION 2015; Matsunoyama Onsen Tourist Information Center, n.d.). The area is known for Tanada/Terrace farming, especially in Niigata Prefecture. Tanada act as the primary landscape attracting tourism, including hot bath ‘onsen’ (Matsunoyama Onsen Tourist Information Center, n.d.; Nagano

2018). Matsunoyama experienced a 46.4% aging rate from 1975 until 2010, and the population decreased by more than half with 5,930 people in 1975 compared with the 2010 population with 2,542 people (Paris *et al.* 2015). Therefore, decreasing population and a high aging rate can be observed as one of the main challenges Matsunoyama communities face today.

Nevertheless, the area comes under the risk zone of landslide disasters and makes the community more vulnerable to natural disasters, especially landslides. For example, in April 1962, cracks appeared in Usagiguchi, and two years after that, a full extension of 3,600 meters,

an average of 900 meters widths, and a total of around 850 hectares of land of the foot of Matsuyama mountain slipped and moved int northeastern direction toward Koido River. The slip consisted of 7 landslides surrounding Matsunoyama (Figure 2).

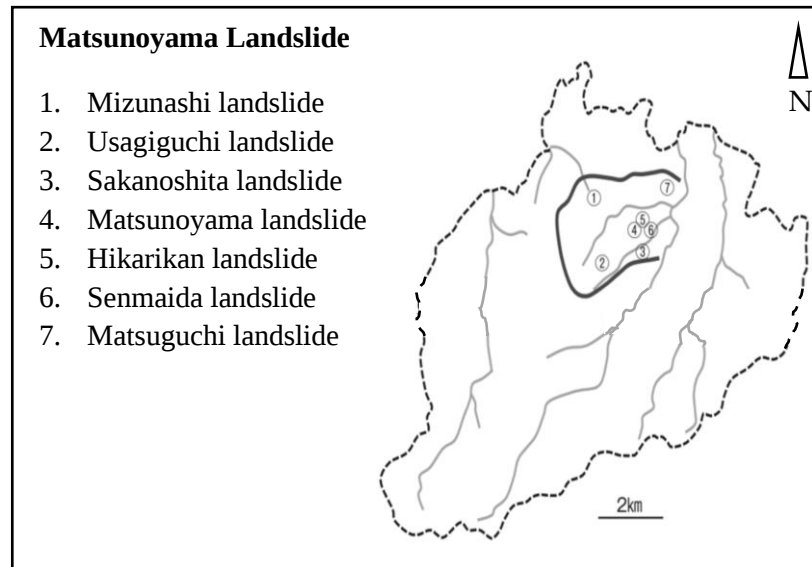


Figure 2. Matsunoyama landslide in 1964

As a result, casualties were 349.9 hectares of paddy field, 371 houses, four schools, 15 public facilities, 98 buildings, 5.4 km of prefectural road, and 14.8 km of town road (Koster 2010). Matsunoyama, primarily surrounded by young mountain ranges, possesses steep slopes with unstable geology and a harsh climate to predict. Some areas are incredibly prone to landslides as a result of the meteorological, geographical, and geological conditions and socio-economic characteristics. Therefore, this study selected three communities residing in the Matsunoyama villages with a long history of landslides, located in the shūroku division. Mizunashi Settlement, Shimo Kawate Settlement (Combination of Matsuguchi and Mioke areas), and Fujikura Settlement were selected for this study based on the advice from the Officials in the Tokamachi city office (Figure 1).

Mizunashi is the largest with 4.07 km², and Shimokawate and Fujikura are 1.40 km² and 0.70 km², in area respectively. Depopulation and aging is the primary challenge that these communities are facing. Approximately all three communities had less than 20% elders (above 65 years) in 1975, but in 2020 the elderly population reached almost 50% in all communities (Table 1). Moreover, the total population is 226,222, and 128 in three divisions Mizunashi, Shimo Kawate, and Fujikura, respectively, in 1975. However, the numbers drastically reduced, and in 2020 the population reached 48, 60, and 30, respectively. Therefore, approximately four-fifths of the total population was depleted in all divisions, with only elders existing in the

community (Table 1). The irregularity of the population and the risk of landslide disasters are challenging for these mountain dwellers' sustainable future.

Table 1. Key demographic characteristics of three study communities.

Shūraku	Land area (km ²)	Year - 1975			Year - 2020		
		Population	Age > 65	%	Population	Age > 65	%
Mizunashi	4.07	226	28	12.39%	48	25	52.08%
Shimokawate	1.40	222	37	16.67%	60	31	51.67%
Fujikura	0.70	128	18	14.06%	30	14	46.67%

2.2 Field Data Collection Process and Methods

To gather data on local knowledge on landslide disasters, interviews of the key informants, group discussions, and household surveys were performed in all three village communities. The key informant interviews were done after initial community entry meetings. Based on the data obtained from the preliminary visit and the interviews, a household questionnaire was developed to understand the commonly shared set of local knowledge in landslide disaster risk reduction.



Figure 3. Preliminary field visits and meeting with relevant government officials and village leaders.

The number of field visits was made in this study. A preliminary field visit was completed during June and July 2020. The main purpose was to get familiar with the field area and meet with relevant government officials and village leaders (Figure 3). The first field survey was completed from 25th August to 27th August 2020. During the visit, key informant interviews and focus group discussions were done in all three communities. Key informants in this study were made up of the members of traditional knowledge holders recommended by the

government officials and the village leaders who met in the preliminary visits. As a second survey, A household questionnaire was developed and distributed on 6th November 2020. Approximately 51% of questionnaire responses were gathered on 23rd November for further analysis.

2.2.1 Key Informant Interviews

After initial community entry meetings in communities, key informants were selected using a convenience sampling approach. Key informant interviews were carried out with five informants, and they were 39 years of age or above and have inhabited in the communities for at least 20 years. Key informant interviews were completed using semi-structured questionnaires (Figure 4). Discussions were focused on local knowledge-based disaster prediction mechanisms and traditional and local disaster coping strategies. In addition, all interviews were recorded in the local language (Japanese) and later translated into English with the help of a professional translator.



Figure 4. Preliminary field visits and meeting with relevant government officials and village leaders.

2.2.2 Household Questionnaire surveys

A household questionnaires survey was designed to assess the shared knowledge on landslide disaster awareness and the perceived traditional and local disaster prediction and coping mechanisms. Mainly the question was designed based on the local knowledge components identified through the in-depth interviews. The questionnaires were distributed among all the households in all three divisions—twenty in Mizunashi, thirty in Shimokawate, and twelve in Fujikura. However, the research team faced difficulties returning all the distributed survey sheets. The main reason behind this is that the aging population. So many households in those communities remained with very older people; they could not fill questionnaire surveys. However, the research team was finally able to receive a reasonable amount of answer sheets with the help of government officials who work with these communities. Thirty-two questionnaire sheets were received from all three divisions: eight, sixteen, and eight, respectively.

In Matsunoyama region, people mainly have an agriculture-based life system. However, the location is a high elevation mountain region with a high level of risk for landslide disasters triggered by heavy rainfall and earthquakes. Therefore, the community in the mountainous areas with knowledge on landslide disasters were interviewed, and textual analysis was carried out using interview data. The NVivo 12 was used to identify nodes and categories extracted from the discussions. First, all recorded interview data were converted into memos before starting the analysis process. Next, open coding is used to read the information and identify the statements related to the primary categories. Then, Axial coding was used to identify the categories or the components of the local knowledge related to landslide disasters risk reduction. In addition, the second field survey, the questionnaire survey data, was initially analyzed using descriptive statistics to investigate awareness over different local knowledge components. And finally used as an input for cultural consensus analysis to identify the common and culturally consensus set of local knowledge over landslide disaster adaptation.

3. RESULTS AND DISCUSSIONS

3.1 Textual Analysis

Initially, several components of the local knowledge on landslides were identified based on the in-depth interview answers by running textual analysis (Figure 5). The community defines the landslide using their own terms. The word “Kura” in the local terms is used for small earth slips, and the name “Noge” and “Nuge” are used if the size of the earth slips larger and cannot be corrected by one person. Large landslide called as “Oonoge”. Therefore these communities use **different terms for landslides in their local language**.

Moreover, the community members in the village know where landslides are possible. According to their knowledge, usually, landslides occur in rice fields and abandoned lands. Their village houses are set up on stable ground, not in a place where landslides are likely to occur, from the wisdom of life. Therefore they received proper knowledge of landslide risk areas from their elders and learned by themselves by living in this landslide risk environment. This means they have deep **knowledge about landslide risks involved in various landuses**. The communities discovered distinct environmental phenomena for use as early indicators for the potential disasters in their living environment. For example, since the three communities in this study had the risk of landslides, they identified different early signs for landslides, such as cracks on the rice fields, movements of animals different from usual, *etc.* Therefore these communities have locally developed methods and **knowledge regarding early signs for landslides**. Rice farming is a part of their life and science past Matsunoyama known for Tanada/Terrace farming, especially in Niigata Prefecture. Most of the terrace lands were abandoned with the depopulation crisis.

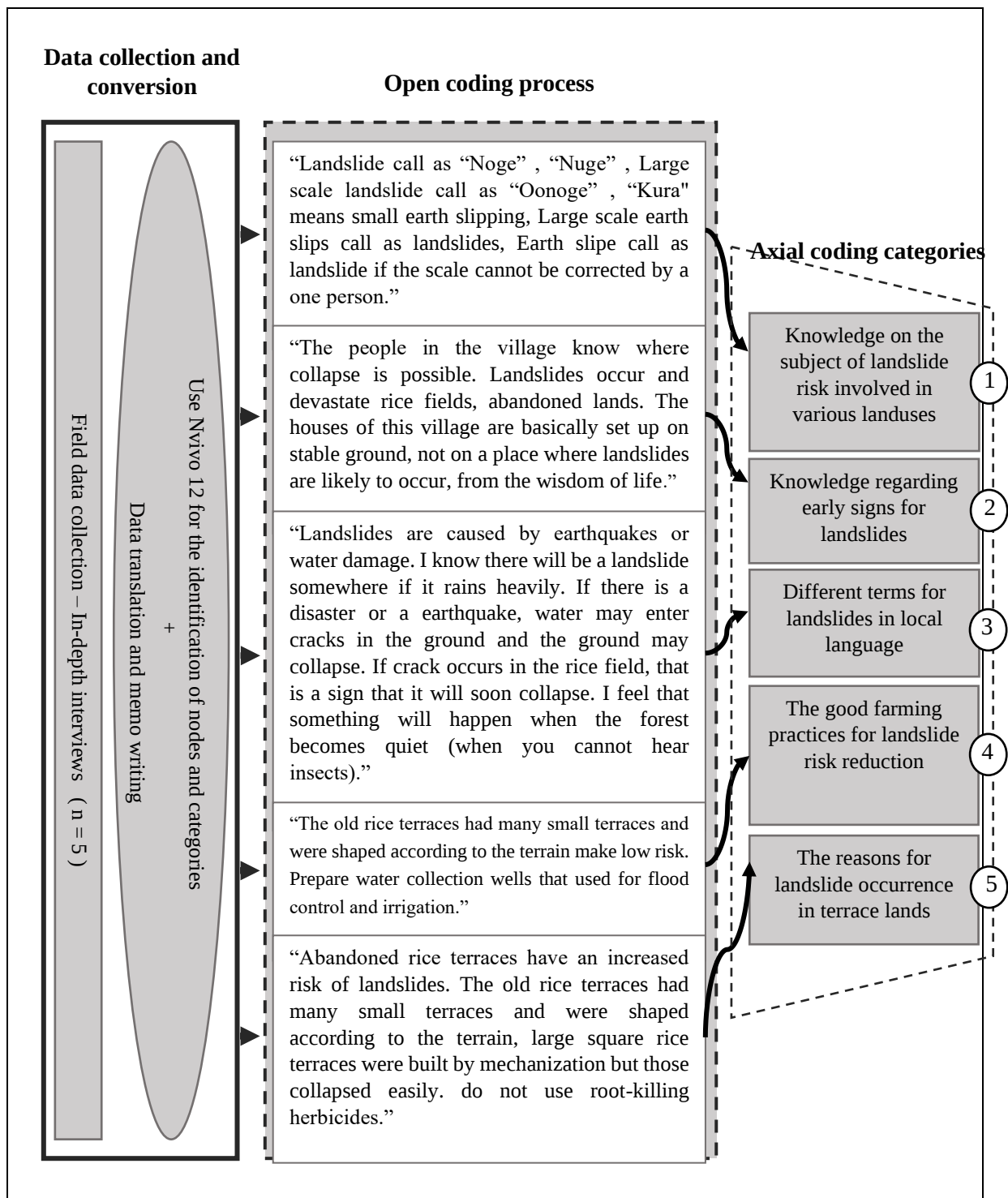


Figure 5. Summary of the local knowledge components extraction process using Text coding.

The area consists of a reasonable amount of rice fields. Accordingly, Mizunashi consists of 0.15 km², and Shimokawate and Fujikura are 0.17 km² and 0.06 km². While engaged in farming in the landslide risk environment, they develop best practices to reduce landslide risk in farmlands. Developing the farmlands without changing the natural shapes of the mountain and

the additional water removal wells are some of their practice methods. This makes it evident that these communities are well aware of *the good farming practices for landslide risk reduction*. Moreover, the community respects their own techniques for farming, but some individuals try to adopt new technologies to improve productivity. This makes positive insights for the production while some techniques increase the risk for landslides. The use of root-killing herbicides and the reshaping of the terrace steps are the few reasons that they highlighted as *the reasons for landslide occurrence in terrace lands*.

3.2 Level of awareness

The questionnaire survey was designed based on the above key knowledge components and the data acquired during the field observations. The data was initially analyzed using descriptive statistical methods to check the level of awareness of the individuals within the communities (Figure 6). Approximately 80% of the participants had more than 40% awareness of local knowledge on landslide disasters. Five individuals have a level of awareness over 75%. They were in age between 50 to 75 years and resided in the area for more than 40 years. They all have good experiences with farming. The good experience in farming and spending a long period in this area made them well aware of the surrounding environment and respond to the stress from natural disasters like landslides. Out of five, one is female.

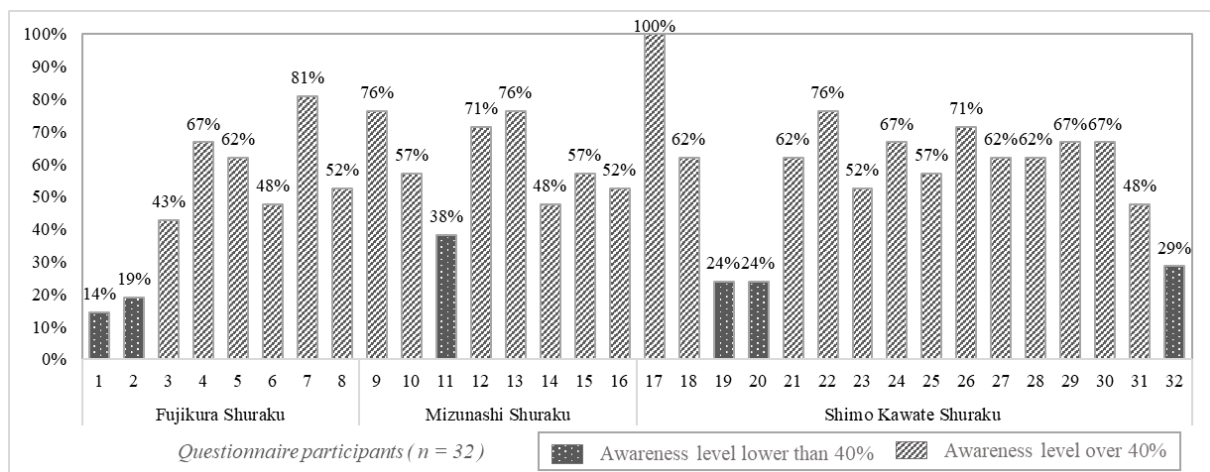


Figure 6. Level of awareness on local knowledge relate with landslides

Moreover, the six individuals had awareness lower than 40%. Three of them were over 80 years old females, making it difficult to respond to questionnaires. The other three resided in the area for less than 20 years and have no experience in farming. The person who was over 80 years have a proper knowledge but could not answer correctly, meaning that 3 people from the sample had low awareness over local knowledge. Mainly to have adequate understanding of

local knowledge, need more experience living in the village. Some students who go outside the village for studies may have less awareness of local knowledge. Therefore, according to the survey results, we can conclude that these communities have properly developed local knowledge systems. In summary, the individuals who have more experience farming in the area for an extended period have more knowledge of landslide disaster risk and best practices to reduce the risk.

3.3 Cultural consensus analysis

To investigate the survey results and test for cultural consensus, the formal consensus model was utilized, and ran the tests were in UCINET 6 (Garcia *et al.* 2020; Lin & Chang 2020; Oravecz *et al.* 2014). As the resulting output, culture-specific answer key for the survey, cultural competency scores for each respondent, and a first- and second-factor eigenvalues ratio were formed. Respondent answers are weighted based on the respondent's relative cultural competency score to produce the culture-specific answer key. It indicates that the respondents who agree with the majority are weighted more strongly, allowing for a more representative and correct answer key that cultural outsiders do not skew. However, if the ratio of first- and second-factor eigenvalues is greater than three, this answer key can be accepted (Harden 1996). The results show the consensus level over three, which means that the condition is met. Furthermore, all participants as a group indicated a shared cultural model: eigenvalue ratio=4.33 (Table 2), mean cultural competency score of the sample=0.60, SD=0.15, and no negative factor loadings. Therefore results can be concluded that respondents draw from a single, shared knowledge set.

Table 2. Summary of the Cultural consensus analysis result

Consensus level	4.33
Largest eigenvalue	12.33
Second largest eigenvalue	2.85
Number of negative loading scores	0

According to our cultural consensus analysis (eigenvalue ratio, competence scores), the results show that there does occur an established cultural consensus model indicating culturally framed local knowledge concerning landslide disasters. The cultural consensus model encompasses the techniques and practices used by the participants to reduce the landslide risk in their livelihood. Furthermore, most participants were aware of the different types of land uses, increasing landslide risks. For example, 61.56% and 62.44% of respondents agreed that

the paddy fields and abandoned lands could impose higher landslide risks while residential, terrace, and forest lands have a low risk of sliding (93.19%, 1.94%, and 82.03%). Due to the depopulation in the rural communities, the number of farmers decreases. Therefore, most paddy fields are abandoned, and unmaintained paddy fields can create high risks of landslide disaster. However, after the landslide incident, the community identified the risk involved and never used those lands for residential purposes (100%), and 77.59% agreed that they keep those land as abundant. Currently, disaster prediction procedures are valuable and effective with advanced technologies. However, in this approach, the local knowledge concerning the early signs is consistent and valuable for the local community. Four major early signs concerning disaster prediction were identified, which were applied by communities for landslides in this study. The majority of the participants (74.44% and 75.16%) agreed that continuous rainfall and earthquake are the primary triggers for landslides and can be used as early indicators because local inhabitants get cautions for the landslide risks as soon as they notice the heavy continuous rainfall incident for three or four days and the earthquake occurrences (Table 3).

Moreover, unusual earth cracks can be easily detected by checking the recently occurred cracks on the ground; local inhabitants can assume the area has a high potential for landslides. In addition, 58.78% of respondents agreed to use newly appeared muddy water springs as early indicators for landslides (Table 3). As per the interview details, the community used different local terms for landslides like “Kura, Noge, Nuge, and Oonoge”. However, 66.22% of questionnaire participants were agreed that they usually used “Noge” to call landslide. The local term for landslide indicates that it is a part of their livelihood and culture. The community adopted the condition and the risk created from the living environment. Since most individuals engage in full-time or part-time farming, they adopt various best farming practices to avoid landslide risk. For example, building farmlands without changing the shape of the mountain while keeping the size of each terrace field small is one best practice that they have used ever since their ancestors (agreed 63.19%).

Moreover, 68.22% of individuals were mentioned that the proper drainage system for the runoff water could reduce the landslide risk of the farmlands. Some farmers are trying to use new machinery in farming. For example, since the larger paddy fields are easy to work with machinery, the farmers try to reshape the terrace fields without considering the landslide risk involved. 55.91% of individuals emphasize that reshaping the paddy lands is the best practice by considering productivity. The depopulation and aging negatively impact the traditional way of farming. Lack of workers and the existing farmers get old and make them use comfortable methods for farming rather than considering risk factors. In addition, depopulation increases the number of abundant farmlands within the area. Therefore, 82.97% of the participants mentioned that the abundant farmlands cause for the landslides occurrences in terrace fields. Other than the above reason, using herbicides and other chemicals can destroy all the grass, plants, and root systems, make the soil loosened, and create earth slides (agreed 70.09%).

Table 3. Cultural consensus analysis responses regarding local knowledge on landslides

Statement	Consensus results	The weighted proportion of respondents who agree with the consensus result (%)
1. Knowledge on the subject of landslide risk involved in various landuses		
A. Types of land use which can increase the landslide risks		
A1. Residential land	Disagree	93.19
A2. Paddy fields	Agree	61.56
A3. Terrace lands	Disagree	91.94
A4. Abandoned lands	Agree	62.44
A5. Forests	Disagree	82.03
B. Best landuse type for landslide occurred land		
B1. Residential land	Disagree	100
B2. Paddy fields	Agree	57.03
B3. Terrace lands	Disagree	100
B4. Abandoned lands	Agree	77.59
B5. Landslide prevention work	Agree	57.78
2. Knowledge regarding early signs for landslides		
C. Triggers for the landslide disaster		
C1. Continuous rain	Agree	74.44
C2. Earthquake occurrence	Agree	75.16
D. Early signs for landslides		
D1. Cracks in the ground	Agree	69.53
D2. Tree tilts downwards	Disagree	65.03
D3. Sounds comes from the tree roots	Disagree	53.03
D4. Muddy water spring	Agree	58.78
D5. Movements of animals different from usual	Disagree	94.34
3. Different terms for landslides in local language		
E. Local term for landslides		
E1. "Noge"	Agree	66.22
E2. "Nuge"	Disagree	65.72
4. The best farming practices for landslide risk reduction		
F. Best farming practices for landslide risk reduction		
F1. Building farmlands without changing the shape of the mountain, Keep the shape of each terrace field small	Agree	63.19
F2. Prepare the fields to be large size to make easier for machinery use.	Agree	55.91
F3. Built access water removal wells	Disagree	64.12
F4. Prepare proper drainage system	Agree	68.22
5. The reasons for landslide occurrence in terrace lands		
G. Reasons for landslide occurrence in terrace fields		
G1. Terrace abandonment	Agree	82.97
G2. Increasing the size of the terrace steps	Disagree	69.59
G3. Use of herbicides and other chemicals	Agree	70.09

3.4 The consensus of local knowledge on landslide disasters

All three communities in this study live in a mountain village in the landslide-prone area of Japan. Nevertheless, they still improved their adaptation to surviving without experiencing a significant landslides disaster. Local knowledge created on disaster experiences must be individually attained and explained by individuals and the community. The community members should understand to lessen their contact with the threats, which would be a direct and efficient approach to decrease disaster hazards and minimize landslides' impact (Hiwasaki *et al.* 2014). The interview results emphasized that the people living in these mountain villages have proper and well-developed local knowledge over landslide disaster adaptation. The area is primarily agricultural livelihood, and a reasonable amount of land was used for rice farming from the historic period. The individuals who engage in agriculture and have lived in this mountain community for an extended period acquire a sufficient amount of experience. The experience or the exposure to the stress from the natural environment like disasters make them develop their methods to living without disaster risk. However, the level of awareness varied with the level of experience and the exposure; the individuals who lived extended periods while engaged in farming have a high level of awareness over local knowledge on landslides, while individuals who live shorter periods and who did not engage in the farming show a low level of awareness. On average, all the community was well aware of the basics of the exposed disasters and the risk involved. In that context, it is evident from the survey findings that this community has a consensus of the local knowledge on landslide disasters. Once consensus is reached, using local knowledge to address landslide disaster risk prevention might guarantee that the risk prevention measures achieved the community needs (MacDonald *et al.* 2000). All the community members have a consensus over different practices and believe in landslide disaster risk reduction. Further, they adopt unique practices and methods which prevent the probable landslide risks within their communities. The risk involved in different landuses, early indicators for landslide prediction, and best farming practices are the main critical aspects in which they are confident. Therefore, the consensus of the local knowledge on landslide disasters is the one main factor facilitating the sustainable future of these mountain communities. Moreover, depopulation and aging have directly affected the livelihood of these mountain communities. The research findings show that the one main issue is terrace abandonment, and the effect of terrace abandonment is the occurrence of degradation processes such as erosion (Galve *et al.* 2015; Pepe *et al.* 2019; Romero-Calcerrada & Perry 2004). This subsequently leads to an increase in landslide risks (Agnoletti *et al.* 2019; Matanle & Rausch 2011). The community and some researchers found the critical condition facing these mountain communities; the issue remains the same and shows the condition moving to the worse in the future (Agnoletti *et al.* 2019; Pepe *et al.* 2019). This trend will direct a more vulnerable environment for livelihood with the effect of natural disasters like landslides.

In summary, terrace abandonment and the reshaping of terrace lands happen because of the population depletion in these mountain communities. At present, the study three communities in a critical socio-economic condition with the potential risk from the living environment attached with landslide disasters; however, the consensus of the local knowledge on landslide

disaster adaptations makes the condition controlled to some extent. Nevertheless the negative trend subsequently leads to an increase in landslide risks and affects the sustainable future of these mountain communities.

4. CONCLUSION

Even though the mountain communities in Japan are depopulated, and in a critical condition, they adapted well to the landslide disaster environment with a unique collection of local and traditional knowledge. The study reveals the unique term for landslide “Noge” emphasizes how much the concept of landslide is embedded in their culture from their ancestors. Furthermore, the research findings indicate how the local knowledge-based practices had enhanced the disaster adaptation level of the community. Knowing the landslide risk involved in different landuses is the key to appropriate landuse planning. However the terrace abandonment and the new farming techniques made the farm land risk in landslides, the community well knowledged in best farming practices to reduce landslide risk. In addition, the community believes different phenomena as early indicators for landslide disasters; the continuous heavy rain and the earthquake as immediate indicators, the earth cracks and muddy springs as other indicators that can be used for landslide prediction.

Furthermore, the consensuses of the local knowledge showed us how well those best practices and beliefs are shared among individuals within villages. Therefore, the all three communities have a consensus of local knowledge, and it is essential for achieving safer livelihood as a unit. However, the transfer of local knowledge is directly affected by depopulation in these mountain communities, which can be leads to the disappearance of valuable local knowledge in the future. In a summary local knowledge and consensuses are key strengths of these communities to adapt to landslide disasters environment. Therefore, the authorities should understand the value of the local knowledge for the sustainability of these mountain communities. Although modern scientific knowledge for disaster risk reduction is vital, it is essential to recognize the role of traditional and local knowledge in enhancing the resilience of local communities, especially in the context of depopulating mountain communities. The research findings initially highlighted the local knowledge in the disaster risk reduction process. Moreover, the findings can act as a key foundation for building a hybrid approach containing local knowledge and scientific knowledge to cope with the risks associated with landslide disasters. As a future study, this research can continue to analyze the impact of the identified local knowledge-based adaptation for landslide disaster risk reduction.

FUNDING

This research partly benefited from the Kurita Water and Environment Foundation Grant [20C020] for field investigations.

ACKNOWLEDGMENTS

The authors are grateful to the Matsunoyama Branch Officials, Tokamachi, especially Ms. MIHOKO Sato, one of the officers in charge, for her warm and good cooperation throughout the field visits. Our special thanks also go to OZ Active Learning (<https://oz-active.com>), the translator who had helped during the translation process. Furthermore, immeasurable gratitude is also extended to the local people who reside in three villages and other informants who shared their valuable insights in completing this study. Finally, we would like to thank MDPI English language editing team for supporting the English language correction.

INSTITUTIONAL REVIEW BOARD STATEMENT

All the surveys of this study were conducted with the support and under the guidance of the officials at the Tokamachi City Matsunoyama Branch Office, Niigata, Japan. Moreover, the study was conducted in compliance with the Nagaoka University of Technology's Regulations on Research Involving Human Subjects. This research survey does not disclose information that identifies individuals, and does not deviate from the above regulations and laws and regulations related to the protection of personal information at the time the research was conducted.

CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

- Agnoletti, M., Errico, A., Santoro, A., Dani, A., & Preti, F. (2019). Terraced landscapes and hydrogeological risk. Effects of land abandonment in Cinque Terre (Italy) during severe rainfall events. *Sustainability*, 11(1): 235. <https://doi.org/10.3390/su11010235>
- Aldrich, D. P. (2011). The power of people: social capital's role in recovery from the 1995 Kobe earthquake. *Natural Hazards*, 56(3): 595–611. <https://doi.org/10.1007/s11069-010-9577-7>
- Aldrich, D. P. (2014). *The externalities of strong social capital: Post-tsunami recovery in Southeast India*. In *Social Capital and Economics* (pp. 191–212). Routledge.
- Aldrich, D. P., & Meyer, M. A. (2015). Social capital and community resilience. *American Behavioral Scientist*, 59(2): 254–269. <https://doi.org/10.1177/0002764214550299>
- Beilin, R., & Reid, K. (2014). It's not a 'thing' but a 'place': reconceptualising 'assets' in the context of fire risk landscapes. *International Journal of Wildland Fire*, 24(1): 130–137. <http://dx.doi.org/10.1071/WF14035>

- Berkes, F. (1999). *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. https://books.google.co.jp/books/about/Sacred_Ecology.html?id=5b8RAgZtxxIC&redir_esc=y
- Berkes, F. (2002). Back to the future: ecosystem dynamics and local knowledge. *Panarchy : Understanding Transformation in Human and Natural Systems*.
- Berkes, F. (2009). Indigenous ways of knowing and the study of environmental change. *Journal of the Royal Society of New Zealand*, 39(4): 151-156 <https://doi.org/10.1080/03014220909510568>
- Carothers, C., Brown, C., Moerlein, K. J., Andrés, L., Lopez, JA, Andersen, DB & Retherford, B. (2014). Measuring perceptions of climate change in northern Alaska: Pairing ethnography with cultural consensus analysis. *Ecology and Society*: 19(4), 27. <https://doi.org/10.5751/ES-06913-190427>
- CITY POPULATION. (2015). The population development of Tōkamachi. https://www.citypopulation.de/en/japan/admin/niigata/15210__tōkamachi/
- Dasanayaka, U. A., & Matsuda, Y. (2019). A study on local knowledge in adaptation to landslide disasters in Sri Lanka. *Engineering Journal*, 23(6): 501–509. <https://doi.org/10.4186/ej.2019.23.6.501>
- Dasanayaka, U., & Matsuda, Y. (2022). Role of social capital in local knowledge evolution and transfer in a network of rural communities coping with landslide disasters in Sri Lanka. *International Journal of Disaster Risk Reduction*, 67, 102630. <https://doi.org/10.1016/j.ijdr.2021.102630>
- de Oliveira, J. A. P., & Paleo, U. F. (2016). Lost in participation: How local knowledge was overlooked in land use planning and risk governance in Tōhoku, Japan. *Land Use Policy*, 52: 543–551. <https://doi.org/10.1016/j.landusepol.2014.09.023>
- Feldhoff, T. (2013). Shrinking communities in Japan: Community ownership of assets as a development potential for rural Japan? *Urban Design International*, 18(1): 99–109. <https://doi.org/10.1057/udi.2012.26>
- Fischer, F. (2000). *Citizens, Experts, and the Environment: The Politics of Local Knowledge*. Duke University Press. <https://doi.org/10.1215/9780822380283>
- Fujita, K., Shaw, R., & Takeuchi, Y. (2012). Linking Mountain Community Practices to Sediment-Related Disaster Risk Reduction in Reihoku, Japan. *Asian Journal of Environment and Disaster Management*, 4(2): 225–245. <https://doi.org/10.3850/s1793924012001150>
- Galve, J. P., Cevasco, A., Brandolini, P., & Soldati, M. (2015). Assessment of shallow landslide risk mitigation measures based on land use planning through probabilistic modelling. *Landslides*, 12(1): 101–114. <https://doi.org/10.1007/s10346-014-0478-9>
- Ganapati, N. E. (2013). Downsides of Social Capital for Women During Disaster Recovery: Toward a More Critical Approach. *Administration & Society*, 45(1): 72–96. <https://doi.org/10.1177/0095399712471491>
- Garcia, A. A., Semken, S., & Brandt, E. (2020). The construction of cultural consensus models to characterize ethnogeological knowledge. *Geoheritage*, 12(3): 1–14. <https://doi.org/10.1007/s12371-020-00480-5>

- Gatewood, J. B. (2012). Cultural models, consensus analysis, and the social organization of knowledge. *Topics in Cognitive Science*, 4(3): 362–371. <https://doi.org/10.1111/j.1756-8765.2012.01197.x>
- Giles, B. G., Haas, G., Šajna, M., & Findlay, C. S. (2008). Exploring aboriginal views of health using fuzzy cognitive maps and transitive closure. *Canadian Journal of Public Health*, 99(5): 411–417. <https://doi.org/10.1007/BF03405252>
- Gollin, L. X., McMillen, H., & Wilcox, B. (2004). Participant-observation and pile sorting: methods for eliciting local understandings and valuations of plants as a first step towards informed community participation in environment and health initiatives in Hawai'i. *Applied Environmental Education & Communication*, 3(4): 259–267. <https://doi.org/10.1080/15330150490882001>
- Harden, C. P. (1996). Interrelationships between land abandonment and land degradation: a case from the Ecuadorian Andes. *Mountain Research and Development*, 16(3): 274–280. <https://doi.org/10.2307/3673950>
- Hilhorst, D. (2003). Responding to disasters. Diversity of bureaucrats, technocrats and local people. *International Journal of Mass Emergencies and Disasters*, 21(1): 37–56. <http://ijmed.org/articles/84/download/>
- Hiwasaki, L., Luna, E., & Shaw, R. (2014). Process for integrating local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation in coastal and small island communities. *International Journal of Disaster Risk Reduction*, 10: 15–27. <https://doi.org/10.1016/j.ijdrr.2014.07.007>
- Indian, J. (2007). The use of local knowledge in the Australian high country during the 2003 bushfires. *Australian Journal of Emergency Management*, 22(4): 27–33. <https://ajem.infoservices.com.au/downloads/AJEM-22-04-06>
- Islam, M. R., Ingham, V., Hicks, J., & Kelly, E. (2018). From coping to adaptation: Flooding and the role of local knowledge in Bangladesh. *International Journal of Disaster Risk Reduction*, 28: 531–538. <https://doi.org/10.1016/j.ijdrr.2017.12.017>
- Johnson, J. C., & Griffith, D. C. (2010). Finding Common Ground in the Commons: Intracultural Variation in Users' Conceptions of Coastal Fisheries Issues. *Society & Natural Resources*, 23(9): 837–855. <https://doi.org/10.1080/08941920802409585>
- Kelman, I., Mercer, J., & Gaillard, J. (2012). Indigenous knowledge and disaster risk reduction. *Geography*, 97(1): 12–21. <https://doi.org/10.1080/00167487.2012.12094332>
- Koster, J. (2010). Informant rankings via consensus analysis: a reply to Hill and Kintigh. *Current Anthropology*, 51(2): 257–258. <https://www.doi.org/10.1086/651073>
- Leith, P., & Vanclay, F. (2017). Placing Science for Natural Resource Management and Climate Variability: Lessons from Narratives of Risk, Place and Identity. *Sociologia Ruralis*, 57(2): 155–170. <https://doi.org/10.1111/soru.12124>
- Lejano, R. P., & Stokols, D. (2021). Analytics for local knowledge: Exploring a community's experience of risk. *Journal of Risk Research*, 24(7): 833–852. <https://doi.org/10.1080/13669877.2018.1476902>
- Li, M., Hasemi, Y., Nozoe, Y., & Nagasawa, M. (2021). Study on strategy for fire safety planning based on local resident cooperation in a preserved historical mountain village in Japan. *International Journal of Disaster Risk Reduction*, 56: 102081. <https://doi.org/10.1016/j.ijdrr.2021.102081>

- Lin, P.-S. S., & Chang, K.-M. (2020). Metamorphosis from local knowledge to involuted disaster knowledge for disaster governance in a landslide-prone tribal community in Taiwan. *International Journal of Disaster Risk Reduction*, 42: 101339. <https://doi.org/10.1016/j.ijdr.2019.101339>
- Lippi-Green, R. L. (1989). Social network integration and language change in progress in a rural alpine village. *Language in Society*, 18(2): 213–234. <https://doi.org/10.1017/S0047404500013476>
- MacDonald, D., Crabtree, J. R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Lazpita, J. G., & Gibon, A. (2000). Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. *Journal of Environmental Management*, 59(1), 47–69. <https://doi.org/10.1006/jema.1999.0335>
- Malla, S. B., Dahal, R. K., & Hasegawa, S. (2020). Analyzing the disaster response competency of the local government official and the elected representative in Nepal. *Geoenvironmental Disasters*, 7(1): 1–13. <https://doi.org/10.1186/s40677-020-00153-z>
- Matanle, P., & Rausch, A. S. (2011). *Japan's shrinking regions in the 21st century: Contemporary responses to depopulation and socioeconomic decline*. New York: Cambria Press
- Matsunoyama Onsen Tourist Information Center. (n.d.). Rice terraces at Matsunoyama. Retrieved December 15, 2021, from <http://www.matsunoyama.com/棚田>
- Mayer, B. (2019). A Review of the Literature on Community Resilience and Disaster Recovery. *Current Environmental Health Reports*, 6(3): 167–173. <https://doi.org/10.1007/s40572-019-00239-3>
- McEwen, L., Garde - Hansen, J., Holmes, A., Jones, O., & Krause, F. (2017). Sustainable flood memories, lay knowledges and the development of community resilience to future flood risk. *Transactions of the Institute of British Geographers*, 42(1), 14 – 28. <https://doi.org/10.1111/tran.12149>
- Meyers, K., & Watson, P. (2005). Legend, ritual and architecture on the ring of fire. Indigenous Knowledge for Disaster Risk Reduction, 17. https://www.sprep.org/att/IRC/eCOPIES/Pacific_Region/314.pdf#page=29
- Miller, M. L., Kaneko, J., Bartram, P., Marks, J., & Brewer, D. D. (2004). Cultural Consensus Analysis and Environmental Anthropology: Yellowfin Tuna Fishery Management in Hawaii. *Cross-Cultural Research*, 38(3): 289–314. <https://doi.org/10.1177/1069397104264278>
- Morris, C. E., Sands, D. C., Vanneste, J. L., Montarry, J., Oakley, B., Guilbaud, C., & Glaux, C. (2010). Inferring the evolutionary history of the plant pathogen *Pseudomonas syringae* from its biogeography in headwaters of rivers in North America, Europe, and New Zealand. *MBio*, 1(3), e00107-10. <https://doi.org/10.1128/mBio.00107-10>
- Murti, R., & Mathez-Stiefel, S. (2019). Social learning approaches for ecosystem-based disaster risk reduction. *International Journal of Disaster Risk Reduction*, 33: 433–440. <https://doi.org/10.1016/j.ijdr.2018.09.018>
- Nagano, M. (2018). Forest School Kyororo. Living with Tanada. Tokamachi City Satoyama Science Museum.

- Nekaris, K. A. I., McCabe, S., Spaan, D., Ali, M. I., & Nijman, V. (2018). A novel application of cultural consensus models to evaluate conservation education programs. *Conservation Biology*, 32(2), 466–476. <https://doi.org/https://doi.org/10.1111/cobi.13023>
- Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness. *American Journal of Community Psychology*, 41(1–2): 127–150. <https://doi.org/10.1007/s10464-007-9156-6>
- Okubo, M., Mohammed, A. J., & Inoue, M. (2016). Out-migrants and Local Institutions: Case Study of a Depopulated Mountain Village in Japan. *Asian Culture and History*, 8(1): 1. <https://doi.org/10.5539/ach.v8n1p1>
- Oravec, Z., Vandekerckhove, J., & Batchelder, W. H. (2014). Bayesian cultural consensus theory. *Field Methods*, 26(3), 207–222. <https://doi.org/10.1177/1525822X13520280>
- Paolisso, M. (2007). Cultural Models and Cultural Consensus of Chesapeake Bay Blue Crab and Oyster Fisheries. *NAPA Bulletin*, 28(1): 123–135. <https://doi.org/10.1525/napa.2007.28.1.123>
- Paris, C. M., Musa, G., & Thirumoorthi, T. (2015). A comparison between Asian and Australasia backpackers using cultural consensus analysis. *Current Issues in Tourism*, 18(2), 175–195. <https://doi.org/10.1080/13683500.2014.920771>
- Pepe, G., Mandarino, A., Raso, E., Scarpellini, P., Brandolini, P., & Cevasco, A. (2019). Investigation on farmland abandonment of terraced slopes using multitemporal data sources comparison and its implication on hydro-geomorphological processes. *Water*, 11(8): 1552. <https://doi.org/10.3390/w11081552>
- Ragin, C. C., & Becker, H. S. (1992). *What is a case?: exploring the foundations of social inquiry*. Cambridge university press.
- Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M., & Evely, A. C. (2010). Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management*, 91(8), 1766–1777. <https://doi.org/10.1016/j.jenvman.2010.03.023>
- Romero-Calcerrada, R., & Perry, G. L. W. (2004). The role of land abandonment in landscape dynamics in the SPA ‘Encinares del río Alberche y Cofio, Central Spain, 1984–1999. *Landscape and Urban Planning*, 66(4): 217–232. [https://www.doi.org/10.1016/S0169-2046\(03\)00112-9](https://www.doi.org/10.1016/S0169-2046(03)00112-9)
- Romney, A. K., Weller, S. C., & Batchelder, W. H. (1986). Culture as consensus: A theory of culture and informant accuracy. *American Anthropologist*, 88(2), 313–338. <https://doi.org/10.1525/aa.1986.88.2.02a00020>
- Ruzol, C., Lomente, L. L., & Pulhin, J. (2021). Cultural consensus knowledge of rice farmers for climate risk management in the Philippines. *Climate Risk Management*, 32, 100298. <https://doi.org/10.1016/j.crm.2021.100298>
- Tinker, A. (2002). The social implications of an ageing population. *Mechanisms of Ageing and Development*, 123(7): 729–735. [https://doi.org/10.1016/S0047-6374\(01\)00418-3](https://doi.org/10.1016/S0047-6374(01)00418-3)
- Tokamachi central government office. (2005). Tokamachi City Overview. <https://www.pref.niigata.lg.jp/uploaded/attachment/92438>
- Traditional Knowledge. (n.d.). World Intellectual Property Organization (WIPO). Retrieved December 15, 2021, from <https://www.wipo.int/tk/en/tk/>

- TSUNAKI, R. (2002). Landslide in Japan. <https://japan.landslide-soc.org/wp19/wp-content/uploads/2019/05/2002.pdf>
- Van Holt, T., Townsend, W. R., & Cronkleton, P. (2010). Assessing local knowledge of game abundance and persistence of hunting livelihoods in the Bolivian Amazon using consensus analysis. *Human Ecology*, 38(6): 791–801. <https://doi.org/10.1007/s10745-010-9354-y>
- Wannous, C., & Velasquez, G. (2017). United Nations Office for Disaster Risk Reduction (UNISDR)—UNISDR’s Contribution to Science and Technology for Disaster Risk Reduction and the Role of the International Consortium on Landslides (ICL) BT - *Advancing Culture of Living with Landslides* (K. Sassa, M. Mikoš, & Y. Yin (Eds.); pp. 109–115). Springer International Publishing. https://doi.org/10.1007/978-3-319-59469-9_6
- Weller, S. C. (2007). Cultural Consensus Theory: Applications and Frequently Asked Questions. *Field Methods*, 19(4): 339–368. <https://doi.org/10.1177/1525822X07303502>
- Zanotti, L., Glover, D. M., & Sepez, J. (2010). Local communities and natural resources: ethnobiology in practice. In E. A. Smith, I. Vaccaro, & S. Aswani (Eds.), *Environmental Social Sciences: Methods and Research Design* (pp. 110–131). Cambridge University Press. <https://doi.org/10.1017/CBO9780511760242.008>
- Zulfadrim, Z., Toyoda, Y., & Kanegae, H. (2019). The integration of indigenous knowledge for disaster risk reduction practices through scientific knowledge: cases from Mentawai islands, Indonesia. *International Journal of Disaster Management*, 2(1), 1–12. <https://doi.org/10.24815/ijdm.v2i1.13503>