Review:

Research for Contributing to the Field of Disaster Science: A Review

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In order to contribute to the field of disaster science, various research in Japan currently focus on the clarification of the phenomenon called "disaster." Due to society's demand for disaster prevention and disaster mitigation, these researches are carried out through collaboration among researchers in science, engineering, humanities, social sciences, etc. These research outcomes are aimed at the following: verification of disaster cases of earthquakes and volcanic eruptions; clarification of the disaster occurrence mechanisms of earthquakes and volcanic eruptions; sophistication of information for disaster mitigation of earthquakes and volcanic eruptions; and development of researchers, engineers, and human resources involved in disaster prevention operations and disaster prevention responses. This article puts these research outcomes together from four points of view: 1) research on earthquakes and volcanic eruptions disaster cases, 2) clarification of disaster occurrence mechanisms of earthquakes and volcanic eruptions, 3) sophistication of information for disaster mitigation of earthquakes and volcanic eruptions, and 4) development of researchers, engineers, and human resources involved in disaster prevention operations and disaster prevention responses.

Keywords: disaster trigger, disaster causative factor, disaster case study, disaster occurrence mechanism, disaster mitigation information

1. Introduction

The Basic Act on Disaster Management in Japan defines a disaster as "damage resulting from a storm, tornado, heavy rainfall, heavy snowfall, flood, high tide, earthquake, tsunami, eruption, or other abnormal natural phenomena, or a large fire or explosion or other causes to be taken care of by the appropriate Cabinet Order and similar to the above in the extent of damage they cause." This paper puts together research outcomes with the focus on the clarification of the phenomenon of "disaster" in order to contribute to the field of disaster science, under the Earthquake and Volcano Hazards Observation and Research Program, designed by the Council for Science and Technology of the Ministry of Education, Culture, Sports, Science and Technology of Japan. This paper also includes research outcomes aimed at the following: verification of disaster cases of earthquakes and volcanic eruptions; clarification of the disaster occurrence mechanisms of earthquakes and volcanic eruptions; sophistication of information for disaster mitigation of earthquakes and volcanic eruptions; development of researchers, engineers, and human resources involved in disaster prevention operations and disaster prevention responses. This is achieved through the collaboration among researchers in science, engineering, humanities, social sciences, etc., taking society's demand for disaster prevention and disaster mitigation into consideration.

According to Mizutani [1], occurrence of a "disaster" is summarized as follows (**Fig. 1**): a "disaster trigger" (hazard) such as a meteorological hazard or a crustal hazard that causes a disaster acts on a "disaster causative factor" (vulnerability) such as a "natural causative factor" and a "social causative factor" to cause and spread a "damage" and an "impact" and is recognized by the society as a "disaster." The seismological and volcanic research communities have been researching the "disaster trigger" as a natural phenomenon. This natural phenomenon acts on the "terrain, ground, and seawater," which are natural causative factors, and thus a disaster phenomenon occurs. Specifically, disaster phenomena include floods, high tides, slope failures, mudflows, ground vibrations,

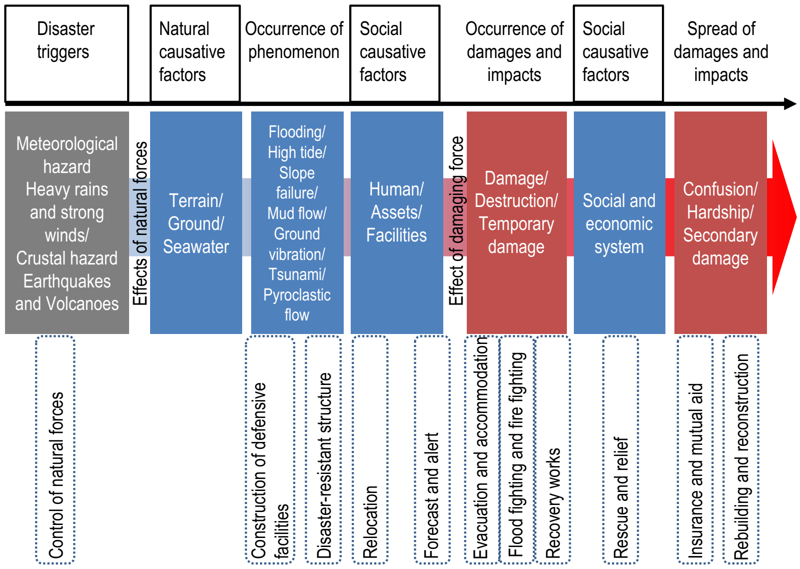

Fig. 1. What chain of factors causes a disaster (partially modified from Mizutani [1]).

tsunamis, and pyroclastic flows. A great magnitude of these disaster phenomena causes direct damages and impacts on human lives, buildings, and social infrastructures. In addition, the social causative factor, which is damage to "human, assets, and facilities" and the like, acts as a damaging force. It causes damage and impacts on the "social and economic system." It also leads to so-called indirect damages and impacts such as "confusion, hardship, and secondary damage." In other words, in order to explain the "disaster" phenomena, it is necessary to explain not only the disaster trigger arising from natural phenomena such as earthquakes and volcanic eruptions, but also the disaster causative factors such as natural environments including terrain and ground, human characteristics, and social mechanisms.

In light of current scientific research outcomes, it is impossible to eliminate the natural phenomena themselves as disaster triggers. Research highly value clarification of the occurrence mechanism of phenomena, damages, and effects, If the mechanisms of the causes are understood, then predictions can be made. Research on the disaster causative factors have been made with the aim to reduce damages and impacts that occur (damage prevention); to prevent the damages and impacts that have actually occurred from further increasing (damage mitigation) in terms of tangible aspects such as structures, lifelines, and information systems. Also, to prevent further damages to intangible aspects such as social organization systems and human behavior. In particular, research on disaster causative factors are called disaster prevention research or, from the point of view of reducing damages and impacts, disaster mitigation research. In order to promote these research as a comprehensive disaster science research, it is necessary to cooperate with research fields relevant to disaster prevention science and disaster mitigation science, such as engineering. This includes architecture, civil engineering, information engineering, and agriculture. It also includes humanities and social sciences such as psychology, sociology, welfare, history, jurisprudence, economics, and geography.

In this section, as research that contribute to clarification of disasters, research outcomes will be put together from the points of view of 1) research on earthquakes and volcanic eruptions disaster cases, 2) clarification of disaster occurrence mechanisms of earthquakes and volcanic eruptions, 3) sophistication of information for disaster mitigation of earthquakes and volcanic eruptions, and 4) development of researchers, engineers, and human resources involved in disaster prevention operations and disaster prevention responses.

2. Research on Earthquakes and Volcanic Eruptions as Disaster Cases

Research on earthquakes and volcanic eruptions as disaster cases include an analysis of historical archived databases on the damaging factors in Kyoto during the 976 Kyoto and Omi Earthquake and the damage situation in Edo city based on pictorial materials related to the 1855 Ansei Edo Earthquake. The latter earthquake occurred at night on November 11, 1855, devastating the southern Kanto area. In particular, it includes an analysis of "Picture of the Great Edo Earthquake" (the archives of the Shimazu family, owned by the Historiographical Institute, The University of Tokyo), handed down in the Shimazu family in the old province of Satsuma. The picture is a scroll painting depicting the scene of damage and reconstruction in Edo city caused by the 1855 Ansei Edo Earthquake. More specifically, the picture depicts a scene of fire in the north of the Satsuma samurai residence where an entire town was burned down. As the picture has turned out to depict specific places and locations that were affected such as residences and a town, the picture scroll is valued as historical material. It is suggested that the picture scroll be used as historical material in order to understand the situation of the city that was reconstructed after the fire in Edo, where fires that were not caused by earthquakes frequently occurred [2]. Regarding the earthquake in Kyoto and Omi that occurred on July 17, 976, and caused damage to Kyoto, its surrounding areas, and the southwestern part of the old province of Omi, the description in a chronicle titled Nihon Kiryaku indicates that the collapse of a temple building of Kiyomizu-dera Temple crushed a total of 50 Buddhist monks and lay people to death. It also indicates that there were many victims killed by the collapse of the main hall alone because it was a festival day and the temple was crowded with worshipers. It has been made clear that the grasp of individual historical situations is important in order to apply knowledge of historical disasters to the present day.

An examination was carried out regarding a transmission technique related to earthquakes and volcanic eruptions [3] in the light of specific situations in past disaster cases. As a challenge for earthquake research to respond to the impact on society in particular, they focused on "How to share the information on shaking to mitigate damage and the subsequent process of recovery and reconstruction." For this purpose, actual past disasters were analyzed and the simulation of future responses was carried out in terms of the number of required days for operations to rebuild the lives of affected people. Specifically, analyses were made on the daily numbers of disaster victim certificates issued in the following cases: Kashiwazaki City, affected by the 2007 Chuetsu Offshore Earthquake; Mashiki Town, affected by the 2016 Kumamoto Earthquake; and Ibaraki City, affected by the 2018 Northern Osaka Earthquake. The actual data on these cases were provided by each local government. As a result, the following three general tendencies have been made clear: 1) the number of issued disaster victim certificates turned to drop in slightly less than three weeks after its initial issuance, 2) the number of issued disaster victim certificates turned to rise again in slightly more than two months, and then converged in over four months, and 3) there is a similar pattern observed in the above tendencies regardless of the amount of damage. On a case-by-case basis, Ibaraki City, which suffered the least damage, was the first to issue certificates, followed by Mashiki Town, which suffered the second least damage. Since the 2011 Great East Japan Earthquake, there has been a tendency to urge the disaster-affected local governments to issue the certificates on the basis that "the timing of issuance of disaster victim certificates affects the speed of rebuilding the lives of the affected people." This can be inferred to be the result of Mashiki Town's response to the social demand. On the other hand, Kashiwazaki City, which saw a gradual increase in the number of issuances overall, had a smaller difference between the increase and decrease in the number of issuances, which suggests that their operation transitions were stabilizing in terms of the issuance operation. Respective approximate curves were obtained for the purpose of modeling the issuance pattern of disaster victim certificates on the basis of these results. By transmitting these research outcomes to the disaster-stricken local governments that are currently responding, those local governments can be expected to make "a strategic behavior change for supporting rebuilding everyday lives on the basis of prediction of future transition" (**Table 1**, **Fig. 2**).

3. Clarification of the Mechanism of Earthquakes and Volcanic Eruptions as Disasters

To clarify the occurrence of earthquakes, a research was conducted to clarify the effect of earthquake disaster triggers on natural causative factors. Based on this, an underground structure modeling method was established. Field verification of application validity in sedimentary plains and sedimentary basins outside Japan was put together. In some cases, an underground structure model for strong motion prediction is not available. This applies to sedimentary plains and sedimentary basins outside Japan such as Taiwan, the Himalayan Frontal Thrust including India and Bhutan, and Algeria. Therefore, methods were developed as correction using the ratio H/V spectral ratio between horizontal motion and vertical motion in the observation records, correction of the source radiation pattern coefficient necessary for reproducing near-source strong motion pulses, and use of the empirical Green's function method, as well as strong motion evaluations of past damaging earthquakes[4–6]. As a result, we have confirmed that, although the accuracy is poorer than that of the strong motion estimations promoted in Japan, the average value can reproduce the time history waveform harmonically with the earthquake motion prediction formula used by engineering in each country. These methods can effectively be used as alternative calculation methods in the transitional period until a good underground structure model is developed. These are important achievements in understanding disasters caused by strong ground motions.

In order to clarify the disaster occurrence mechanism of volcanoes, the ash fall risk analysis assuming a large-scale eruption of Sakurajima volcano was divided into (1) estimation of an ash fall distribution in accordance with eruption scenarios and weather scenarios, and (2) impact analysis in accordance with the quantitative predictions of ash fall. Through analysis of fields where disasters caused by ash fall are predicted, it was confirmed that volcanic ash affects various social systems by its conductivity and weight in wet conditions and by volcanic gas components adhering to it [3]. Subsequently, the three fields, namely roads, aviation, and buildings, were set as the target fields for the ash fall risk analysis and the thresholds determining individual disaster influences were examined. On an assumption of volcanic smoke of the scale of the 1914 Taisho eruption, the ash fall distribution was calculated on the basis of the meteorological scenario for 3890 days, and an ash fall hazard database was developed. Volcanic

Table 1. Actual status of issuance of disaster victim certificates in four recent earthquake disasters.

Disaster Name	2018 Hokkaido Eastern Iburi Earthquake	2018 Northern Osaka Earthquake	2016 Kumamoto Earthquake	2007 Niigata Chuetsu Offshore Earthquake
Disaster-affected local governments	Abira Town	Ibaraki City	Mashiki Town	Kashiwazaki City
Date of disaster occurrence (date of the main shock)	September 6	June 18	April 16	July 16
Disaster victim certificate issuance start date	September 30	July 23	May 20	August 17
The number of days taken from the day of disaster occurrence to the date of issuance	Day 25	Day 36	Day 35	Day 33

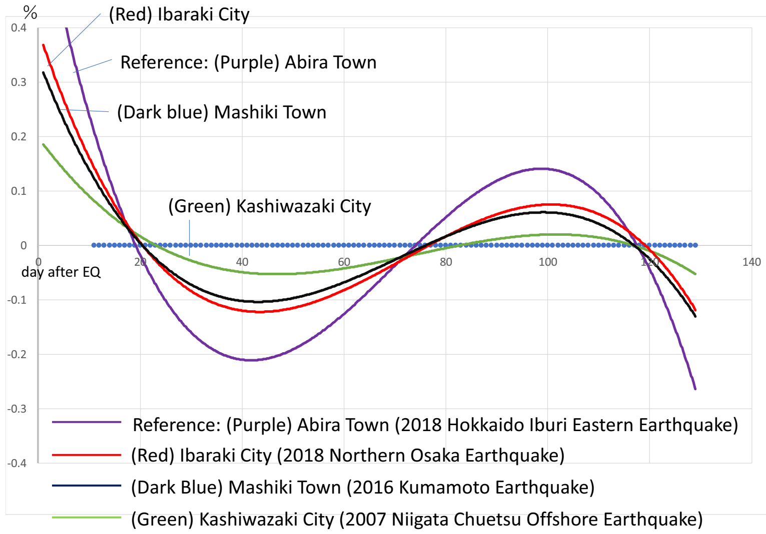

Fig. 2. Modeling of disaster victim certificate issuance applied to four earthquake disasters (from "FY2018 Annual Report: Earthquake and Volcano Hazards Observation and Research Program" [3]).

ash transport simulation by the PUFF model was used for prediction calculation of the ash fall distribution. In addition, a significant tendency for the ash fall distribution in the event of large-scale eruption on Sakurajima was found by calculating the ash fall distribution probability under certain conditions. This includes changes and the influence of westerly winds over Sakurajima and strong wind velocity including typhoons. Using the calculated ash fall distribution and its probability distribution, the ash fall risk in the analysis target items, i.e., the three fields of roads, aviation, and buildings were analyzed. In the aviation field, the ash fall probability distribution was calculated for each threshold as set for 20 airports in Japan, and the eruption time of ash fall at the Haneda Airport and the Niigata Airport is alarming. In order to avoid risks, such as the collapse of buildings, we calculated the number of people requiring evacuation. Considering changeable weather conditions, the daily number of people requiring evacuation was calculated for a total of 730 days during 2013 and again in 2017. The largest number of people who required evacuation in 2017 was 625. A total of 186 people on August 23 and 635,171 on September 16, 2013. The average number of people requiring evacuation from May to October each year exceeded 100,000, suggesting that the implementation of evacuation is expected to be difficult (**Fig. 3**). The outcome is of great importance, considering an evacuation during an actual ash fall disaster.

The concept of "vulnerability" based on the disaster-affected experience in the 2011 Great East Japan Earthquake, guidelines for assessing the vulnerability of communities to disasters were examined through quantitative and qualitative analyses. The disaster preparedness of communities were further examined through a qualitative analyses for the area expected to be affected by the Nankai Trough Earthquake. Specifically, the surveys and research were conducted on the basis of working hypotheses related to the following vulnerability components: 1) space (land use, land conditions, urban planning, urban functions, etc.), 2) disaster prevention consciousness and disaster culture (collective memories of disasters and evocation devices, disaster preparedness, etc.), 3) social cohesion (local community organizations, disaster prevention organizations, Nonprofit Organizations (NPOs), their inter-organizational relationships, collaboration with the government, etc.), and 4) disaster countermeasures (tangible countermeasures such as disaster prevention facilities and intangible countermeasures such as disaster prevention plans). In particular, a questionnaire survey was conducted in communities of five cities

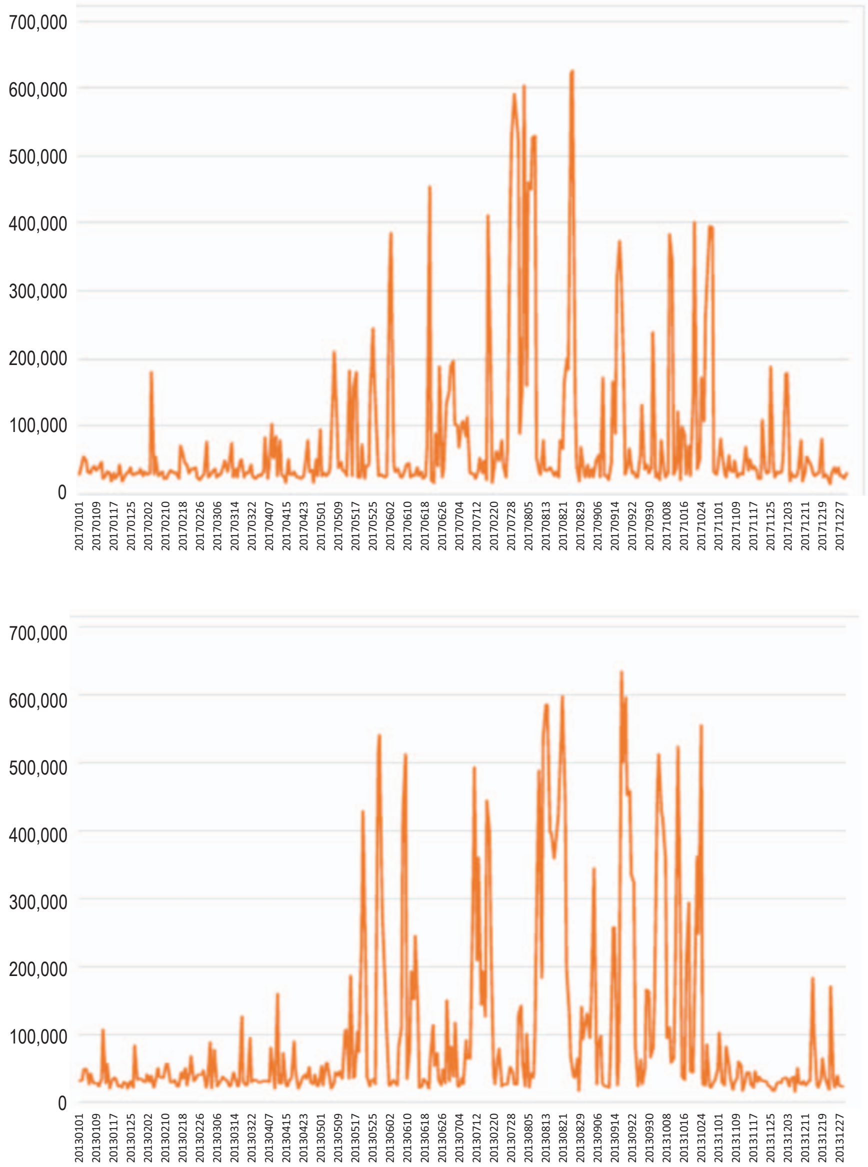

Fig. 3. Transitions in the number of people requiring evacuation throughout one year for an advanced widearea evacuation plan assuming large-scale volcanic eruption on Sakurajima (Top: 2017, Bottom: 2013) (from "FY2018 Annual Report: Earthquake and Volcano Hazards Observation and Research Program" [3]).

and five towns (Ishinomaki City, Kesennuma City, Natori City, Higashimatsushima City, Iwanuma City, Watari Town, Yamamoto Town, Shichigahama Town, Onagawa Town, and Minamisanriku Town) in the tsunami-affected areas of Miyagi Prefecture. In particular, the analysis of changes in living environment conditions such as relocation (change in space) after the earthquake indicates that 1) the living conditions of the community have deteriorated as a whole compared to those before the earthquake. Such tendencies are particularly remarkable related to access to shopping, public transportation convenience, and employment and working conditions (**Fig. 4**) and 2) there are significant differences in living environment changes depending on whether or not relocation takes place (**Fig. 5**). Thus, both positive and negative changes are significant in the relocated areas. In this sense, living environment conditions tend to polarize among the relocated areas [7]. All of these findings suggest a disharmony between disaster prevention projects (relocation) and urban planning and livelihood reconstruction. It is necessary to deepen the understanding of the actual situation through field surveys, to develop a regional typological analysis framework to grasp the vulnerability, and to make use of it for present situation analyses and disaster prevention measures for the earthquake prone areas of Nankai Trough.

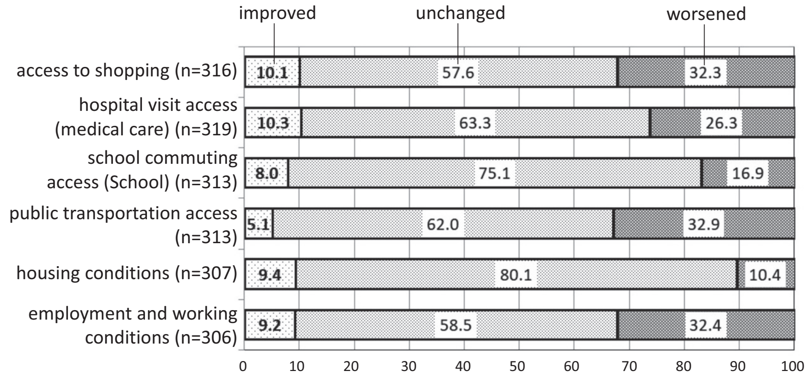

Fig. 4. Changes in living environment conditions after reconstruction in areas affected by the Great East Japan Earthquake (from "FY2018 Annual Report: Earthquake and Volcano Hazards Observation and Research Program" [3]).

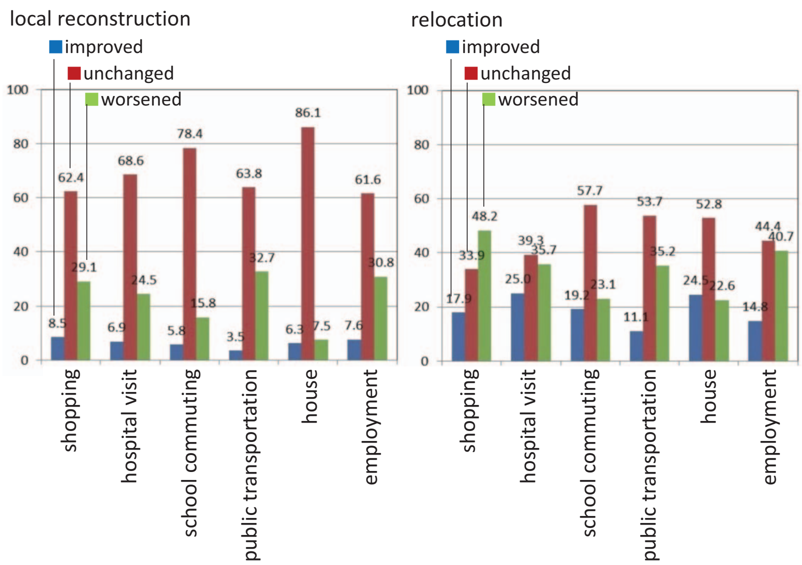

Fig. 5. Changes in living environment conditions by type of housing reconstruction in areas affected by the Great East Japan Earthquake (from "FY2018 Annual Report: Earthquake and Volcano Hazards Observation and Research Program" [3]).

4. Sophistication of Information for Disaster Mitigation of Earthquakes and Volcanic Eruptions

Regarding sophistication of information for disaster mitigation of earthquakes, from the aspect of humanities and social research of disasters, the following utilization methods were integrated: geospatial information (G spatial information), geographic information system (GIS), and satellite positioning (GPS, quasi-zenith positioning system, etc.). In particular, through an integrated utilization method of satellite positioning, using quasi-zenith satellites etc., geospatial information and GIS were developed. A research on evacuation in the event of a disaster in cold, snowy areas was conducted; issues were identified, and proposals were made for countermeasures [8]. After this, an information system was built for disaster prevention and disaster mitigation including a high-precision evacuation navigation system of which a utilization method was developed [9]. Next, an integrated utilization method of geospatial information and GIS was developed to strengthen regional disaster prevention capabilities. Research was conducted on the use of these sophisticated technology for disaster prevention and disaster mitigation[10, 11]. These research discuss the possibility that urban development increases the disaster risk of earthquake and tsunami disasters and increases social vulnerability to disasters. It examines the effectiveness of countermeasures by making use of geospatial information. These research include analyses at different spatial scales such as local level, municipal level, and neighborhood association level and have identified issues for disaster prevention and disaster mitigation at each scale [12]. Furthermore, the effective use of GIS and geospatial information for disaster prevention was examined by presenting open lectures on local disaster prevention, providing disaster prevention education to local governments, and making contributions to local commu-

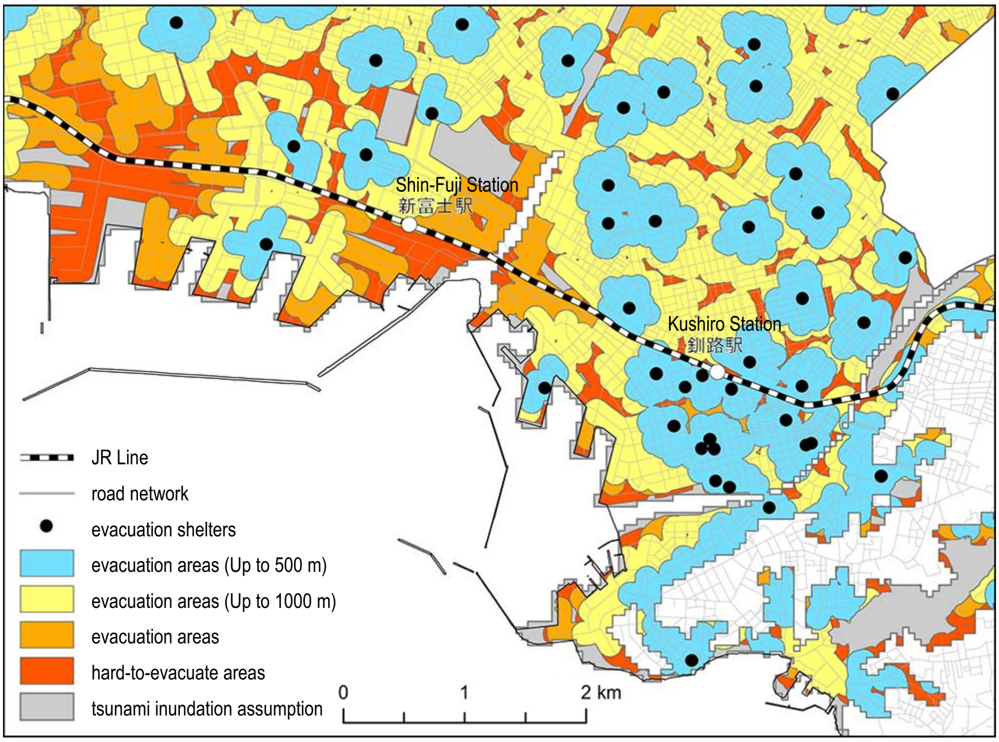

Fig. 6. Simulation results of evacuation areas and hard-to-evacuate areas in the event of occurrence of tsunami in Kushiro City (from "FY2018 Annual Report: Earthquake and Volcano Hazards Observation and Research Program" [3]).

nities [13] (**Fig. 6**). Those research have yielded significant outcomes on the development of a method to predict disasters on an actual spatial scale and to clarify issues on disaster prevention and disaster mitigation, through the successful verification of the results as disaster prevention education and community contribution by local governments.

A social survey was carried out on aftershock information and evacuation behaviors in the 2016 Kumamoto Earthquake [14]. In the Kumamoto Earthquake, two earthquakes of seismic intensity 7 and its aftershocks greatly affected the evacuation of the affected people and the restoration activities of the affected areas. This survey was aimed to clarify whether the information on the aftershocks had been properly conveyed to the affected people, what kind of impact the information on the aftershocks had on the evacuation behavior of the affected people, and how the affected people evaluated the information sources of the aftershocks. The survey also clarified the overall picture of the affected people's behaviors after the earthquake as well as their recovery and reconstruction. The survey was conducted jointly with the Earthquake and Disaster-Reduction Research Division, Research and Development Bureau, the Ministry of Education, Culture, Sports, Science and Technology of Japan and the analysis results were published as a paper. In particular, risk recognition before the earthquake occurred was surveyed. People were asked whether they had thought that an earthquake was going to occur due to an active fault in their area, to which 69.7% of them answered that they were not aware of an active fault. The survey indicated that about 70% of the residents did not know about the existence of an active fault in their area. This was followed by "I suppose no earthquake will occur" by 17.3%, "An earthquake is likely to occur within the 21st century" by 6.9%, "An earthquake is likely to occur in the next decade or so" by 2.9%, "An earthquake is likely to occur within a few years" by 2.3%, and no response by 0.9%. About 30% of the residents who were aware of the active fault had believed that an earthquake would probably not occur (**Fig. 7**). Residents were asked, after the quake, if they thought there might be another big aftershock. In consideration of whether to have evacuated when the foreshock occurred, about 40% of those who evacuated ($n = 1,655$) estimated the likelihood of occurrence of aftershocks high such as "It will occur I suppose no earthquake will occur" (34.3%) and "It will occur within three days" (3.3%). About another 40% estimated the likelihood of occurrence of aftershocks low such as "It will not occur again for the time being" (28.9%) and "I didn't think about the aftershocks" (10.5%). Among those who had not evacuated ($n = 1,517$), approximately 60% of them estimated the likelihood of occurrence of aftershocks low such as "It will not occur again for the time being" (37.9%) and "I didn't think about the aftershocks" (23.3%) ($\chi^2(5) = 208.9$, $p < .01$) (**Fig. 8**).

Following the eruption of Mt. Ontake on September 27, 2014, examinations and proposals were made on the content of and how to convey disaster information that would be useful to local residents and tourists, as well as for per-

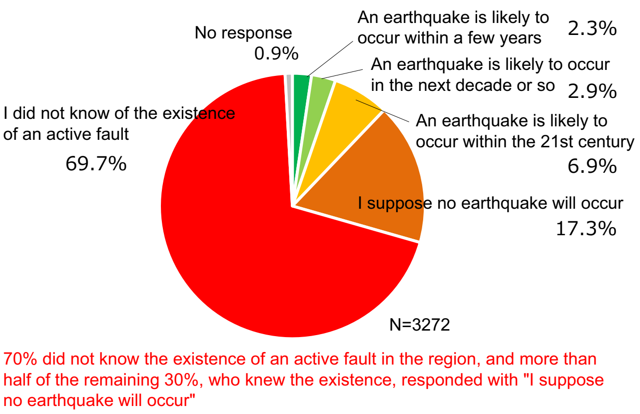

Fig. 7. Recognition of active fault in the area before occurrence of earthquake (social survey on aftershock information and evacuation behavior in the 2016 Kumamoto Earthquake).

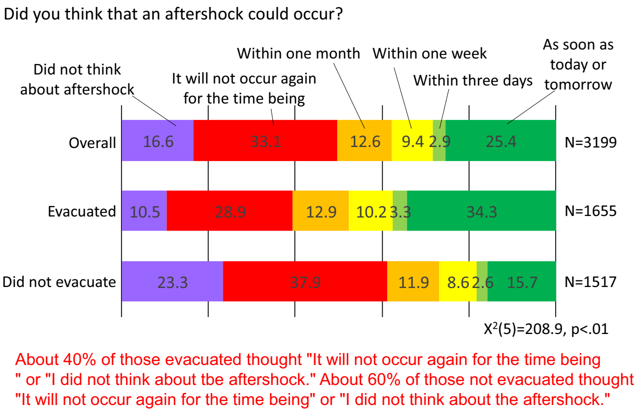

Fig. 8. Recognition of the possibility of aftershocks following the foreshock on April 14, 2016 (social survey on aftershock information and evacuation behavior in the 2016 Kumamoto Earthquake).

sonnel in charge of information conveyance such as municipal officials [15]. In particular, regarding the volcanic disaster information, an awareness survey on the eruption of Mt. Ontake and its countermeasures were conducted for residents on the Nagano Prefecture side (Kiso Town and Otaki Village), as well as an awareness survey for those who were climbing the mountain in the event of the eruption. As a result of the analysis, it has turned out that there was not much difference in recognition per region of a prior eruption risk. Three years have elapsed since the eruption, but those who experienced the eruption still experience high levels of stress. The results of surveys conducted in Gifu and Nagano Prefectures were also compiled and compared. In addition, a hearing survey was conducted in the Nagano Prefecture about the operation status of the Ontakesan Volcano Meister, which was newly set up after the eruption. In addition, a workshop was held in Osaka-cho, Gero City, Gifu Prefecture, and other places to share the results of the resident awareness survey and opinions on how to convey information on volcanoes were exchanged (**Fig. 9**).

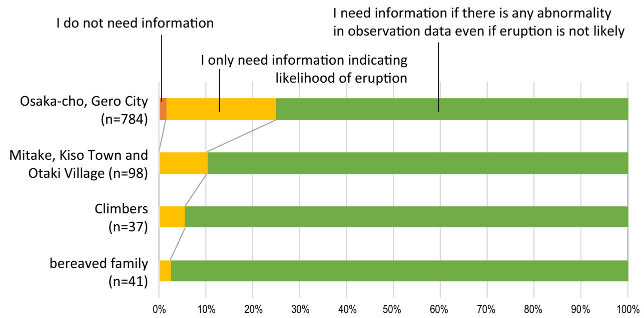

Fig. 9. Needs for information provision in the event when changes in volcanic activity are observed (from "FY2018 Annual Report: Earthquake and Volcano Hazards Observation and Research Program" [3]).

5. Development of Researchers, Engineers, and Human Resources Involved in Disaster Prevention Operations and Disaster Prevention Responses

Field surveys on damage and communication were conducted in Italy, New Zealand, and Taiwan, where major earthquakes occurred in 2016 and 2017. The aim was to contribute to the refinement of long-term forecast information by establishing a communication method that makes uncertain information about the long-term earthquake forecast and tsunami triggers useful for disaster mitigation. A social survey was conducted with 750 residents who were at risk of being affected by seismic activities on the San Andreas Fault in the San Francisco Bay area. The survey result indicates that explicit specialist admission of uncertainty in risk estimates increases confidence that the specialists are honest and trustworthy, resulting in significant trust [16].

A research was conducted toward the development of a support system for local governments in Hokkaido to comprehensively grasp the current situation. Also, to carry out appropriate disaster prevention measures through the quasi-real-time collection and integrated display of various kinds of observation information from relevant organizations, available via internet sites linked to disaster prevention information such as volcano information (**Fig. 10**) [17]. In 2018, temporary explanatory materials were released regarding Mt. Tokachi in June, and information on the crater area of Mt. Meakan was released in November, which were events testing the effectiveness of the system. On September 6, the 2018 Hokkaido Eastern Iburi Earthquake, which measured a maximum seismic intensity of 7, occurred, causing major damage due to a large-scale landslide. The entire province also suffered an entire electrical power blackout. This led to the acquisition and incorporation of display functions

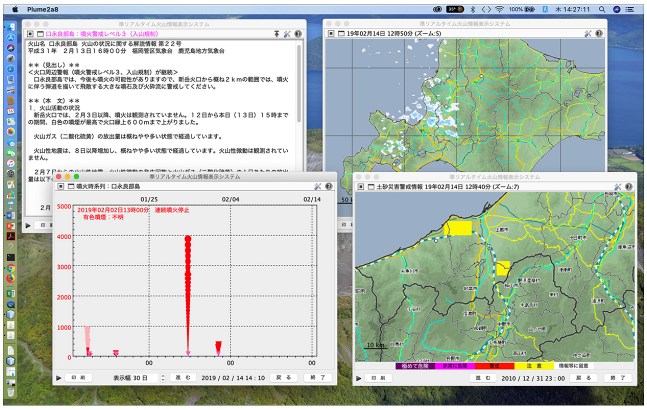

Fig. 10. Desktop displaying four information windows (Upper left: Eruption warning and explanatory information; Lower left: Eruption time series; Upper right: High-resolution rainfall radar image; Lower right: Sediment disaster warning judgment mesh information) (from "FY2018 Annual Report: Earthquake and Volcano Hazards Observation and Research Program" [3]).

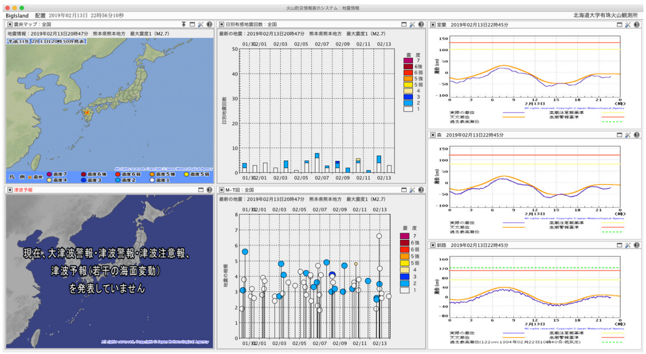

Fig. 11. Epicenter map and tsunami information displayed in integrated window (experimental) (daily frequency of earthquakes, magnitude-time distribution map, and tide level observation information. Earthquake frequency display using a stacked bar chart format in which the maximum seismic intensity is indicated in color, and the bars are stacked every time the earthquake information is updated, so as to grasp time course of earthquake activity. The magnitude-time distribution map also indicates the maximum seismic intensity in color and circle size as well as the magnitude) (from "FY2018 Annual Report: Earthquake and Volcano Hazards Observation and Research Program" [3]).

for earthquake and seismic intensity information systems (**Fig. 11**). Acquiring and displaying functions for high-resolution rainfall radar images were also added. As for the system utilization, Biei Town, which has Mt. Tokachi, and Kushiro City, which has Mt. Meakan, have installed the system in their visitor facilities for the purpose of providing visitors (including tourists and climbers) with volcanic disaster prevention information on a real-time basis. This shows that the system has been praised and accepted by the local government.

6. Conclusions and Future Prospects

With a focus on the clarification of the phenomenon of "disaster" in order to contribute to the field of disaster science, this paper has put together the research outcomes aimed at verification of the following: earthquakes and volcanic eruptions as disaster cases; clarification of the disaster occurrence mechanisms of earthquakes and volcanic eruptions; and sophistication of information for disaster mitigation of earthquakes and volcanic eruptions. Also, the development of researchers, engineers, and human resources involved in disaster prevention operations and disaster prevention responses, through collaboration among researchers in science, engineering, humanities, social sciences, etc., taking social demand for disaster prevention and disaster mitigation into consideration.

Specifically, in the research of disaster cases of earthquakes and volcanic eruptions, the earthquake response in damaging earthquakes was examined by studying historical databases that had appeared prior to the start of modern observation. A transmission technique prototype of findings related to earthquakes and volcanic eruptions in the light of past disaster cases was modeled on the basis of actual disaster responses, such as the issuance of disaster victim certificates. In clarification of the disaster occurrence mechanism of earthquakes and volcanic eruptions, field verification of application validity of the underground structure modeling method in sedimentary plains and sedimentary basins inside and outside Japan, as well as data sharing by a server, were started. Also, advanced wide-area evacuation in cases of "ash fall damage" for which countermeasures have not been developed in particular at volcanic eruptions, was investigated. As for the concept of vulnerability, the examinations were carried out in terms of humanities and social sciences using the Great East Japan Earthquake as an example. In sophistication of information for mitigating disasters caused by earthquakes and volcanic eruptions, with Hokkaido as an example, an evacuation support system using geospatial information, GIS, and satellite positioning in an integrated manner was developed. Social surveys have revealed residents' lack of risk consciousness of volcanic disasters and also their need for information. With regard to the development of researchers, engineers, and human resources involved in disaster prevention operations and disaster prevention measures, examinations were carried out on the residents' risk consciousness of earthquakes and the reliability of specialists, and the construction and verification of a quasi-real-time volcanic information distribution system specialized in GUI were carried out.

For the future, it is important to carry out further verification, systematization and theoretical construction as an evolutionary research. Specifically, the research of disaster cases of earthquakes and volcanic eruptions will include further collection of disaster cases of natural disasters. This includes information on earthquakes, tsunamis, and volcanic disasters. There will be continuous examinations on the response of and lessons learned from people during disasters, the reconstruction process, and the overall picture of the disaster research. Examinations are also needed on multiple disasters, based on materials from historical archives databases and research databases. The clarification of earthquake disasters and volcanic eruptions will include the effect of earthquake disaster on natural causal factors. This will include verification of the validity of the application of underground structural modeling methods, based on a strong seismogram database in sedimentary plains and sedimentary basins in and outside Japan. It include examination of the concept of vulnerability, implementing quantitative surveys and qualitative surveys and verification, from the humanities and social sciences perspectives. Examinations and verifications of the hypotheses have been made clear by the existing research. The sophistication of information to mitigate disasters such as earthquakes and volcanic eruptions will include the development of an integrated utilization method of satellite positioning by quasi-zenith satellites and other means, geospatial information, and GIS, as well as evacuation investigations carried out in the event of a disaster. Information will also take into account the regional characteristics of snow and cold regions, identification issues, proposing countermeasures and comprehensive verification conducted through volcanoes comparisons on how residents receive information regarding volcanic disaster. The development of researchers, engineers and human resources involved in disaster prevention operations and disaster prevention measures will play an important role when surveys and analyses are conducted on residents' disaster risk consciousness. Reliability on the specialists and verification of the needs of recipients regarding the volcanic information distribution system on the results utilized by local governments are also important issues.

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