Utilization of geospatial information for recovery and rehabilitation from the northern Kyushu heavy rainfall disaster in July 2017

N Kameyama¹, Y Mitani¹, H Taniguchi¹ and Y Okajima¹
¹Department of Civil Engineering, Graduate School of Engineering, Kyushu, Japan University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

E-mail: kameyama.naoki.660@s.kyushu-u.ac.jp

Abstract. Unexpected torrential rains have occurred recently due to global warming. There is "limits of public help" in such a disaster. Therefore, "self-help" and "mutual help" become more important to protect lives. Improving these helps enhances disaster resilience. The purpose of this research is to propose initiatives utilizing geospatial information in recovery and rehabilitation phases and to indicate the effects of using geospatial information in the initiatives. The initiatives have conducted for rehabilitation in Toho village, which was damaged by the Northern Kyushu Heavy Rainfall Disaster in July 2017. One initiative is formulating a rehabilitation plan. Meetings are held to reflect residents' opinions to the plan; using the map is useful to collect and share the opinions. Residents could discuss concrete future visions by using a map, and the rehabilitation plan reflected the opinions of residents could be published. The other initiative is Risk Communication. Many kinds of geospatial information are collected in it, and the Risk Map is published. The map shows the dangerous places and evacuation sites, and residents could understand their location, then the map enhanced disaster resilience.

1. Introduction
These days, torrential rains exceeding expectations have occurred often due to abnormal weather caused by global warming. Many lives have been lost by floods and slope failures caused by the torrential rains. In such a disaster, it is difficult for local governments to support all residents quickly, and local governments themselves may suffer, and their function may be suspended. The Japanese government says that there is a limit to the "public help" that the government can provide [1]. In order to protect lives from disasters, "self-help" in which residents should prepare for disasters or evacuate voluntarily and "mutual help" in which residents help each other to the rescue, guide evacuation or management shelters are important.

In addition, geospatial information is utilized more and more in the field of disaster management. In Japan, in the case of the Great East Japan Earthquake, much geospatial information such as aerial photographs and tsunami inundated areas was collected from the beginning of the disaster. The information was widely utilized at the response stage and recovery stage [2]. Obviously, supporting using geospatial information enables detailed analysis based on location and more optimal decision-making. However, there are many problems such as it is difficult for local government staff to utilize geospatial information in GIS, the accuracy and precision of data are not clear, and GIS cannot be
used immediately at the time of disaster happening. Further researches and use cases utilizing geospatial information are required.

In Toho village, Fukuoka prefecture, torrential rain happened in July 2017, which is called Heavy Rain in Northern Kyushu in July 2017, then many floods and slope failures occurred. Three lives and many infrastructures such as roads, houses, rivers, and bridges are lost by the disaster. Kyushu University has supported the village at the beginning of disaster and has provided various support for these three years as Kyushu University Disaster Support Team. The village has much vulnerability because the living area of the village is surrounded by rivers and mountains and very close to them, and 42.7% of the total population in 2019 is elderly people over 65 years old [3]. Checking a sediment disaster hazard map published by the village, most of the houses are on sediment disaster-prone areas that are designed by Fukuoka prefecture. In addition, there is not a floods hazard map in the village, and estimated flood areas are not considered because all rivers running in the village are not designed rivers of flood analysis. Therefore, no one understands where it is dangerous due to floods visually.

The village can be divided into four areas. In this paper, the four areas are called "region". The regions can be actually decided by 15 smaller areas. The 15 areas are called "district" in this paper. The districts also can be divided by many much smaller areas that contain about 10-30 houses. The smaller areas are called "community" in this paper.

In this research, in order to carry out the recovery and rehabilitation in which their theme is “Safe and Reliable Village Development”, two initiatives would be conducted. One initiative is formulating a rehabilitation plan reflecting the opinion of residents in 2017. The other one is Risk Communication, which can recognize the risk of their living areas and decide appropriate evacuation sites and routes in 2018. A risk map would be created after risk communication. The aims of this paper are to propose initiatives utilizing geospatial information in recovery and rehabilitation phases and to indicate the effects of using geospatial information in the initiatives.

2. Formulating rehabilitation plan
Toho village decided to formulate a rehabilitation plan in 2017, the year that disaster occurred. A rehabilitation planning committee has been established to reflect the opinions of academic experts, organizations, and residents in the plan. The committee has set up an assembly of residents in each region to reflect the opinions of residents widely. There are two types of resident participation [4]. One is "formal participation" in the case where substantive decision-making has already ended by the local government. The other one is "substantial participation" in the case where the outcome of resident participation influences the final decision-making. In the Great East Japan Earthquake, although many local governments tried to get residents to participate, there were not a few local governments that took “formal participation” such as just holding briefing of a definite plan. The reason is that they do not understand the way of "substantial participation" and its importance since local governments have experienced only the process with "formal participation". Besides, a meeting to find out damage situation with residents which were held by the village got records of the only document. Therefore, it was difficult to understand the damage situation and the needs of residents based on the specific location. In this research, we would hold a “formal participation” meeting using geospatial information and formulate a rehabilitation plan which reflects the opinions of residents.

2.1. Methodology
In Toho village, a work-shop style community meeting is held three times as the assembly of residents. The local government, residents and Kyushu University join the meetings. Geospatial information is utilized at the community meeting to collect information and form consensus based on location. The methodology of formulating a rehabilitation plan would be shown.

2.1.1. First community meeting. The purposes of the first meeting are to collect damage information and to understand the current situations and problems of their living area. The meeting is held in each of the four regions, and there are small tables to have discussions in every district in the meeting place.
Pens, sticky notes, and B0-size district maps are prepared. One facilitator participates in each table to help the discussion. The damage information is collected divided into three categories: nature, work, and living. The three categories correspond to the three goals of the basic idea of a rehabilitation plan so that the opinions of residents could be reflected in the plan. Participants write damage information on the three colored sticky notes assigned to each category and draw damage areas on the map. The map has an aerial photograph as a base map and polygons which interpret damage areas of floods and slope failures. In the maps published by Google or Esri, the geospatial information of buildings and roads is not enough to use at the meeting. Thus, the aerial photograph was considered as an appropriate base map to collect detailed information. Regarding the damage interpretation, floods and slope failures occurred in a wide area in the village. Therefore it might take much time if participants have to draw all damage information on the map. In order to collect useful information in a limited time, the damage information which can be interpreted from the aerial photographs is described in advance. An example of the maps used at the first meeting is shown in figure 1.

2.1.2. Second community meeting. The purposes of the second meeting are to review the current situation and problems clarified at the first meeting and to decide the future visions of the rehabilitated village. One facilitator joins in each district table, as well. As a support item of discussion, a summarized map is prepared in each table. The map has digitized damage information, which is collected at the first meeting. First, participants discuss things to do for recovery and rehabilitation based on the three categories. Next, they decide the goals of five years later for each category, then decide an overall goal of five years later. During the discussion, the participants review the results of the first meeting using the maps. An example of the maps used at the second meeting is shown in figure 2. As the figure shows, there are two types of legends. One is three categories used at the first meeting. The explanations of damage information written on sticky notes are described as text in layout view of ArcGIS with the category legend. The other one is damage types such as floods, slope failures, broken roads, etc. The legend of damage types is generated from consideration of contents in all written map. The damage information is digitized in ArcGIS as geospatial information with damage type legend. In addition, infrastructure information is added to the map to locate the position of the map.

2.1.3. The process to formulate the reconstruction plan after the second community meeting. It is prepared in a rehabilitation plan that the pages which show measures of each category and each region policy of each category. After the second community meeting, the opinions and the goals decided at the second meeting are arranged and applied to the pages. A draft of the plan is brought at a third community meeting, and residents give their opinions about the draft. The plan is revised based on the opinions of residents and published as the Toho village rehabilitation plan. The plan also has the summarized maps used at the second meeting to show the results of the meeting.

2.2. Effect of using geospatial information
By drawing information with pens and sticky notes on the map at the first meeting, detailed damage information could be collected based on location divided into three categories, and damage information which cannot be interpreted from the aerial photograph could be collected. As a result of digitizing the damage information in GIS, it becomes possible to improve readability, unify the style, use together with other information, and facilitate updating. By summarizing the damage information divided into three categories and damage types, residents could understand where and what kind of issues there are in their areas at a glance.

At the second meeting, the presence of the summarized maps allows the discussion without mistaking what and where the participants are talking. In addition, since the participants could confirm the current conditions and issues of districts, collected at the first meeting, based on location, participants could discuss concrete future visions. It directly causes creating a concrete plan that
reflects the opinions of residents. The map plays important roles in not only keeping records of damage information and opinions of residents based on location but also creating a concrete plan.

On the other hand, at the first meeting, both the facilitators and the residents pointed out that it was difficult to understand where the maps showed because the maps did not have any other information except the aerial photographs. To solve the problem, the summarized map used at the second meeting includes the geospatial information of infrastructures, such as facilities and railways. The information contained in the maps used at the second meeting is shown in table 1. Describing the location of this information enables the participants to speed up the understanding of the location.

There was another problem with the first meeting. We did not set detailed rules of work-shop, which are how to use pens, sticky notes, and maps to collect damage information. For that reason, there was a bias in the accuracy of products depends on the tables, such as drawing by only black pens or by colorful pens considering the meaning of the color, drawing detailed information on the map or on only sticky notes, drawing information by residents or by facilitators. Therefore, when digitizing with GIS, a large amount of time was consumed to interpret the letters and to set legends. Some of the letters written by residents were too messy or small to read. Hence it is necessary to decide drawing rules such as a drawer, pen color, and legend to save digitizing time and improve qualities of products. In addition, to utilize geospatial information efficiently, it is considered that the damage information might be able to be collected as digital data from the beginning. However, it is not easy to use some electronic devices such as PC at the meeting in which elderly people are the majority of participants. Therefore, it is required to combine analog methods and digital methods.
Table 1. Main geospatial information list and whether the information is used at each meeting.

| Geospatial information                      | Data type | First community meeting | Second community meeting |
|---------------------------------------------|-----------|--------------------------|--------------------------|
| Aerial photograph before disaster           | Raster    | Yes                      | Yes                      |
| Aerial photograph after a disaster          | Raster    | No                       | No                       |
| Slope failures area                         | Polygon   | Yes                      | Yes                      |
| Floods area                                | Polygon   | Yes                      | Yes                      |
| River line                                 | Line      | Yes                      | Yes                      |
| Village boundary                           | Polygon   | No                       | Yes                      |
| Railway                                    | Line      | No                       | Yes                      |
| Station                                    | Line      | No                       | Yes                      |
| Facility                                   | Point     | No                       | Yes                      |
| Building                                   | Polygon   | No                       | No                       |
| Road                                       | Line      | No                       | No                       |
| Position of damage information             | Poly/ Line/ Points | No | Yes |
| Explanation of damage information          | Text      | No                       | Yes                      |

3. Risk communication

The rehabilitation plan says that the rehabilitation phase is the first three years, 2017-2019, the village would develop further village safety and reliably in the phase. The plan says “Enhancing disaster resilience” as one of ten main measures. In this research, risk communication is held in the village so that the village staffs, residents, and experts consider disaster of the village to enhance disaster resilience.

Risk communication is one of the consensus-building methods to share risk information among stakeholders. Many researchers have proposed risk communication methods for a natural disaster. In this research, risk communication for a natural disaster is held in the rehabilitation phase. The features of risk communication are that it has two meanings of rehabilitation and mitigation and that geospatial information is utilized. Risk communication has three main purposes. The first is improving residents’ awareness of disaster management. The second is collecting detailed risk and infrastructure information from residents. The third is creating a risk map that describes risk information, evacuation sites, and routes, which can be used while residents are evacuating.

3.1. Methodology

Risk communication is a work-shop style of disaster management and has five main steps. The first step is a prior field survey. Its purposes are to understand the area features and to take pictures of critical points. The second is the first risk communication meeting. It is a work-shop style meeting, and its purposes are to collect risk and infrastructure information and to consider evacuation sites and routes. The third is the posterior field survey. Its purpose is to confirm collected information in the first risk communication meeting, whether it is appropriated, especially evacuation sites. The information confirmed by experts is used in the next steps. The forth is the second risk communication meeting. It is also a work-shop type meeting, and its purposes are to decide evacuation sites and routes and to confirm the information used in risk map. The final step is creating a risk map and distributing it to all residents.

In risk communication, it is necessary to prepare a high-precision and editable base map in order to consider the detailed area and to combine with various geospatial information. However, the village did not have its own digital geospatial information. The village could use only infrastructure information published in open data, but any data, even data published by Geospatial Information Authority of Japan, are insufficient in terms of accuracy, amount of information, and update frequency to be used in risk communication. There is no infrastructure information reflected the situation after the disaster as well. Therefore, in this research, the infrastructure information such as buildings and roads created based on the aerial photos of three different seasons. The list of created information is
shown in table 2. A base map that contains this infrastructure information is used in risk communication as Toho village base map.

3.1.1. Prior Field Survey. The local government, residents, and the university have a field survey together before holding a risk communication meeting. If experts of disaster management who host risk communication are not familiar with the area, the discussion does not get deeper. Therefore, the experts need to grasp the regional features and the danger points by survey with the residents. Additionally, the survey can be a valuable opportunity for residents to ask experts about the dangers and anxieties of the area. What to do in the survey is to find places that correspond to categories designated in advance, to take pictures of that place, and to take simple notes. The categories list is shown in table 3. In the case of Itoshima city, Fukuoka prefecture, a digital camera, and paper maps were prepared to record survey information [5]. However, there are some issues that investigators sometimes need to check aerial photographs and geological maps during the survey; the photos were taken by the digital camera could not be found out where/what the photo indicated after the survey. Therefore, this research solves the problems by developing an app specialized in information collecting. The app capture and the function are shown in figure 3. The app is able to import data as a layer as much as users want if the data is prepared in GIS. In this research, Standard Map, an aerial photograph taken before the disaster and Toho village base map is prepared as base maps. Two aerial photographs were taken after the disaster, a geological map, a landform classification map, and sediment disaster-prone areas are prepared as selectable layers. The layers can change its transparency. In addition, at the time of posting, it is possible to select a category set in advance and post a photo with a category. Regarding the way to select categories, since it is necessary to post large quantities of photos quickly during the survey, the automatic input function referred to the previous post is adopted, and the input way is not typing in a blank but selecting from a list. The app enables users to change the location of the picture manually. Even the digital camera with GPS could record geotags which contain the following information: date, time, latitude, longitude, and direction, however, geotags which recorded the just place taken a picture are not useful in the case of taking a picture of a distant mountain or of densely populated houses.

3.1.2. First Risk Communication Meeting. The meeting is held in each of 15 districts, and there are small tables to have a discussion in every community in the meeting place. The reason is that participants need to discuss the more detailed regional risks than at the time of formulating a rehabilitation plan. Maps prepared for the meeting contain Toho village base map and information collected by prior field survey. The meeting is carried out according to a detailed scenario drawing rule for each topic. The scenario has three main steps, collecting information, having lectured, and considering evacuation. The first is collecting four types of information: residents and building information, damage information, road information, and risk information. At the time of collecting the information, participants use color pens, seals, and sticky notes designated by the scenario. The information such as what geology is or what land use was in the past is provided by using GIS. The third is considering evacuation. A temporary evacuation site and an evacuation route are considered based on the work-shop results and the explanation. A temporary evacuation site, in this research, means a site in which residents evacuate in the situation that it is too late to evacuate an official shelter or a safe site that can be evacuated at first. Any places, even such as houses and parking lots, can be temporary evacuation sites. Table 3 indicates damage information and evacuation information collected in the first risk communication meeting.

3.1.3. It is creating a Risk Map. The risk map is created by organizing the collected information with GIS. An example of a risk map is shown in figure 4. The map has all the collected information shown in table 3. The front page has a map indicated the area and the back page has an emergency contact field, then risk map is laminated and distributed to all residents. Providing an emergency contact field on the back side assumes a situation where public phones and other people's mobile phones can also
make calls in the modern age that relies on mobile phones. Laminating has the advantages that information can be added using a permanent marker, and there is no problem with bringing it out when it rains. At the time of distributing risk map, a questionnaire about risk communication and risk map is conducted with all residents to evaluate them.

3.2. Effect of using geospatial information

By using the base map, which contains detailed infrastructure information, it becomes easier for residents and facilitators to make discussions and become efficient to digitize the collected information in GIS. On the other hand, there were issues such as lack of information caused by unclear aerial photographs and changes due to demolition and rehabilitation after the disaster at the beginning of risk communication. In order to prepare higher-quality infrastructure information, questions which ask for infrastructure situation are prepared in the first risk communication meeting. Therefore, it is possible to maintain accurate, detailed, and fresh information of even sheds, new houses, and trail. This could eliminate the suspiciousness of the residents due to the uncertainty of the information.

By using the app in a prior/posterior field survey, pictures could be collected with a category based on an accurate location. Using the layer display function, users could survey more detail than with only paper maps. For example, when users inspect slope failures and debris flows, users could see the top of collapse with the aerial photo or check valleys with contour. Therefore, users could know the slope failures using many kinds of geospatial information even from the road. In addition, by posting a picture with a category, it is easy to immediately figure out what the photo means at the time organizing many pictures in GIS. And changing the location of the picture manually, for example, the user can record a picture with location information not on the road but on the house. Therefore, it is promoted to utilize the XY data of pictures, XY data could be symbolized and labeled based on the category field.

Regarding the first risk communication meeting by preparing a detailed scenario, it is possible to reduce the difference in the accuracy of each table. And when we could digitize the collected information quickly and easily because the information is properly categorized. Therefore, the detailed scenario improves efficiency and sophistication in digitizing the information as geospatial information. Rethinking the area through the meeting using the map leads to the discovery and re-recognition of the feature and the risk of the area.

The village has a sediment disaster hazard map but does not have a flood hazard map. It causes there is no information about risks in the village except sediment disaster prone areas. In this disaster, the damage caused by the small rivers which do not have any data was remarkable, but not the big rivers that have analysis data. From this situation, it is clear that the damage estimation of the small river should be prepared. Therefore, an idea of this research is that to collect information on the areas which had damaged in this disaster could become information which indicates the danger of floods. However, floods of this disaster are not common, because it was caused by the obstruction of driftwood. Since there would be bias in the only records of specific disaster to use for general hazard maps, the information of not only this disaster but also a disaster in 2018 and other disaster occurred in the past is collected. This is how widely useable information on flood risk could be collected. The role of the information is explained in risk communication, then the value of floods damage information could be enhanced.

The collected information and what the information indicates are shown in table 3. To set the temporary evacuation site and the evacuation route could improve the awareness of residents about evacuation. Since the Risk map has many kinds of risk information, residents could understand where they should be careful, and the government and residents might be able to conduct measures of prevention in advance. Therefore, a risk map enables residents to evacuate without any hesitation.

The results of the questionnaire are shown in figure 5. It shows that the risk map could be used for evacuation. For even non-participants, about 80% of them say that risk map is useful for evacuation. In addition, over 95% could understand dangerous points, evacuation sites, and routes, and the participants of risk communication have a higher level of understanding than non-participants. The
result denotes that joining a risk communication meeting helps to understand what risk map shows. Also, it denotes that risk map using geospatial information with legends and the high-quality base map is easy to understand even for persons who see it for the first time.

**Table 2. Infrastructure information list.**

| Information                        | Data type |
|-----------------------------------|-----------|
| Aerial photographs after a disaster | Raster    |
| Aerial photographs before disaster | Raster    |
| Contour                           | Line      |
| Boundary of village               | Polygon   |
| Boundary of region                | Polygon   |
| Building                          | Polygon   |
| Facility                          | Point     |
| Bridge                            | Point     |
| River                             | Polygon   |
| Small river                       | Line      |
| Dam                               | Polygon   |
| Railway                           | Line      |
| Station                           | Line      |
| Road                              | Line      |
| Land classification map           | Polygon   |
| Geological map                    | Polygon   |
| Soil map                          | Polygon   |
| Sediment disaster hazard map      | Polygon   |

**Table 3. Collected information and significance in risk communication (RC).**

| Information                        | Prior Field Survey | First RC Meeting | Posterior Field Survey | Significance                                                                 |
|-----------------------------------|--------------------|------------------|------------------------|------------------------------------------------------------------------------|
| Disaster happened place           | Collect           | Collect          | Check                  | To indicate the damaged area                                                 |
| Evacuation site                   | No                 | Collect          | Check                  | To indicate a dangerous area especially floods                               |
| Evacuation route                  | No                 | Collect          | Check                  | To be used in an emergency situation                                          |
| House of the person requiring support | No             | Collect          | No                     | To show the houses of the person requiring support when evacuating such as elderly and baby |
| Deterioration building            | Collect           | Collect          | Check                  | To indicate building which might break when big earthquake happens           |
| Roofing tile along the road       | Collect           | Collect          | Check                  | To indicate roofing tile, which might fall down, damage someone, and obstruct the road. |
| Gutter without cover              | Collect           | Collect          | Check                  | To indicate gutter which is dangerous when the gutter is filled with rain water |
| Fragile concrete block wall       | Collect           | Collect          | Check                  | To indicate a block wall which might break and obstruct the road when a big earthquake happens |
| Caution intersection              | No                 | Collect          | Check                  | To indicate a dangerous intersection when residents are evacuating           |
| Caution road                      | Collect           | Collect          | Check                  | To indicate unsuitable road due to narrow, steep and wild to use for evacuation |
Figure 3. Capture and function explanation of field survey app.

Figure 4. An example of a risk map.
Figure 5. Questionnaire results.

4. Conclusions
This study proposes two initiatives of rehabilitation conducted in Toho village, which suffered from the Northern Kyushu Heavy Rainfall Disaster of July 2017. The initiatives are mainly hosting workshop style meetings so that the opinions of residents could be reflected in the rehabilitation. Many geospatial information used to collect and share information are very effective.

Regarding formulating a rehabilitation plan, by using the map which has digitized damage information collected from residents, residents could discuss concrete future visions based on location. The rehabilitation plan is created based on the opinions and future visions of residents, so the village could create a rehabilitation plan that reflected the opinions of residents. In addition, it is effective to use appropriated maps for gathering information and discussion. Maps should contain the information that stood out in the area, such as facilities and railways.

Regarding risk communication in the rehabilitation phase, high precision base map leads to collect risk information in detail easily. By creating risk information and evacuation information as geospatial information, a risk map could be created. Residents could understand the locations of dangerous points, evacuation sites, and routes with the map. The map could be used at the time of evacuating and has effective in enhancing disaster resilience.

Using geospatial information at the meeting which residents also join, the discussion can proceed based on location, and the conference can be advanced one. However, at present, the combined use of analog and digital methods is essential for utilizing geospatial information. Since to digitize information takes a great deal of effort, it is required to save labor in digitization.

References
[1] Cabinet Office Japan 2015 White Paper on Disaster Management 79
[2] Geospatial Information Authority of Japan 2017 Basic Plan for the Advancement of Utilizing Geospatial Information 4
[3] Toho Village Disaster Management Concil 2015 Toho Village Disaster Management Plan 5
[4] Ubaura M 2015 Lessons learned from recovery process of Tohoku region World Conference on Disaster Risk Reduction public forum
[5] Muraoka N Minata Y Ikemi H Tsukihara M and Nagao S 2014 Study on disaster risk communication using geospatial information system in Itoshima City Fukuoka Prefecture GIS Association of Japan