Research article

Issues of Disaster Recovery Management and Application of GIS and UAV for Resilience in Agricultural Land and Infrastructure

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Received 9 April 2018 Accepted 1 November 2018 (*Corresponding Author)

Abstract Natural disasters have caused enormous impacts on rural societies in both developed and developing countries for the recent years. Due to climate change, the frequency and intensity of extreme weather have increased and it is predicted to be more rampant for the coming decades. As rural societies are mainly dependent on agriculture, the rapid recovery and reconstruction of damaged agricultural lands and infrastructure is crucial to enhance their resilience. The rapid measures and actions in the post-disaster can reduce the impacts and can help farmers save their livelihoods as well as consumers ensure their provisions. This paper focuses on administrative issues in the recovery management in the post-disaster period in Japan. Especially, it takes up the underlying issues that impede the disaster recovery process and the application of Geographic Information System (GIS) and Unmanned Aerial Vehicle (UAV) in case of earthquake and flood disasters including storms and heavy rainfall. The data was collected through questionnaire survey to the agricultural departments in all the prefectural offices in Japan. From the results, the administrative issues were attributed to the complexity of project procedures and documentation, human resources, rural planning, the lack of capacity in construction companies, in most of the prefectures. The use of GIS and UAV was limited in many prefectures due to the lack of knowledge or experience. However, GIS could help the recovery processes quicken for some prefectures. Based on the findings, it is suggested to make a manual about GIS database building which can be shared among prefectural offices and farmers to inherit the past lessons and enhance resilience for the future.

Keywords disaster recovery, resilience, rural society, GIS, UAV

INTRODUCTION

The impacts of natural hazards have increased due to climate change and caused disasters all over the world. At the same time, due to the excessive land development and population increase in vulnerable areas have also increased the disaster risks. These have brought an urgent need in our society to enhance resilience. Paying attention to resilience in rural society, the rapid recovery in agricultural land and infrastructure stricken by disasters is a key to reduce the impacts, saving farmers' livelihoods and provisions to market. This paper focuses on the administrative issues for disaster recovery in agricultural land and infrastructure, and the application of Geographic Information System (GIS) and Unmanned Aerial Vehicle (UAV) in Japan. In Japan, GIS database on agricultural information system was prepared by the Ministry of Agricultures, Forestry and Fisheries of Japan (MAFF) from 2006 to 2010 and started operating by an association of farmers in each prefecture called the Land Improvement Association since 2011. UAV has been increasingly applied in the field of civil engineering, environmental measurement and geographic survey.

In Japan, when agricultural land and infrastructure are damaged by natural disasters above the certain standards, there is a governmental system called "the Rehabilitation Project of Disaster Stricken Agricultural Land and Facilities" to support a part of the cost of disaster rehabilitation. The prefectural offices need to collect disaster information from affected municipalities and apply to the government for funding before launching the rehabilitation works. Therefore, it is important to conduct swiftly the whole process of the project for the early recovery. For this, MAFF has tried to simplify the project procedures and has worked out in some cases (Yoshikawa et al., 2007; Arita et al., 2008; Senda et al., 2013). There has been one case reported that GIS was successfully applied to the rehabilitation project for simplification of the process (Senda et al., 2013). However, there have been issues which caused the delay and lengthening of the rehabilitation project, due to various reasons such as, the inaccessibility in remote areas (Asahiro et al., 2014), the lack of capacity and limited number of construction companies (Arita et al., 2008), the lack of personnel and experience of staff in the municipality office (Miyasato, 2007; Arita, 2008), the loss of motivation of local farmers and making agreement with them about reconstruction plan (Arita et al., 2009).

These previous studies focused on one single case of a disaster rehabilitation project. Therefore, there is a need to study which covers more widely to identify the general existing issues in the rehabilitation project.

OBJECTIVES

The objective of this research is to identify the existing delay issues including the application state and usefulness of GIS and UAV in the Rehabilitation Project of Disaster Stricken Agricultural Land and Facilities by the administration of Japan. From the results, it aims to form a suggestive method for improvement of the rehabilitation management. Japan is targeted as a research site as one of the world-leading countries in the disaster prevention and mitigation measures. It is expected that the results of this research is applied to other disaster-prone countries. The kind of disaster was focused on earthquake including tsunami and flood disasters including heavy rainfall and storm.

METHODOLOGY

The research applied questionnaire survey for data collection and statistically analyzed the results. The questionnaire survey sheets were distributed to a section of the agricultural department, which is in charge of the rehabilitation project, in all the forty-seven prefectural offices and prefectural Land Improvement Association offices for a few prefectures in Japan. The questionnaire sheet was consisted of two versions, earthquake disaster including tsunami, and flood disaster including heavy rainfall and storm. The questions were mainly concerned about the existing issues that cause the disaster recovery projects delayed or lengthened in case of the last disaster that each prefecture experienced since 2000, the application state of GIS and UAV, and the useful GIS data for the rehabilitation.

The questionnaire sheets were made in Japanese and distributed by email between September and November 2017 and responded by thirty-one prefectures out of forty-seven prefectures, that is 65.9%. Among them, thirty respondents are from prefectural offices and one is from Land

Improvement Association. Prefectures which experienced the rehabilitation project for earthquake since 2000 were nineteen, and all of the thirty-one prefectures experienced the project caused by flood disasters. The number of valid response was low for some questions due to the lack of information or still being under the investigation.

The limitation of this research can be attributed to the target of respondents and the limit of the objective disasters. In Japan, each municipality including city, town or village rather than the prefectural office is more directly in charge of the rehabilitation project. Therefore, there is a possibility to obtain more detailed and accurate data from municipalities than prefectural offices. In addition to that, the questions about the cause of delay were intended to inquire only about the latest case that each prefecture experienced after 2000. As the situation and issues vary from disaster to disaster, the results can differ depending on the case of disaster selected in each prefecture.

RESULTS AND DISCUSSION

Cause of Delay and Lengthening in the Rehabilitation Project

The launching time of the first and last rehabilitation project among all the projects in each case of disaster after a disaster occurrence is as shown in Fig. 1. For the case of earthquake, most of the first disaster project is launched within four months. On the other hand, for the case of flood disasters, although many cases are implemented within fourteen days, it becomes low in 'within one month' and 'two months' but high again in 'within four" or 'six months'. For the last project, most of the cases are launched later than six months. Hence, it takes a long period to implement all the rehabilitation projects in most of the cases.

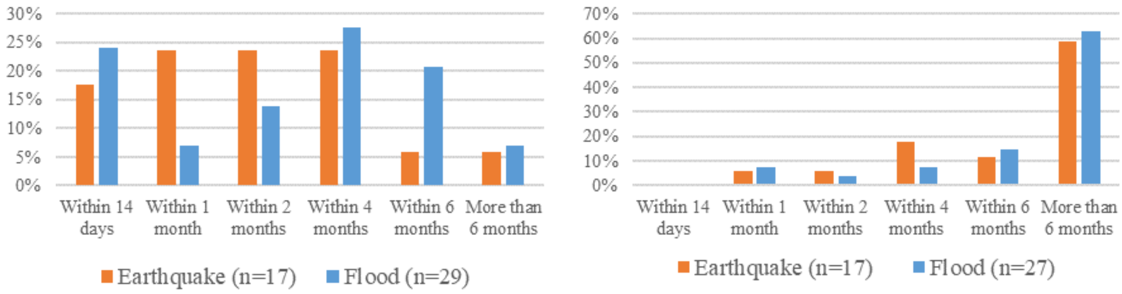
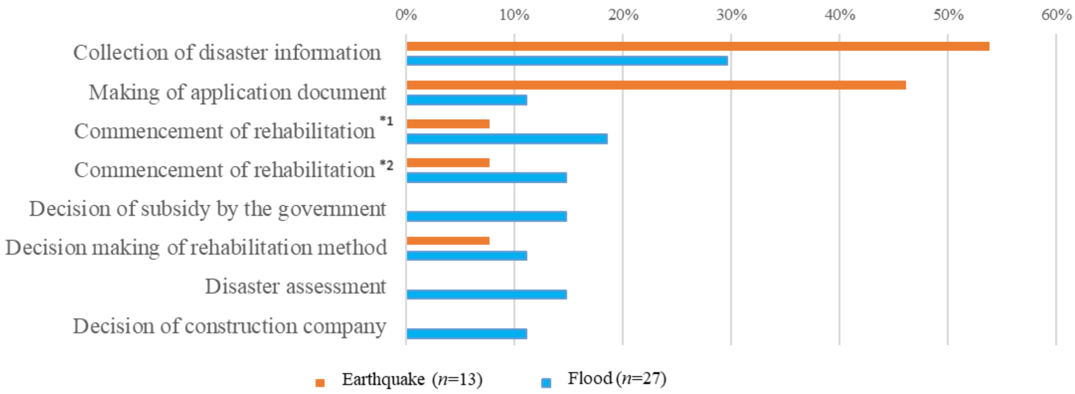


Fig. 1 Launching time of the first (left) and last (right) rehabilitation project in each case



*Note. *1 Commencement of rehabilitation due to the lack of labor force in construction company*
**2 Commencement of rehabilitation due to the lack of available construction company*

Fig. 2 Procedure taken longer than expected

The procedures which took longer than predicted were as shown in Fig. 2. Collection of disaster information takes long in many prefectures for both disasters. Preparing the application document of the rehabilitation project plan also takes long due to its complexity especially in the case of earthquake. Launch of rehabilitation works also takes a long time due to the lack of capacity or availability of construction companies for both disasters. Compared to the cases of earthquake, the cases of flood are attributed to more variety of issues. It may be related to the delay of launching time of the rehabilitation work as seen in Fig. 1.

The causes of delay in the project were identified as seen in Fig. 3. Most of the causes are attributed to the limit of capacity of officers such as the lack of, knowledge about the rehabilitation project, and labor force in municipalities, and difficulty to control the project team in the time of emergency. Other main factors are response to the affected farmers such as making agreement with them for rehabilitation plans and individual response to each farmer where farmer's association is not formed. Damage which cannot be found immediately after the occurrence of disaster was also raised.

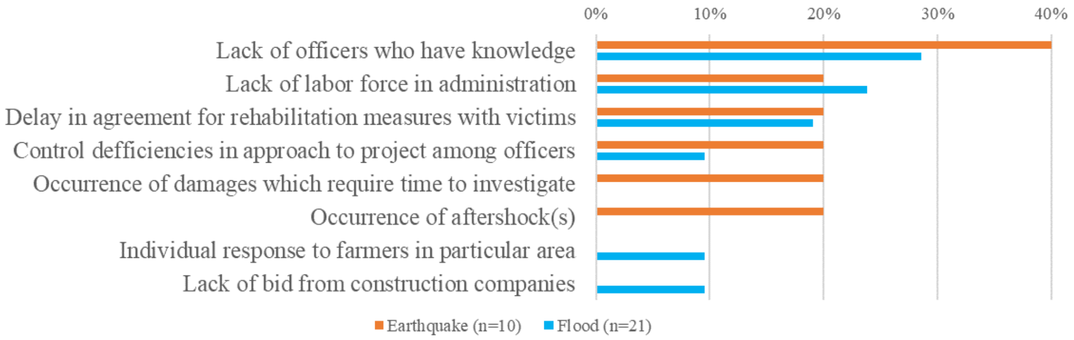


Fig. 3 Cause of delay in rehabilitation project

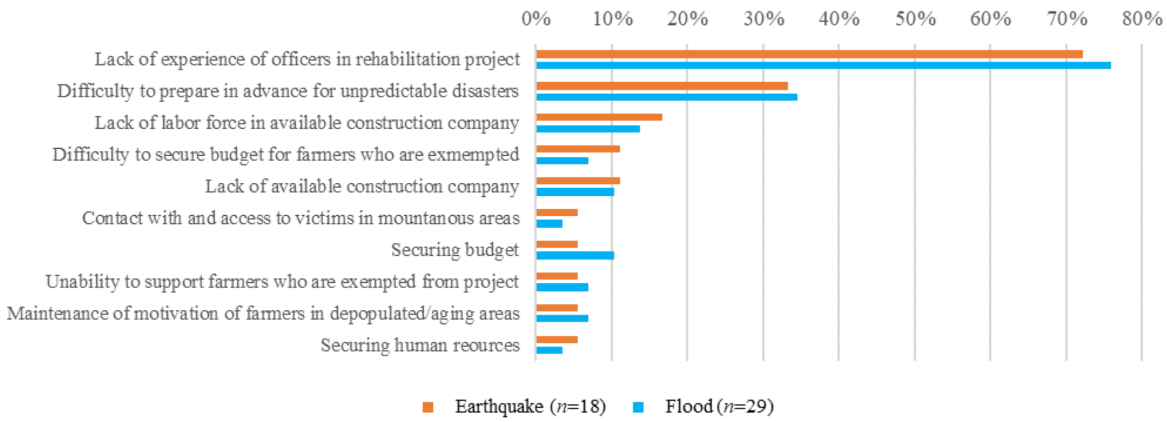


Fig. 4 Difficulty of municipalities in the disaster measures in the rehabilitation project

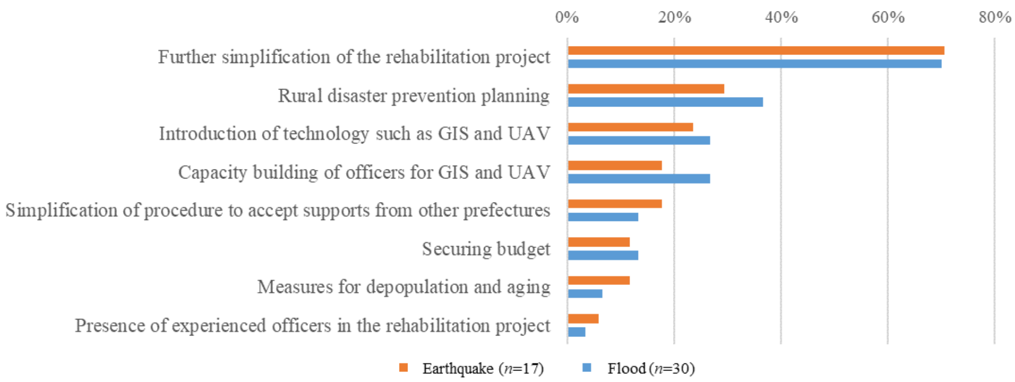


Fig. 5 Issues to be solved to make the rehabilitation project smooth and faster

Difficulties that municipalities face to cope with disasters in the rehabilitation project varied among many factors as shown in Fig. 4. The difficulty which most of the prefectures face was the lack of experience by officers in the rehabilitation project. The second highest was the unpredictability of natural disasters. Lack of capacity or availability of construction companies were also the reasons of delayed. The limit of budget in administration is also a difficulty for them to implement the project and to respond to affected farmers who were exempted from it due to the smaller scale of damages than the standard of the project regulation.

The issues that officers consider that should be solved to make the rehabilitation project smoother and faster were also identified as seen in Fig. 5. From the main answers, it can be divided into three large groups: 1) simplification of the rehabilitation project process; 2) rural planning that takes account of disaster occurrence; and 3) introduction of GIS and UAV and development of human resource in these technology.

Use of Geographic Information System and Unmanned Aerial Vehicle

Many prefectures did not apply GIS for the rehabilitation project in both earthquake and flood disasters. As seen in Table 1, the reasons whether they used GIS or not are attributed to their experience of preparedness in the pre-disaster time or the presence of skilled human resource in GIS. As the results, the number of skilled officers in GIS is still limited in the administration offices and capacity building of officers is highly needed.

Table 1 Reasons of GIS usage/non-usage in rehabilitation project by prefectures

Reasons of GIS usage/non-usage in rehabilitation		Response rate	
		Eq (n=9)	Hy (n=18)
No used/almost not	The limited number of skilled officers in GIS	22.2%	5.6%
	There was no need to use GIS	55.6%	66.7%
	Use of GIS was limited in the pre-disaster time	22.2%	11.1%
	There was no experience to use GIS in rehabilitation	44.4%	22.2%
	GIS data was not owned	11.1%	0.0%
	GIS was not popular at the time of disaster	11.1%	0.0%
		Eq (n=5)	Hy (n=10)
Used	There were enough experts on GIS	0.0%	30.0%
	GIS was regularly used in the pre-disaster time	60.0%	30.0%
	There was experience to use GIS in rehabilitation	20.0%	50.0%
	Difficulty for field survey	20.0%	0.0%
	To make report of the disaster damages	0.0%	10.0%

GIS data which were applied in the project and regarded as important to collect before and after disasters by officers are shown in Table 2. The required data were relatively similar between both disasters. Information of farmland owner, utilization of agricultural water, farmland and cadastral map, facility of agricultural water, topographical map, aerial photograph and farmland area are highly needed to collect in the pre-disaster time. To collect disaster information and identify whom to contact after the disaster occurrence, the information of farmland owner is expected to obtain in the pre-disaster and updated regularly. To identify the extent of damage, it is important to have information about the state of agricultural water utilization and the water use facilities, and farmland such as farmland map, cadastral map, and farmland area before disasters. Topographical map is also useful to compare the affected area between the pre- and post- disaster time as disasters can change topography and the surrounding environmental condition. Therefore most of these data were also recognized as the data which should be obtained immediately after the disasters. Images obtained by UAV was relatively high. In the post-disaster, some areas are not accessible immediately and it is difficult to obtain satellite images of objective area soon. Therefore, UAV is considered very helpful to collect information of various damages to humans and agricultural infrastructure. The prompt data collection is also expected to enable us to avoid the second or third disasters by finding underlying issues. In the real situation in sites, agricultural conditions are directly affected by disasters and the pre-disaster state is not measureable anymore after stricken. Therefore, it is considered very important to obtain various related data since the pre-disaster time to identify the impact of damage and avoid the unequal treatment or relief to farmers or arguments among farmers as it causes delay in rehabilitation.

Table 2 GIS data used and considered useful in the rehabilitation project

	GIS data that had been owned in the pre-disaster time		GIS data used to collect disaster information		GIS data used rehabilitation and reconstruction		GIS data that should be prepared in the pre-disaster		GIS data that should be collected immediately after disaster	
Type of GIS data/No. of respondents	Eq (*n*=14)	Fl (*n*=30)	Eq (*n*=5)	Fl (*n*=12)	Eq (*n*=4)	Fl (*n*=7)	Eq (*n*=12)	Fl (*n*=20)	Eq (*n*=11)	Fl (*n*=21)
Farmland gradient	0%	3%	0%	0%	0%	0%	8%	10%	9%	14%
State of farmland improvement	7%	43%	20%	17%	25%	0%	25%	25%	27%	19%
Information of planting crops	0%	7%	0%	0%	0%	0%	33%	5%	9%	0%
Farming history	0%	0%	0%	0%	0%	0%	8%	5%	0%	10%
Information of land owner/cultivator	7%	13%	40%	8%	25%	14%	67%	50%	27%	29%
State of irrigation and drainage water	0%	23%	0%	8%	0%	14%	42%	55%	27%	29%
Irrigation and drainage facilities	14%	60%	40%	25%	50%	14%	42%	30%	36%	29%
Topographic map	14%	60%	60%	50%	50%	43%	42%	45%	27%	33%
Soil map	7%	13%	20%	0%	0%	0%	8%	10%	9%	10%
Land-use map	0%	17%	0%	8%	0%	14%	8%	15%	18%	19%
Farmland and cadastral map	21%	33%	80%	33%	75%	29%	42%	40%	18%	43%
Farmland area	14%	27%	40%	25%	50%	43%	42%	55%	18%	33%
Hazard map	0%	13%	0%	0%	0%	0%	0%	10%	0%	10%
Landslide prevention area	0%	17%	0%	0%	0%	0%	25%	15%	27%	14%
Laser profilerdata	7%	0%	20%	0%	25%	0%	0%	5%	9%	5%
Digital orthophoto	7%	3%	20%	0%	25%	0%	0%	0%	s	0%
Satellite image	7%	0%	0%	8%	0%	14%	0%	15%	9%	14%
Aerial photograph	21%	57%	60%	67%	75%	71%	25%	45%	36%	43%
UAV image	0%	3%	0%	17%	0%	14%	0%	10%	9%	24%

Table 3 Reason why prefectures do not introduce UAV

	No budget	No experts	No experience	No need	Other
Eq (*n*=25)	28%	36%	56%	8%	4%
Flood (*n*=22)	36%	45%	45%	14%	0%

UAV was not introduced in most of prefectures. Among thirty-one prefectures, only three prefectures use it for improvement of agricultural productivity, management of agricultural facilities, disaster mitigation, collection of disaster information or disaster rehabilitation and reconstruction. Although many prefectures understand the usefulness of UAV for the disaster management, they do not have a plan to introduce at the moment. Most of the reasons were no skilled human resource, no experience and the lack of budge as seen in Table 3. On the other hand, most of prefectures did not know the usefulness of UAV for evaluation of agricultural productivity. Therefore, if farmers, farmers' association or prefectures understand the usefulness and apply UAV in the daily basis, the data can be accumulated regularly and useful for the time of disaster recovery.

CONCLUSION

As the results are shown above, the prefectures have faced many administrative issues for disaster recovery in agricultural land and facilities. For the improvement in the administrative process, the following measures as disaster preparedness in the pre-disaster time are suggested.

1. Creation of opportunities for officers to enhance their knowledge and technique about the rehabilitation project and GIS/UAV;
2. Improvement of the rehabilitation project systems such as simplification of documents and dispatch of experienced officers from other prefectures;
3. Rural planning on the premise that disasters occur at any occasion and dissemination of the procedure of the rehabilitation project to local farmers;
4. Understanding the capacity of construction companies in each local area;
5. Preparation of manual for GIS database application for the rehabilitation project.

These measures are expected to support officers to conduct the rehabilitation process more smoothly and quickly. In the post-disaster time, as collection of disaster information needs to be done effectively and rapidly, it is suggested to collect important data quickly by field survey, GIS database, satellite image and aerial photograph, and furthermore, UAV in case that the disaster-stricken areas are not immediately accessible. In addition, to continuously improve the disaster rehabilitation process and use the past experiences, it suggests to make a GIS database manual in the model of GIS database building as shown in Fig. 6. It can be improved in a way of Plan-Do-Check-Act (PDCA) cycle as the red arrows indicate. During the pre-disaster time, information are collected in GIS database (Plan). The database is used during the rehabilitation project (Do). After the project, the method needs to be reviewed (Check) and improved and published (Act). This model and manual can be useful for not only Japan but also many countries to enhance rural resilience by expediting rehabilitation process. Capacity building of not only officers but also farmers in GIS and UAV will also be important as these technology help them for both disaster rehabilitation and the daily management of agricultural land and facilities to improve the productivity.

The future study will need to cover not only prefectural offices but municipality offices to obtain more accurate answers and abundant samples.

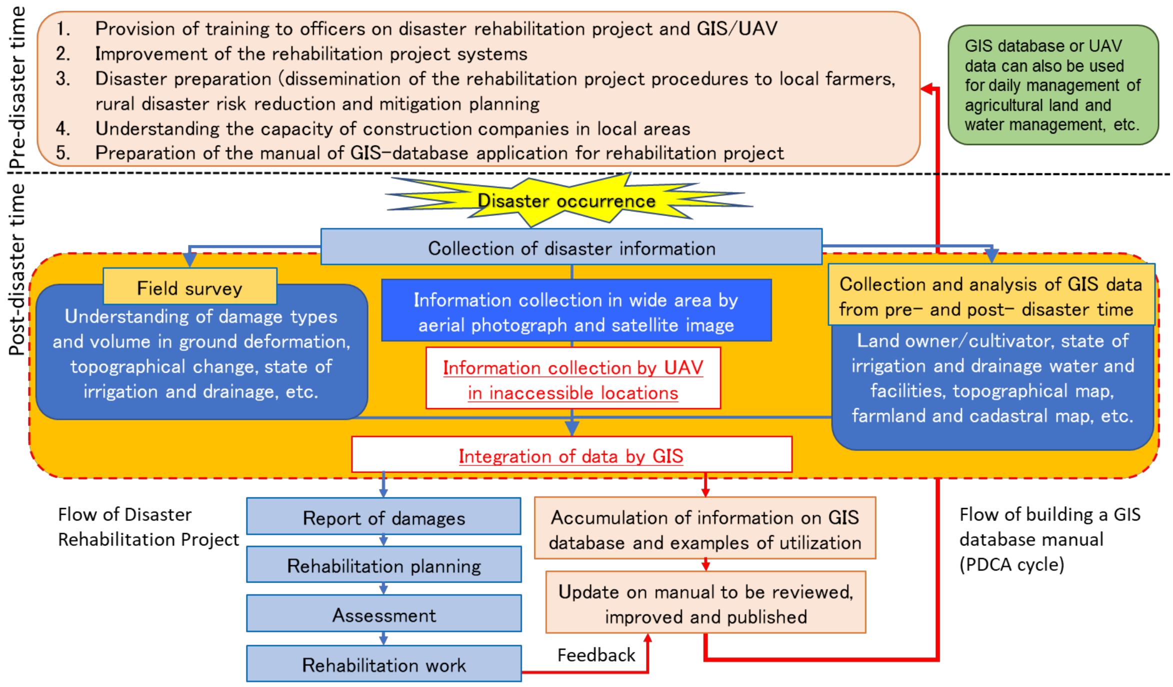


Fig. 6 Flow of a suggestive model of building a GIS database manual

ACKNOWLEDGEMENTS

This work is supported by Daigaku-senryaku-kenkyu project from Tokyo University of Agriculture. We would like to thank the prefectures which cooperated with participating the questionnaire survey.

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