DISTINCTION OF THE LIQUEFACTION IN SATELLITE IMAGE

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ABSTRACT

A large area of Japan was damaged by liquefaction caused by the Tohoku earthquake in 2011. It damaged various infrastructures such as roads, residences, industrial facilities and sewers, and there is still little prospect of recovery in some areas. Field surveys were conducted to grasp its extent and degree of liquefaction, but it took too much time and man power to investigate all areas because liquefaction spots were scattered over a large area. Therefore, we tried to develop the methodology to grasp the distribution and degree of damages caused by liquefaction quickly and accurately for the emergency response and the recovery plan in national level. We have developed the methodology to detect liquefaction areas by using high spatial and spectral resolution satellite images. To verify the spectral aspect of the methodology, we introduced three actions such as field survey, analysis of spectral characteristics of liquefaction as a laboratory experiment using spectrometer, and analysis of satellite data. As for the field survey, we visited the liquefaction sites and got the information about the materials which appeared in mixture at the site, such as sands, water and pavement. As for the laboratory experiment, we reproduced each scene of liquefaction site and measure the spectrum data of the state of liquefaction by spectrometer. As for the satellite data analysis, we applied these spectral characteristics to high resolution satellite data (ex. Rapid-Eye) to identify the degree of liquefaction. The results were evaluated by the comparison with the field information. This study clearly showed us that the potential capabilities of satellite sensors for identifying and mapping the liquefaction plots. After the verification, we proposed the assignment to establish the methodology of discrimination.

1. INTRODUCTION

A large area of Japan was damaged by liquefaction caused by the Tohoku earthquake in 2011. For example, Tokyo bay area was damaged by liquefaction at least in $42km^2$, which is world's largest according to The Japanese Geotechnical Society (2011). It damaged various infrastructures such as roads, residences, industrial facilities and sewers, and there is still little prospect of recovery. Until now, there have been two major methodologies to grasp the areas damaged by liquefaction. One is the field survey. Actuary, field surveys were conducted to grasp its extent and degree of liquefaction, but it took too much time and man power to investigate all areas because liquefaction spots were scattered over a large area. And the other one is aerial photo interpretation. However, it also took too much time to interpret aerial photos. Besides, coverage of one aerial photo is too small to grasp vast area, and the spatial information on the image is limited within visible light. Therefore, we considered that it is useful and important to develop the methodology to grasp the distribution and degree of damages caused by liquefaction quickly and accurately for the emergency response and the recovery plan in national level.

In Japan, several techniques of remote sensing, especially using satellite image, have been utilized for liquefaction since 1995, when Han-Shin Awaji Earthquake disaster occurred. So, we focused on the methodology using high spatial and spectral resolution satellite images to detect liquefaction areas. We considered that we could overcome the weak points of above two methodologies, and grasp the distribution and degree of damages caused by liquefaction quickly and accurately. There is the past study using satellite images to detect liquefaction areas. Matsuoka et al.(2001) conducted the research on the liquefaction damage caused by Han-Shin Awaji Earthquake disaster in 1995. They used the images taken before and after the earthquake by Landsat/TM, and compared pixel value of them. However, because the resolution of satellite image was too low, it was not obscured whether the methodology using satellite images was effective or not.

So, we focused on high spatial and spectral resolution satellite images, and aimed to validate the effectiveness of its use and propose the assignment to establish the methodology of discrimination.

2. STUDY AREA

We selected study areas to verify the methodology using high spatial and spectral resolution satellite images. The study areas were Itako and Kamisu in Ibaraki prefecture in Japan (figure 1). There are two reasons why we selected these areas for our study. Firstly, these areas were seriously damaged by liquefaction caused by the Tohoku earthquake according to the report by Fire Information Res. Center [e]. Secondly, we could verify the effectiveness of the methodology easily because these areas were investigated by field survey conducted by Pro. Koseki et al. of University of Tokyo just after the Tohoku earthquake.

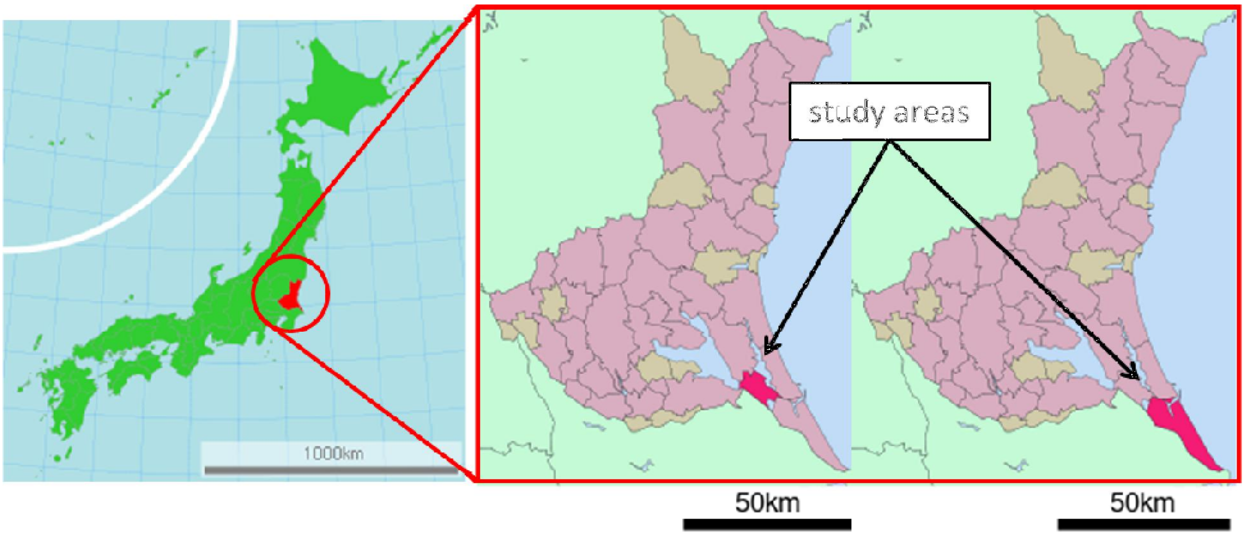

Figure 1 study sites in Japan

3. METHODOLOGY

To verify the spectral aspect of the methodology, we introduced three actions such as analysis of satellite data, analysis of spectral characteristics of liquefaction as a laboratory experiment using spectrometer, and field survey.

3.1 Analysis of satellite data

We tried to extract the areas of liquefaction using the high spatial and spectral resolution satellite images taken by GeoEye-1. The characteristics of satellite image of GeoEye-1 are shown in table 1.

We regarded jet of sand on roads as the index to detect the liquefaction areas. Specifically, we compared the satellite images of the study areas before and after the Tohoku earthquake, and regarded the foreign substances on the roads in the image after the earthquake which didn't exist in the image before the earthquake as jet of sand caused by liquefaction. The images we used in this research had been taken on March 13, 2010 and March 26, 2011.

The steps are as follows.

1) Extract the parts of road from the two images
2) Overlap the road images made in the 1st step, and detect the areas where jet of sand happened

We used the software ENVI to do these steps.

In the 1st step, to extract the parts of road, we collected some pixels of paved road in each image and decided the threshold digital number of each band to identify road. And in the 2nd step, we overlapped the two images derived from the 1st step and detected the jetted sand areas by regarding that if the roads existed before the earthquake were not identified as road after earthquake, they were covered with sand caused by liquefaction.

The result of analysis is shown in Figure 2. In Figure 2, the white areas are detected as road in both two images, and the green areas are detected as jetted sand. The reddish areas are detected as the objects which exist only in the image before the earthquake. In this figure, the Hinode distinct and the Fukasiba district are detected as areas of jet of sand. These districts were damaged by liquefaction seriously according to the report of field survey conducted by Pro. Koseki et al. of University of Tokyo (not printed). So, we considered that this result of analysis had measurable validity. But, some areas with no jetted sand were also detected as the jetted sand areas. So, we have to improve this methodology by revising the threshold value or introducing a new index of liquefaction.

Table 1 Characteristics of GeoEye-1 data

name	revisit days	bands	resolution	information volume
GeoEye-1	3 days	red, green, blue, near infrared	1.64m	11 bits

Figure 2 Extraction of jetted sand areas on the roads by overlaying two GeoEye-1 images

3.2 Analysis of spectral characteristics

It is known that the reflectance of sand is much different from that of asphalt. So, if the analysis is correct, the characteristics of spectral data of jetted sand areas in analysis should be related to that of local sand. To verify the validity of the spectral data of the satellite data, we conducted laboratory experiment. We used a spectrometer (HandHeld 2 spectroradiometer, ASD) to measure the spectral data of the sand sample which we had collected at the study areas. We measured the spectral data of sand sample of absolute dry condition, and compared its result with the spectral data of satellite image. Figure 3 shows the reflectance data of sand sample of absolute dry condition, and Figure 4 shows that of pixels which were detected as jetted sand and road in the image after the earthquake. There is clear difference between jetted sand and road especially around 600nm and longer wavelength, and it is considered that this difference is caused by the spectral characteristic of sand. To make sure of it, we measure and compare the spectrum of roads in study areas.

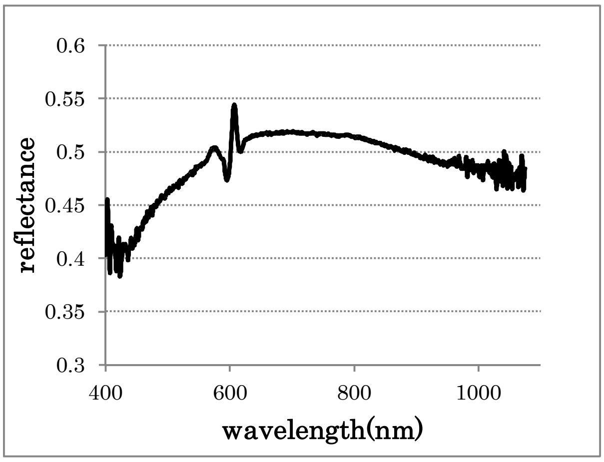

Figure 3 Spectral data of dry sand

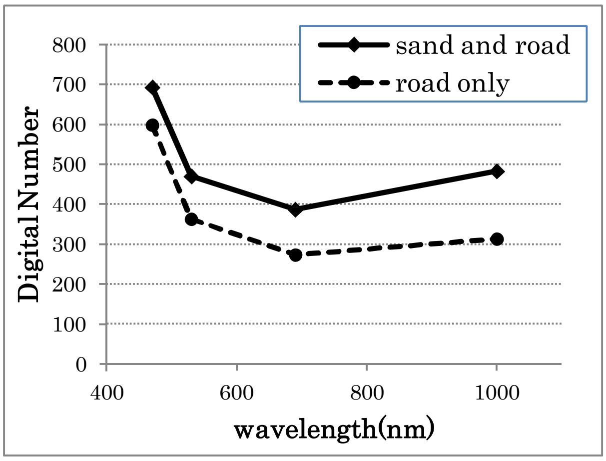

Figure 4 Spectral data of satellite data

3.3 Field survey

To verify the integrity of the result of satellite image analysis, we have done the field survey. We looked around the areas detected as jetted sand area. As a result, it turned out that the areas classified as jetted sand area were rather overestimation, and some structures and farms which had similar spectral characteristics were detected by error.

4. DISCUSSION AND FUTURE WORK

The result of this research at the moment is summarized as blow.

・The methodology to extract liquefaction areas regarding the jet of sand on road as index in satellite images is effective

・It is very likely that the spectral characteristic of jetted sand area on road depends heavily on paved road condition

We could verify the effectiveness of the methodology to detect liquefaction areas using high spatial and spectral resolution satellite images. But, there are still many problems to be verified such as the accuracy of detection, the validity of spectrum data of detected areas, and so on.

Therefore, in the future research, we continue further studies based on those three actions. In analyzing satellite images, we would like to review the threshold values of road and jetted sand and introduce the new index to detect liquefaction areas. In laboratory experiment, we will measure the spectrum of sand sample under various conditions of sample and lightning, such as the water content and thickness of sands and the angle of the light source. In field survey, we will conduct hearing investigation to grasp the accurate situation of those days and verify the integrity of analysis. After those verifications, we would like to gradually extend the target areas of this methodology.

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