EXTRACTION OF SLOPE FAILURE BEHIND AGRICULTURAL RESERVOIRS DUE TO HEAVY RAINFALL USING REMOTE SENSING

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ABSTRACT

Heavy rain in July 2018 in West Japan caused serious damage in small agricultural reservoirs. It is difficult to know the damage situation of many reservoirs in case of sudden disaster. Therefore, the utilization of the satellite remote sensing is very useful to detect the damaged reservoirs. However, it is difficult to directly extract the damaged reservoir because the reservoir is too small. In this study, quick way to detect the slope failure behind the reservoirs is tried by analyzing SAR satellite images and optical satellite images. The analyses were carried out using the multiband image after the disaster obtained from World View-2 and HH single polarization image before and after the disaster obtained from PALSAR-2. In the analysis by optical image, the difference between GSI and NDVI was used to extract the slope failure areas. The slope failure areas behind the reservoir was detected by extracting only the slope located at a slope larger than 30 degrees and the radius of the reservoir within 30 m. According to the official report from Yamaguchi local government, 4 slope failures behind the agriculture reservoirs in Iwakuni City were confirmed. Our extraction method with the optical image can detect 6 slope failures which are suspected to damage the reservoirs. In the analysis by SAR image, color mixing method was used. 13 slope failures were detected. 4 slope failures occurred behind reservoirs.

Keywords: remote sensing, VNIR, SAR, agricultural reservoir, slope failure

1. INTRODUCTION

The heavy rainfall occurred in west part of Japan in the first week of July 2018. It caused severe damage in agricultural reservoirs, so the effective way of countermeasures for reservoir safety have been considered. There are 200,000 agricultural reservoirs in Japan, and 10,000 in Yamaguchi prefecture alone. So, it is difficult to know the damage situation of many reservoirs in case of sudden disaster. Therefore, the utilization of the satellite remote sensing is very expected useful to detect the damaged reservoirs. The satellite remote sensing is a technique for observing the surface of the earth surface with an artificial satellite without contacting the object directly. However, it is difficult to identify the damaged reservoir directly because the reservoir is too small.

In this report, A case study of detection and extraction of the slope failure behind the reservoirs is performed. The analyses were carried out using the VNIR(Visible + Near Infra-red band) image with 0.5 m resolution after the disaster obtained from WV110 camera of World View-2 and HH single polarization image with 3m resolution before and after the disaster obtained from PALSAR-2, which is L-band SAR installed in the satellite ALOS-2. In the analysis by optical image, the difference between GSI and NDVI was used to extract the slope failure areas. In the analysis by SAR image, additive color method was performed.

Additionally, another case that has severer damaged than the previous case referred are shown.

End of the report,

2. OVERVIEW OF SATELLITE IMAGES

This section describes the satellite images used in this study. Table 1 shows specifications of VNIR and SAR images. Image 1 is the VNIR image after the disaster. Image 2 and 3 are selected as the SAR image before the disaster and after the disaster respectively. These two images ware products from observations under the same orbital conditions. In analysis of the VNIR image, an area of 5 km * 5 km shown in Figure.1 was set as the ROI(region of interest). In analysis of the SAR images, an area of 22 km * 18 km was set as the ROI.

Table1. satellite images used in analysis at Iwakuni region

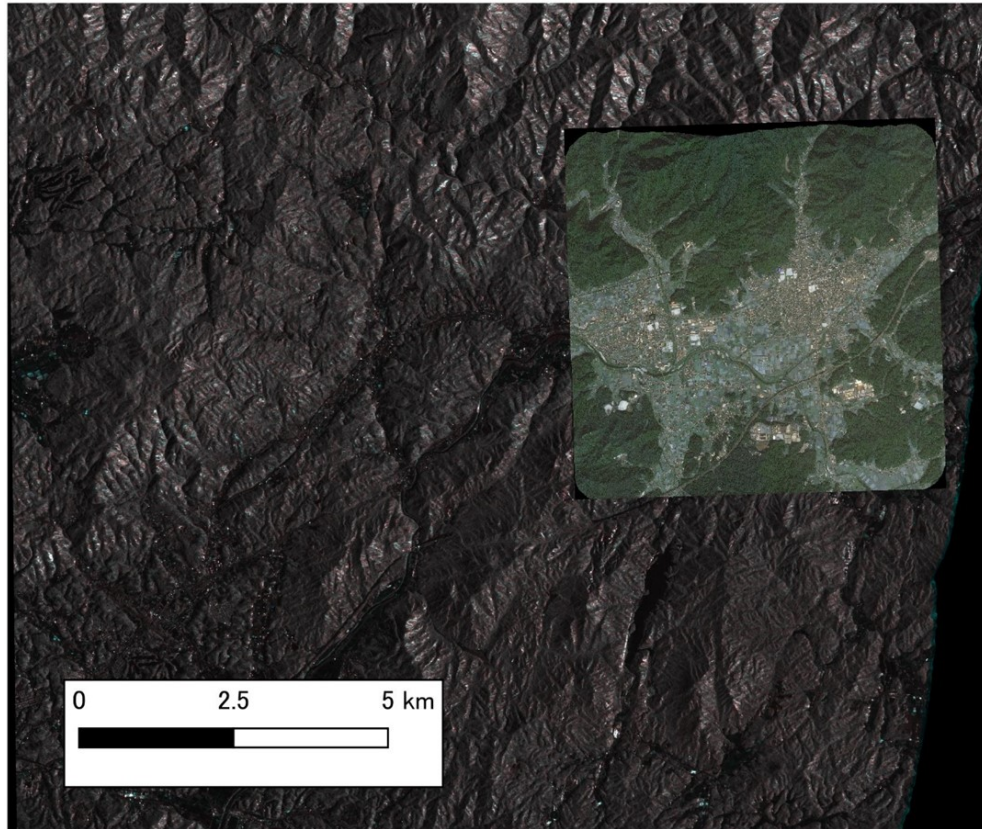| Name	Date of observation	Satellite	Sensor	band	Resolution (m)	Scene ID
Image 1	Nov 11 2018	WorldView-2	WV110	Red, Green, Blue, NIR	0.5	10300100866E4000
Image 2	July 4 2018	ALOS-2	PALSAR-2	HH single polarization	3	ALOS2222082930-180704
Image 3	July 18 2018	ALOS-2	PALSAR-2	HH single polarization	3	ALOS2224152930-180718

Figure 1. Satellite images and their ROI

3. DETECTIOIN OF DAMAGED RESERVOIR BY SATELLITE IMAGE ANALYSIS

3.1 VNIR satellite image analysis

VNIR image analysis is based on the characteristics of NDVI (Normalized difference vegetation index), which uses the characteristics of red visible light absorption and infrared light reflection and scattering of vegetation, and GSI (grain size index; which estimates the roughness of topsoil particle size from the wavelength of light.) Using the two indices in, extract bare areas suspected of being damaged. In this study, VNIR images of Kuga and Shuto regions in Iwakuni City were processed. The NDVI expressed by equation (1) takes a value from -1 to 1, and the higher the value, the higher the vegetation activity. The GSI expressed by equation (2) takes a value from -1 to 1, and higher values indicating closer to bare ground.

$$NDVI=\frac{IR-R}{IR+R} \tag{1}$$

$$GSI=\frac{R-B}{R+G+B} \tag{2}$$

Here, IR, R, G, and B indicate the values of the near-infrared, visible red, visible green, and visible blue bands of the pixels in the image respectively. NDVI and GSI are obtained from the VNIR image after the disaster. GSI / NDVI difference images were processed. As an example, Figure 2 shows a slope failure site around

Morishige Reservoir in Kuga. On the Geographic Information System, the GSI / NDVI difference value of the pixel in the image was set to 0.20 as a threshold, and pixels having the calculated value larger than the threshold were extracted as bare areas then the polygons are created. Next, only those polygons located on a slope with a slope of 25 degrees or more and within 30 m around the reservoir were extracted as collapse sites behind the reservoir. Figure 2(b) shows the results.

3.2 SAR satellite image analysis

SAR images were analyzed using the additive color method. In this method, the single polarization monochrome image before the disaster is assigned to the red band, and the image after the disaster is assigned to the blue and green band. As an example, Figure3 shows the processing results at the slope failure site around the Morishige reservoir. The spots where the scattering intensity has increased after the disaster are seen in cyan, and the spots where the scattering intensity is weak appear in red. For example, in places where the scattering intensity is high, it is considered that the vegetation area has changed to a bare area due to slope failure. Such processing was performed in the area including Kuga and Shuto region in Iwakuni City, and the northeastern tip of Shunan City.

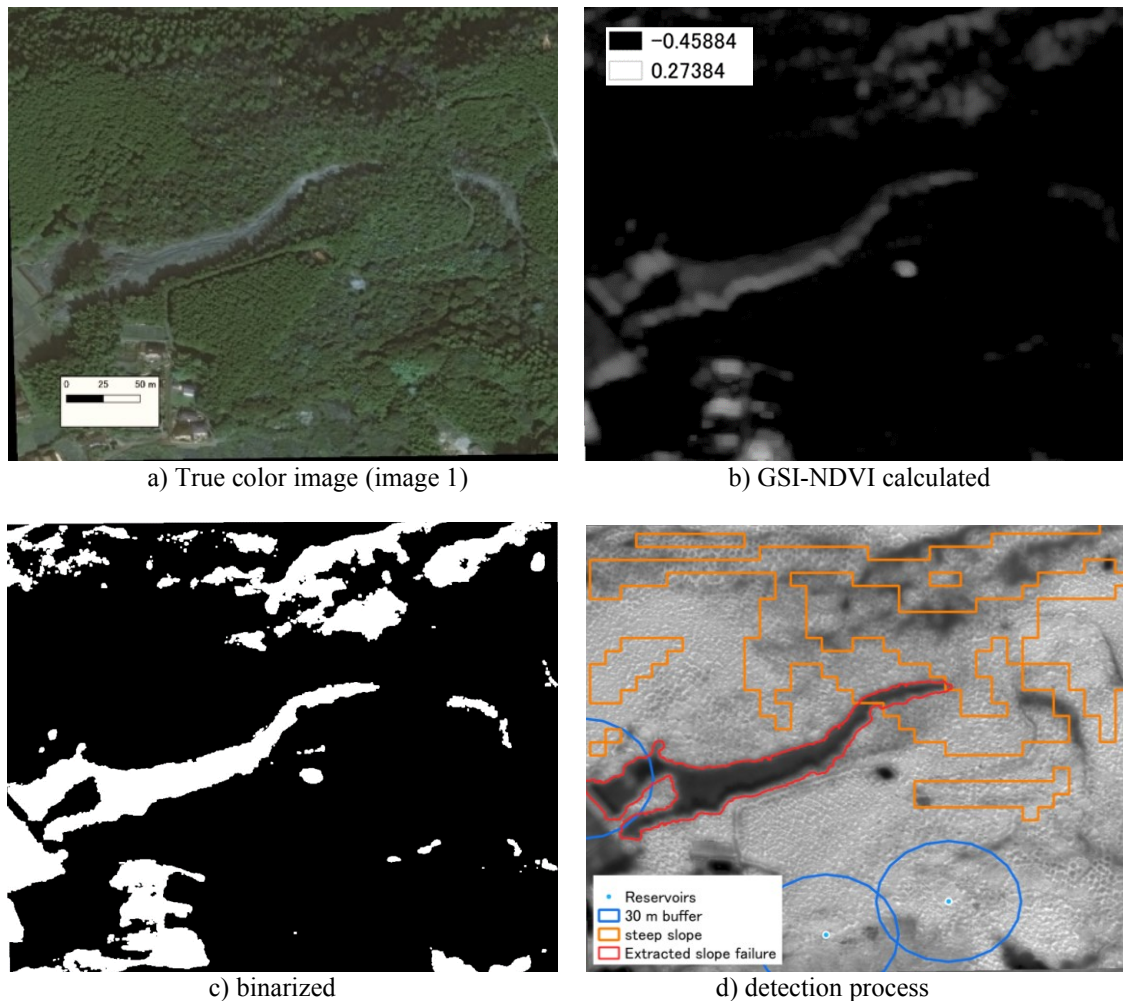| a) True color image (image 1)	b) GSI-NDVI calculated
c) binarized	d) detection process

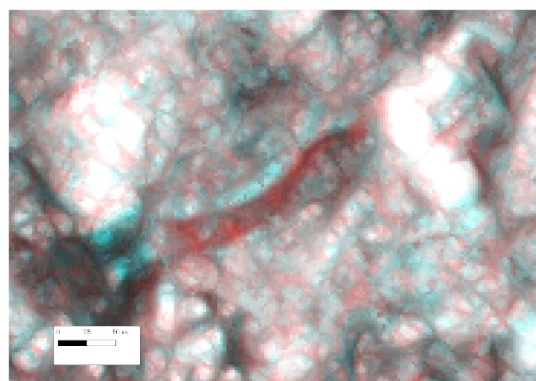Figure 2. procedure of VNIR analysis at Morishige reservoir

Figure 3. additive color SAR image at Morishige reservoir; image 2 (Red) and image 3 (Cyan)

4. VERIFICVATION OF THE ANALYSIS RESULT

4.1 Verification: VNIR satellite image analysis

According to the field survey, four reseervoirs were confirmed in the target area because the slope collapse occurred in the background. Table 2 shows the geology, slope, rainfall and landslide area of the landslide. In this extraction method, six ponds were detected because there was a suspicion of a slope failure behind. Figure 4 shows the results. Of the four locations that had been confirmed in the field survey to have occurred within the target area, all four locations were detected. Since the VNIR image before the disaster was not used in this extraction method, bare land without collapse was also extracted. However, the improvement of the base map makes it possible to evaluate the difference before and after the disaster, and it is also possible to detect only newly occurring slope failures.

4.2 Verification: SAR satellite image analysis

In the analysis using SAR images, 13 slope failures were detected within the target area. Table 3 shows the detected geology, slope, and rainfall at 13 locations. Of these, four occurred behind the pond. In fact, two out of four locations where slope failures occurred behind the reservoir were detected. Some ponds could not be detected because the scale of the damage was small compared to the resolution of the image, and the position of the collapse slope was shaded in relation to the orbit of ALOS-2. In the future, it should be investigated how to support the damage detection using ALOS-2 SAR images observed immediately after the damage by combining with the conditions of vulnerability such as rainfall and geology on the geographic information system.

Table 2. Characteristics of slope failure behind reservoir in VNIR analysis

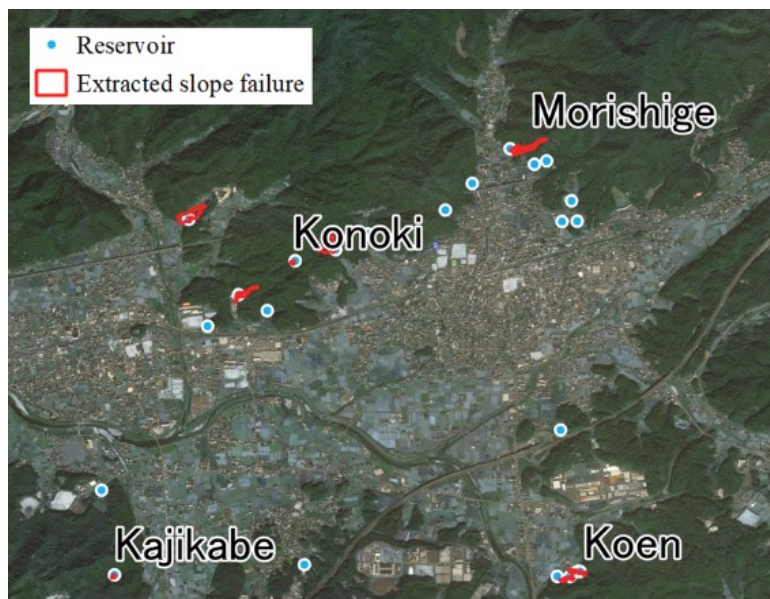| Name ID	Geological features	Slope (degree)	Total rainfall from July 5 to 6 (mm)	Collapse area (m²)	Detection	
					VNIR	SAR
Morishige	Complex rock	34.9	300	7034.56	✓	✓
Koen	Granite	31.4	280	2914.46	✓	✓
Konoki	Granite	27.6	320	563.35	✓	-
Kasjikabe	Granite	30.8	320	390.81	✓	-

Figure 4. Detection result by the VNIR image analysis

Table 3. Characteristics of the detected slope failure in SAR analysis

| ID	Geological features	Slope (degree)	Total rainfall from July 5 to 6（mm）	Remarks
1	Granite	42.3	340	
2	Granite	26.1	340	
3	Granite	38.6	340	
4	Granodiorite	33.6	340	Behind Reservior
5	Granodiorite	39.9	340	
6	Granite	34.4	340	
7	Complex rock	39.2	340	
8	Granite	34.4	340	
9	Granite	33.1	340	
10	Granodiorite	27.5	320	
11	Chart	34.9	300	Behind Reservior
12	Granite	31.4	280	Behind Reservior
13	Granite	29.1	320	Behind Reservior
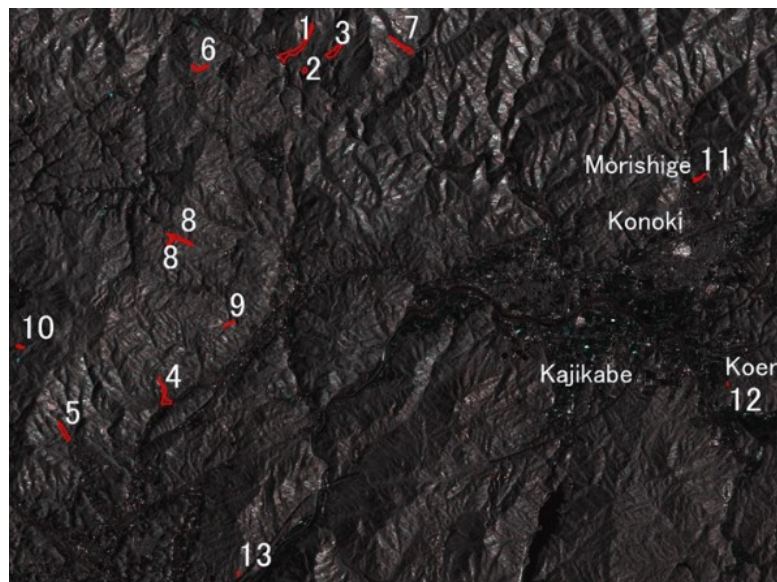
Figure 5. Detection result by the SAR images analysis

5. EXAMPLE OF DETECTION OF THE SEVERELY DAMAGED RESERVIOR

In July 2017, heavy rain in northern Kyushu caused damage to a large-scale reservoir with a breakwater at Yamanokami reservoir in Yamada, Asakura City. Taking this reservoir as an example, how a SAR image captures a larger-scale reservoir breach is shown. Figures 6 and 7 are aerial photographs taken around the reservoir before and after the disaster, respectively, taken by the Geographical Survey Institute (GSI) of Japan. The slope around the pond collapsed because it was located in the center of the surface image, and the pond collapsed due to inflow into the pond and debris flow with driftwood from upstream. After the disaster, the reservoir became flooded and the area became bare. Figure 8 shows the SAR images before and after the disaster subjected to additive color mixing. The area that was the pond water surface before the disaster became strong in cyan because it became bare land. In the area where the surrounding slope collapsed and became cliff-shaped, the red intensity was strong because the scattering intensity was lower than before the disaster. Thus, in SAR image analysis, not only the surrounding slope failure but also the pond break can be detected.

6. CONCLUSIONS

The analysis using VNIR images with a resolution of 50 cm was able to detect the collapse point with high accuracy even for small-scale damage. However, there were some locations that were detected incorrectly. In the future, in order to reduce false detections, we will evaluate the difference from the pre-disaster VNIR

Figure 6. Aerial photo of Yamanokami Reservoir before the heavy rain in 2017 (GSI Japan)

Figure 7. Aerial photo of Yamanokami Reservoir after the heavy rain in 2017 (GSI Japan)
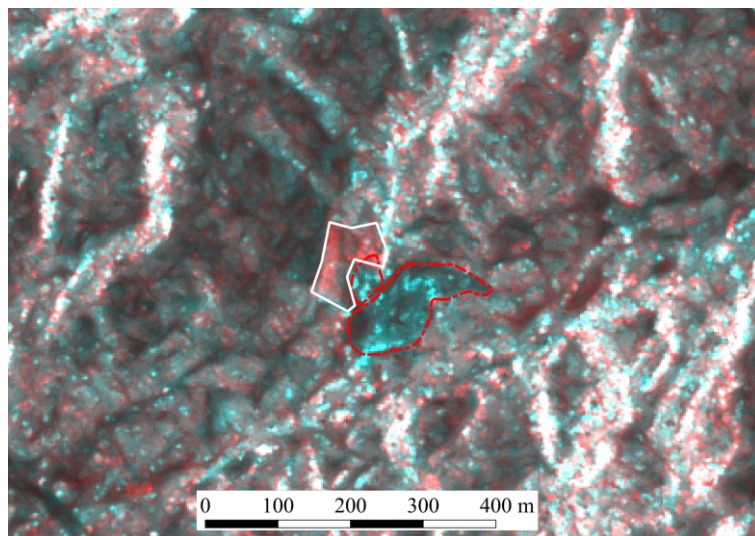

Figure 8. Detection result by the SAR images analysis

image obtained through the maintenance of the base map. In the analysis using SAR images, there were undetectable collapses due to resolution and imaging conditions. However, it was shown that it is possible to detect a large-scale disaster that should be dealt with immediately by analyzing the observations made immediately after the disaster. Since the extraction method used in this study can be automated, rapid disaster response can be expected.

ACKNOWLEDGMENTS

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