ANALYSIS OF WATER SURFACE CONDITIONS IN LAKE HOSENKO, JAPAN USING ALOS AVNIR-2 DATA

Yoichi Kageyama, Kenichi Miura, Makoto Nishida and Daizo Ishiyama
Graduate School of Engineering and Resource Science, Akita University,
1-1 Tegata Gakuen-Machi, Akita 010-8502 Japan; Tel: +81-18-889-2786;
E-mail: kageyama@ie.akita-u.ac.jp

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ABSTRACT: This paper estimates the water surface conditions of the Lake Hosenko appeared from the ALOS AVNIR-2 data, and analyzes seasonal change of its water surface conditions. The Tamagawa, Akita, Japan, is a remarkably acidotrophic river because strongly acidic thermal water of the Tamagawa hot spring flows into the Tamagawa river; the river water, in turn, flows into the Lake Hosenko and Lake Tazawako. However, this strong acidic water contained arsenic and iron hydroxide in past investigations. The finding indicates that arsenic in the stream water is removed as absorbed element on the surfaces of amorphous iron hydroxide, and it is transported to the downstream of the Tamagawa River. Remote sensing serves as a powerful technique for monitoring seasonal changes. One of them is the ALOS AVNIR-2 data. Therefore, this paper estimates the water surface conditions appeared from the AVNIR-2 data. First, band data were selected for use, on the basis of the reflective properties of the band data and the iron hydroxide. Second, the surface information of the Lake Hosenko was classified using fuzzy c-means and water information of the Lake Tazawako, and finally we analyzed the seasonal changes of water surface situation. As an experimental result for the September and May data, it was found that the seasonal differences of water surface situation of the lake Hosenko should be caused by the amount-of-water change and water temperature changes. Also, the classification results showed that the degree of belonging to the pollution state from iron hydroxide was possible to quantitatively evaluate the water conditions.

1. INTRODUCTION

The Tamagawa, Akita, Japan, is a remarkably acidotrophic river because strongly acidic thermal water of the Tamagawa hot spring flows into the Tamagawa river. The Tamagawa hot springs area, as well as Taiwan, is famous as a place to produce Hokutolite. The river water, in turn, flows into the Lake Hosenko and Lake Tazawako; e.g., arsenic content of thermal water of the Ohbuki spring, major hot spring in the Tamagawa area, had a range from 1.8 to 3.4 ppm (Tazaki, K., and Watanabe, H., 2004, Sato, H., Ishiyama, D., Mizuta, T. and Sera, K., 2004). Occurrence of arsenic in the amorphous iron hydroxide was confirmed (Sato, H., Ishiyama, D., Mizuta, T. and Sera, K., 2004, Sato, H., Ishiyama, D., Mizuta, T., Sera, K., and Enda, Y., 2005). The finding indicated that arsenic in the stream water is removed as absorbed element on the surfaces of amorphous iron hydroxide, and it is transported to the downstream of the Tamagawa River.

To investigate the water quality conditions, water samples directly to the target points is a common practice to analyze them. However, it is difficulty in estimating the situation of the entire study area. Remote sensing serves as a powerful technique for monitoring environmental and seasonal changes; several studies regarding surface water quality in the lake have been reported (e.g., Zhang, Y., Pulliainen, J., Koponen, S., and Hallikainen, M., 2002, Matthews, M. W., Bernard, S., and Winter K., 2010). Presently, various remote sensing data are used according to the required purpose. One of them is the Advanced Land Observing Satellite (ALOS) Advanced Visible and Near Infrared Radiometer type-2 (AVNIR-2) data (JAXA Web site). A technique to understand water surface conditions by taking account of the characteristics of the data used and

target as well as various disturbances in the data should be developed. In our previous study, we have proposed a method to estimate the water surface quality regarding poisonous substance of the Lake Hosenko appeared from ALOS AVNIR-2 data (Kageyama, Y., Miura, K., Nishida, and M., Ishiyama, D., in press). The method has adopted fuzzy c-means (FCM) (Takagi, M., and Shimoda, H., 2004); however, it is necessary to consider how to set initial points in FCM. Also, the use of water information of the Lake Tazawako, located at the downstream of the Lake Hosenko, may improve accuracy of the classification map regarding the water quality.
Therefore, this paper estimates the water surface conditions of the Lake Hosenko using FCM and water information of the Lake Tazawako. First, band data of the AVNIR-2 were selected for use, on the basis of the reflective properties of the band data and the iron hydroxide. Second, the surface information of the lake Hosenko was classified using FCM and water information of the Lake Tazawako, and finally we analyzed the seasonal changes of water surface situation.

2. ALOS AVNIR-2 DATA

The ground sample of the AVNIR-2 is 10 m for bands 1 through 4. The regression period is 46 days (JAXA Web site), and cloud cover conditions reduce the number of useful images, impeding continuous monitoring. This study has focused on the seasonal changes of water surface quality. Figure1 shows four images used for analysis. They were acquired on September 29, 2006 (i.e., the first Sep. data), September 17, 2008 (i.e., the second Sep. data), May 2, 2008 (i.e., the first May data) and May 5, 2009 (i.e., the second May data).

3. DATA ANALYSIS

The method applied for estimating water surface quality from the AVNIR-2 data consists of the

(a) September 29, 2006

(b) September 17, 2008

(c) May 2, 2008

(d) May 5, 2009

Figure 1. ALOS AVNIR-2 data (RGB; Band 3, 2, 1).

preprocessing and application of FCM to make classification maps. The proposed method is described in the subsequent sections.

3.1 Preprocessing

The preprocessing adopted in the study has three steps. First, ground control points (GCP) were selected and then geometrically corrected by using the second order conformal transformation. The average of RMS error was computed to be 0.16. Because staggered array elements have been adopted in the AVNIR-2, a maximum of 1-pixel registration error can occur by the nearest neighbor interpolation (JAXA Web site). So, the resampling process employed cubic convolution (Takagi, M., and Shimoda, H., 2004) in the study. Second, atmospheric correction was performed. Finally, the range of the Digital Numbers (DNs) in the water areas is much smaller than those in the land regions, and then masking was performed for the land regions.

3.2 Classification maps made by FCM

Remote sensing data have various disturbances such as atmospheric effects, surface wave effects, and noise measurement system. Given these restrictions, the DNs of the data include uncertainties. We assume that the DNs are fuzzy numbers. Fuzzy set theory provides useful concepts and tools to address uncertainties. FCM is a clustering algorithm which allows one pixel to belong to two or more classes. This paper adopts FCM to classify water surface situation (See Figure 2). First, the study area applied by the masking was divided into two classes (i.e., C1 and C2). The DNs of the C2, corresponding to iron hydroxide, were higher than those of the C1, which is almost unrelated to iron hydroxide. The initial point of the C1 was selected from the average of the high region of the histogram obtained from the Lake Hosenko; that of the C2 is the average of the low region of

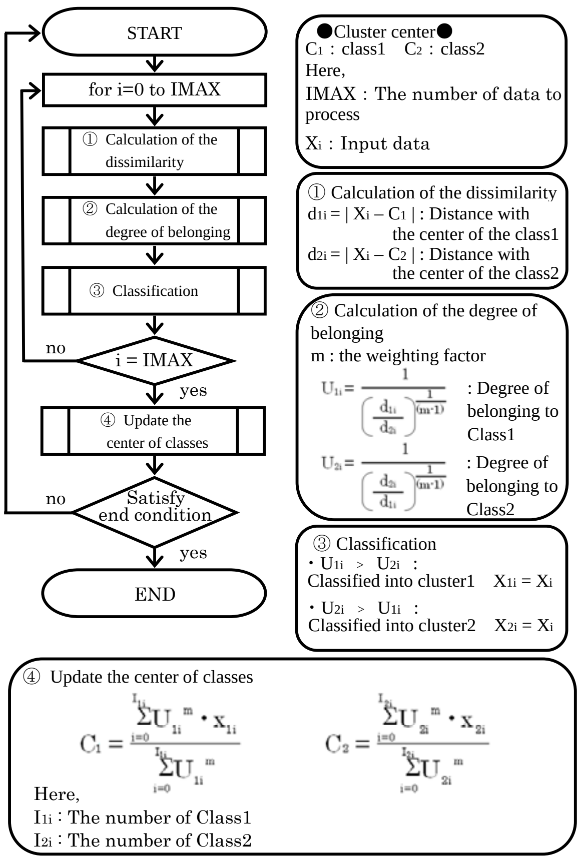


Figure 2. Flowchart of FCM adopted in this study.

the histogram obtained from the Lake Tazawako. Second, clustering was ended when the number of moving pixels between the two classes turned into 1% or less of the whole number of pixels.

4. RESULTS AND DISCUSSION

4.1 Realities acquired by an expert

In order to estimate water surface quality in the Lake Hosenko by remote sensing, an expert regarding the Tamagawa was interviewed. The acquired knowledge was summarized as below:
(1) The main pollutant of the lake is iron hydroxide, and it is adsorbed arsenic.
(2) The situations of highest pollution exist in the upper part of the lake, and gradually weakening, while falling in the lake.
(3) Because the water temperature changes occur in the lake, there is a possibility that the flow changes.

4.2 Selection of band data

For the reflectance of iron hydroxide (USGS Web Site), which is the main contamination substances in the lake, it is indicated that the highest reflectance in the wavelength range of band 4 (0.76 to 0.89 micrometers), as shown in Figure 3. Figure 4 shows the 4th band data of the second May data. However, the region had the low reflectance at water surface, and difficulty in extracting the details of water quality information. It was also clear that band 1 (0.42 to 0.50 micrometers) data with low reflectance of the iron hydroxide had very little possibility in extracting water quality information. Therefore, we used band 2 (0.61 to 0.69 micrometers) and band 3 (0.76 to 0.89 micrometers).

4.3 Selection of mask image

As shown in Figure 1, the amount of water in the lake changes greatly in each data. Figure 5 shows comparison result of the water areas with their original masked data. This revealed an impact on the water surface conditions due to differences in water depth. By using the mask of the first September data with the smallest water area, the lake water does not exist in the upper and the right part, it is indicated that depth of water is considerably shallow at these points. In order to remove the influence of the bottom of lake information by the difference of water levels, the mask created from the first September data with the smallest water areas was used for analysis.

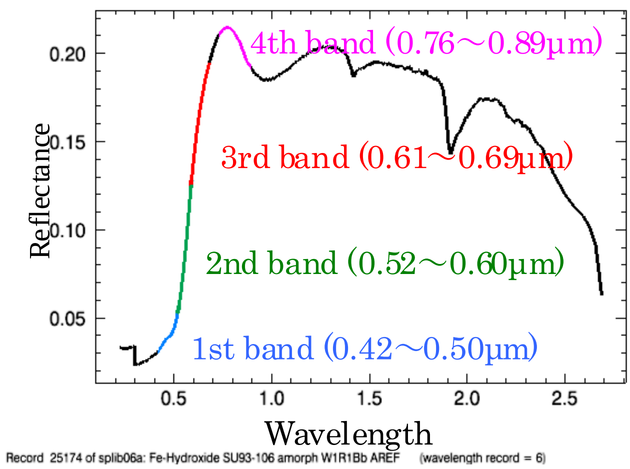


Figure 3. Reflectance of iron hydroxide (USGS Web Site) and wavelength range of band data.

4.4 Classification result with FCM and water information of the Lake Tazawako

The band 2 classification maps are shown in Figure 6. It is found that the degree of belonging to the class C2 is decreasing towards the lower part from the upper part of the lake, and that the maps are globally in agreement with expert's knowledge. In both bands 2 and 3 of the first and second Sep. data, the good results were also obtained. That is, according to the water going downstream, the values related to iron hydroxide become smaller.

Comparing the May data with the Sep. data, while global water surface situation are similar, it is

Figure 4. 4th band of the second May data.

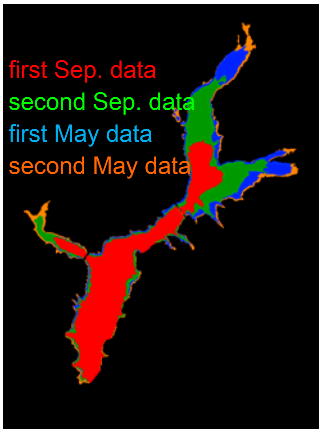
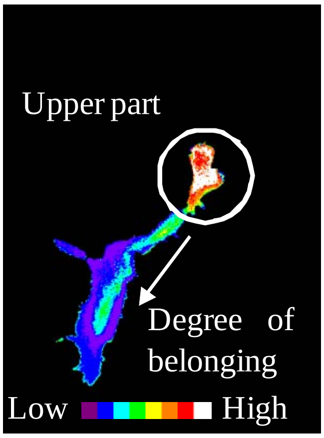
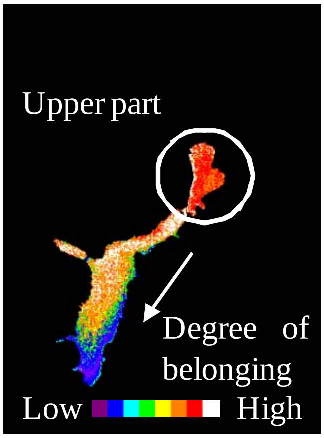


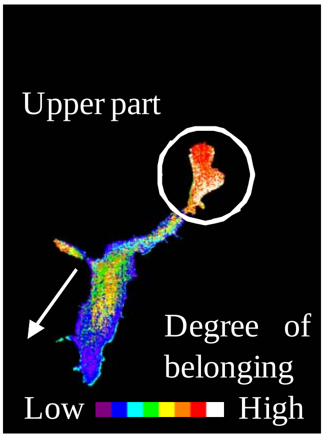
Figure 5. Comparison result of the water areas with their original masked data.



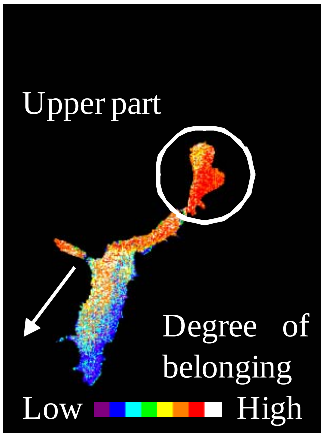
(a) September 29, 2006



(b) September 17, 2008



(c) May 2, 2008



(d) May 5, 2009

Figure 6. Classification maps made by FCM.

revealed that seasonal differences in the flow of the lake. Specifically, in the classification maps of the Sep. data, it flows down in the center part of the lake; it flows down in the left part on the contrary when using the May data. These conditions should be caused by the amount-of-water change and water temperature changes in the lake. The finding is effective for understanding the environmental status of the Tamagawa downstream region. And, the FCM results can express the degree of belonging to the pollution state from iron hydroxide, which makes possible to quantitatively evaluate the water surface conditions.

5. CONCLUSIONS

This study has estimated the water surface quality in the Lake Hosenko, Japan by using the ALOS AVNIR-2 data. The main results were as follows:

•From the relation between the reflective properties of water and iron hydroxide, it was shown clearly that 2nd and 3rd band data was effective in especially presumption of the water surface quality of the Lake Hosenko.

•The FCM classification results were globally in agreement with the findings of experts. It was shown clearly that the AVNIR-2 data was useful to understand the water surface quality of the whole lake due to the iron hydroxide.

•ALOS AVNIR-2 data was found to be useful in estimating the seasonal variation in lake water.

•The FCM results, which used water information of the Lake Tazawako, showed clearly that it was useful to quantitative evaluation of the water surface quality of the Lake Hosenko.

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