Environmental Analyses of Industrial Waste using Satellites and On-site Sensors

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The biggest illegal dumping site in Japan was found on the border between Iwate and Aomori Prefectures about 50 km away from Hachinohe city. It caused major social problems such as environmental contamination and must be reverted to its natural state. To monitor and analyze the environmental changes, a remote sensing system was established using artificial satellites and on-site sensors. From February, 2004, a large amount of data including satellite images, water quality data and weather data has been collected using this system. In this paper, these data was analyzed to explain the state of contamination and the state of recovery. Satellite images from several different satellite sensors were combined for vegetation analysis and topographic analysis. The result manifested topographic characteristics of the site and the changes of green vegetation. And the relationship between the changes of water quality and the existence or the removal of industrial wastes was explained. These will be powerful tools for dealing with industrial waste.

Key Words : Environmental analyses, Industrial waste, Remote sensing, Topographic analysis

1 INTRODUCTION

Recently, many big illegal dumping sites were found in Japan. It is a big problem to find a common and fast way to forecast and deal with them. One of the biggest illegal sites was found on the border between Iwate and Aomori Prefectures, located about 50 km away from Hachinohe Institute of Technology. The area of this dumping site was 27 hectares, and total amount of waste amounted to about 820,000 m³. The dumped waste was mainly sludge, incomplete RDF (Refuse Derived Fuel), and incinerated ash. Indeed, a small amount of VOC (Volatilizable Organic Compound), dioxin ($C_{12}H_4O_2Cl_4$), and medical waste was detected.

An environmental monitoring system using artificial satellites and ground observation apparatus was established to collect and analyze the environmental data. The satellite data, including NASA's Terra and Aqua images, spectral SPOT images, Aster DEM (Digital Elevation Model) data and Quickbird data, was analyzed for vegetation analysis and topographic analysis in a wide area. And the data from ground observation apparatus, including pH, electric conductivity and temperature of water, and weather data, was analyzed in detail to establish the changes of the environment.

2 REMOTE SENSING SYSTEM AND ANALYSIS METHODS

2.1 System for collecting and analyzing satellite data

Satellite data is appropriate for continually observing and surveying a widely polluted area, such as environmental monitoring of industry waste. Data from NASA's Terra-1 (EOS-AM) and Aqua (EOS-TM) EOS satellites was received directly by an antenna installed on the roof of a building on our campus. MODIS (Moderate Resolution Imaging Spectrometer) sensors carried by satellites have 36 channels of various wavelengths. This data was used for analyzing environmental information such as temperature and vegetation[1]. Moreover, a color multispectral SPOT image of 10 m spatial resolution, a panchromatic SPOT image of 2.5 m spatial resolution, Aster DEM data and a Quickbird image of 2.4 m spatial resolution were used for analysis by the ENVI software.

2.2 On-site observation system

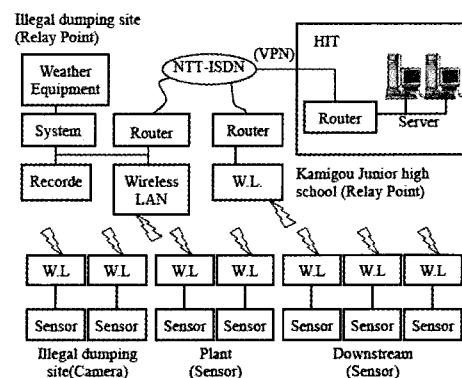Figure 1 shows the on-site observation system for reception,

Figure 1: On-site observation system

processing and analysis of the data from on-site sensors. Five water quality analyzers, weather measuring equipment and two infrared cameras were set up at the dumping site. Data was then transmitted to the monitoring PC in the university every three minutes. The items measured were pH, electric conductivity, temperature, flow rate, wind direction, wind velocity, air temperature, and precipitation. This system and field work was used to back up the satellite images for better accuracy.

3   VEGETATION ANALYSIS AND TOPOGRAPHIC ANALYSIS

3.1   Vegetation analysis using SPOT images

Data fusion is the process of combining multiple image layers into a single composite image[2]. In this case, HSV Sharpening was used as a way for data fusion. Two SPOT satellite images (a color multispectral image of 10 m spatial resolution and a panchromatic image of 2.5 m spatial resolution, which exhibit complementary characteristics of spatial and spectral resolutions, June 17, 2004), were combined to produce an output image that contains the color from the multispectral image and high spatial resolution from the panchromatic image[3].

First, the color multispectral image was transformed from the red-green-blue color space into hue-saturation-value color space. The value band was replaced with the 2.5 m spatial resolution image and stretched from zero to one to fill the correct data range. Then the hue and saturation from the color multispectral image and value from the high special resolution image were transformed back to red-green-blue color space.

The Figure 2 is the output image, which is a false color infrared photograph. Bright red areas on the image represent high infrared reflectance, corresponding to healthy vegetation, either under cultivation, or along rivers. Slightly darker red areas typically represent native vegetation such as shrub and grassland. In this case, the scale of red areas is much less than other areas, meaning that there was less on-site vegetation than in the surrounding area. Moreover, by Comparing with the SPOT2 image for 1992 (Figure 3), we are able to find decrease in the amount of vegetation and determine those areas that had changed in that period.

3.2   Topographic analysis using DEM data

The DEM data consists of a sampled array of elevations for a number of ground positions at regularly spaced intervals[4]. The DEM data of 15 m spatial resolution on the site was combined with a Quickbird image of 2.4 m spatial resolution to obtain high spatial resolution. The output image is a three-dimensional visualization of the site and its surrounding areas, and it is shown in Figure 4. In addition, the elevation of the site is about 440 m.

Figure 5 is a classification output map that classified each pixel
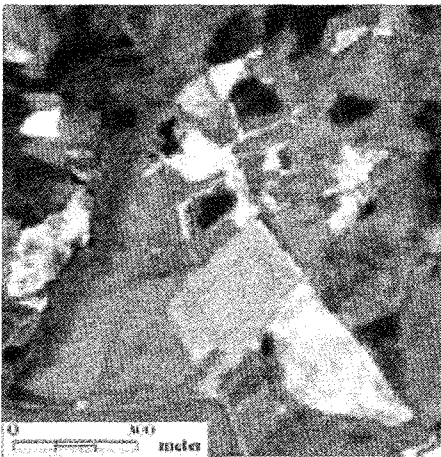

Figure 2:   Fused image from a multispectral image and a panchromatic image

Figure 4:   Three-dimensional visualization by combining the DEM data with Quickbird data

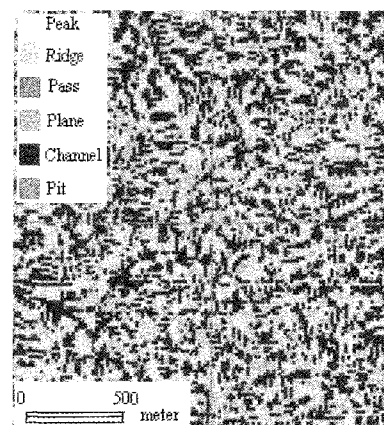Figure 3:   SPOT2 image for 1992

Figure 5:   Map of topographic analysis using DEM data

into one of the following terrain types: peak, ridge, pass, plane, channel, or pit. The topographic features were determined by fitting a quadratic surface to the digital elevation data for the entered kernel size and calculating the slope and curvatures of the surface. It was confirmed that the cross of the two orange lines, the entrance of the site (E 141.06.04, N 40.16.37) was a ridge. And the terrain types of the rest were all confirmed from this map.

4 ANALYSIS OF THE WATER QUALITY

The illegal dumping site is near water supply source, so the water quality is very important to local inhabitant's lives. Five water quality analyzers were installed at the new water supply source (Point 1), the former water supply source (Point 2), in the vicinity of the Kumahara River (Point 3), at the intake (Point 4) and the outlet (Point 5) of the water purification plant as shown in Figure 6.
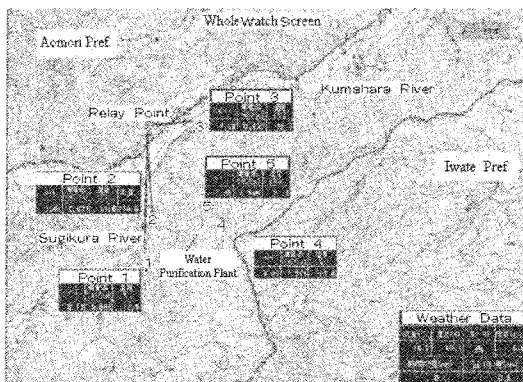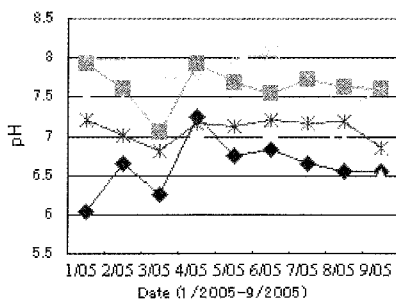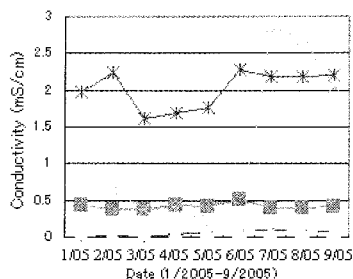

Figure 6: Distribution of water quality analyzers

a: Changes of pH

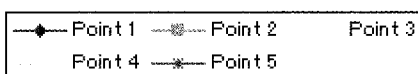b: Changes of electric conductivity

Figure 7: Changes of water quality

Figure 7 shows the changes of water quality on pH and electric conductivity from January, 2005 to September, 2005. In this figure, pH and electric conductivity of the water on the site (Point 4) were higher than normal water (Point 1 and Point 3), e.g. the mean pH value of Point 4 from January, 2005 to September, 2005 was about 7.78, while that of Point 3 was near 7. The water purification plant was established to purify the polluted water. Electric conductivity value of Point 5 was high because of chemicals, while the pH of that reduced to about 7. On the other hand, data of its surrounding areas (Point 1 and Point 3) was similar to those of the normal water. So for the moment, pollution still didn't diffuse.

Although the electric conductivity value of Point 4 surged violently in this period, the pH value reduced to some extent. This should be due to the water purification plant and the removal of waste. The water purification plant was changed from old one to new one in July, 2005. At the same time, the sensor on Point 4 was reset. The removal began from November, 2004, and 30,552 tons of waste (22,792 tons of solid waste and 7,760 tons of fluid waste) was removed until September, 2005. But, only 4.56 percent of waste in Aomori Prefecture was removed. It is needed to remove the waste more quickly.

5 CONCLUSIONS

After the illegal dumping site on the border between Iwate and Aomori Prefectures was found, the environmental monitoring system was established using satellites and ground observation apparatus to constantly observe the illegal dumping site. Tasks which require days or weeks to survey on the site can be accomplished in near real-time. The data collected by this system was analyzed to help to improve environment.

Two SPOT images were fused to improve the presentation by using HSV Sharpening. The result was a color composite image of enhanced spatial resolution. The scale of green vegetation was shown in this false color infrared photograph. We can find decrease in the amount of vegetation and determine those areas that had changed in that period by comparing images that were recorded in different years. The three-dimensional visualization of the site was combined using DEM data and Quikbird data, and each pixel of the DEM data were classified into terrain types by topographic analysis. The changes of water quality were analyzed on pH and electric conductivity. In our view, pollution in the site still doesn't diffuse and the water quality is improving little by little because of the water purification plant and the removal of waste. But it is needed to more repaid remove the waste. In the future, new satellite data and ground data will be sequentially collected by this system. This will be compared with current data to understand and forecast environmental changes.

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