Possibility of Monitoring of Waste Disposal Site Using Satellite Imagery

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Abstract

Waste management is one of the expected applications for satellite imagery. This study investigated the usefulness of monitoring waste on land areas using data from the currently operated earth observation satellites ALOS (Advanced Land Observing Satellite) and Quickbird. The Japanese ALOS has two optical imagers, PRISM and AVNIR-2, and an L-band synthetic aperture radar (PALSAR). Quickbird is a commercial high-resolution satellite that provides submeter-resolution imagery. Surface changes associated with legal and illegal waste disposal were examined using ALOS imagery in Miyagi prefecture, Japan. The results indicate that a landfill site can be identified and temporal changes in the disposal site are clearly evident on PRISM imagery. Pan-sharpend PRISM and AVNIR-2 images are useful for image interpretation. Quickbird has a nominal ground resolution of 0.6 m for panchromatic imagery and 2.4 m for multispectral imagery. The ability to use Quickbird data to identify garbage of different size and material was examined. A junkyard with a size of approximately 6 x 4 m was clearly evident on pan-sharpened images obtained on June 2003. The same junkyard was identified in the image obtained on September 2006, and it had expanded to approximately 10 x 4 m. A target within an area with vegetation was identifiable, but another target of almost the same size in an area with bare soil was difficult to see. A waste-tire dumping site was also used to assess what could be identified from Quickbird data. Spatial resolution improvements, shorter observation intervals, and data-cost reductions could make satellite imagery practically useful in waste monitoring.

1. Introduction

The importance of waste management in environmental control is increasing. Remote sensing is anticipated to be useful in ameliorating this problem, especially in the monitoring of waste disposal sites. Garofalo and Wobber (1974) suggested the usefulness of aerial photographs for solid-waste management and planning. Many studies have demonstrated the effectiveness of applying visual interpretation techniques to airborne data (Ottavianelli *et al* , 2005). For example, Barnaba *et al*. (1991) described a procedure for performing comprehensive inventories of waste disposal sites over country-sized areas on Suffolk county (New York, United States) based on historical aerial photographs. Folkard and Cummins (1998) used airborne hyperspectral data to monitor soil contamination, particularly around landfill sites. The usefulness of spaceborne data has also been evaluated. Phillipson *et al*. (1988) tested the suitability of SPOT satellite images for monitoring land-cover changes that could be significant in investigations of landfills. Brivio *et al*. (1993) applied the spatial autocorrelation method to Landsat TM data, and concluded that it appears to be an effective tool for producing an inventory and assessment of waste-disposal sites. The potential of spaceborne synthetic aperture radar (SAR) remote sensing and SAR interferometric processing for detecting landfill sites was evaluated by Ottavianelli *et al*. (2006). These studies have shown that the usefulness of remote sensing data in waste management depends on sensor parameters, including the spectral, spatial, and temporal resolutions. However, ambiguity in the results by image spatial and spectral dimensions has been pointed out.

The possibility of using remote sensing data to detect illegal dumping has also been discussed. Tomiyama *et al*. (2005) assessed the capability of detecting illegal waste dumping sites using airborne SAR data. A method that uses IKONOS satellite data and GIS (Geographic Information System) data to identify unknown landfills over large areas was validated by Silvestri and Omri (2008).

The present study investigated the applicability of recently launched satellite sensors to waste management. ALOS (Advanced Land Observing Satellite) is a Japanese satellite launched in 2006 that has three sensors: PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping), AVNIR-2 (Advanced Visible and Near Infrared Radiometer type 2), and PALSAR (Phased Array type L-band Synthetic Aperture Radar). PRISM is a panchromatic sensor that can observe the earth surface from three directions to generate a digital surface model. Its spatial resolution is 2.5 m on nadir viewing. AVNIR-2 is a multispectral optical sensor with a spatial resolution of 10m. PALSAR is a SAR with a range resolution of about 10 m on fine-mode imagery. Quickbird is an American commercial high-resolution satellite launched in 2001 that has sensors that acquire 0.61m panchromatic and 2.44m four-band multispectral images. The usefulness of using ALOS imagery to monitor known waste disposal sites and Quickbird imagery to identity illegal dumping were examined. The goal of this research was to clarify the usefulness and limitations of detecting surface changes in Japanese waste disposal sites by visual interpretation of images obtained by currently operated satellites.

2. ALOS Data Sets

2.1. Study Area and Test Sites

Public and private waste disposal sites in Miyagi prefecture, Japan, were the focus of this study. Thirty public waste disposal sites were managed by the local government of Miyagi prefecture as at 1 October 2007 (Miyagi prefecture, 2008). The Ishidumori landfill site was selected as a target site. This is the largest public waste disposal site in Miyagi prefecture, and is located in Tomiya-cho (north of Sendai city) and has a total landfill capacity of 6,412,000 cubic m. The site has a total area of 800,000 sq m and a landfill area of 348,400 sq m. The landfill operation started in 1986 and will finish in 2011. The main landfill material is ash from incineration factories. Other disposal sites, such as the Morisato landfill site and Otsurusawa waste disposal site, were also examined. The Morisato landfill site (whose landfill operations have ended) is located in Rifu-cho, north of Sendai city. The Otsurusawa waste disposal site is located in Taiwa-cho and is managed by Miyagi Environment Public Corporation. The Morisato landfill site is about 1 km from the Otsurusawa waste disposal site. The local government monitors private disposal sites, and the sites of interest in this research included several private disposal sites with known locations.

2.2. Data and Analysis

ALOS PRISM, AVNIR-2 and PALSAR data were analyzed in this study. The observation dates were 28 December 2006, 1 March 2007, 15 November 2007, and 2 July 2008 for PRISM data, and 26 November 2006, 25 December 2006 and 1 March 2007, 15 November 2007, 17 May 2008, and 2 July 2008 for AVNIR-2 data. Pan-sharpend images of the target area were generated from PRISM and AVNIR-2 data. Assuming that the surface of the target area was almost the same over a 3-days period, PRISM and AVNIR-2 data sets with an observation interval of three days were pan-sharpened. Targets in the obtained images were identified.

PALSAR fine-mode intensity images acquired between June 2006 and August 2007 were also examined. Their polarization was HH, and the observation off-nadir angles were 21.5°, 34.3°, 41.5°, and 50.8°. Both ascending and descending data were examined.

2.3. Results and Discussion

Obvious changes in land surface were identified at the Ishidumori landfill site and interpreted from obtained PRISM images (Fig.1). For example, progressing landfill was evident in the south part of landfill sites within circle A in the figure. Objects were evident on the ground in December 2006 within circle B, and this had disappeared in November 2007. The area within circle C was covered by vegetation in November 2007 but appeared to be open ground with a supply road appearing in the image obtained in July 2008. These surface changes could be identified on PRISM imagery; however, pan-sharpend imagery is much more helpful for extracting surface changes by visual interpretation, especially in areas with vegetation. It is necessary to consider how the radiance differs with time and season in each observation, because the radiance is affected by the transmittance and the solar zenith angle (Iikura and Yokoyama, 1999). Only seasonal vegetation changes were identified at the Morisato landfill site. Several surface changes were found at the Otsurusawa waste disposal site, but none were obvious at the Ishidumori landfill site.

It was impossible to identify land-surface changes at waste disposal sites from the visual interpretation of PALSAR intensity images. Features of the landfill sites were hidden by speckle pattern, with only containers on private waste disposal site being distinguishable because they cause double-bounce.

3. Quickbird Data Sets

3.1. Test Site and Data

The usefulness of Quickbird imagery for detecting illegal dumping was examined on the Taihaku campus of Miyagi University, Sendai city. Panchromatic and multispectral Quickbird data acquired on 21 September 2006 with an off-nadir angle of 19° and on 5 June 2003 with an off-nadir angle of 23° were analyzed. Several buildings had been reconstructed between 2005 and 2007 in the study area. Garbage on the campus represented targets for verifying whether identification was possible. Ground-based

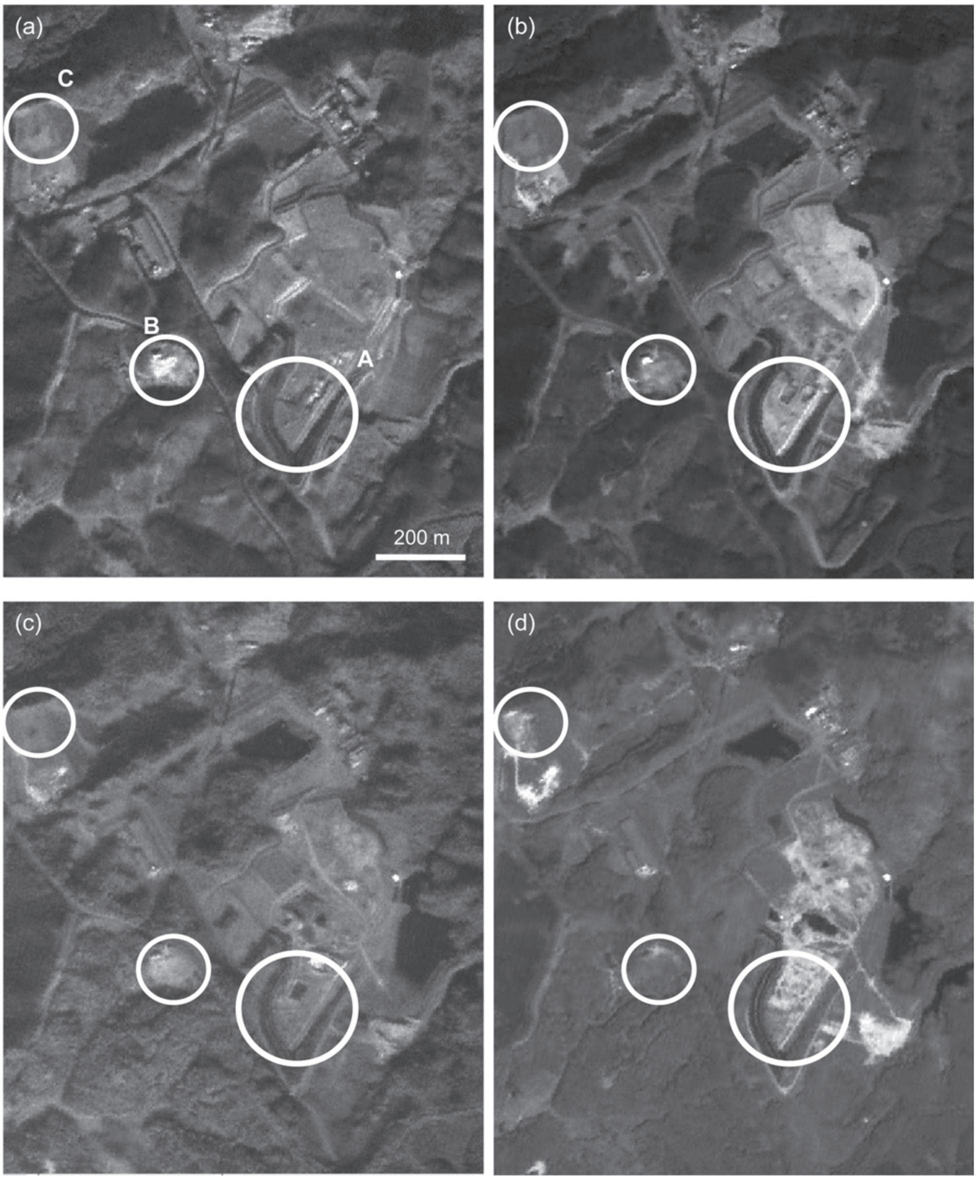

Fig. 1. ALOS PRISM imagery acquired with nadir viewing of the Ishidumori landfill, Miyagi prefecture on 28 December 2006 (a), 1 March 2007 (b), 15 November 2007 (c), and 2 July 2008 (d). Circles show the areas where temporal change were identified. (PRISM images are shown here due to the journal not including color pages.)

observations were carried out on 25 September 2006, which confirmed the presence of derelict concrete, iron, paper, plastic objects, and a junkyard with a size of approximately 10 x 4 m (Fig.2).

The Nakaniida area of Kami-cho, Miyagi prefecture, was also investigated, which contained a private waste-tire dumping site occupying about 1,200 sq m. This was used to assess what could be identified from Quickbird data obtained on 5 August 2005. Pan-sharpened images were generated from panchromatic and multispectral data.

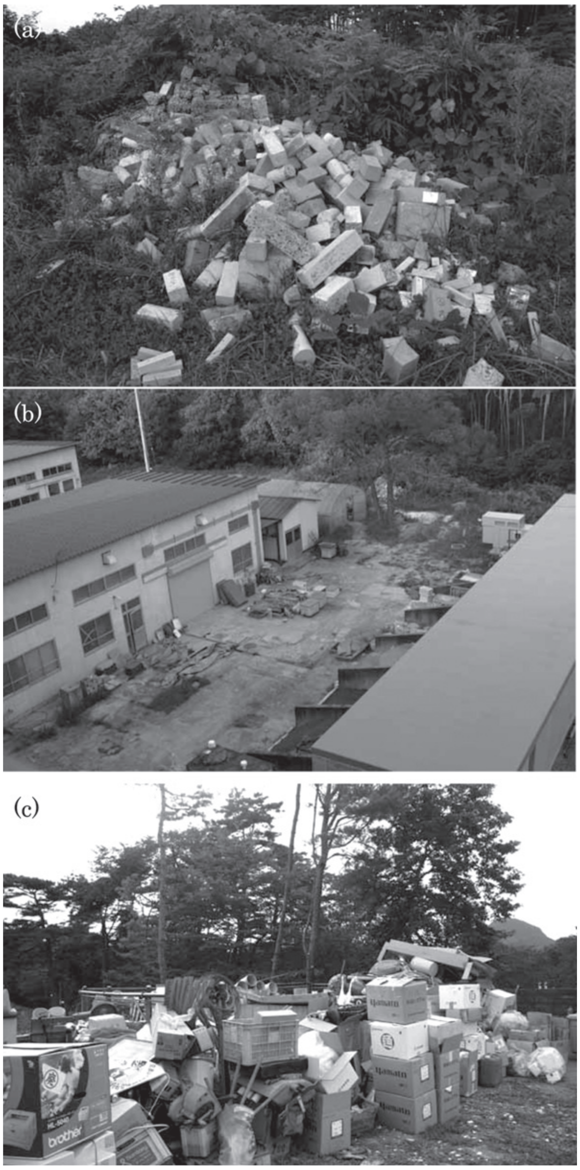

Fig. 2. Garbage on Taihaku campus, Miyagi University, observed on 25 September 2006 by ground based observations. Scrap concrete (a), iron and plastic lying on bare soil (b), and a junkyard (c).

3.2. Results and Discussion

3.2.1. Garbage on Taihaku Campus

Scrap concrete larger than approximately 2 x 2 m could be identified in the area with vegetation on Quickbird pan-sharpend images, as shown in Fig.2 (a). This target could also be identified on panchromatic images (Fig.3 (a)), but multispectral information greatly helped to distinguish between concrete and vegetation due to their differing spectral characteristics. It was difficult to identify scrap iron and plastic with a size of approximately 2 x 2 m lying on bare soil (Fig.2 (b)) in either panchromatic or pan-sharpend images. Plastic, concrete, and bare soil generally exhibit high reflectance. A junkyard with a size of approximately 4 x 10 m was identifiable

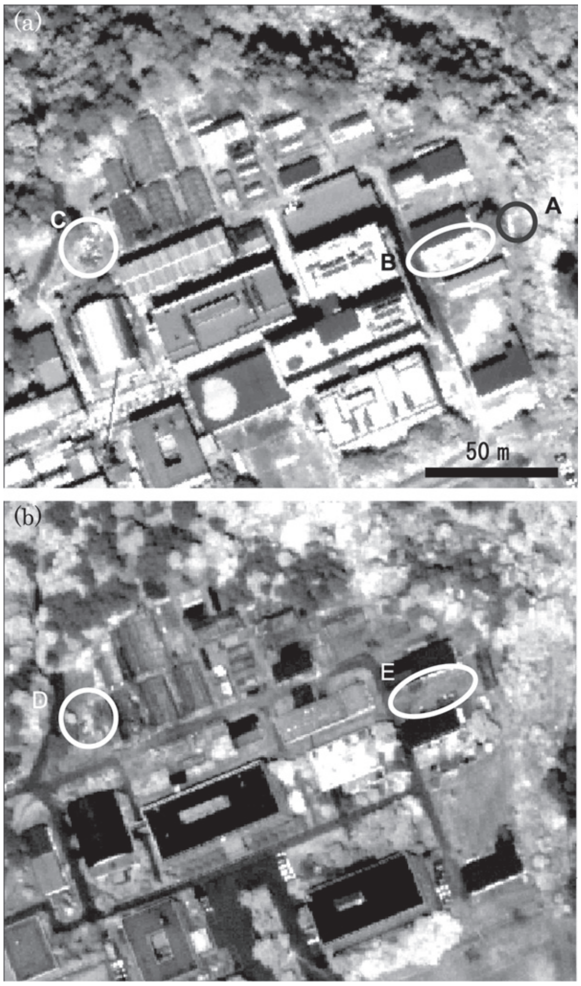

Fig. 3. Quickbird panchromatic images of Taihaku campus, Miyagi University obtained on 21 September 2006 (a) and 5 June 2003 (b). Areas labeled “A”, “B” and “C” correspond to Fig.2 (a), (b) and (c), respectively. Areas labeled “D” and “E” are described in the main text.

on both panchromatic and pan-sharpened images, as shown in Fig.2 (c). This junkyard was surrounded by vegetation, and it appeared as an area with a high reflectance and inhomogeneous texture in panchromatic images. Multispectral information facilitates discrimination between garbage (paper, plastic, and iron) and vegetation. This area was identifiable as a junkyard on images acquired on 5 June 2003, as shown by circle D in Fig.3 (b), and had an estimated size of approximately 4 x 6 m. Garbage or other subjects were thought to be present on the ground within ellipse E in Fig.3 (b).

Quickbird is the currently operated civilian satellite that provides the highest resolution ground imagery, and allows approximately 2 x 2 m of garbage surrounded by vegetation to be identified. Although actual field information is necessary for detailed image interpretation, it is possible to assume the presence of garbage and its extent if the underlying circumstances are known.

3.2.2. Waste-Tire Dumping Site in Kami-cho

The private waste-tire dumping site in Kami-cho was large enough to identify from Quickbird panchromatic and multi-spectral imagery (Fig.4). It appeared as a dark and smooth area on panchromatic images, and with a relatively low reflectance area on bands 1 to 4 in multispectral images. The mean values for extracted typical area on land representing waste tires, water, forest, agricultural field, buildings, and soil in each band are plotted in Fig.5. The waste-tire area looks similar to water except in the near-infrared area (band 4), where its value is higher than that of water.

Fig. 4. Quickbird panchromatic imagery on a part of Kami-cho, Miyagi prefecture. The circle shows a private waste-tire dumping site.

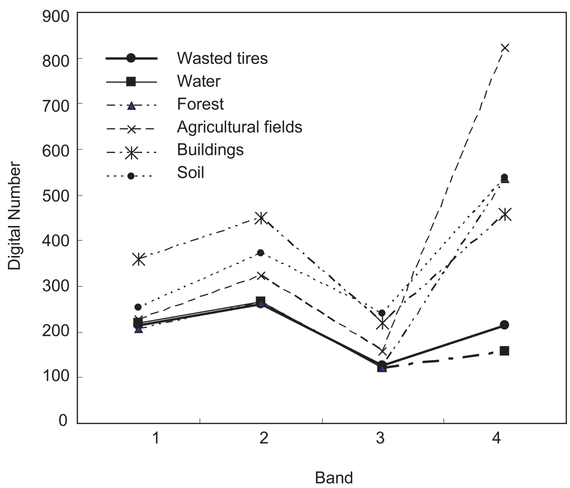

Fig. 5. Plots of mean digital numbers in extracted area from representing waste tires, water (pond), forest, agricultural fields, buildings, and soil for band 1, 2, 3 and 4 of multispectral Quickbird imagery.

4. Conclusion

Waste management is an important task for local governments in Japan, which administer waste disposal sites and landfills to ensure that they operate appropriately, and also monitors illegal dumping. Satellite imagery can be used to monitor the usage and extent of private and illegal dumping sites that have already been identified. Visual interpretation of satellite data is a practical method for local governments to manage waste disposal sites, with spectral characteristics of satellite data being useful for identifying the illegal dumping of waste. One of the problems is discriminating between materials with similar spectral characteristics. The practical application of satellite imagery to waste monitoring requires improvements to sensor spatial resolutions, shorter observation intervals, and reductions in the cost of data.

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References

Barnaba, E. M., W. R. Philipson, A. W. Ingram, J. Pim (1991) The use of aerial photographs in county inventories of waste-disposal sites. Photogrammetric Engineering and Remote Sensing, 57(10): 1289-1296.

Brivio, P. A., I. Doria, and E. Zilioli (1993) Aspects of spatial autocorrelation of Landsat TM data for the inventory of waste-disposal sites in rural environments. Photogrammetric Engineering and Remote Sensing, 59(9): 1377-1382.

Folkard, A. M. and D. I. Cummins (1998) Hyperspectral remote sensing of the spread of soil contaminants from landfill sites. Conference Proceedings Contaminated Soil '98: 153-161.

Garofalo, D. and F. Wobber (1974) Solid waste and remote sensing. Photogrammetric Engineering sand Remote Sensing, 40(1): 45-59.

Iikura, Y. and R. Yokoyama (1999) Correlation of atmospheric and topographic effects on Landsat TM Imagery. Journal of the Remote Sensing Society of Japan, 19, 1: 2-16 (in Japanese with English abstract).

Miyagi prefecture (2008) Environmental white paper in Miyagi - reference - (CD-ROM) (in Japanese).

Ottavianelli, G., S. Hobbs, R. Smith, K. Morrison and D. Bruno (2005) Assessment of hyperspectral and SAR remote sensing for solid waste landfill management. Proceedings of 3rd ESA CHRIS proba workshop.

Ottavianelli, G., S. Hobbs, R. Smith, K. Morrison and D. Bruno (2006) SAR Interferometric products and hyperspectral data for monitoring solid waste landfill operations. Proceedings of 4th ESA CHRIS proba workshop 2006.

Phillipson, W. R., E. M. Bamaba and A. Ingram (1988) Land-cover monitoring with SPOT for landfill investigations. Photogrammetric Engineering and Remote Sensing, 54(2): 223-228.

Silvestri S. and M. Omri (2008) A method for the remote sensing identification of uncontrolled landfills: formulation and validation. International Journal of Remote Sensing, 29 (4): 975-989.

Tomiyama, N., T. Yamanokuchi and C. Yonezawa (2005) Detection of illegal waste using Pi-SAR data, Proceedings of the 38th Conference of the Remote Sensing Society of Japan: 163-164 (in Japanese with English abstract).