Evaluation of Slope Hazards and Landslide-Triggering Factors in Korea

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Abstract

There are many slope disasters nationwide in Korea during the rainy season hit by severe rain storm and typhoon from June to September every year. The Korean peninsula was indirectly affected by typhoons 12th Nakri and 11th Halong taken place in August, 2014. The rainfall in August was 369 mm, reaching 138% of an average rainfall of August, while the rainy days were 18.2 that are about 5 days longer than its average. It is acknowledged that diverse factors such as topography, geological features, forest types, and forest fire are combined to induce slope disasters in Korea, even though the rain is one of the main causes. Therefore, it is hard to predict the causes of slope disasters only based on the rain parameter. In this study, landslide vulnerability as a function of swelling clay minerals was evaluated using ASTER satellite imageries. We examined spectral characteristics changes based on the field survey, XRD, XRF analysis, and spectroscopic analyses using GER 3700 portable spectrometer on soil samples obtained from landslide sites, together with ASTER satellite imageries. According to the results analyzed, most landslide areas are made up of illite-rich clay minerals and their spectral properties show differences in the SWIR. The particle size and mineral composition were analyzed through the six bands of SWIR on the basis of spectral characteristics. Illite, one of representative swelling clay minerals, shows characteristic absorption features: Fe^{2+} and Fe^{3+} at 0.9 and 1.0 μm, broad water absorption features near 1.4 and 1.9 μm, and additional Al-hydroxyl features at 2.2, 2.3 and 2.4 μm, respectively. These absorption properties correspond to the band 5, band 6 and band 7 in the ASTER imageries. This study showed the spectral characteristics of the soils and ASTER imageries by applying $SWIR_{illite}$ model for the multiplication ratio between wavelength bands, leading to a conclusion that the applicability of ASTER satellite imageries, combined with analyses of swelling clay minerals, has potential to evaluate and predict the landslide hazards.

Keywords: landslide, spectral reflectance, clay mineral, ASTER, band math

1. Introduction

Due to properties of contraction and expansion, clay minerals negatively not only affect construction but also produce discontinuities and shear planes on natural slope, leading to slope unstability that finally causes landslide. The source of expandability of clay minerals arises from chemical attraction of water molecules which are included between sheets in the clay structure. When clay minerals no longer hold water, clay sheets become separated, and thus clay structures gradually begin to be unstable. Such properties are common in most soils (Gray and Murphy, 2002) and serve as main indicators that explain soil expandability and attraction in engineering geology (Al-Rawas, 1999; Fall and Sarr, 2007). Clay minerals have different mineral structures, and physicochemical properties. Soil expandability causes main problems encountered in engineering geology and is considered intrinsic properties attributed to the presence of active clay minerals (Al-Mukhtar et al., 2010; Al-Rawas, 1999; Bell, 1999; Kim et al., 2005; Seco et al., 2011; Shi et al., 2002; Snethen, 1975; Sridharan and Gurtug, 2004).

To monitor the presence of clay minerals is considered one of the most important factors to identify potential expandable soils and characterization and quantification of soil are essential in evaluation of soil expandability.

Remote sensing has been used as one of the most convenient methods to identify spectroscopic properties in domestic mine areas because it has an advantage of identification of alteration minerals and rocks easily and quickly based on spectroscopy, though it has limitations to characterize mineral classification (Chi and Lee, 2007; Son et al., 2011; Lee et al., 2011).

Here, we used spectrophotometer that is relatively cheap and commonly used in many research institutes in Korea to measure clay minerals in soil samples taken from areas where landslides took place, and analyzed the applicable possibility to ASTER satellite images.

2. Experimental Methods

2.1 Mineral analysis and Spectrophotometer

We analyzed size distribution and mineralogy of soil taken from landslide areas, together with XRD and XRF analyses. After drying soil samples, randomly oriented samples for XRD were prepared using averaged samples with 0.075 mm sieving. XRD analysis, using Rigaku (made in Japan) Ultima IV, was performed with CuKα radiation at 60 rpm of the XRD sample holder in order to improve the reproducibility and to minimize the error of probe distribution which allows the diffraction intensity with respect to sample orientation to be homogeneous. XRF analysis, using Rigaku ZSX Primus Ⅱ, was carried out on samples with irradiation at 20 mm in diameter, Rh target, 50 kV and 50 mA for 20 minutes. As a spectrometer, GER-3700 spectroradiometer that can measure a range of 323～2,526 nm was used for soil analysis in the field, with consideration of sample preparation, methods and conditions to obtain an objective and qualified spectroscopic reflectance.

2.2 ASTER Imagery Data

ASTER, one of the NASA satellite systems, was launched in 1999 for the purpose of obtaining multi-spectroscopic satellite data. ASTER satellite images provide a total of 15 bands information including VNIR, SWIR, and TIR: each has 15 m, 30 m, 90 m volumetric resolution, respectively (Fujisada, 1995). The scanning area of ASTER imagery covers 60 km × 60 km, commonly used for investigation of mineral resources on a large scale. Especially, SWIR(Shot Wave Infra Red) of the 1.6～2.43 μm region has 6 bands segmented, so it has the merit to extract mineral resources and to differentiate absorption bands of clay minerals.

This study aimed at analyzing landslide using information band, based on spectroscopic properties of clay minerals related to the spectroscopic properties of ASTER imagery.

3. Results and Discussion

3.1 Mineralogy and Chemical Analysis of Soil

Based on XRD quantitative analysis of soils from landslide areas, all areas (18 sites) show abundant clay content exceeding 50 %, all of which are composed of kaolinite and illite. YI 07, YI 08, and YI 13 areas contain illite content higher than 60 %. When kaolinite content is included in the total clay content, their contents are higher than 70 %. Especially YI 13 sample contains 67 % illite and includes 77.3 % clay content when considering kaolinite(Figure 1).

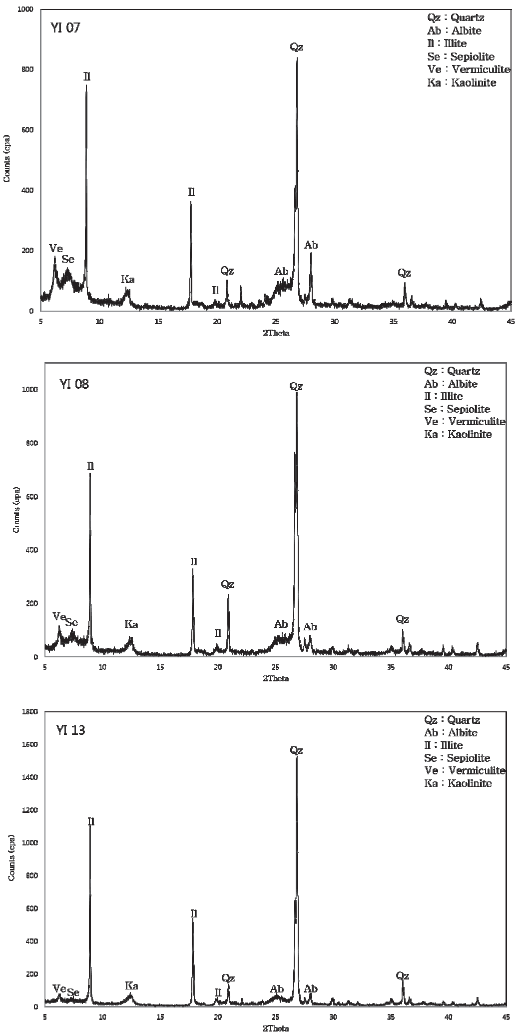

Fig. 1 XRD anslysis of samples YI 07, 08, and 13 collected from the landslide sites

The spectroscopic reflectance of illite, one of clay minerals in soils from the landslide shows absorption of Fe^{2+} and Fe^{3+}occurring at 0.9 and 1.0 μm wavelength, with strong absorption due to OH and H_2O at 1.4 and 1.9 μm wavelength. In addition, there are absorption related to Al-hydroxyl at 2.2, 2.3 and 2.4 μm wavelength(Figure 2).

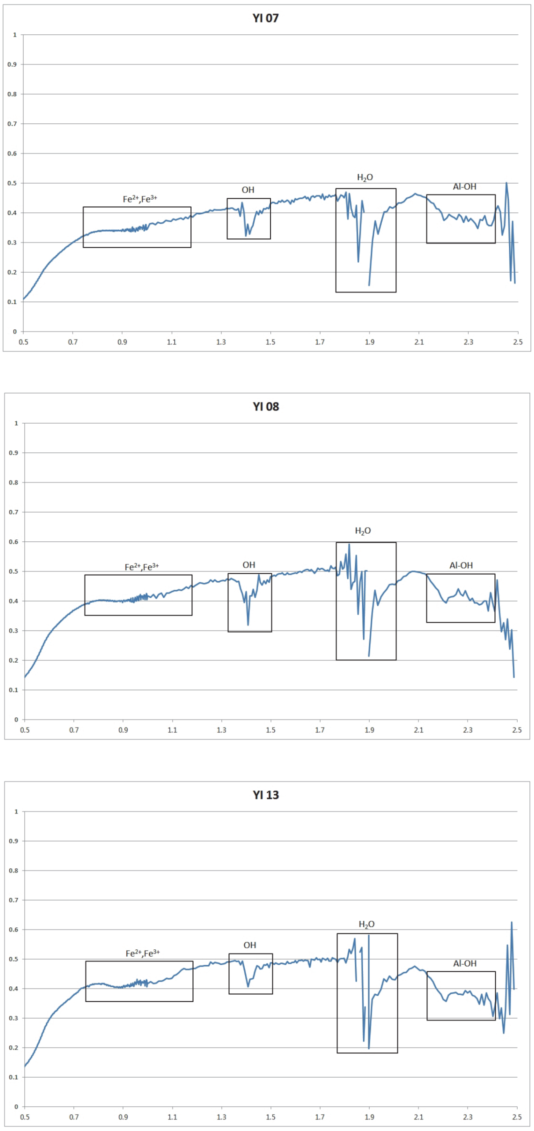

Fig. 2 Reflectance spectra of YI 07, 08, and 13 soil sampled from the landslide locations

3.2 ASTER applicability

After applying $SWIR_{Illite}$ model using ASTER images taken in 17, April, 2004, the images were synthesized using R/G/B(band 6/band 7/$SWIR_{Illite}$) (Figure 3). Areas with blue series and bluish green series correspond to the areas enriched in illite content. According to comparison of areas where landslides took place in July, 2011 and ASTER images applied to $SWIR_{Illite}$ model, it is apparent that most landslides took place on the illite-rich areas on valley, except for areas with slope angles of below 10°, higher than 40°, wide contour areas, alluvium areas expressed in yellow, and highlands where blue series is wide and dense. Therefore we believe that spectral sensing using ASTER imagery has potential for protecting and preventing landslide. In addition, it is expected that more reliable database will be established if intensive comparison and comprehensive examination are verified using the illite content in soils from areas where no landslide takes place, with application of $SWIR_{Illite}$ model.

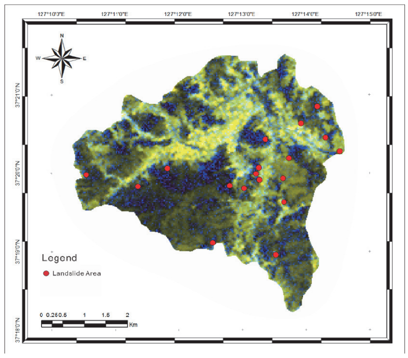

Fig. 3 False color composite image on a topographic map using band 6, band 7, and $SWIR_{Illite}$

4. Conclusions

In this study, we confirm the application of ASTER imagery, multi-spectroscopic satellite images taken in April, 2004, to the landslides around Cheoin-gu, Yongin city, Gyeonggi Province.

The spectroscopic reflectance of illite, one of clay minerals in soils from the landslide shows absorption of Fe2+ and Fe3+occurring at 0.9 and 1.0 μm wavelength, with strong absorption due to OH and H2O at 1.4 and 1.9 μm wavelength. In addition, there are absorption related to Al-hydroxyl at 2.2, 2.3 and 2.4 μm wavelength. It is evident that different absorption and reflectance properties are clearly observed depending on specific soil compositions.

ASTER spectroradiometic results similarly correspond to the distribution properties of expandable minerals which were obtained from field investigation and mineral analyses. It is expected that more reliable database will be established if GIS spatial analysis and statistical analyses are combined using the clay content in soils from areas where no landslide takes place, with application of ASTER satellite imagery.

Acknowledgements

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