Soil Water Content Variation Regression Analysis Using Hyperspectral Camera in Weathered Granite Soils

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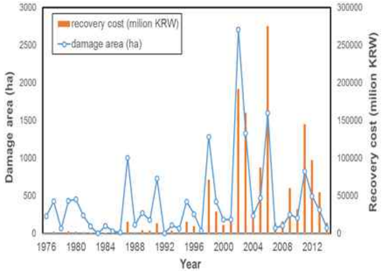
Background and Aims

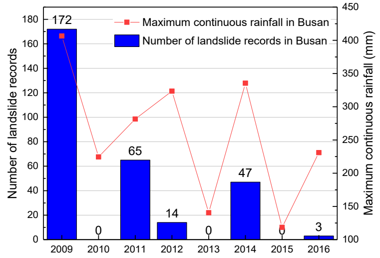
Damages caused by landslides or debris-flows during the rainy season in Korea have become more prevalent and severe since the beginning of the global climate change, which gave rise to the growth in the magnitude and frequency of extreme precipitation events (Fig. (A)).

Soil water content is one of the most common physical parameters that can trigger landslides or debris-flows. Accordingly, it is of much importance to determine or predict the water content quickly and non-destructively (Fig. (B)).

In this study, a simple method to estimate the soil water content variation in a wide area was proposed using hyperspectral near-infrared images. The reflectance data of granite soils were measured by reflecting the soil samples with different wavelengths in the visible and near-infrared (VNIR) regions using hyperspectral cameras.The measured reflectance and parameters were used to build a water content prediction model using the Partial Least Square Regression(PLSR) analysis. In the water content prediction model, the Area of Reflectance(Near-infrared, NIR) parameter was the most suitable parameter to determine the water content. The results demonstrate that the hyperspectral camera combined with the PLSR model can be a useful and non-destructive tool for the determination of soil water contents in the weathered granite soils which can be encountered in the landslide susceptible areas.

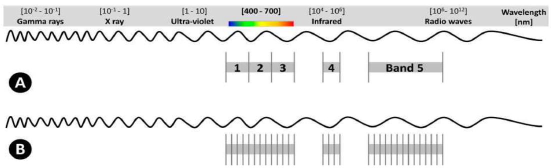


(A)

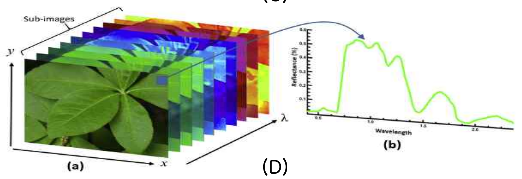


(B)

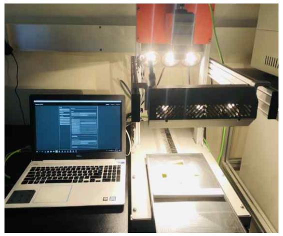
Methodology



(C)



(D)



Spectral Range	400 – 1000 nm
Spectral Bands	224
Spectral FWHM	5.5 nm
Spatial Sampling	1024 px
Frame Rate	330 FPS full frame 9900 with 1 band selected
FOV	38˚
F-number	F/1.7
Camera SNR (Peak)	600:1
Camera Interface	GigE Vision or CameraLink
Dimensions	150 x 85 x 71 mm
Weight	1.26 kg

(E)

- What is spectroscopy

Spectroscopy is the study of the interaction between matter and electromagnetic radiation. The spectroscopy, primarily in the electromagnetic spectrum, is a fundamental exploratory tool in the fields of physics and chemistry, allowing the composition, physical structure, and electronic structure of matter to be investigated at atomic and molecular scales.

- Difference between multispectral and hyperspectral

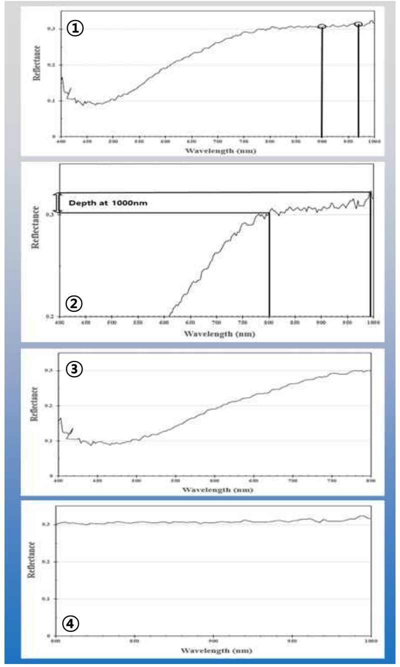
The main difference between them is the number of bands and their width. The multispectral imagery generally ranges from 5 to 12 bands that are represented in pixels and each band is acquired using a remote sensing radiometer. The hyperspectral imagery consists of a much higher band number, which can range from: hundreds to thousands, arranged in a narrower bandwidth (5-20 nm, each) (Fig. (C)).

- Principle of hyperspectral camera

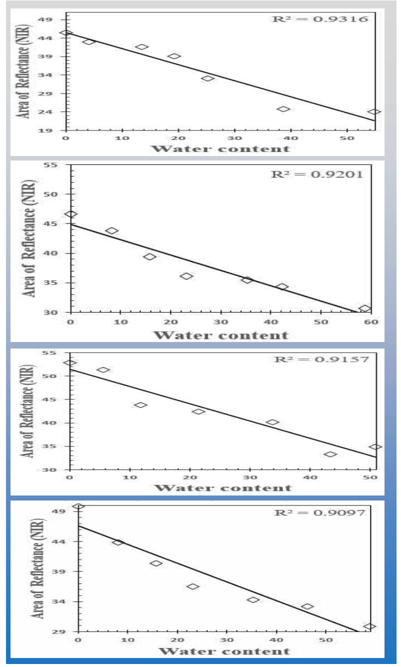
Hyperspectral camera is a relatively new technology that involves the integration of two acquisition modes: spectroscopy and imaging. It simultaneously measures spectral signatures and spatial information from a test material within the sensor field of view. Spectral information is collected at each point and mapped onto every pixel in a rectangular spatial arrangement (Fig. (D-a)). Each pixel of the image will thus contain a NIR or visible spectrum. This technology uses one dimension of a 2D sensor for measuring a line of the sample. Dedicated optics into the system separate the wavelength over the other dimension of the sample. In order to measure the whole product, the sample needs to move in order to acquire another line below the previous one. The full data obtained is called a Hypercube, which will contain the complete image with a spectrum for each pixel (Fig. (D-b)).

Regression analysis

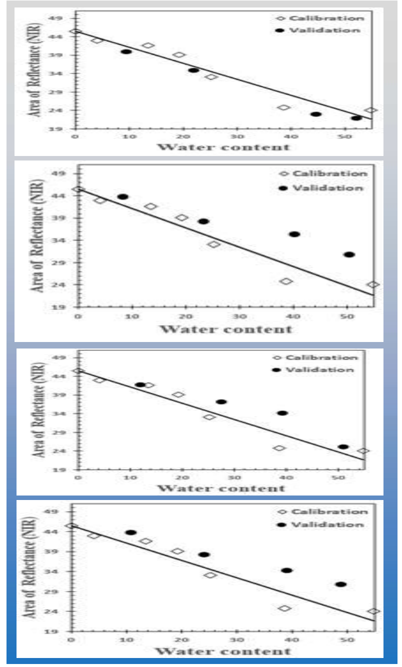
(F)



(G)



(H)



The samples used in this study are granite weathered soil samples collected from four areas of Mt Umyeon, Mt Guryong, Mt. Daemo, and Mt. Hwangryeong. First, sieve analysis was performed using soil that passed through No. 40. In addition, the soil was completely dried at 110 degrees for 24 hours in a dryer. Then, water was added in steps to measure the water content in 11 steps, and a total of 44 water content values were obtained. The 32 water content values were used to develop a water content prediction model, and the remaining 12 water content values were used for validation. In all soil samples, the reflectance tended to decrease as the water content increased.

- Fig. (F) shows the parameters related to the soil water content in the visible and near-infrared regions(VNIR). Fig. (F-①) is the water index divided by the reflectance of 970nm and the reflectance of 900nm. Fig. (F-②) represents the depth of the VNIR, 800nm to 1000nm. Fig. (F-③) is the area of reflectance in the visible ray, and Fig. (F-④) is the area of the reflectance in the near-infrared. Partial Least Square Regression (PLSR) analysis was performed by setting each parameter and water content as variables.
- Fig. (G) illustrates the relationship between the soil water content and the Area of Reflectance (Near-infrared, NIR) parameter of each Mt Umyeon, Mt Guryong, Mt. Daemo, and Mt. Hwangryeong. In the water content prediction model, the Area of Reflectance (Near-infrared, NIR) parameter was the most suitable parameter to determine the water content. The parameter was applicable regardless of the soil types, as the coefficient of determination (R2) exceeded 0.9 for each soil sample.
- Fig. (H) presents the mean absolute percentage error (MAPE) results for four granite weathered soils. Data of 32 water contents from four samples were used for calibration to develop a water content prediction model, and 12 water contents were used for validation. The MAPE of weathered Mt Umyeon soil is 6.2%, the Mt Guryong soil has 14%, the Mt. Daemo soil has a MAPE of 9.2%, and the Mt. Hwangryeong soil has 13.3% of MAPE. Therefore, as a result of regression analysis, it was found that the developed water content variation prediction model is a relatively accurate prediction.

Conclusions and future work

- This paper presents the relationship between soil water content and spectroscopic characteristics (reflectance).
- Samples used were of four weathered granite soils (Mt Umyeon, Mt Guryong, Mt. Daemo, and Mt. Hwangryeong).
- Regression analysis showed that the area of the reflectance (NIR) soils is the most relevant parameter with soil water content, the parameter was applicable regardless of the soil types, as the coefficient of determination (R^2) exceeded 0.9 for each soil sample.
- The mean absolute percentage error (MAPE) was less than 15% when compared with the actual water content of the soil. Therefore it was found that the developed prediction model of water content variation is a relatively accurate prediction.
- For further development, a model that incorporates soil classification would be required to improve the accuracy of the model and to predict a higher range of water contents.

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