Analysis of Spectral Characteristics of Riverbed Material using Hyperspectral Image

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ABSTRACT : *The domestic river environment is more uncertain to predict physical, chemical, and biological changes due to not only climate change but also river maintenance such as four-river project. However, the research and evaluation of the river environment is still scant, so the research technology of advanced countries is only used as it is. Thus, suitable the development of research and evaluation technologies for the domestic river environment is urgent. Recently, advanced technology of river environment survey have pushed beyond the limits of existing point measurement methods, and demand for the development of the river space survey technology is also increasing. In particular, the survey of river environment using hyper spectral image can obtain detailed data on a wide area over a short period of time, and it has the advantage of minimizing the possible risk of field measurements. This study analyzed the estimation of the riverbed material and correlation between the spectral using hyper spectral image by distributing the riverbed material within the experimental channel. Through this study, the field application of river environment management technology using hyper spectral sensors can be assessed. In addition, it is expected that investigation of the river environment will be possible quantitatively by developing algorithms for estimating riverbed materials, water levels and vegetation distribution based on spectral.*

KEYWORDS - *Remote sensing, Hyper spectral image, River environment, Riverbed material, Hydraulic experiment*

I. INTRODUCTION

Remote sensing is a method of acquiring information by collecting and analyzing electromagnetic waves reflected from the target without direct contact with the object by using sensors mounted on platforms such as satellites or unmanned aerial vehicles. Remote sensing data can be classified into two categories. The first category is passive remote sensing systems which collect electromagnetic radiation that is reflected or emitted from the surface, such as aerial photographs and satellite images. The second category is active remote sensing systems which emit electromagnetic waves toward the surface and collect radio waves that are backscattered and returned toward the sensor system, such as microwaves and sonar. Passive remote sensing is an economical method that can be used to obtain information on a wide area with uniform accuracy by acquiring images that are generally visible. Active remote sensing overcomes the limitations of passive remote sensing, which is highly influenced by sunlight and weather, in order to acquire data in cloudy or rainy weather. In addition, active remote sensing can obtain much more information than passive remote sensing due to the use of invisible infrared rays and microwaves [1].

Until now, the development of optical image sensors has been driven mainly towards improving spatial resolution and radiation resolution. Compared to the early multispectral sensors mounted on Landsat and NOAA satellites and commercial high-resolution multispectral sensors that improved spatial resolution up to about 1 m, the technology progress of image sensors in terms of spectral resolution is relatively marginal. Multispectral images are mainly the results of detecting radiant energy reflected or emitted from the surface of less than 10 limited wavelength sections. However, there are limits to expressing the complete spectral characteristics of various types of objects such as those of vegetation, geological features, rocks, and water. The complete spectral information of the target is required to extract more accurate information related to the physical and chemical properties of the object. This consideration has led to the development of hyperspectral image technologies [2].

Unlike ordinary cameras, hyperspectral sensor images are obtained by subdividing the visible ray area (400 nm~700 nm) and the near infrared ray area (700 nm~1000 nm) into hundreds of wavelengths, in order to detect a much more diverse spectrum of light than what is capable of the eyes of the general public [3, 4]. In addition, the spectral information unique to the target can be extracted because each pixel has specific intensity value information for ultraviolet, visible light, and infrared wavelengths. In this regard, the method overcomes the limitations of conventional RGB image analysis technologies to identify and quantify more information within the image.

Recently, research that has applied hyperspectral image processing technologies has been attempted in various fields. Park et al. [5] performed land coverage classification using aerial hyper spectral image, and Seo[6] evaluated and analyzed the sub-classification of the land coverage map provided by the Ministry of Environment using aerial hyperspectral image. In addition, Cho et al. [7] compared and analyzed the suitability and classification accuracy of hyperspectral image and multispectral images for the classification of forest tree species and presented that classification using hyperspectral image is favorable in areas with diverse objects with similar spectral characteristics.

In the field of river environment management, the rise of advanced river environment survey methods, such as hyperspectral image, significantly improved limitations that required much manpower, time, and cost to investigate river environments, in addition to enabling the survey of dangerous areas that cannot be measured by humans. However, there is lack of research on spatial classification for river management as most of the research is focused on evaluating water quality or the growth of specific vegetation [8, 9]. The demand for forecasting and managing changes in physics, chemistry, and biology is increasing due to large-scale river improvement projects, such as the previous four-river project. Moreover, considering the rapid development of drones and satellite technologies, the technology to survey river environments using images is expected to develop further in the future. In particular, drones are capable of acquiring high-resolution data in a shorter period of time at relatively low altitudes compared to satellites and manned aircraft [10]. In addition, we can now acquire images with higher spectral resolutions and analyze river environmental factors using drone-based hyperspectral image due to the development of lightweight micro hyperspectral sensors that can be installed on drones. However, there is a lack of research on extracting underwater spectral information in rivers [11].

The purpose of this study is to develop a technology that can estimate underwater information in rivers, such as the water level, riverbed materials, and the types and distribution of vegetation, by using hyperspectral information, and to evaluate the feasibility of applying hyperspectral sensor images in the field by performing hydraulic experiments according to the water and river bed conditions.

II. LOCATION AND APPARATUS OF EXPERIMENT

2.1 LOCATION

The experiment was performed at an outdoor channel located in the River Experiment Center of the Korea Institute of Civil Engineering and Building Technology in Andong city, South Korea where it is easy to control the flow rate and maintain a constant water level. The total extension, width, and height of the water channel are 50 m, 2 m, and 1.4 m, respectively, and the maximum flow rate is 0.5 m^3/s as shown in Fig. 1.

Figure 1. View of REC and experiment site

2.2APPARATUSES

The images were taken by installing Nano-Hyperspec, an ultra-compact hyper spectral sensor, developed by Headwall (US) on an Aibot X6 drone (Aibotix)as shown in Fig 2. This study divided 3 cases according to the water level and used ENVI software (ENVI 5.3, Exelis Visual Information) to analyze the wavelength and data value of the images.

Figure 2. Hyperspectral sensor and test flight

III. RESULTS AND CONSIDERATION

Fig. 3 shows hyperspectral images and Table 1 shows the maximum data value and the corresponding wavelength of visible ray (400 nm-780 nm) and near infrared ray area (780 nm1000 nm) for each case. Case 1 (water level 0.0 m) showed the highest data value and the data value decreased as the water level increased due to the effect of water. In the case of soil, gravel, and cobble, the wavelength that showed the maximum data value for each case was 584 nm-606 nm, which is in the visible ray area, and reed showed the maximum data value in the range of 646 nm-678 nm. Vegetation exhibited the maximum data value at near infrared ray (780 nm).

Fig. 4 is a graph that shows the change in data values by water level. When the water level increased by 0.6 m, the material data values were decreased as follows: soil decreased by 26.49%, gravel by 29.75%, cobble by 20.28%, reed by 21.59%, and

Table 1. Relationships between value and wavelength

vegetation by 38.01%. However, in the case of vegetation, the rate of decrease was lower than that of other materials, and in terms of near infrared ray, we observed areas where the data value increased as the water level increased.

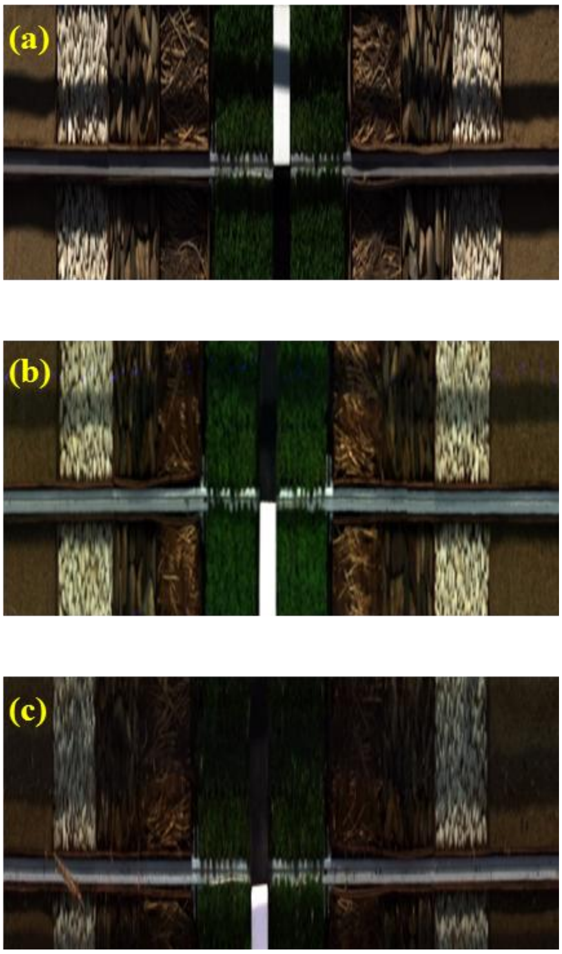
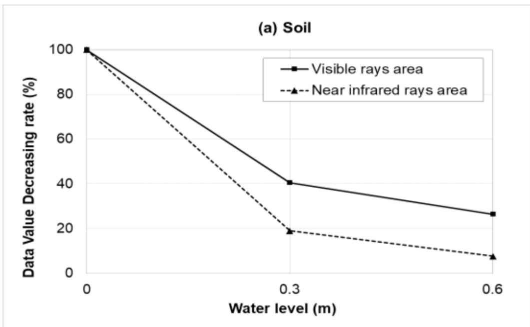


Figure 3. Hyperspectral images (a) case 1 (b) case 2 (c) case 3



Case	Area	Materials for experiment									
		Soil		Gravel		Cobble		Reed		Vegetation	
		Data Value	Wave length	Data Value	Wave length	Data Value	Wave length	Data Value	Wave length	Data Value	Wave length
1	Visible ray	1008	606	1778	606	784	606	718	678	413	557
	Near infrared ray	651	780	1000	780	467	780	499	780	1014	780
2	Visible ray	408	584	935	584	264	584	387	678	351	713
	Near infrared ray	124	784	189	785	87	785	166	785	232	784
3	Visible ray	267	584	529	584	159	584	155	646	157	557
	Near infrared ray	50	805	62	807	46	783	53	805	59	805

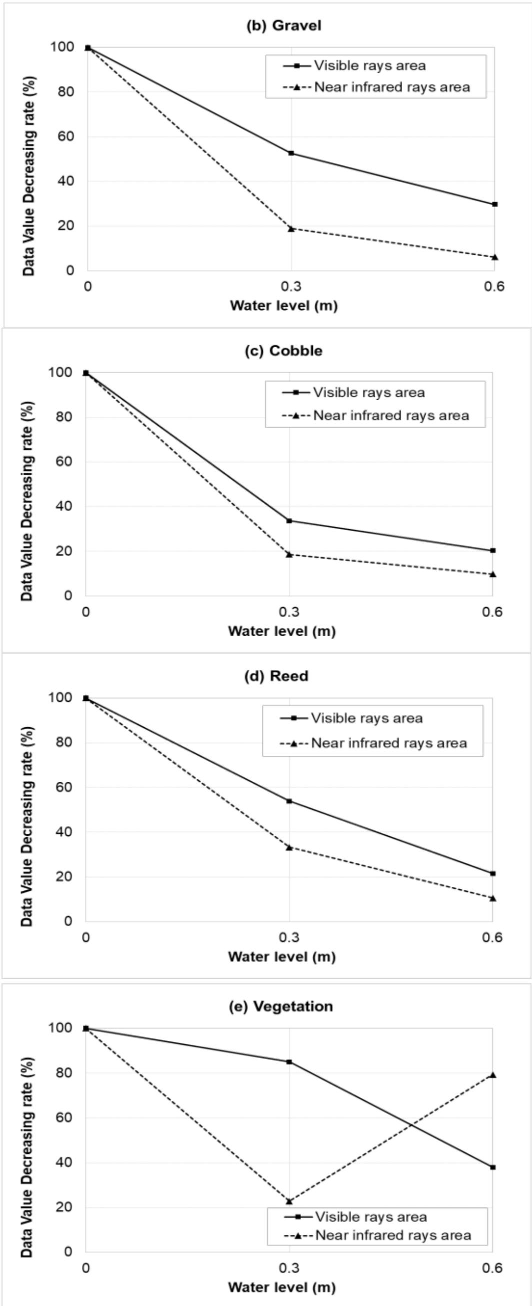


Figure 4. Comparisons of data value decreasing rate on case (a) soil (b) gravel (c) cobble (d) reed (e) vegetation

IV. CONCLUSION

The purpose of this study was to perform hyperspectral image analysis on riverbed materials in order to analyze the maximum data value and the maximum data value reduction rate according to the water level for visible and near infrared rays. Therefore, we fabricated an experimental water tank using soil, gravel, cobble, reed, and vegetation and obtained images by installing hyperspectral sensors on a drone. This study used the ENVI program to analyze the wavelength and data value of each material.

As a result of analyzing the images, there was a difference in maximum data value depending on the material, and the data value decreased as the water level increased. In particular, the maximum data value of vegetation was observed in the near infrared ray and the data value reduction rate according to the water level was also low. This can be used as a basis for hyperspectral image analysis of vegetation areas and we may even be able to analyze the water depth and materials in rivers using hyperspectral image. In addition, we can evaluate the feasibility of applying river environment management technologies using drones and hyperspectral sensors, and expect to quantitatively investigate river environments by developing algorithms for estimating riverbed materials, water levels, and vegetation distribution based on spectral information in the future.

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