Ground-based camera system for monitoring herbage biomass in Italian ryegrass field

Fan Xinyan1, Kensuke Kawamura1,2, Jihyun Lim1, Rena Yoshitoshi1, Norio Yuba1,3, Hyo-Jin Lee4 and Yuzo Kurokawa2,4

Introduction

Background

- Italian ryegrass is one of the most important and widely used winter forage crop (approx. 61,000 ha) in Japan.
- Monitoring seasonal changes of herbage biomass (BM) and nutrient status of forage crop is important for practical fertilizer management and yield prediction.

Purpose

- Develop a simple and cost-effective sensing system using V-NIR camera as a ground-based remote sensing device.
- Investigate seasonal changes of herbage BM in an Italian ryegrass field with the time-series image data.

Materials & Methods

Study site and field measurements

Location

Setouchi Field Science Center, Hiroshima University (34º 23' N, 132º 43' E)
- Annual mean temperature: 13.6 ºC
- Annual precipitation: 1453.5 mm

Field measurements

- eight times measurements in Jan–May, 2013 (Number of sample: n = 114)
- Aboveground biomass (BM, g m⁻²)
- Surface sward height (SSH, cm)

V-NIR camera system

- Exposures: 10:30, 12:00 and 13:30 in a day.
- Sensor: Red (R), green (G), blue (B) and NIR (2592 × 1944 pixels [8-bit], JPEG)
- Spatial resolution: 0.625 mm
- Experimental design: 2.5 m nadir view; 1.6 m × 1.2 m footprint
- Cost: approximately 80,000 JPY

Image processing and statistical analysis

Time-series image processing

- Extract digital number (DN) from daily image (12:00)
- Average DN value within region of interest (ROI)
- Calculate color intensity by normalized algorithm
- Software: Matlab version 7.14 (Mathworks Inc., Sherborn, MA, USA)

Regression analysis to estimate BM

- Polynomial regression: Ratio color index (RCI) and Normalized difference color index (NDCI)
- Predictive accuracy: Coefficients of determination (R²) and Root-mean-squared error (RMSE)

Smoothing and quick growth stage detection

- Smoothing: HANTS (Harmonic ANalysis of Time Series) algorithm based on Fourier analysis (Verhoef 1996)
- Quick growth stage (QGS): The peaks of second derivative values of BM seasonal change identify the start and end of QGS.

Results

Regression model for BM estimation

- Polynomial regression based on (a) RCI (RCI(G,NIR)) and (b) NDCI (NDCI(G,NIR)) using G and NIR channels.

Seasonal changes of 4 color channels and BM

- The NDCI using G and NIR channels showed the best predictive accuracy to estimate BM (Figure 1). Using the model, seasonal changes of BM and its quick growth stage could be calculated (Figure 3). We expected that these information include useful insights for farmer to determine appropriate timing of fertilizer application and cutting.

Acknowledgements

We are grateful to all the staff of the Setouchi Field Science Center, Saijo Station, Hiroshima University, for their assistance in field experiments. This work was partially supported by the Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Young Scientists (B) (No. 23760286).