Precision farming is defined as a management strategy of using information technology to gather site-specific data from multiple sources and it should be applied not only in upland crop production but also in forage production. For the monitoring and mapping of pasture, satellite imagery has been widely used to evaluate pasture condition to monitor long term changes in large area. However, it has some limitations like limited operational flexibility and fixed spatial and spectral resolution. Ground-based spectral measurement tends to be operator-dependent and labor intensive, nevertheless it is easier to apply the appropriate sampling strategy. The objective of this study is to demonstrate potential of various remote sensing tools for estimation and mapping of pasture green biomass (GBM) and quality in fine scale pasture. For estimation and mapping of pasture parameter, the potential of two kinds of ground-based spectral measurements (hyperspectral measurement and multispectral measurement) and ALOS/AVNIR-2 satellite image were demonstrated.

Legume content in grass-legume mixtures is a key parameter for deciding the forage quality and the amount of fertilizer application to the pasture due to nitrogen (N) fixation. To estimate legume content in a grass-white clover (WC) mixed pasture, we searched for robust hyperspectral wavebands from in situ canopy reflectance spectra over the 400–2350 nm range comparing a phased regression with a bootstrap procedure (PHR-BS) and forward stepwise multiple linear regression (FS-MLR). Canopy reflectance data and plant samples were obtained from 50 selected sites during two seasons (n = 100); spring (May) and summer (July) 2007. Although selected wavebands were similar in the PHR-BS and FS-MLR, PHR-BS gave a higher predictive accuracy (44–74%) than FS-MLR (35–73%). Selected wavebands in the final models were blue (400–456 nm) and red bands (659–670 nm) in visible wavelength, red-edge region (704–724 nm), near infrared regions (813, 937, and 1121 nm), and shortwave infrared regions (2303–2344 nm) that are mainly linked to known biochemical components such as chlorophyll, N, lignin and cellulose. These results suggest that legume content in grass-legume mixtures can be predicted by in situ canopy reflectance, and that the predictive ability of the model can be improved by wavelength selection using the PHR-BS method.
It is now accepted that partial least squares (PLS) regression with waveband selection might improve their predictive accuracy in multivariate calibration of models to describe pasture mass and quality. Recently, genetic algorithm (GA) has been shown to be a suitable method for selecting wavebands in the laboratory calibrations. This study aimed to investigate the performance of genetic algorithms PLS (GA-PLS) regression analyses for estimating GBM, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and crude protein (CP) concentrations of herbage and herbage mass in CP (CPm) from field hyperspectral data at canopy scale. The predictive ability of GA-PLS was compared with that of iterative stepwise elimination PLS (ISE-PLS) and standard full-spectrum PLS (FS-PLS), using first derivative reflectance (FDR) spectra data. Canopy reflectance measurements and plant sampling were obtained from 50 selected sites in each of two seasons; spring (May) and summer (July) 2007. For all parameters, cross-validated coefficients of determination ($R^2$) increased and root mean square error values decreased, respectively, with GA wavebands selection. The number of wavebands selected in GA-PLS model ranged between 63 (4.0% of all 1,563 available wavebands) and 167 (10.7%), suggesting that over 89% of wavebands were redundant. Between ISE-PLS and GA-PLS models, higher $R^2$ values and lower root mean squared errors of prediction were obtained from GA-PLS prediction for all parameters except CP concentration. Particularly, GA based waveband selection greatly improved ADF ($R^2 = 0.68–0.77$) and ADL ($R^2 = 0.47–0.59$) predictions. These results suggest that pasture quality and GBM can be predicted from field hyperspectral measurements using a GA-PLS model, and that the GA-PLS has the advantage of tuning the optimum bands for PLS regression, giving better predictive ability.

The potential of ground based hyperspectral measurements was demonstrated to estimate GBM and CP concentrations of a mixed-sown pasture for site-specific grazing management. The mixed-sown pasture consisted of a relatively flat section renovated by over-seeding a grass (Subunit 1, 2.6 ha) and a hilly aged section (Subunit 2, 5.0 ha). Hyperspectral reflectance and plant data were collected for 22 days in August 2009 from 88 plots within the two subunits. For mapping, separate spectral readings, without plant sampling, were obtained from a total of 347 plots along permanent transects in the pasture. Genetic algorithm-based wavebands selection with partial least squares (GA-PLS) regression analyses was performed to predict GBM and CP concentrations using both reflectance and first derivative reflectance (FDR) data sets. Then, geostatistical analysis with semivariograms was conducted to determine sampling interval of GBM and CP concentration in Subunits 1 and 2. In the GA-PLS analysis, the most accurate results were obtained by calibration of GBM using FDR (cross-validated coefficient of determination, $R^2_{cv} = 0.55$; cross-validated root mean square error, RMSECV = 42) and of the CP concentration using raw reflectance ($R^2_{cv} = 0.42$, RMSECV = 2.02). Geostatistical analysis with semivariograms showed that, at the landscape scale, the GBM patch sizes in Subunits 1 and 2 were 31 and 67 m, respectively, and those of the CP concentration were 37 and 54 m. These values indicate that the spatial distribution patterns of these pasture parameters were more heterogeneous in Subunit 1 than in Subunit 2. The analysis result also indicates that the sampling interval for GBM and CP concentration should be less than 15 m. This work shows the ability to estimate the spatial distribution of GBM and CP concentration for the implementation of site-specific grazing management.

The potential of a hand-held crop measuring device measurement was demonstrated to
identify the effect of cutting on spatial and temporal variations of GBM and CPm in a mixed-sown pasture (5.0 ha). For GBM and CPm estimation, normalized deferent vegetation index (NDVI) was measured with vegetation sampling at 50 plots. For the mapping purpose, NDVI of a total of 347 plots along permanent transects in the pasture were measured two times before cutting and two times after cutting. Applying regression analysis, the NDVI was moderately correlated with GBM ($R^2 = 0.53$) and highly correlated with CPm ($R^2 = 0.71$) over the sampling dates from June to August 2010. Geostatistical analysis with semivariograms showed that patch size of GBM was about 38 m in late June and 37 m in early July, whereas that of the CPm was about 37 m and 41 m before cutting. After cutting, patch size of GBM and CPm were dramatically increased in early August (GBM, 448 m; CP content, 729 m) and decreased in late August (GBM, 92 m; CP content, 85 m), which means that the spatial distribution patterns of GBM and CPm became strongly homogeneous after cutting. Geostatistical analysis also indicates that the sampling interval for GBM and CP content should be less than 19 m before cutting and should be less than 41 m after cutting.

The potential of ALOS/AVNIR-2 images for herbage green biomass (GBM) estimation was investigated in a mixed-sown pasture (7.6 ha). For GBM estimation, field measurements were conducted from a total of 347 plots along permanent transects with 10 m interval on 28-30 June and 23-25 August, 2010. To determine the relationship between AVNIR-2 images and ground-measured GBM, regression analysis using vegetation indices (including normalized difference vegetation index (NDVI), green normalized difference vegetation index (NDVIgreen) and soil adjusted vegetation index (SAVI)) and multiple linear regression (MLR) analysis were conducted. After regression analysis, MLR model ($R^2 = 0.45$) was more precise than vegetation indices (NDVI, $R^2 = 0.27$; NDVIgreen, $R^2 = 0.28$; SAVI, $R^2 = 0.25$) and MLR model showed practical accuracy (evaluation index value = 26.3%). Generated spatial distribution map of GBM using MLR model from AVNIR-2 images showed that average of GBM was increased from June to July (June, 241.1 g DM m$^{-2}$; July, 257.4 g DM m$^{-2}$) and gradually decreased from July to September (August, 245.5 g DM m$^{-2}$; September, 235.2 g DM m$^{-2}$).