Introduction

Dead biomass is an important component of the landscape in the grassland biome. It is defined as the quantity per unit area of non-living (dead or decomposing) plant material. Accurate estimates of dead biomass are required for a broad range of applications including carbon cycling and radiative transfer models, the management of soils, wild fire risk assessment, evaluating the effects of grazing, and for accurate landcover classifications. This study evaluates the use of spectral bands and vegetation indices in conjunction with regression models to map dead biomass in an area of upland grassland in Grasslands National Park, Saskatchewan. The use of Landsat imagery in mapping larger areas is also demonstrated.

Objectives

1) Determine the spatial resolution at which variations in the percentage of dead biomass are detectable.
2) Evaluate the suitability of various bands and broadband vegetation indices to estimate the proportion of dead biomass; generate regression models using in situ measurements and the suitable vegetation indices and bands;
3) Generate and validate a map of percentage dead biomass using the regression model and additional sampling data; and
4) Demonstrate the potential use of Landsat ETM+ imagery for creating maps of dead biomass using the derived regression models.

Methods

Unbalanced nested sampling scheme

An unbalanced nested sampling scheme was constructed as per Webster et al. (2006) with n=32 sampling locations (see Figure 1). At each location, spectral refection in the Landsat bands 1-5 were taken using a ground radiometer mounted 1.5m above the ground, and a 50x50cm vegetation plot was clipped, sorted, dried and weighed. Various vegetation indices (NDVI, MSI, GMVI, NDII, SAVI, SPI, NDI and NLII) were calculated using the raw spectral data, and the proportion of dead to total biomass was computed.

Variance analysis

A variogram analysis (Figure 2) was computed using the R statistical package. The variogram was used to determine the optimal sampling interval for additional linear sampling.

Mapping dead biomass at the field scale

Additional radiometer points were collected on linear transects spaced 200m apart at 150m intervals for an area of approximately 135ha. Tension spline interpolation, in conjunction with regression models to map dead biomass in an area of upland grassland in Grasslands National Park, Saskatchewan. The use of Landsat imagery in mapping larger areas is also demonstrated.

Regression models

Ordinary least squares (OLS) regressions were run using the SPSS statistical package. Independent variables were selected on the basis of high correlations with proportion of dead biomass and theoretical appropriateness of use. Regression models were validated using the "jack-knife" method, also known as leave-one-out cross validation (see Olden and Jackson, 2000).

Mapping large areas with Landsat imagery

A Landsat 7 ETM+ scene (path 36, row 26) from August 2001 was obtained for the study area (more recent images are not yet freely available). Because of the age of the image and the lack of validation data for that time period, only a demonstration of how to convert the images to maps of percentage dead biomass will be included.

The image was atmospherically corrected with the ATCOR2 model, yielding reflectance values. These reflectance values were used to compute NDII. NDII was then converted to percentage dead biomass using the NDII regression equation. Values were scaled linearly to match the expected range of 0 to 100% dead biomass.

Results

Observable scale of dead biomass

The variogram (Figure 2) indicated lowest variance for sampling intervals of 100 to 200m. This is indicative that dead biomass communities occur at a scale of approximately 150m in upland grasslands, and that the lowest variability between two plots occurs when the plots are separated by that distance. This result partially supports the findings of Zhang et al. (2007).

Suitability of bands and vegetation indices

The highest correlations with proportion of dead biomass occur with the NIR band (R = -0.717, p = 0.01), MSI (R = -0.770, p = 0.01), GMVI and NDII (R = -0.762, p = 0.01) and NLII (R = -0.740, p = 0.01). Vegetation indices were highly correlated with each other (R > 0.9) with the exception of NDCI.

Two nearly equivalent significant models were retained (Table 1). Both models use indices based on the NIR and SWIR bands, the MSI and NDII. The blue band was found to increase adjusted R² values.

Discussion

Both regression models were successful in accounting for approximately 60% of the variance in the proportion of dead biomass. The addition of landscape parameters (gradient, slope, aspect) or canopy parameters (LAI) might improve the models. The models also have high standard errors (around 18.6%) due in part to measurement and instrument errors, and also to the wide range of dead biomass observed.

Jackknife cross-validation provided an assessment of the models’ accuracy (RMSEP) and precision (r). Both models are precise (cross-validated r = 0.786 and 0.772), but have lower accuracies (RMSEP = 18.573% and 19.080%), confirming the indications given by the high standard errors. Overall, both models performed satisfyingly.

The maps show patterns of dead biomass that appear to be linked closely to topography (which influences moisture availability). The areas of high proportion dead biomass correspond to depressions in the landscape where moisture accumulates. Conversely, areas of low proportion dead biomass (especially to the north) are linked to eroded soils and more arid areas. The level of detail obtained with a 150m sampling interval is appropriate for the scale of the area mapped.

Because the distribution of Landsat reflectance values was different than the field distribution, the regression models returned unexpected results. Proportion of dead biomass was expected to range from 0 to 1, but extreme values (including negatives) were observed that did not correspond to expectations.

Conclusions

We have shown that ground-based radiometry can be used in combination with vegetation indices to predict and map the proportion of dead biomass on the landscape. Results indicate that the variability in estimates of dead biomass is minimized when using a sampling interval of approximately 150m.

Two regression models were produced and validated with the jackknife cross-validation method. Two shortwave vegetation indices, MSI and NDII, were found to make the best predictors of dead biomass.

Maps were generated using tension spline interpolation, and appear to show relationships with landscape characteristics such as elevation. The method worked well at the field level, but satellite imagery should be used as demonstrated if larger areas are to be mapped.

References


Acknowledgements

This project was funded in part by Agriculture and Agri-Food Canada as part of the Government Related Initiative Project (GRIP). We also wish to thank Rob Sissens and Pat Fargen for their assistance.