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THE USE OF AIRBORNE IMAGING SPECTROMETER DATA TO DETERMINE EXPERIMENTALLY INDUCED VARIATION IN CONIFEROUS CANOPY CHEMISTRY

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ABSTRACT

A study is underway to determine whether experimentally induced differences in forest canopy chemical composition can be detected using data from the Airborne Imaging Spectrometer (AIS). Treatments have been applied to an even-aged forest of Douglas-fir trees near Mt. Taylor, New Mexico.

Work to date has stressed wet chemical analysis of foliage samples and correction of AIS data. Plot treatments have been successful in providing a range of foliar nitrogen concentrations. Much time was spent investigating and correcting problems with the raw AIS data. Initial problems with groups of drop out lines in the AIS data were traced to the tape recorder and the tape drive. Custom adjustment of the tape drive led to recovery of most missing lines. Remaining individual drop out lines were replaced using averages of adjacent lines. Application of a notch filter to the Fourier transform of the image in each band satisfactorily removed vertical striping. The aspect ratio was corrected by resampling the image in the line direction using nearest neighbor interpolation. Future work will include examination of first and second difference AIS spectra from study plots at bands known to contain information about a given foliar constituent and exploration of multiple stepwise linear regression techniques for determining spectral bands correlated to foliar chemical composition. Acquisition of AIS or Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) data prior to bud break and during the growing season has been requested for 1987.

INTRODUCTION

Biochemical composition of forest canopies is related to biogeochemical cycling in forest ecosystems. It has been suggested that fertile forest ecosystems which cycle large amounts of elements have greater potential for element losses to the atmospheric and hydrologic systems, while infertile systems with low nutrient turnover have low losses (Matson and Vitousek, submitted). One objective of this research is to correlate foliar biochemical ratios with nitrogen turnover rates and nitrous oxide evolution in forests with varying fertility. A second objective, which is the subject of this paper, is to determine whether experimentally induced differences in forest canopy nutrient and biochemical composition can be detected using data from the Airborne Imaging Spectrometer (AIS).

STUDY SITE

The study site is in a Douglas-fir forest near Mt. Taylor, New Mexico and was established by collaborators in the School of Forest Resources at Northern Arizona State University. Treatments include replicated control, fertilized, irrigated and saw dust-treated 25m x 25m plots. Monthly fresh foliage samples have been collected and are being analyzed for nitrogen, phosphorus, amino acids, lignin, starch, cellulose, and proteins. Preliminary wet chemical analysis indicates that foliage from fertilized plots exhibits markedly higher concentrations of nitrogen than those from other treatments. Ratios of amino acids:total nitrogen and concentrations of starch also differ among treatments and across seasons.

Table 1.0 shows N concentration in mg/g for eight of the study plots. Allometric equations for Douglas-fir at this site are being prepared at Northern Arizona State. These equations should provide reliable estimates of foliage mass. Nitrogen concentration will be multiplied by the foliage mass to obtain the total nitrogen content for each plot. Preliminary calculations done using allometric equations for Douglas-fir in Washington indicate that the nitrogen content of the plots ranges between 100.8 kg/ha and 205 kg/ha.

Table 1.0 Foliar nitrogen concentration of one and two year needles

SITE	TREATMENT	TOTAL N mg/g
C1	CONTROL	8.52
C2	CONTROL	9.09
I1	IRRIGATED	8.62
I2	IRRIGATED	9.52
S1	SAWDUST	10.02
S2	SAWDUST	10.22
N1	NITROGEN	14.08
N2	NITROGEN	14.54

REMOTE SENSING

Data collection

AIS-2 data at spatial resolutions of approximately 7m and 10m were acquired with the NASA C-130 aircraft over the study site on September 18-19, 1986. These data were obtained both in Tree mode with a useable range of 800-1600nm and in Rock mode with a useable range of 1600-2400nm. NS-001 Thematic Mapper simulator data, color infrared and natural color photography were also obtained.

Processing and Corrections

Upon initial inspection of the data large groups of drop-out lines were observed. This problem was reported to the NASA Ames Data Management facility. They had their tape drive adjusted specifically to read the high density tape containing the data of interest and were eventually able to recover most of the groups of lines that had been missing after the initial decommutation. (In a subsequent mission for these investigators at another site, a newer one inch on-board tape recorder was used to record the AIS data and a newer tape drive was used to decommutate the data, eliminating the problem.)

Examination of the newly decommutated data revealed individual drop out lines. Each pixel in these lines was replaced by the average of the corresponding pixels in the two adjacent lines. Vertical striping, striping in the along-track direction, was also observed. It was removed by applying a notch filter to the Fourier transform of the image in each band as described by Hlavka (1986).

Even after the lines were replaced and the image was destriped, it was difficult to locate the study site. The scene appeared blurry. After consultation with the NASA Ames Data Management Facility and the Jet Propulsion

Laboratory it was discovered that the image aspect ratio was incorrect due to "overscanning". The AIS had imaged the same ground area more than once, giving it a blurry appearance. The amount of "overscanning" was calculated using the following equation(1).

$$\text{number of times over-scanned} = \frac{\text{Aircraft altitude in ft.} \times \text{AIS instantaneous field of view in radians}}{\text{Aircraft speed in ft/sec} \times \text{integration time of the AIS sensors in sec.}} \quad (1)$$

The result of this calculation was used to determine the scale to which to resample the image in the line direction using nearest neighbor interpolation. Resampling corrected the aspect ratio and produced a sharp image from which to locate study sites.

FUTURE WORK

Much time was spent investigating and correcting problems with the raw AIS data. Now that the image is in a useable form, study plots will be located in the images and an average DN value will be extracted from a 3 x 3 pixel window in each band for each plot. These values will be used to create a spectrum for each plot. First and second difference transformations (the first order approximation of the first and second derivative) will be performed. These spectra will be examined at bands that the literature and previous studies indicate contain information about a given leaf constituent. Multiple stepwise linear regression techniques as described in Swanberg and Peterson (1987) and Wessman et al. (1987) will be explored as a possible means to identify spectral bands that are correlated to foliar chemical content.

AIS-2 data examined here were acquired in September. Since foliar chemical composition changes throughout the growing season, we have requested acquisition of AIS-2 or Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) data before bud break as well as during the height of the growing season this year. We hope to observe spectral changes related to change in foliar chemical composition.

CONCLUSIONS

We have found that the experimental treatments applied to Douglas-fir forest have successfully changed foliar element content and biochemical concentrations. These treatments have provided a controlled test site with which we can examine AIS capabilities for determining canopy chemistry. Initial problems with AIS-2 data were with missing lines, vertical striping, and the aspect ratio. These problems have been corrected and future work will include examination of first and second difference AIS spectra from study plots at bands known to contain information about a given foliar constituent and exploration of multiple stepwise linear regression techniques for determining spectral bands correlated to foliar chemical composition. Acquisition of AIS or AVIRIS data prior to bud break and during the growing season has been requested for 1987.

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