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Spectral Reflectance of Vegetation in the Idaho Cobalt District--Potential for Exploration Using Remote Sensing

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Abstract

Spectral reflectance measurements were made in the Idaho Cobalt District using a field-portable spectroradiometer. Engelmann spruce and lodgepole pine growing in soils enriched in Co and Cu had higher reflectance between .50 and .65 µm and between .75 and 1.30 µm than the same species growing in background areas. Douglas fir displayed less variation in the visible, but occurred infrequently in mineralized areas, so that the sample size is small. Attempts to detect these differences in Landsat Thematic Mapper data have been unsuccessful to date, probably due to noise from canopy density variations and strong topographic control of tree distribution. High-spectral-resolution data may provide a means for mapping stressed vegetation in this region.

Introduction

Previous geobotanical studies have shown that high metal concentrations in rocks and their associated soils lead to changes in the spectral reflectance of vegetation which can be detected using a variety of remote sensing techniques (Milton and others, 1983; Milton and others, 1985; Collins and others, 1983; Darch and Barber, 1983; Birnie and Francica, 1981). A number of studies (Milton and others, 1983; Collins and others, 1983) have used high-spectral-resolution aircraft data to recognize a shift in the long wavelength edge of the chlorophyll absorption band centered at .68 µm to shorter wavelengths in vegetation growing over porphyry copper mineralization. Darch and Barber (1983) used multi-seasonal Landsat Multispectral Scanner data sets with their broad spectral bands to aid in locating vegetation associated with metal anomalies. Labovitz and others (1983) used a portable radiometer, configured to mimic Landsat Thematic Mapper (TM) bands 3 (0.63-0.69 µm), 4 (0.76-0.90 µm), and 5 (1.55-1.75 µm), to study mixed-deciduous forests growing on mineralized and background sites. This report evaluates the reflectance of the forest canopy associated with cobalt and copper mineralized rocks and soils in the Idaho Cobalt District of the Salmon River Mountains, Idaho.

Setting

The Idaho Cobalt District is a northwest trending zone of copper and cobalt mineralization in Lehmi County, approximately 30 km west of Salmon, Idaho (fig. 1). The terrain is rugged, ranging in elevation from 1150 m to 2750 m. The forest of the region is predominantly Douglas fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), and less abundant Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Lodgepole pine and Engelmann spruce are found growing in soils with both high and low copper and cobalt values. Subalpine fir is found growing only on sites with high to intermediate copper and cobalt values, although it is distributed more widely elsewhere in the northern Rocky Mountains. Douglas fir is more common on sites with low to intermediate copper and cobalt values, although it occurs occasionally at anomalous sites.

Cobalt occurrences in the area are the result of syndepositional cobalt enrichment in the Proterozoic Yellowjacket Formation (Hahn and Hughes, 1984; Erdman and Modreski, 1984). The rocks of the Yellowjacket Formation are thought to be turbidity current deposits from several coalescing fans (Hahn and Hughes, 1984; Erdman and Modreski, 1984). Some mafic tuffs and mineralogically similar dikes and sills are also included in the Yellowjacket Formation. The rocks of the region have undergone metamorphism ranging from greenschist facies to higher grade schists and gneisses (Erdman and Modreski, 1984). Metamorphic remobilization concentrated the stratabound metals in stratigraphic and structural traps (Erdman and Modreski, 1984). The primary ore minerals are cobaltite, chalcopyrite, pyrite, and pyrrhotite.

Methods

Copper and cobalt data from soils collected by Bennett (1977) were used to guide the selection of sampling sites in this study. The soil samples were collected on a 1.6 km by 1.6 km grid at depths of 15-30 cm below the humus layer. Sites for vegetation sampling were chosen to coincide with areas of intermediate to high copper and cobalt values and areas with background values. Branches from Douglas fir, lodgepole pine, Engelmann spruce, and subalpine fir were collected whenever present at sample sites. Branches from several trees of each species present were clipped using long-handled pruning shears. The cut ends of the branches were then wrapped with water-soaked paper towels and stored loosely in open plastic bags.

Spectral reflectance of the samples was recorded in the evenings following sample collection using a field-portable spectroradiometer. The dual-beam instrument allows simultaneous acquisition of spectral reflectance from two targets, in this case a Halon standard and a vegetation sample. The data are recorded and stored digitally by microprocessor. A stripchart record of each spectrum or a ratio of the simultaneously acquired spectra can also be obtained. Our data were recorded as ratioed spectra calibrated in percent reflectance of the sample relative to the Halon standard. A quartz halogen lamp was used as the energy source.

The vegetation samples were cut anywhere from three to fifteen hours prior to recording their spectra. We conducted several tests to determine the effect on the spectra of cutting the vegetation prior to the measurements. Our conclusion was that by keeping the cut surfaces of the branches moist, spectral changes did not occur over this period of time.

Spectral Variations

The reflectance spectrum of vegetation is influenced by three characteristics in three different parts of the spectrum (fig. 2) (Knipling, 1970). Absorption in the region from 0.40-0.69 μm is attributed to plant pigments. High reflectance in the region from 0.76-1.10 μm is attributed to internal leaf scattering and cell structure of the vegetation. Leaf water is the primary influence in the 1.35-2.50 μm spectral region.

Our analyses demonstrate that spectral variations occur between vegetation growing in soils with anomalous amount of metals and vegetation growing in background soils, as has been reported by other workers (Chang and Collins, 1983; Collins and others, 1983; Birnie and Francica, 1981; Yost and

Wenderoth, 1971; Howard and others, 1971). Reflectance in the green through the red parts of the spectrum (0.50 to 0.68 μm) tends to be higher for Engelmann spruce and lodgepole pine growing in anomalous soils that for these species growing in background soils (figs. 2 and 3). In this spectral region, the reflectance of Douglas fir growing in anomalous soils, however, is slightly lower than of those growing in soils with background values (fig. 4). The reflectance values of all three species growing in anomalous soils is higher than those growing in soils with background values in the spectral region controlled by cell structure (0.76-1.10 μm) (figs. 2-4). A cross-over occurs in the transitional region between the parts of the spectrum influenced by cell structure and leaf water, approximately 1.3 to 1.4 μm. The reflectance of all three species is lower for samples grown in anomalous soils in the region influenced by water absorption in the vegetation (1.35-2.50 μm) (figs. 2-4).

Some of the spectral variations occur in the spectral regions covered by TM (fig. 2) and might be detectable in TM data. To date, however, we have not successfully differentiated vegetation growing in anomalous and background sites using TM data. Our approach was to use a Munsell hue-intensity-saturation algorithm (Raines, 1977) to mask the rocks in the scene, leaving only what we believe to be pixels dominated by vegetation. After masking, a color ratio composite (CRC) image using TM band ratios 4/7, 3/2, and 4/3 was created. These particular ratios were chosen to optimize the spectral variations between vegetation growing in mineralized and background soils (fig. 2). The 3/2 ratio was used in spite of the opposite variation in this spectral region in Douglas fir (fig. 4) because this species occurs infrequently in mineralized areas. All three ratios were considered necessary because their cumulative effect would be to enhance the subtle spectral differences found in each.

Several factors may have influenced our results. In some areas the trees growing on the anomalous sites are stunted and chlorotic. Also, the needles on these trees appear to be less abundant than the needles on the trees growing in background sites, in which case more soil would be seen by the TM sensor than in background areas. If this were true, then by masking everything in the TM data but pixels dominated by vegetation, we could have inadvertently masked the areas with highly stressed vegetation. We tested this theory by looking at a CRC image without a mask of any kind. The vegetation in anomalous and background areas could not be differentiated. A second factor which plays a very important role is the extremely steep topography in this region. Azimuthal variations in the steep mountain slopes leads to marked changes in vegetation communities and may be a more controlling factor in vegetation distribution than substrate. That is, the minor changes in vegetation distribution in mineralized areas may be overwhelmed by larger changes due to topographic position. These variations are very evident in the TM data. A third factor that affects the vegetation is the variability in elevation throughout the study areas, which influences where species grow.

The spectral variations seen in the reflectance spectra, while small, are within the detection limits of some currently available airborne sensors. With higher spatial, and perhaps spectral, resolution, the problems of thinning vegetation and topography can possibly be overcome.

Conclusions

1. Spectral reflectance of canopy trees growing over cobalt and copper mineralization in the Idaho Cobalt District shows consistent variations compared to reflectance of trees in background areas.

2. These spectral variations were not detected in ratioed Landsat TM data, probably because of noise from density variations in the tree canopy and the strong influence of topography.

3. With high spectral and spatial resolution data from airborne sensors, it may be possible to distinguish vegetation growing in mineralized areas from vegetation growing in background areas.

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Figures

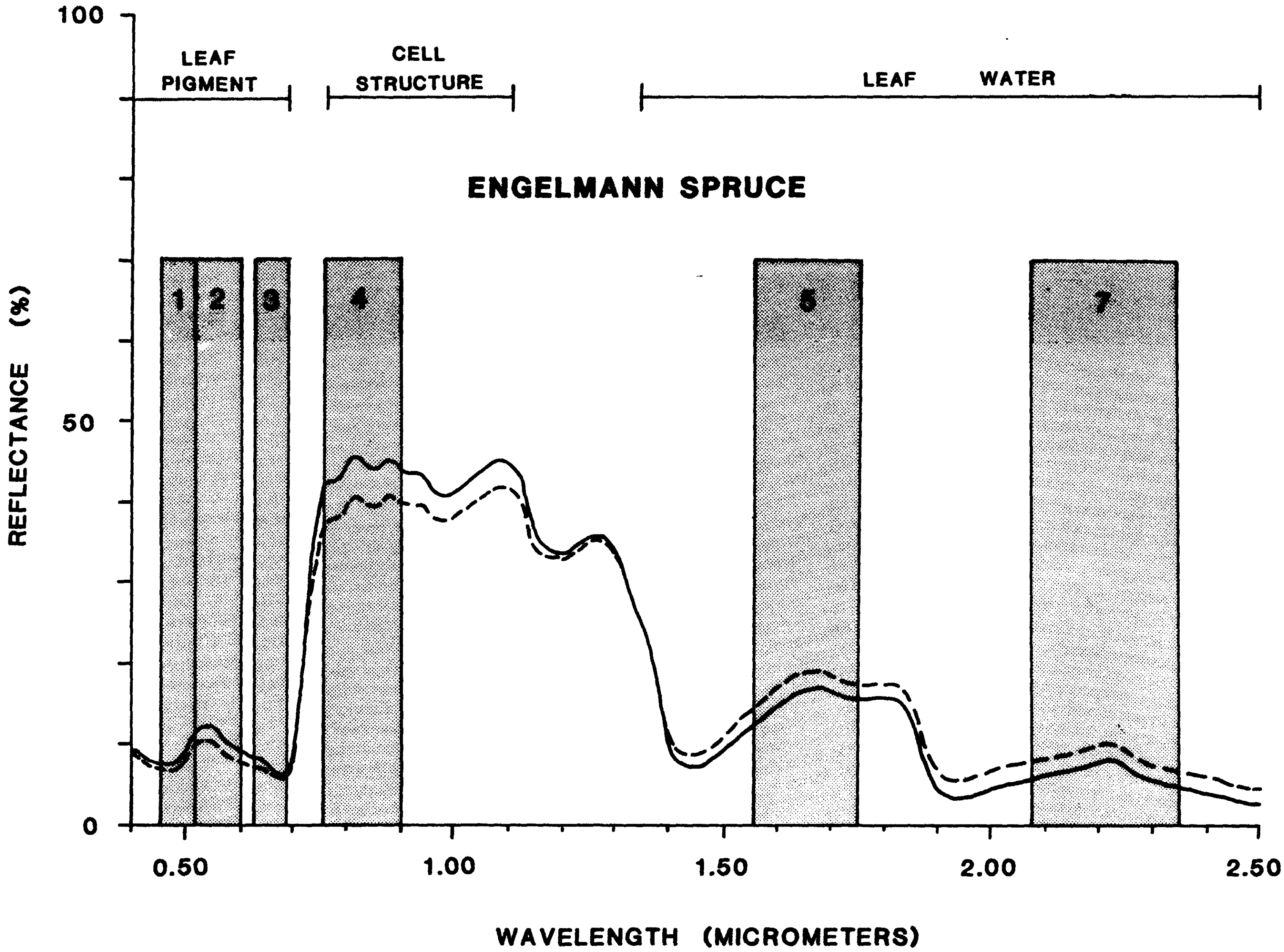
Figure 1. Map showing location of study area.

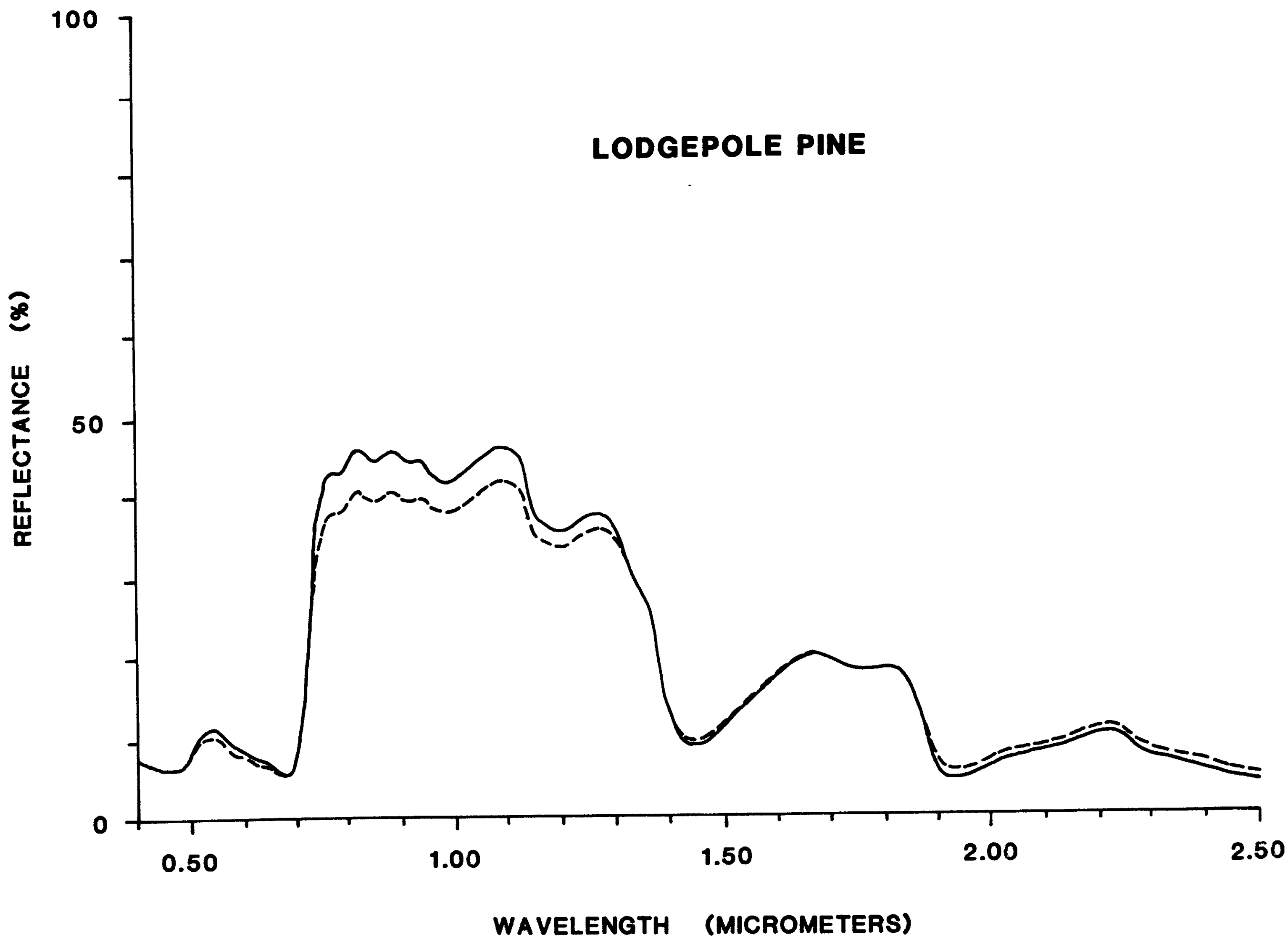
Figure 2. Average reflectance spectra of Engelmann spruce (*Picea engelmannii*) growing in soils with anomalous (solid line) and background (dashed line) amounts of copper and cobalt. Positions of Thematic Mapper bands are shown by stipple pattern.

Figure 3. Average reflectance spectra of lodgepole pine (*Pinus contorta*) growing in soils with anomalous (solid line) and background (dashed line) amounts of copper and cobalt.

Figure 4. Average reflectance spectra of Douglas fir (*Pseudotsuga menziesii*) growing in soils with anomalous (solid line) and background (dashed line) amounts of copper and cobalt.

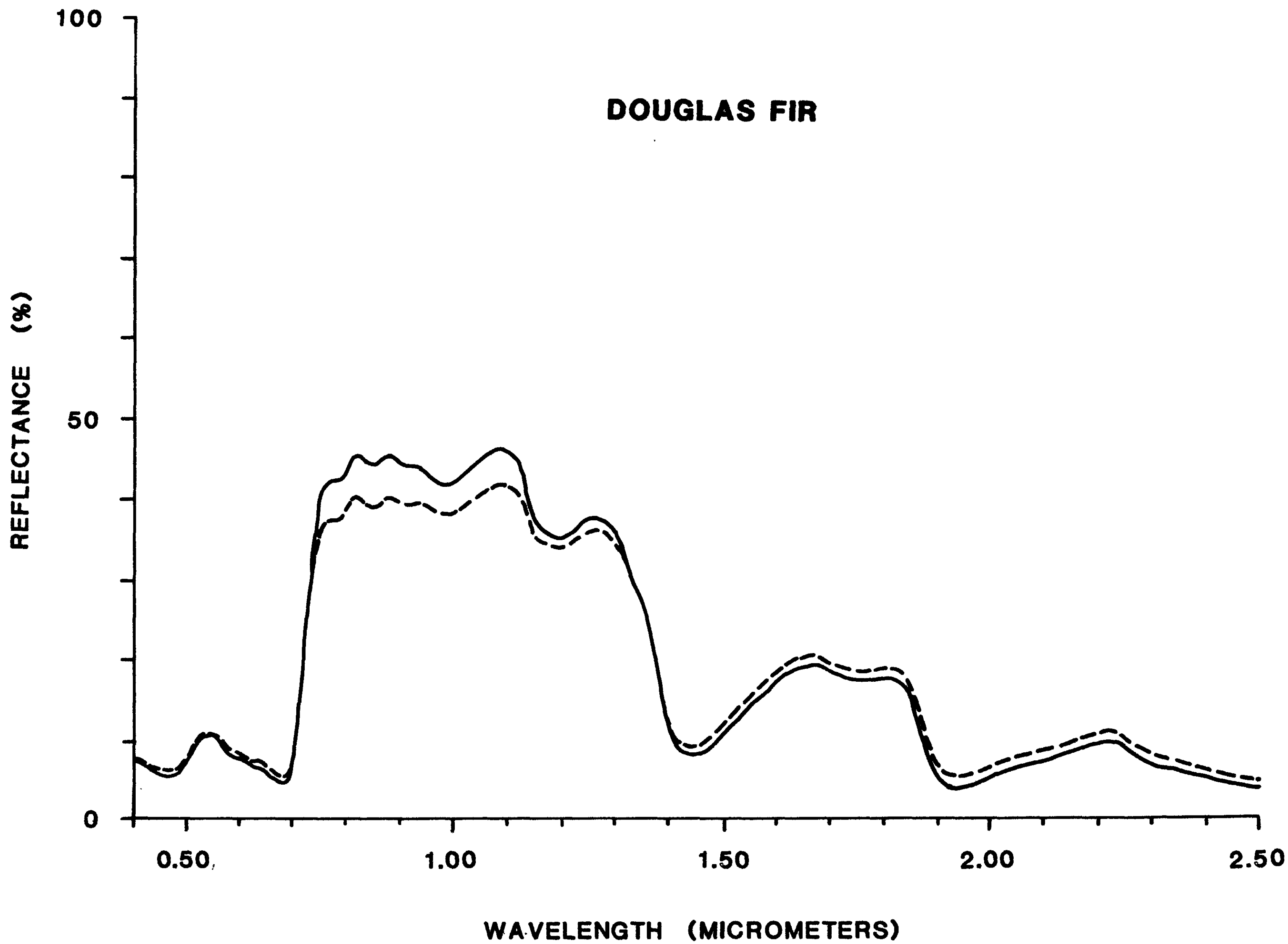

116°
49°
STUDY AREA
SALMON
IDAHO
42°
0
200 MI
0
200 KM


ENGELMANN SPRUCE
LEAF PIGMENT
CELL STRUCTURE
LEAF WATER
1
2
3
4
5
7
REFLECTANCE (%)
100
50
0
0.50
1.00
1.50
2.00
2.50
WAVELENGTH (MICROMETERS)



LODGEPOLE PINE
100
50
0
REFLECTANCE (%)
0.50
1.00
1.50
2.00
2.50
WAVELENGTH (MICROMETERS)

8


DOUGLAS FIR
100
50
0
REFLECTANCE (%)
0.50
1.00
1.50
2.00
2.50
WAVELENGTH (MICROMETERS)