Spectralradiometry and caribou range classification

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Abstract: The utility of Landsat in caribou range studies has been limited by problems of heterogeneity in cover type at the scale of pixles and by logistic barriers to ground truthing. Spectralradiometry provides an economical way of collecting ground truth data that are precisely comparable with Landsat data and which could provide a basis for hierarchic key classification rather than classification based on prinicipal components analysis. Spectral curves are presented for six common cover types and it is shown how the information could be used to develop classification criteria. Airborne data which could have provided a direct comparison with Landsat data proved to be too highly variable because of equipment constraints but there do not appear to be any significant barriers to developing the technique.

Key words: caribou, range, Landsat, spectralradiometry, Ungava, Quebec.

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Introduction

There are many reasons for wanting to be able to map accurately the ground cover of caribou range. Among them are questions of range size and distribution, food availability, food preference, and relationship between behaviour and the enviroment. However, the large size and geographic remoteness of caribou range makes detailed mapping through conventional means difficult, expensive and consequently for many regions, unlikely. Satellite imagery has been widely recognized as providing new opportunities (Thie *et al.*, 1974).

While great advances have been made using Landsat data, the problem of formulating consistent, accurate and precise classification algorithms has limited the utility of Landsat for heterogeneous environments and sites for which it is difficult to collect ground-truthing information. Thus for agricultural landscapes where the land use assures homogeneity over field-size blocks, and where land users typically have detailed information available about cover type, growth stage and ground conditions, it is possible to produce very detailed maps from Landsat. However, for wilderness areas, and particularly those areas where there is a high degree of variablity and mixing in the assemblages of dominant species at a scale finer than that of useful management blocks and even finer than pixle size, it has proven very difficult to produce useful maps. These problems are acute in the case of caribou range (Cihlar *et al.*, 1978; Thompson *et al.* 1980; Bråcher and Meredith, 1985) and are compounded by the difficulty of collecting detailed and widespread ground truthing data.

Landsat records the intensity of reflectance from a pixel area as a single value for each of four wave bands (0.5-0.6 um, green; 0.6-0.7 um, red; 0.7-0.8 and 0.8-1.1 um, both infrared). Both of the major methods of deriving classifiers (supervised and unsupervised (Alfoldi, 1978)) presume a fixed and consistent - though rarely defined - correlation between the distribution of pixel intensity values and the nature of the corresponding ground surface type. The final precision is a function of the amount of pre- or post-classification ground truthing and the uniformity of the landscape.

Ground truthing consist of recording physical parameters of study sites within the area covered by the Landsat image. Such characteristics as dominant species, age of community, soil moisture and nutrient status, and elevation and aspect may be recorded. Correlations will then be sought between these data and the digital reflectance data from Landsat. However, because the relationship amongst the range of known parameters and the four-variable Landsat data must be interpretted subjectively by the analyst (and ultimately classes are defined and named subjectively), and because the statistical treatment of the variance of the Landsat data may mask, and itself be made ambiguous by, significant anomalies, there is a kind of «black box», trial-and-error, empiricism in most classification.

Spectralradiometry provides the opportunity for collecting detailed refectance curves or spectral signatures for single species, species assemblages, or physiognomic cover types (*sensu* Hare, 1959). From this information it is possible to determine precisely what radiation is being directed back towards the Landsat sensors. The information should be useful in developing non-statistical classification algorithms and in distinguishing attributes on the ground which can be expected to be detectable and distinguishable by Landsat.

This paper reports on spectralradiometric data collected for several dominant cover types in the region of Schefferville, Quebec and discusses its consistency and its potential utility for Landsat classification.

Methods

Using sites that had been studied in previous range classification work (Bracher and Meredith, 1985) areas were selected which had representative and characteristic cover types. The work began with ground level reconnaissance of pure stands and continued with low level aerial surveys.

A portable spectralradiometer (Li-Cor Model 1800) was used to collect site-specific spectral signatures of known plant species growing in pure stands or of common assemblages of species. Readings were taken under field conditions over a range of from 0.4 um to 1.1 um at .005 um intervals. Species and/or cover type, exposure, sky conditions and height and position of the sensor were noted. Reading were taken from 2 m or less with a handheld sensor or were taken from a sensor mounted on a plane flying as low as 50 m and as high as 200 m above ground.

Date were plotted on graphs (0.3 um intervals) for comparison of subject matter and recording conditions.

Integrals were calculated for the parts of the spectrum conforming to Landsat sensors. Integral values, band ratios, and total reflectance were plotted for comparison. Clearly distinct patterns were sought as a basis for classification algorithms.

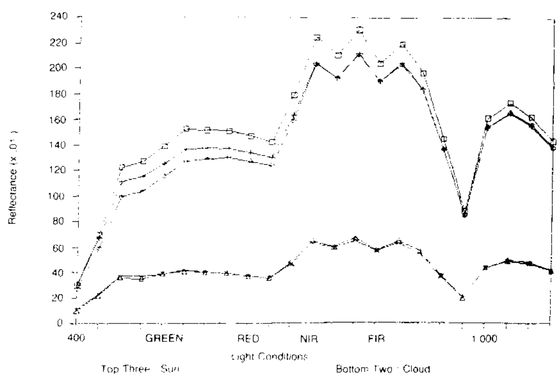

Fig. 1. Spectral curves for five lichen samples in differing light conditions. Top three curves are for full sunlight, bottom two are in open shade.

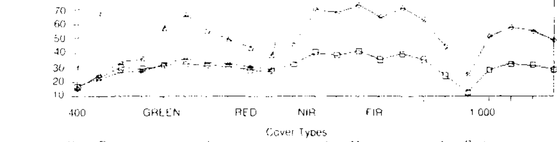

Fig. 2. Average spectral curves for four different cover types. From top to bottom at near infra-red (NIR) they are Lichen, Birch, Moss, Rock. Averages are of three or more samples. All values were recorded under full sunlight.

Results and discussion

Similar cover types show consistent patterns of reflectance although the intensity of reflectance varied with the cloudiness (Fig. 1). It can be seen that readings for three different lichen (*Cladina alpestris*) dominated sites monitored in full sun the refeectance curves are very similar. For the two sites monitored under cloud the patterns of reflectance were similar although values were much lower. It is clear from this that sites visible from Landsat but shaded by cloud will be statistically distinct from fully lighted areas covered by the same species unless pattern of reflectance, rather than net reflectance, is considered. This can be accomplished through the use of ratios rather than absolute values.

Whereas there is uniformity within a single species, there are conspieuous differences in patterns and values (averages) under uniform light conditions between species groups (Fig. 2). Of the four cover types shown it is evident that while in some cases pairs for species are similar over part of the spectrum, no two are identical throughout. However, these date are more complete than is obtainable from Landsat.

Converting these to integrals gives relative values which are comparable to Landsat data for a single pixel (Fig. 3). From these it is possible to sort visually on the basis of differences in reflectance in single bands, the six species that were selected for ground level study.

These same data may be presented as total reflectance (Fig. 4.a.), or to compensate for variation in total reflectance intensity, as proportions for total reflectance (Fig. 4.b.). Each of these presents a distinct quantitative profile of the cover type which may be used by an analyst in the selection of sorting criteria.

If integrals for the four spectral bands are used to calculate the six possible sets of band ratios (Fig. 5), differences are further highlighted. From four variables twelve can be generated and plotted graphically for use by the analyst in attempting to identify optimal classification criteria.

In attempting to distinguish the six selected cover types on the basis of data which is structurally comparable to Landsat data, three parameters appear to be sufficient: ratios of green or red to near IR, ratios of visible to IR, and total reflectance (Fig. 6).

Results for mixed vegetation from airborne readings proved much less distinctive, with very high coefficients of variation for each of the nominal cover types. This was found to be a result of the field-of-view of the sensing

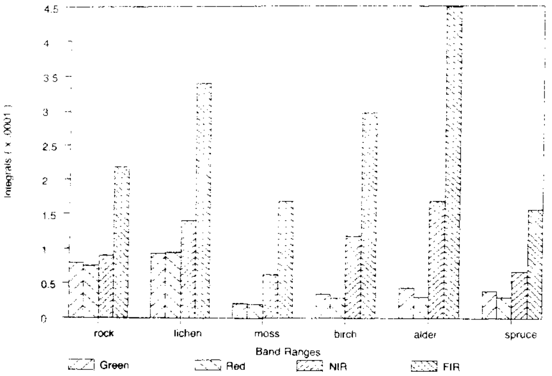

Fig. 3. Integrals for Landsat bands for selected low, pure-stand cover types. Columns within each block are, left to right, green, red, near infra-red, far infra-red. Blocks are, left to right, rock, lichen, moss, birch, alder, spruce.

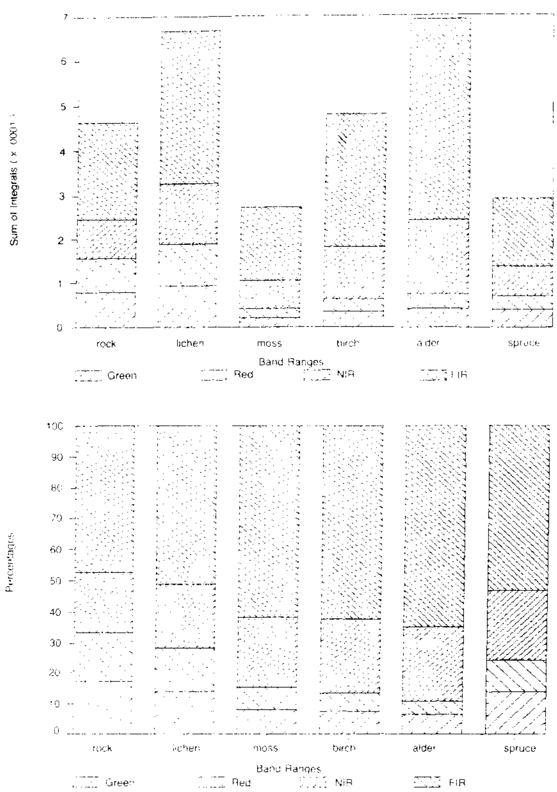

Fig. 4. (a) total reflectance and (b) distribution of reflectance for selected low, pure-stand cover types. Blocks within each column are, bottom to top, green, red, near infra-red, far infra-red. Columns are, left to right, rock, lichen, moss, birch, alder, spruce.

receptor: readings were taken from a larger and more heterogeneous area than had been hoped despite the low elevation of the aircraft. This techincal problem is relatively minor: a range of different field-of-view sensors are presently manufactured for different applications (though none presently is as restricted as this task requires), or an existing sensor could be remounted and recalibrated in such a way that wide-angle light would be blocked. Only funding and access have prevented this being tested. In principle the techniques used for the pure stands will be applicable to recording spectral signatures of mixed species stands. However, until more data are available it is impossible to know if there are clear distinctions or gradual transitions between the spectral signatures of useful physiognomic classes.

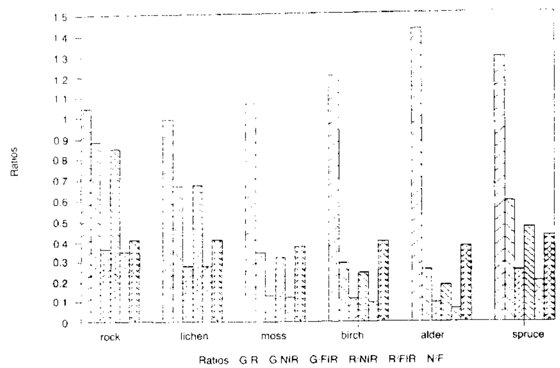

Fig. 5. Band ratios for data in Figure 4. Columns within blocks are, left to right, ratios of: green/red, green/NIR, green/FIR, red/NIR, red/FIR, NIR/FIR. Blocks are left to right, rock, lichen, moss, birch, alder, spruce.

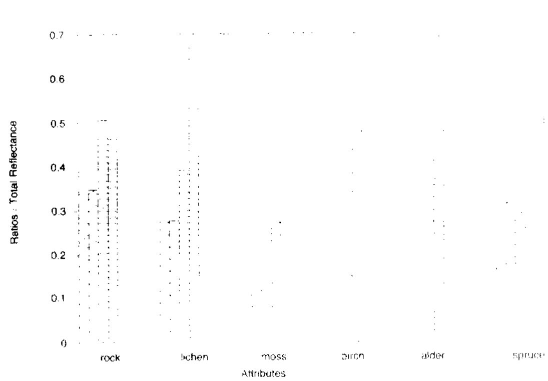

Fig. 6. Selected attributes of reflectance. Columns within blocks are, left to right, green/NIR, red/NIR, green+red/NIR+FIR, total reflectance.

Conclusion

The ability to record accurately from known sites the same information that is recorded by satellite permits much more freedom to develop a testable rationale for sorting Landsat data into useful classes. A dendritic or hierarchical selection key for the cover types shown in Fig. 6 could be based on three parameters.

Airborne data which provides information at a physiognomic scale directly comparable to that measured by Landsat, will be required before classification and mapping comparisons can be made between structured nonstatistical classification keys and conventional classifiers based on principal components analysis.

If the precise spectral signatures of defined cover types are known, it will be possible to select unambiguously pixles which conform to defined criteria sets. This will not eliminate the problem of heterogeneous pixles, but it will provide tools for the informed assessment of groups of pixels which are unclassified, double classified or patently incorrectly classified by conventional means.

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