USE OF THE MINIMUM NOISE FRACTION (MNF) TRANSFORM TO ANALYZE AIRBORNE VISIBLE/ INFRARED IMAGING SPECTROMETER (AVIRIS) DATA OF NORTHERN FOREST TYPES

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1. INTRODUCTION

Due to its continuous sample of spectral information from 400 to 2450nm, the Airborne Visible/ Infrared Imaging Spectrometer (AVIRIS) collects data in spectral regions affected by atmospheric gases. This interference is attributed to the absorption of energy by water vapor, carbon dioxide, and ozone that adversely affects the quality of the reflectance data of ground targets in these regions. Researchers have developed algorithms to process AVIRIS channels to maximize the useful information naturally masked by atmospheric disturbance (Curran and Dungan, 1989; Gao *et al*, 1993; Roger and Arnold, 1996). These methods are useful as an exploratory method for visualizing spectral trends in surface features scanned by AVIRIS.

The Minimum Noise Fraction (MNF) transform (Green *et al*, 1988) is an algorithm consisting of two consecutive data reduction operations. The first is based on an estimation of noise in the data as represented by a correlation matrix. This transformation decorrelates and rescales the noise in the data, by variance. At this stage, the information about between band noise has not been considered. The second operation accounts for the original correlations, and creates a set of components that contain weighted information about the variance across all bands in the raw data set. The algorithm retains specific channel information because all original bands contribute to each of the components' weighting. Often, most of the surface reflectance variation in a data set can be explained in the first few components, with the rest of the components containing variance as contributed primarily by noise (Boardman, 1993). Weighting values for each component can also be examined, pointing to the raw bands that are contributing most to the information contained in the dominant components. The dominant components are then used to transform the data back to its original spectral space, resulting in the same number of transformed channels as the original data provided.

By examining the spectral trends of specific forest types across these transformed channels, areas of interest that are unique by species may become apparent. The objective of this study is to utilize the MNF transform to reduce noise components and analyze AVIRIS data of selected northern forest species. Areas of interest are defined to show differences across traditional electromagnetic regions (*i.e*., visible red, near-infrared, *etc*.); changes in the magnitude of mean reflectance between species by channel; and variance between band pattern of spectral reflectance. Ultimately, the goal is to derive useful representations of AVIRIS data to improve forest inventory and monitoring over large areas.

2. METHODS

2.1 Study Site

This study was conducted in the greater Orono area in central Maine (Figure 1). Agricultural lands, wetlands, upland forests, and urban features characterize this area. Two research forests are contained within the scene, providing a variety of management units for comparison of natural stands.

2.2 Data Preparation

Two scenes of AVIRIS data (July 1994) were acquired from NASA's Jet Propulsion Laboratory (JPL) and mosaicked to form a 614 by 1,000 pixel image. The same area was subset from a 1991 (June) Landsat Thematic Mapper (TM) image. Twelve representative forest type plots (Table 1) were determined from field visits and aerial photos. The locations of the plots were digitized over the Landsat image with the aid of GPS points collected in the field. All plots were examined to assure that no significant change occurred between 1991 and 1994.

2.3 The MNF Transform

The MNF transform was run on the raw AVIRIS mosaic, providing an output of 224 components. Eigen weighting values and visual assessment of individual components was used to indicate components that maximize the variance for the entire data set. The first 10 components were determined to contain over 99% of the total variance in the data, and were subset into a new image. The subset of dominant components was then used to drive the inverse transform and produce 224 new bands. As a final step, the new data set was georeferenced to the 1991 Landsat TM image.

A preliminary assessment of the validity of the MNF transform was performed by visually comparing the reflectance trends of the same forest type polygon for both the transformed and raw AVIRIS bands (Figure 2). A field plot was selected because it was the most homogeneous area available in the image. Visual assessment of raw AVIRIS data showed that the bands numbered greater than 150 consist of data dominated by noise. Use of the MNF transform is justified because transformed bands show variance in reflectance for those channels, indicating that information related to the image variance may be concealed by noise in the raw data.

Transformed data was spectrally analyzed for each forest type. Within category representative types were used as a basis for logical comparisons and to indicate areas of interest.

3. RESULTS/ DISCUSSION

Using the mixed hardwood signature as a reference, we can see that there is separability between the sampled hardwood species (Figure 3). Red oak shows the same spectral shape across all 224 transformed bands, but has both higher positive and negative extremes where peaks occur. The alder signature does not have the same shape as the other two hardwoods, indicating that some other factor may be influencing its spectral signature (*i.e.*, shrub-like structure or wet site).

For softwood types, all plotted species show the same spectral shape over the 224 bands, as compared to mixed softwood (Figure 4). More specific areas of interest are apparent between species on a band-by-band inspection, with the most species variability occurring in the near-infrared region.

Wetland type comparison (Figure 5) with the inclusion of the alder type supports the suggestion that moisture is influencing its spectral signature. Also, there are more mean differences between the wetland types examined. Given the band-by-band variation evident in Figure 5, future studies may find that AVIRIS separates wetland types with more accuracy than hardwood or softwood types.

The three plantation types examined (Figure 6), all have the same spectral shape from the visible blue to the near-infrared regions, with white pine plantations showing a higher reflectance over the entire range. Variations between plantation types in the mid-infrared region show different spectral shapes that are not as evident in other forest type comparisons. There is much spectral variance between treatment in the eastern larch plots (Figure 7). Eastern larch (*Larix spp*.) is a wet-site species in Maine. Variations demonstrated by this comparison may be associated with a combination of water absorption and stand structure (plantations are drier sites, with stems occurring with uniform spacing).

The regeneration plot used in this study was not a result of a recent harvest. Therefore, the understory has had time to redevelop and cover the bare ground (which may add to mean reflectance values). It would still be expected that the regeneration plot would have a higher reflectance across the visual spectral range based on the sparceness of vegetation within each individual pixel compared to the natural stand. This is not the case with our study. However, this plot shows the expected lower reflectance means in the near-infrared region when compared to both hardwood and softwood mixed stands.

4. CONCLUSIONS

Results for this study were limited by availability of reference data. Adequate sample plots were difficult to locate and quantitative structure measurements were not possible 5 years after the imagery was acquired.

This study indicates that the MNF transform can be an effective tool for visualization of northern forest type spectral patterns with variations between forest types apparent between transformed bands. Subsets by spectral region may also be useful for further processing of AVIRIS data. The objective of this study was met and future research will expand on its findings.

Restraints were imposed during the design of this study due to its preliminary nature. Those restraints will be removed and methods expanded for a more in-depth examination of this topic. A larger sample of forest types, including more treatment types (i.e., herbicide and clearcut) will be located, and their inclusion into the digital environment will be improved. For example, it was often difficult to locate field plots on the digital imagery for digitization due to constraints in spatial resolution. The availability of reference plots within the study site limits their size, but image-processing technology such as "region growing" algorithms will be incorporated to eliminate interpreter error. The type polygons of interest will be selected for their spectral separability as determined from aerial photos, ground observation, and standard statistical methods. Finally, the transformed bands will be rescaled to contain data ranges between 0 and 255 to facilitate interpretation and comparison with other data sources.

5. REFERENCES

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Table 1. Forest types selected for this study.

Plot Name	Composition and Scientific Name
Hardwood Types	
1. northern red oak	*Quercus rubra*
2. speckled alder	*Alnus incana*
*3. mixed hardwood	Birch-beech-maple mix *Betula spp., Fagus spp., Acer spp.*
Softwood Types	
4. eastern larch	*Larix laricina*
5. eastern hemlock	*Tsuga canadensis*
*6. mixed softwood	Spruce-fir-hemlock mix *Picea spp., Abies spp., Tsuga spp.*
Wetland Types	
*7. bog	Contains standing water Ericaceous shrubs
8. northern white cedar	*Thuja occidentalis*
Plantations	
9. eastern larch plantation	*Larix laricina*
*10. red pine plantation	*Pinus resinosa*
11. white pine plantation	*Pinus strobus*
12. ***regeneration***	

** Denotes types that were pre-selected as representative types for visual comparisons*

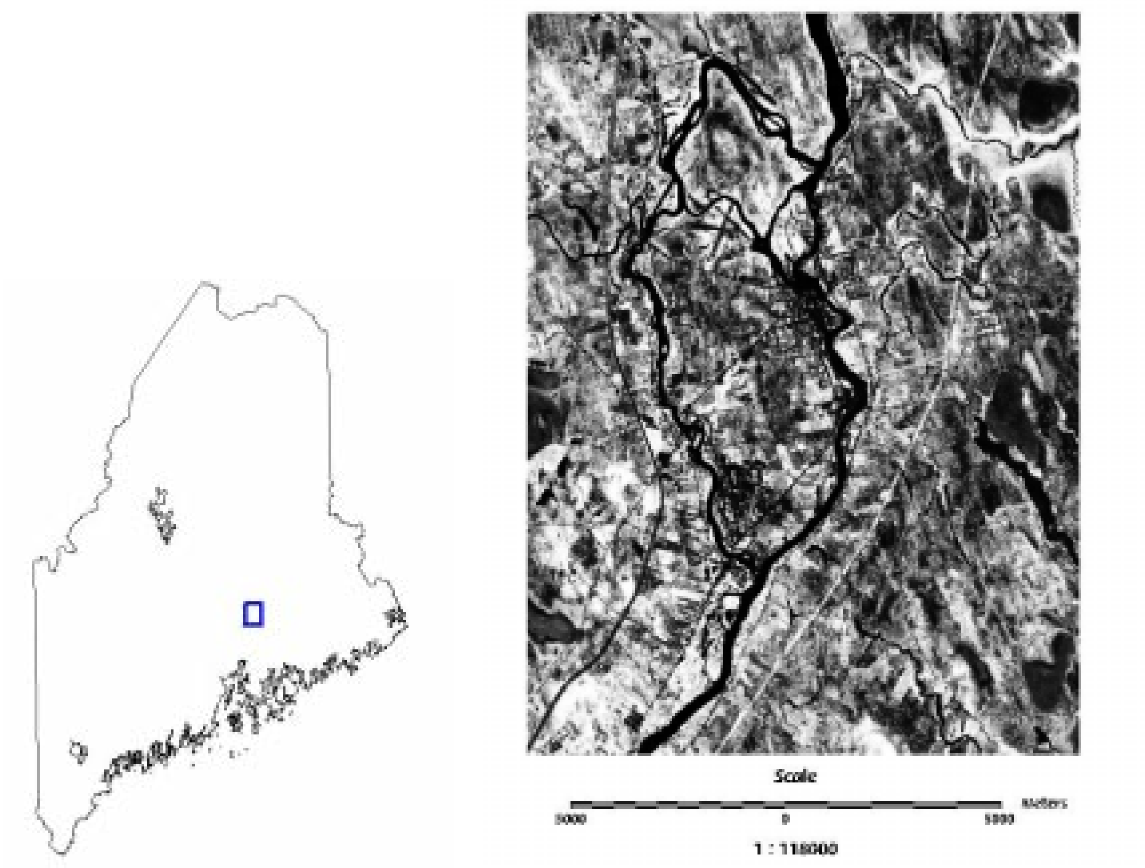

Figure 1. Study site

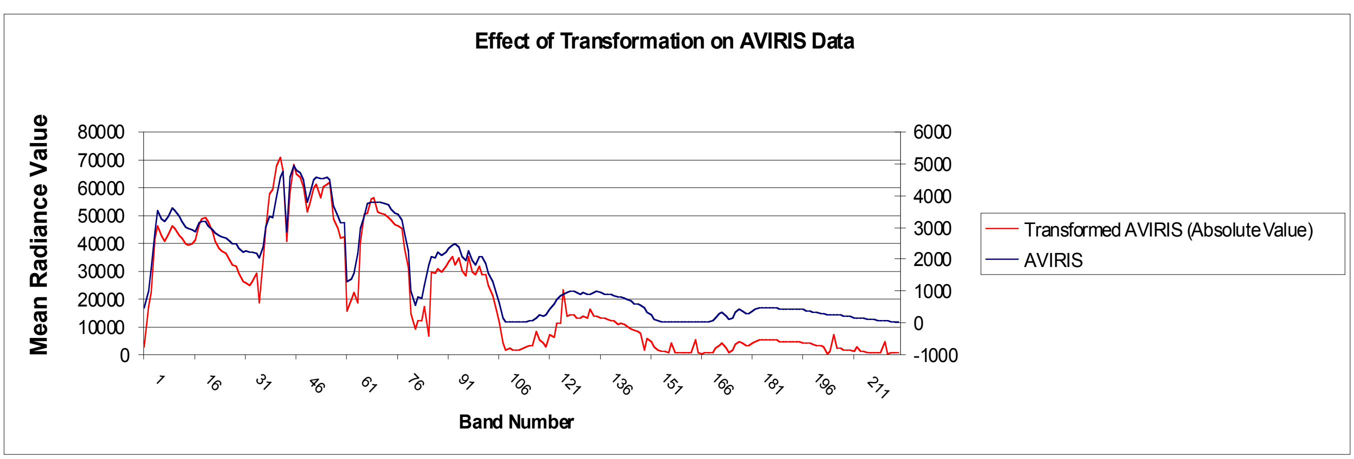

Figure 2. Comparison of raw AVIRIS to MNF transformed bands.

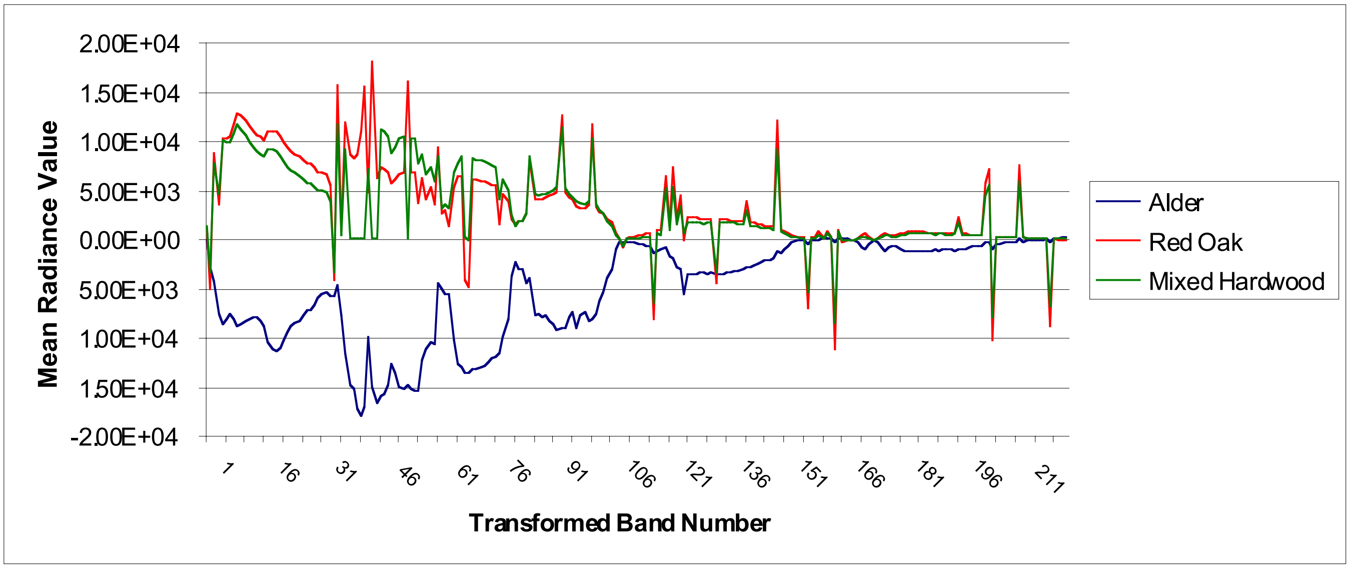

Figure 3. Hardwood type comparison.

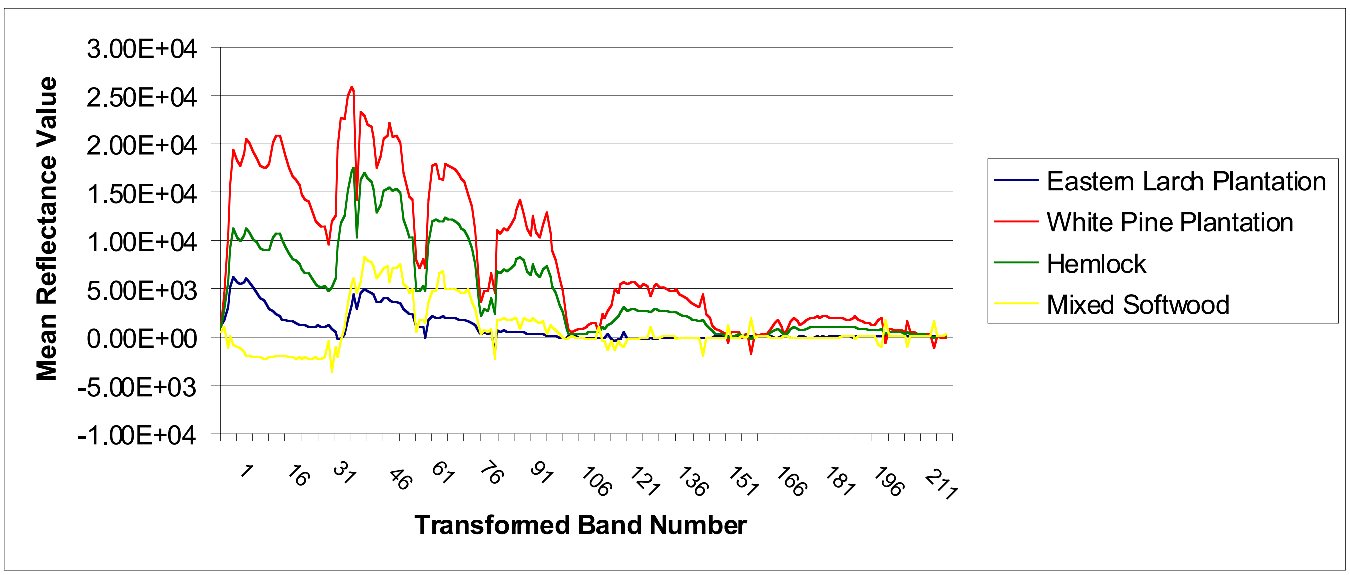

Figure 4. Softwood type comparison

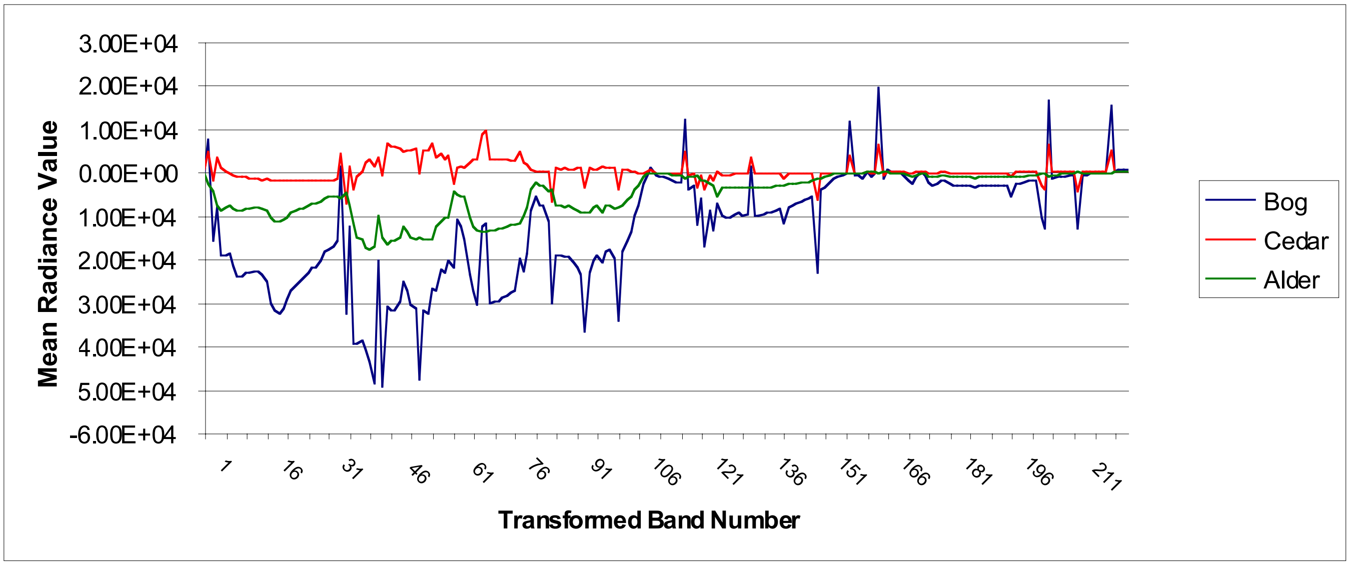

Figure 5. Wetland type comparison.

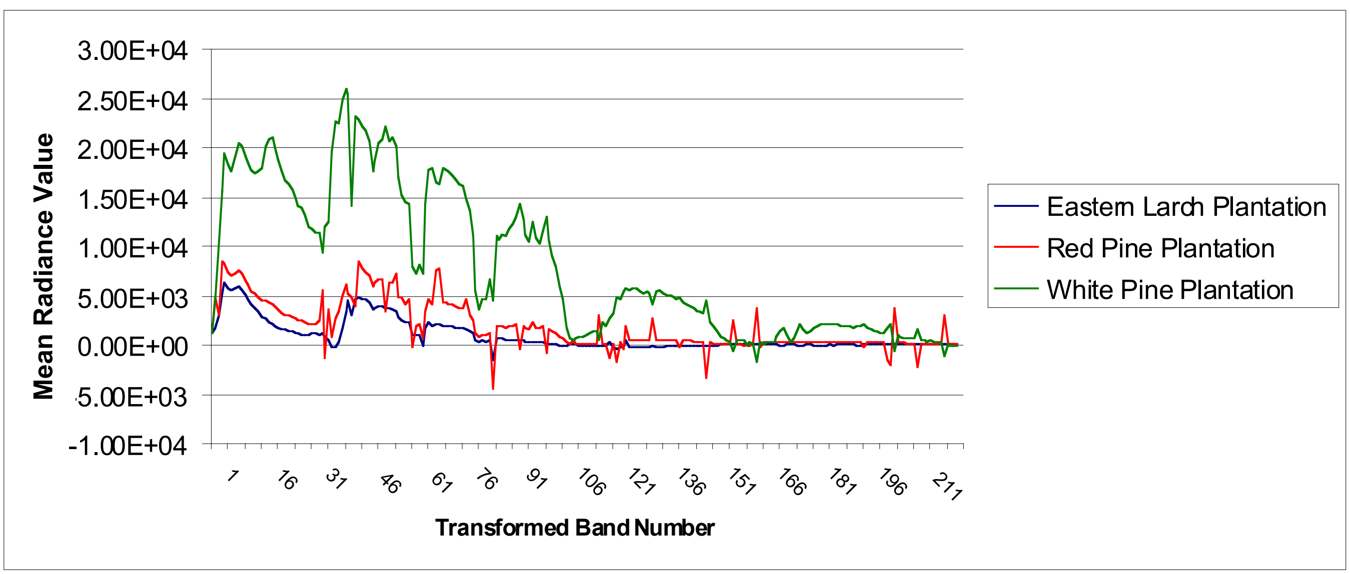

Figure 6. Plantation type comparison.

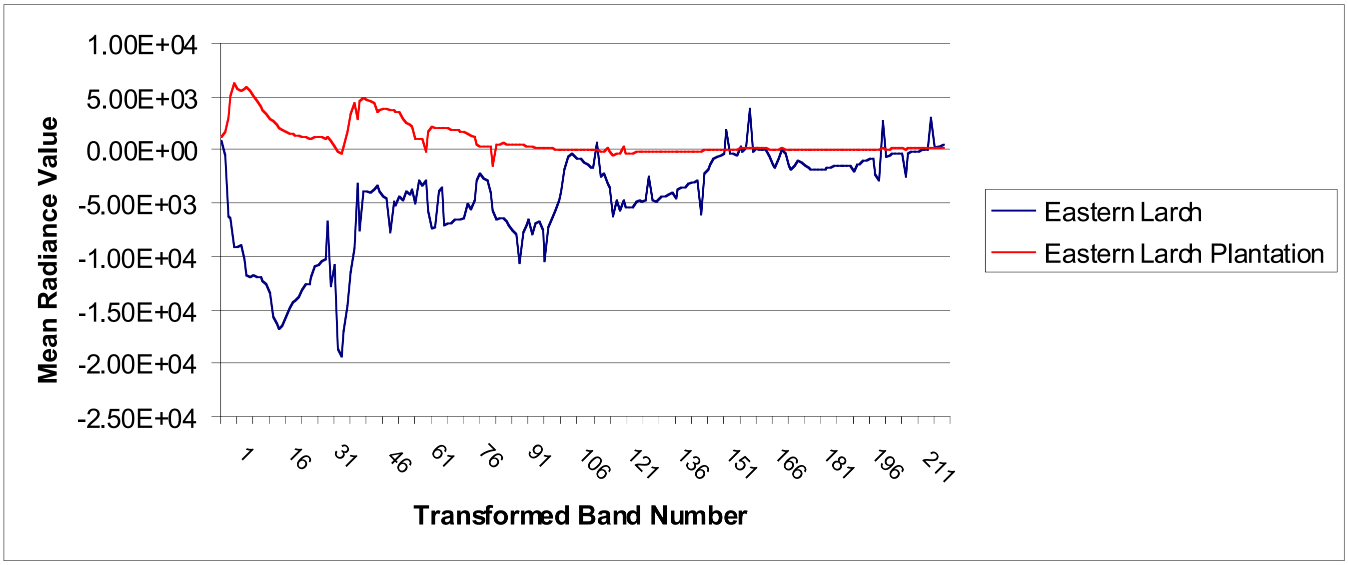

Figure 7. Plantation verses natural stand comparison

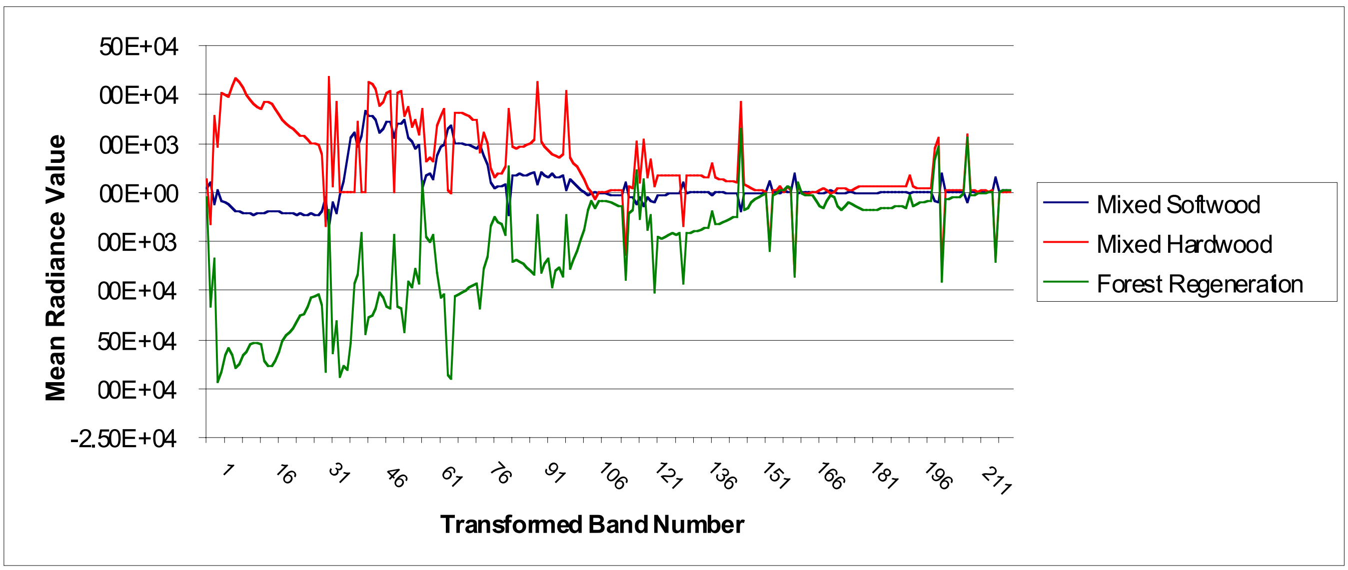

Figure 8. Regeneration to mixed stand comparison.