A COMPARATIVE ANALYSIS OF VERY HIGH RESOLUTION MULTI SPECTRAL SENSOR SYSTEMS WITH MULTI STAGE SENSOR SYSTEMS DATA IN FEATURE EXTRACTION FOR MOUNTAINOUS TERRAIN.

H. Hugh L. Bloemer, Professor, Ohio University, Athens, Ohio, USA
James O. Brumfield, Professor, Marshall University, Huntington, West Virginia, USA
Janette C. Gervin, Instrument Manager, NASA/Goddard Space Flight Center, Greenbelt, Maryland, USA
Joseph A. Langdon, Information Specialist, NASA/HQ, Washington, DC, USA
Charles Yuill, Professor, West Virginia University, Morgantown, West Virginia, USA

Commission VII, Working Group 10

KEY WORDS: Forestry, Simulation, Multi-spectral, Spatial, Spectral, Infrared Photography, Mountainous, Terrain

ABSTRACT

Mountainous terrains have been largely ignored because they present numerous difficulties from a remote sensing perspective in that process and change often occur on a much smaller spatial scale. Higher spatial frequency variabilities require higher resolution spatial analysis over similar spectral bands to extract comparable features. Multistage sampling, involving field studies, and aerial sensor measurements of the Spruce Knob area forest of the Appalachian Mountains illustrates a comparative level of information that may be extracted at different spatial resolutions. This research investigates forest species and forest associations discrimination by optimization of spatial resolution or instantaneous field of view(IFOV 0.1 m - 6.0 m) for selected spectral bands and selected sensor systems. Feature extraction in pattern recognition is affected by natural and artificial spatial frequencies. These features include forest species identification in vegetation associations, hydrologic expression, folded strata, joints, fractures and low order drainage in mountainous terrain. This differs from the artificial periodicities of the electro-optical imaging systems. These vegetation association features are evaluated by field techniques, analysis of variance, cluster and discriminate analysis, in a geobiophysical modeling system environment.

The research has been conducted including via primary data collection, preprocessing, and evaluation of remotely sensed data and feature extraction. The results utilize multistage sampling with 1993 and 1995 digitally derived data from Color Infrared Photography; simulating multi spectral data to provide a viable alternative for remotely sensed derivations of vegetation associations in mountainous terrain. Utilizing digitized CIR photography leads to adjusted variables for more reliable modeling of geobiophysical data for forestation cycles, geologic, climatic and hydrologic processes for long term forest ecological assessment, management practices and global change impact evaluation.

INTRODUCTION

The mountainous regions of the world are a major source of the flood and estuarine coastal plains. These plains are home to the larger proportion of earth's population. The condition of the mountains with regard to hydrology, vegetation, lithologic outcrops, and their effects upon regional and, ultimately, global cycles impacting the forests are linked(Comins and Noble, 1985). The mountains have been largely ignored due to the complexity of the terrain interwoven intricately through geologic, hydrologic, climatic and biologic processes in the generation and rejuvenation of the forests. Mountainous terrain presents numerous difficulties from a remote sensing perspective in that process and change often occur on a much smaller spatial scale than typically observed on large plains. Higher spatial frequency variabilities require higher resolution spatial analysis over similar spectral bands to extract comparable features (Brumfield, et al, 1983). Multi-stage sampling for computerized geobiophysical model of the Spruce Knob mountainous area forested ecosystem of the Appalachian Mountains illustrates a comparative level forestry and related geologic information that may be extracted at different spatial resolutions (Bloemer, et al, 1994; Wriggley, et al, 1985).

This research investigates forest species and forest associations discrimination that may eventually be correlated with geologic lower order drainage, lineaments, soils and rock outcrops through optimization of spatial resolution or instantaneous field of view (IFOV 0.1 m - 11.0 m) for selected spectral bands from various photographic and electro-optic sensor systems (Levin, 1978) . The resulting data are used for feature extraction affecting pattern recognition in species identification in forest associations that can be evaluated by field analysis of variance (Mills, et al, 1963). Further, the discrimination of naturally varying spatial frequencies resulting from vegetation, hydrologic low order drainage, folded strata, joints, and fractures with slope, aspect and elevation effecting microclimate in mountainous terrain, from artificial periodicities of the recording systems are evaluated by a field analysis of variance, cluster and discriminate analysis, and Fourier Analysis (Boyd, et al, 1982, 1983; Oberly and Brumfield, 1991).

Preliminary results by Oberly and Brumfield, 1991, Bloemer and Brumfield, 1992, and others involving EOS/TM simulator and orbital data sampling of different dates and scenes involving dissected plateau forested mountains, indicate that both high and low spatial frequencies, due to natural and instrumentation periodicities, can affect feature extraction in pattern recognition. Forest association variance in heavily dissected terrain is revealed by preliminary research results by Yuill, 1992, Mills et al, 1963, and others. USDA/USFS preliminary investigations, and Yuill, 1992, indicate that a one-half meter to fifteen meter (0.5 - 15.0) IFOV/multi-spectral electro-optical systems are useful in identifying vegetation species and associations. Previously, TM data were evaluated utilizing an optical image processing system. This parallel set of processes was performed by digital Fast Fourier Transforms (FFT) and filters (Oberly and Brumfield, 1991). Results showed a three to five data number variance, in a very low frequency sinusoidal wave, for the TM band 1 data. Further, utilization of the MIPS digital image processing systems on the October 2, 1989 TM band 2 data demonstrated that more apparent patterns were present in the West Virginia forested mountain data (Bloemer and Brumfield, 1992). These periodicity and interference patterns can greatly impact geobiophysical modeling of data, e.g., forest canopy parameters such as the 'red-edge effect,' in assessing the health of the forests(Oberly and Brumfield, 1991; Bloemer and Brumfield, 1992; Gross, et al, 1987). Further, these parameters in pattern recognition, must be taken into account, for they can affect the validity of a model's outcome(Peterson, et al, 1988; Wessman, et al, 1989; Card, et al, 1988). The contention of these researchers is that the periodicities and higher spatial frequencies occurring in nature can be effectively utilized to enhance feature extraction given the spatial resolution to identify these higher frequency associations. This research investigates varying spatial frequencies without modifying the spectral nature of the data other than transforming from an optical to a digital domain. Utilizing spatially adjusted variables can lead to more reliable modeling of geobiophysical data for forestation cycles, geologic and hydrologic processes for long term forest ecological assessment and global change impact evaluation (Wriggley, et al, 1985). These variables may involve the biosphere, atmosphere and climate, particularly with emphasis on altitude, latitude, slope, aspect and micro-climate variations in mountainous terrain (Tucker, et al, 1985).

This paper is part of a scientific research program in the early stages of design and strategic implementation planning and investigation. Because of West Virginia's dissected plateau mountainous terrain, the identification of forest associations in current SPOT, Landsat TM and MSS systems do not provide spatial resolutions of suitable accuracy in forest association/species identification or physiognomic analysis in ecosystem evaluation, management or global change mitigation(Bloemer, et al, 1994). One result, as a component of the research, is the US Forest Service's evaluation of very high resolution multi spectral electro-optical systems from aerial platforms for imaging forest associations and species for visual interpretation and identification with a high rate of success(Yuill, 1992). These electro-optical systems have similar bands as NASA's LANDSAT designs involving visible and near infrared spectra. Their IFOV range is typically 0.5m to 11m. We contend that higher resolution systems are increasingly using spatial frequencies that are likely to be problematic but can enhance feature extraction in the digital and optical domains (Oberly and Brumfield, 1991; Bloemer et al, 1994 and Yuill, 1992).

Digital and optical feature extraction of sensor data from aerial platforms are investigated, compared and evaluated for pattern recognition. This is accomplished via very high spatial resolution simulated multi-spactral data from scanned photography for forest associations. Naturally occurring periodicities of geologic, hydrologic, climatic and biologic features tend to have higher frequencies in mountainous terrain. Therefore, these researchers contend that understanding the expression of naturally occurring spatial frequencies is germane to understanding forest ecological and geologic patterns in mountainous terrain associated with higher spatial frequency multi spectral system data. This research is focused on the forest associations data for future generation simulator, aerial and orbital sensor systems design and engineering for longer term evaluation of the ecological conditions associated with existing research programs, particularly, those using forest and earth resources in mountainous terrain.

RESEARCH METHODS AND TECHNIQUES:

In nature there are spatial frequencies related to geologic, hydrologic, climatic and biologic features particularly in mountainous terrain. A data collection system with current non military orbital high IFOV sensor systems cannot resolve the high spatial frequencies and is, therefore, inadequate in forest species and association identification in mountainous terrain. These systems and data were investigated at the participating universities and NASA with the optical transform instrumentation and digital image processing software available in a geobiophysical modeling environment (Oberly and Brumfield, 1991). It is proposed to look at the sensor data in question through parallel investigations of optical and digital transforms and feature extraction techniques, partially funded through a NASA EPSCoR grant. Cluster analysis, discriminate analysis, analysis of variance and field analysis are utilized in evaluating natural and sensor identified spatial frequencies.

Study Area - Rationale for Appalachian Mountain Site Selection

The Spruce Knob USGS 7.5 minute quadrangle is chosen for its representative eastern United States mountainous forested conditions with high natural spatial frequencies and periodic disturbances by forest management practices, agricultural and recreational impacts. These mountains are northeast/southwest trending of folded and heavily eroded sedimentary rocks. Stream patterns are trellis accented with natural and manmade ponds/lakes. Strata of Pennsylvanian and Ordivician age underlie the area. Northern deciduous hardwood forest and red spruce with patches of red pine compose the 1000 m plus elevation vegetation communities(Adams et al, 1989). Further, sources of periodicities may well be the underlying geology. faults, joints, fractures, commonly referred to as lineaments in remotely sensed images. They are a source of natural cyclicity in spectrally analyzed images. Alternating stratigraphic lithologies in folded mountainous terrains with colluvial sluff would be expected to contribute a natural periodicity, and, furthermore, vegetation establishment and patterns are in part controlled by slope, aspect, micro-climate and elevation as well as chemistry and moisture associated with rock strata and soil type. The orientation of stream pattern development in low order streams can be influenced by the direction of systematic jointing in rock. Without better understanding of the contribution of natural biotic and geologic frequencies, a full evaluation of images periodicities and spatial frequencies is not likely to be attained. The comparative feature extraction and evaluation techniques developed are expandable to other mountainous regions of the world.

Data-requirement for Simulated Multistage Spatial and Spectral Bands in a Near Temporal Time Frame

Simulated multi spectral sensor data derived from digitized 1993 and 1995 CIR Photography ranging from 550 nm, to 850 nm band with 0.1 m and 11.0 m IFOV resolution are employed. The CIR 1:12000, 1993 and 1:6000, 1995 photography was optically scanned with a Nikon AX-1200 flat bed scanner with Scantouch and ADOBE Photoshop software at 2400 , 1400, 650, 150, and 50 dpi with digital output of 1400, 550, 200, 120, 60 and 30 dpi respectively. Also using differing filters for red, green, and blue with f stop settings at normal or increased to 0.75 f stop increase for scanning for separate bands corresponding to 0.5-0.6nm, 0.6-0.7nm, 0.7-0.85nm of the CIR respectively was achieved with this system. These data are then compared with ground control data collected and GPS registered in July and October of 1995. These data, along with elevation, are incorporated in a geobiophysical modeling system software for performing the various digital multi-variate mergers analyses .

Analysis

The data sets are subjected to principal components analysis, supervised sampling procedures for the same aerial extent for each site with close geographic position maintained for signature analysis in feature separability, histogram analysis of the samples and a comparative analysis of each sample variance for category separability and cluster based feature extraction techniques for spatial evaluation(Yuill, et al, 1991; Bloemer, et al, 1994; Oberly and Brumfield, 1991). The features and sample areas represented are: maple beech (60%/40%) association; maple beech (40%-60%) association; maple spruce (60%/40%) association; red pine spruce (80%/20) association; red pine spruce (80%/10%) association; spruce yellow birch (80%/20%) associations; field meadow shrub rock (50%/20%/20%) association; field meadow rock soil (40%/30%/20%) association; road/limestone meadow (90%/10%) association; open canopy maple beech (30%/40%/30%) association. These features are then compared to the GPS registered ground control field data in a geobiophysical modeling system for spatial, statistical and mathematical analysis for evaluation. Computer graphic displays are utilized for comparative evaluation of sample data sets.

RESULTS AND CONCLUSIONS

The differing IFOV's ranging from 0.1-11m with comparative analysis as stated in technique as given in the example frequency histograms for infra red, red and green respectively of figures 1, 1.6m and 2 , 0.2m, demonstrate that larger IFOV than about 1.0 m results in a more fragmented spectral frequency sample set than a set less than one meter. The characteristics of the spatial distribution of the vegetation assemblages, compared to field mapping of the vegetation, suggest an intermittent discontinuity of spectral frequency that has resulted from integration of the spectral energies apparent at higher resolutions (IFOV). In fact, histogram display of 2.6m IFOV resulting from groupings of frequencies comparable to ground cover distribution provided a classification similar to higher frequency (IFOV) cluster classification (Figures 3 and 4). These results are particularly noticeable for sample features that are spatially and spectrally similar (Figures 1 and 2). However, it should be noted that at higher IFOV, the frequency of the data numbers increases while the apparent variance decreases; the separability of the spectral types increase for the mean of the type in each spectral band (Figures 5 & 6). This suggests that increased separability of spectral features that are spectrally similar, figure 7 & 8, may be further separated by higher spatial frequencies that provide more of a spectral continuum which may be spatially associated. For a fixed number and width of Multi spectral bands, with decreasing IFOV, the data become more continuous and the individual data frequency variance decreases in a constant sample area of fixed size within a particular vegetation category. This provides better opportunities for characterization of the sample within its population and the variance of the population.

The next generation of air and space borne sensor platforms need significantly higher spatial and spectral resolution if foresters, earth scientists and planners are to monitor, inventory and evaluate the resource conditions and rejuvenation capacity that mountain forest ecosystems provide. Factors, which contribute to the degeneration of the mountainous regions of the world, must be investigated, to mitigate the degradation of the intricate cycles that support forest ecosystems. These results demonstrate the validity that higher spatial resolutions are necessary to monitor and evaluate the higher frequency variability of mountainous terrain in a timely fashion for longer term forest ecological processes interaction in global change.

REFERENCES

Adams H S., Stephenson J.L., 1989. Old-growth red spruce communities in the Mid-Appalachians, Vegetation, 85, pp.45-56.

Adams, H S., Stephenson J.L., Blasing T. J., Duvick, D.N., 1985. Growth-trend declines of spruce and fir in the mid-Appalachian subalpine forests, Environmental and Experimental Botany, 25, pp 315-325.

Bloemer, H.H.L. and J.O. Brumfield, 1992. Periodic and Interference Patterns in Earth Observation Systems (EOS) Sensor Data Affecting Feature Extraction in Geobiophysical Modeling of Mountainous Terrain. In: Proceedings of the Second International Symposium on High Mountain Remote Sensing Cartography. Institute of Remote Sensing Application, Chinese Academy of Science, Beijing.

Bloemer, H.H.L., J.O. Brumfield, J.C. Gervin, J.A. Langdon, and C. Yuill, 1994. Interpretation and Optimization in Geobiophysical Modeling of the Biosphere and Hydrosphere with Emphasis on Mountainous Terrain. In Proceedings of the 3rd International Symposium on High-Mountain Remote Sensing Cartogrphy, Mendoza, Argentina, November 7-13.

Boyd, R., J.O. Brumfield, and W. Campbell, 1983. A Comparison of the Usefulness of Canonical Analysis, Principal Components Analysis, and Band Selection for Extraction of Features from Thematic Mapper Simulator (TMS) Data for Land Cover Analysis. The Seventh International Symposium On Remote Sensing Of the Environment, Ann Arbor, Michigan, May 9-13.

Boyd, R., J.O. Brumfield, and W. Campbell, 1982. Optimization of a Non-Traditional Unsupervised Approach for Land Cover Analysis. In: Proceedings of the National Conference on Energy sponsored by NASA, Am. Plan. Assoc., USNRC and Remote Sensing Society, Baltimore, MD, Sept. 9-12. NASA Conference Publication CP-2261.

Brumfield, J.O., R.G. Witt, R. Marcell, H. Blodget, 1983. Comparative Techniques Used To Evaluate Thematic Mapper Data for Land Cover Classification In Logan County, West Virginia. Principal Investigator Presentation In: Proceedings of the Landsat-4 Science Characterization Early Results Symposium, at NASA/GSFC, Greenbelt, MD February 22-24. NASA Conference Publication 2355.

Comins, H.N. and..I.R. Noble, "Dispersal, Variability, and Transient Niches: Species Coexistence in a Uniformly Variable Landscape. American Naturalist, 126.

Gross, M.F., M. A. Hardisky, V. Klemas, and P. L. Wolf, 1987. Quantification of Biomass of the Marsh Grass Spartina Alterniflora Loisel Using Landsat Thematic Mapper Imagery. In: Photogrammetric Engineering and Remote Sensing, 53, pp.1577-1583.

Levin, S.A., 1978. Pattern Formation in Ecological Communities. In: Spatial Patterns in Plankton Communities, ed. J.H. Steele. Plenum Press, New York.

Mills, H.L., S.E. Clagg, J.O. Brumfield, et al, 1963. The Physiognomic Classification of the Vegetation of the Florida Everglades. Rreport to the U.S.Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi, Contract # DA-22-079-eng-322.

Oberly, Ralph E. and J.O. Brumfield, 1991. Illustrating Physical Principles Through Comparative Feature Extraction Techniques in Optical and Digital Image Processing. Society of Photo-optical Engineers at the International Conference on Optics in Education, Leningrad, USSR, Sept. 28 - Oct. 1.

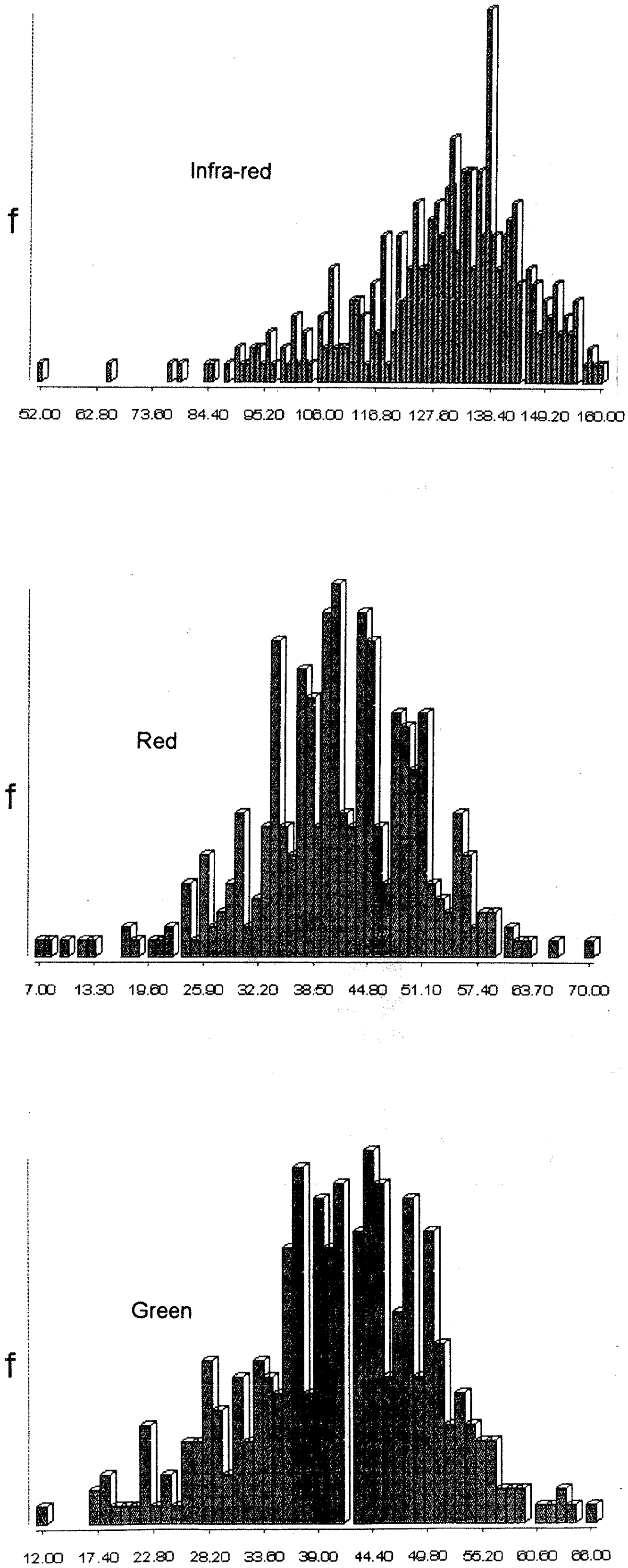
Peterson, D. L., J. D. Aber, P. A. Matson, D. H. Card, N. Swanberg, C. Wessman, and M. Spanner, 1988. Remote sensing of forest canopy and leaf biochemical contents. Remote Sensing of Environment, 24, pp. 85-108.

Tucker, C.J., C. Vanpraet, M.J. Sharman; and G. Van Ittersum, 1985. Satellite remote sensing of total herbaceous biomass production in the Senegalese Sahel: 1980-1984. Remote Sensing of Environment, 17, pp.233-249.

Wessman, C. A., J. D. Aber, and D. L. Peterson, 1989. An evaluation of imaging spectrometry for estimating forest canopy chemistry. International Journal of Remote Sensing, 10, pp.1293-1316.

Wriggley, R.C., Halvka C.A., Card, Buis J. S., Schowengerdt R. A., 1985. Measurement of Thematic Mapper Data Quality. Machine Processing of Remotely Sensed Data - Quantifying Global Process: Models, Sensor Systems, and Analytical Methods. In: Proceedings of the 11th International Smposium, West Lafayette, IN, June 25-27. Institute of Electrical and Electronics Engineers (IEEE), pp 303-314.

Yuill, Charles B., 1992. Integration of Remote Sensing with Statewide GIS Analysis. The West Virginia Biodiversity Project: USDA Forest Service Conference on Landscape Level Research in the Appalachians. Elkins, West Virginia, March 1992.



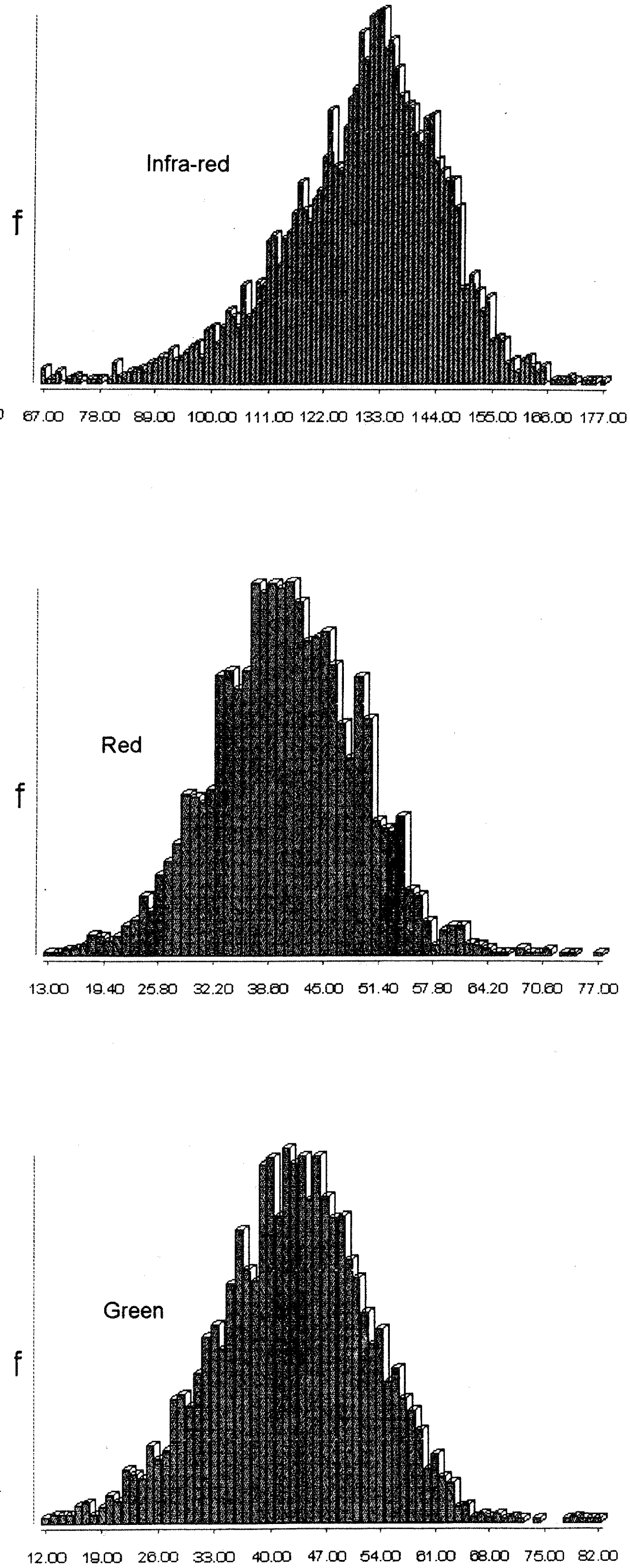


Figure 5 1.6m IFOV in infra-red, red and green of 40% maple and 60% beech.

Figure 6 0.6m IFOV in infra-red, red and green of 40% maple and 60% beech.

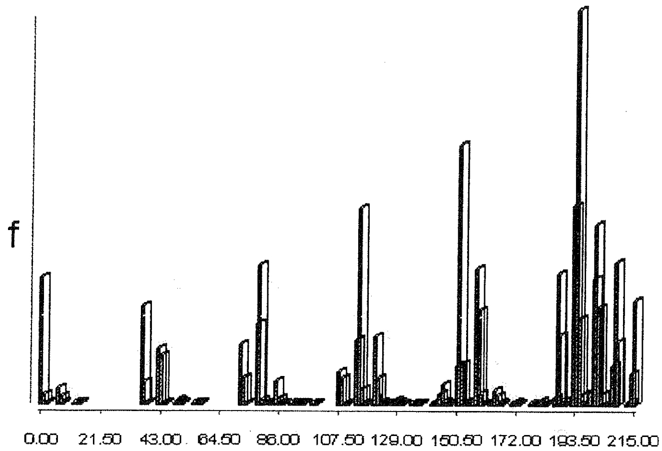


Figure 3 2.6m IFOV in infra-red, red and green composite.

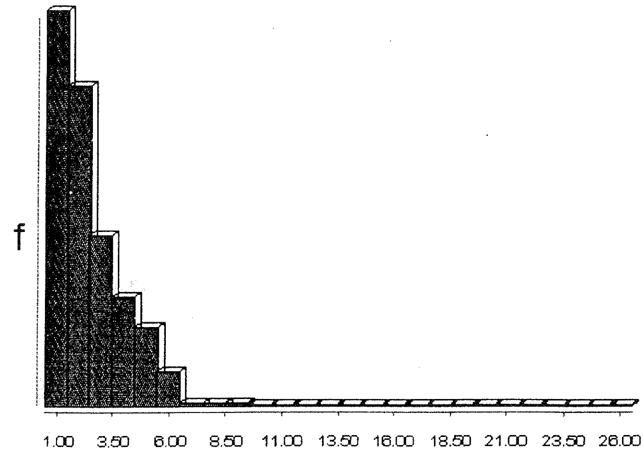


Figure 4 Cluster analysis groupings of raw data at 2.6m IFOV.

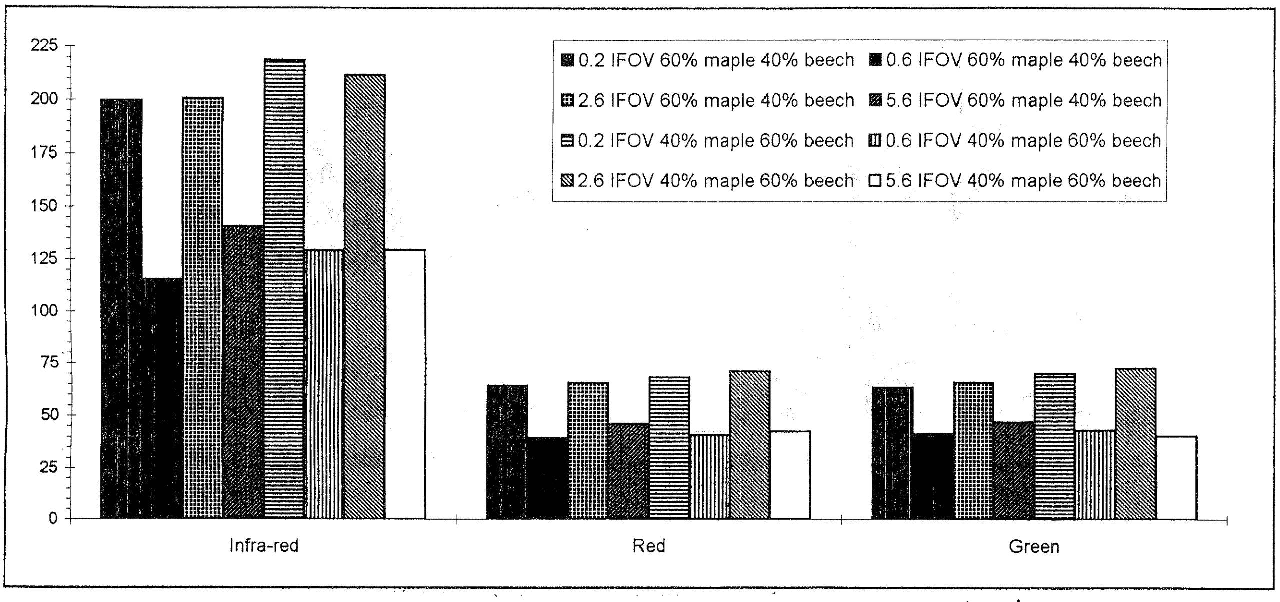


Figure 7 Best Comparative Sample Separation for 60% maple 40% beech and 40% maple 60% Beech at IFOV ranging from 0.2m to 5.6m.

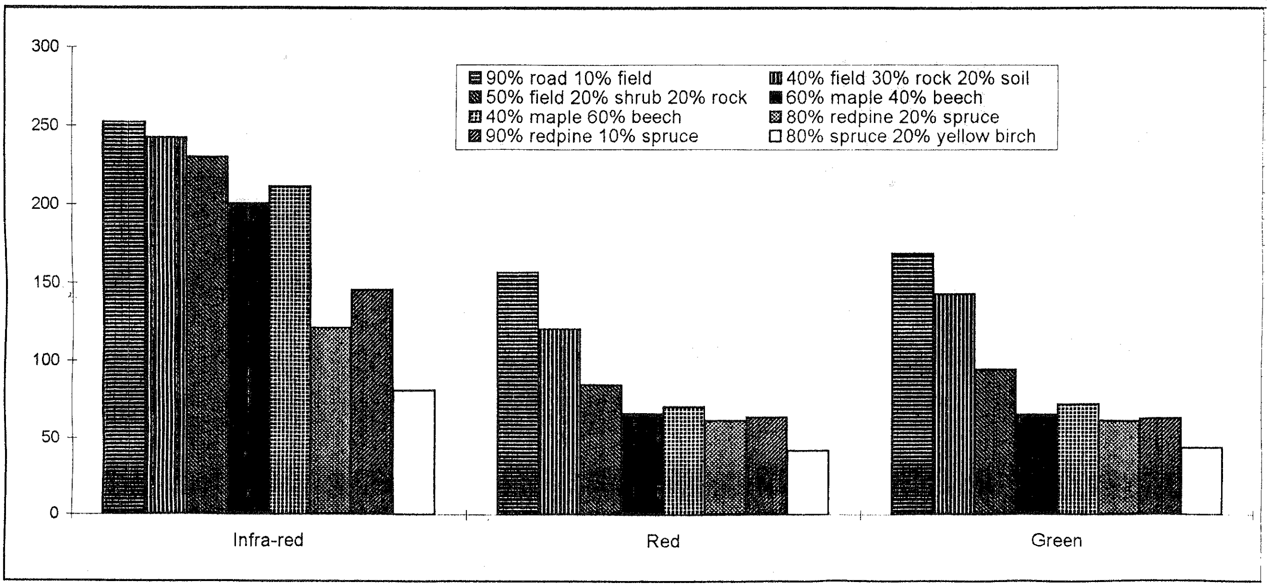


Figure 8 Signature Comparison of all features at 2.6m IFOV.

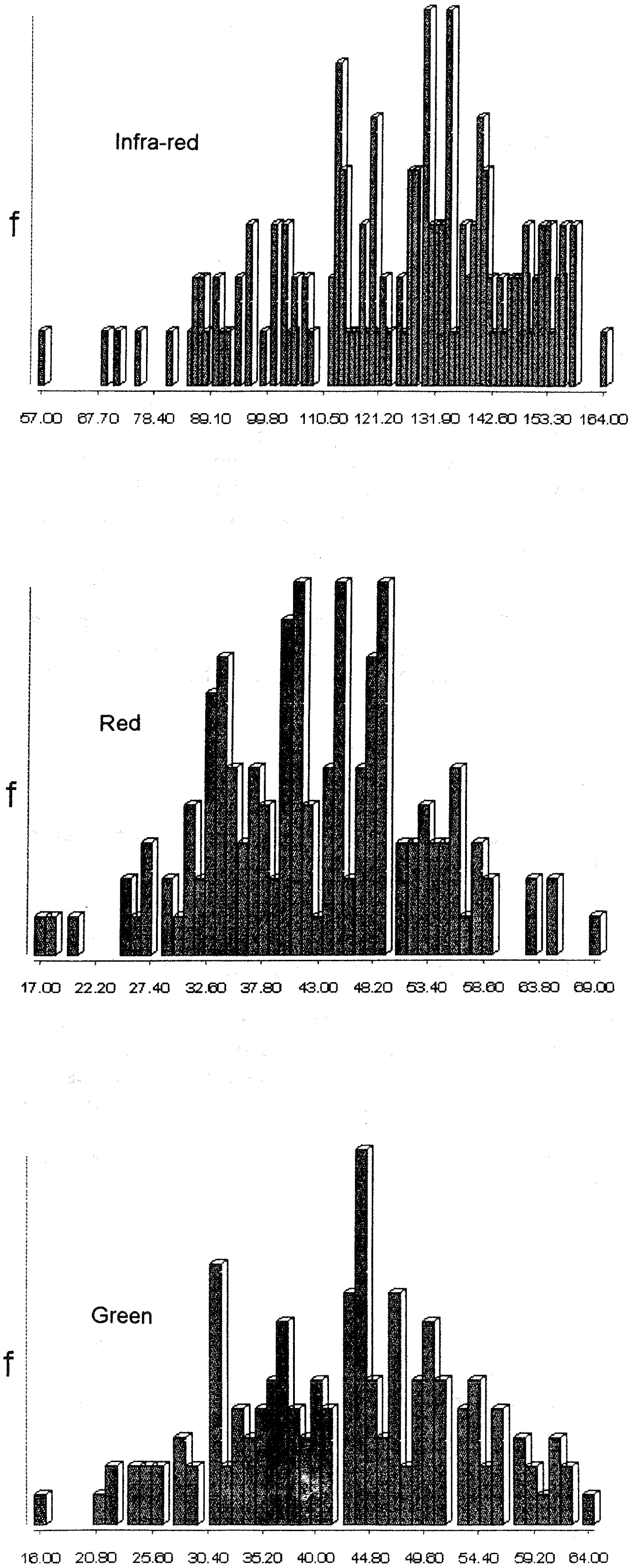


Figure 1 1.6m IFOV in infra-red, red and green of 60% maple and 40% beech.

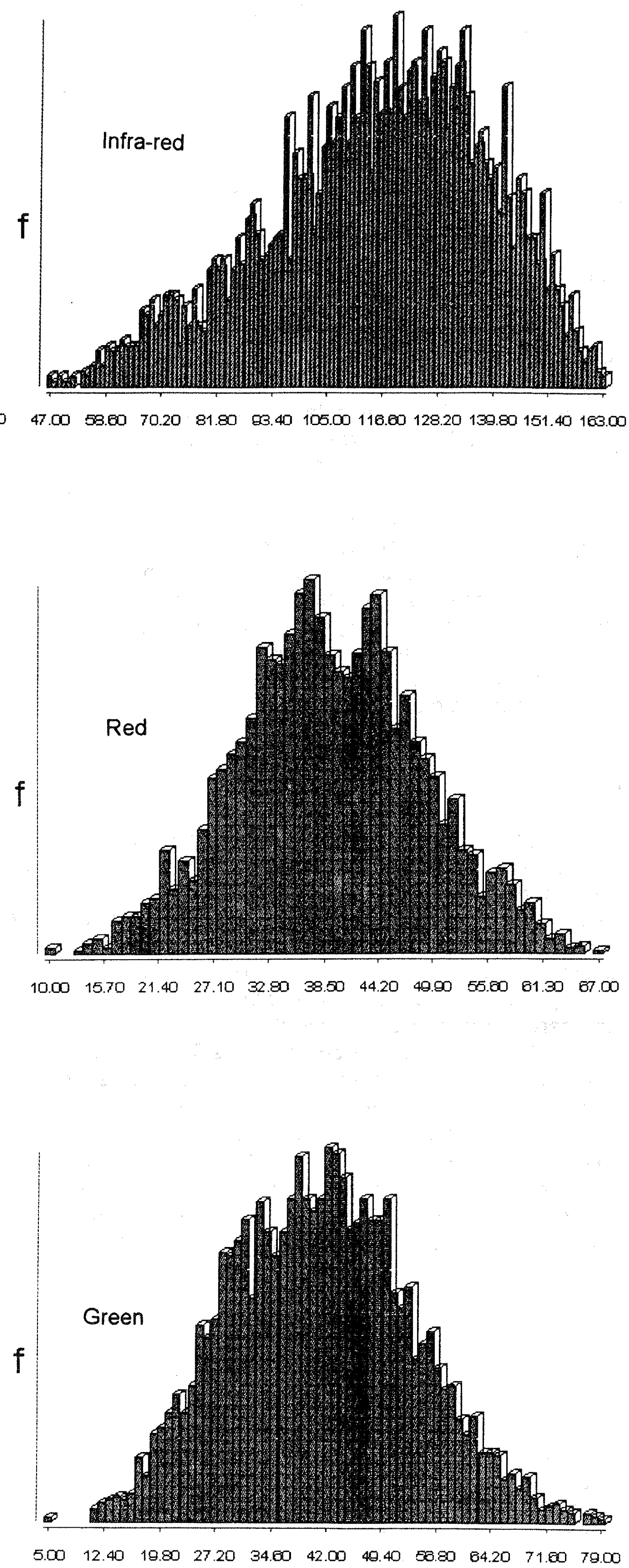


Figure 2 0.6m IFOV in infra-red, red and green of 60% maple and 40% beech.