INTERPRETATION OF DECIDUOUS TREES AND SHRUBS IN CONIFER SEEDLING STANDS FROM LANDSAT IMAGERY

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ABSTRACT

It was studied if the conifer seedling stands with undesirable deciduous trees and shrubs can be delineated from stands without deciduous shrubs. Parallelepiped classification and maximum likelihood classification of Landsat MSS imagery were used. In the interpretation small windows were picked up from the imagery. The windows with the seedling stand to be checked in the middle were picked up automatically by coordinates. Only those windows of the whole imagery were classified. The best results were obtained using the first two principal components calculated of Landsat imagery. The classification accuracy was high with seedling stands exceeding the area of two hectares. The framework for an operational system is presented.

INTRODUCTION

Clear cutting and planting is one of the most used ways to regenerate forest. In boreal areas conifers are usually planted. In Finland about 80 percent of planted area is planted for Scots pine *Pinus sylvestris* L. Scots pine is a light demanding tree and the pine seedlings are threatened by deciduous trees and shrubs, which grow at earlier ages faster and shadow pines. Deciduous trees must be removed once or twice before pines are tall enough to compete with them. In Finland the Regional Forestry Board has to check all the seedling stands after about five years from planting. Some half of pine seedling stands have too much deciduous trees and shrubs and they have to be checked again after putting in order.

It was studied if conifer seedling stands with harmful deciduous trees and shrubs can be delineated from stands without deciduous shrubs with numerical interpretation of Landsat imagery. In a positive case it was assumed that ground work could be diminished.

Interpretation of tree species and species groupings from Landsat imagery is a common application. Bryant et. al. (1980) have got accurate results in estimating areas of softwood, hardwood and mixed wood but in test point sampling the accuracy was much lower. Mayer (1981) has interpreted four conifer species groupings with the overall accuracy of 88 percent in test point sampling. Shimabukuro et. al. (1980) have reached over 90 percent accuracy in supervised interpretation of Pine (*Pinus* spp.) and *Eucalyptus* spp. regeneration areas. All trees were under 20 years old in this study.

Conifers differ from deciduous trees especially in the near infrared area of the spectrum (Kharin 1973, Kalensky and Wilson 1975). This difference is caused by different cellular structure (Hildebrant 1976). If the amount of deciduous trees in a seedling stand is to be estimated one must find spectral values which separate biomass classes of deciduous trees. Several authors (Tucker et. al. 1975, Tucker 1979, Ajai et. al. 1983) have noted a high negative correlation between the biomass, clorophyl content and red light reflectance and corresponding positive correlation in the near infrared reflectance. Reflected radiation from a seedling stand is a complex composition of reflectances of many plant species. Deciduous trees and conifers have usually only partial crown closure in the seedling stands and the lesser vegetation influences the radiation. The radiation of a seedling stand depends on the history of the stand and on the richness of the site type. The whole vegetation cover, trees as well as the lesser vegetation , reflects the site type (Kharin 1973, Hildebrant 1976, Jaakkola and Saukkola 1980).

MATERIALS AND METHODS

Ground truth data

The study area is situated in Southern Finland (61° 00` N - 61° 50` N, 22° 45` E - 24° 45` E, total area about 8 200 sq. km). It nearly encompasses the area of the Regional Forestry Board of Pirkka-Häme. The annual regeneration area of the private properties in Pirkka-Häme is about 7 000 hectares. The Regional Forestry Board of Pirkka-Häme provided so called regeneration plans of about one hundred seedling stands. These five to seven years old stands were a part of regeneration areas to be checked by the Forestry Board in 1982. They were taken for potential ground truth areas. Seedling stands were selected all over the in study area and they had to have a minimum area of two hectares and a minimum dimension of about one hundred meters. This restriction was placed because of the coarse resolution of Landsat MSS. The regeneration plans included among other things the area of the stand, the site type, planted species, the year of regeneration cutting, and a map of the stand.

The potential ground truth areas were delineated on 1 : 60 000 panchromatic aerial photographs and 36 of the total one hundred were field checked. The species, abundance and length of deciduous trees and shrubs and the corresponding information of conifer plants were registered of ground truth areas. In addition to this the site type and species composition of lesser vegetation were checked. In over two thirds (69 percent) of ground truth areas the deciduous shrubs hampered conifer plants so much that the regeneration area was in unsatisfactory condition (figure 1).

Phases of interpretation

The interpretation methods used were: 1) Parallelepiped classification with Landsat MSS bands 5 and 7, 2) Parallelepiped classification with the first two principal components calculated of

Figure 1. A typical pine seedling stand with harmful deciduous shrubs and small trees. Most common species are Betula pubescens Ehrh., B. pendula Roth., Sorbus aucuparia L. and Alnus incana Moench, Willd.

Landsat imagery, and 3) Maximum likelihood classification with all four Landsat MSS bands. The Landsat 3 MSS imagery, path 205, row 17, used was acquired on 12th August 1982. It was processed with a Nova-Comtal color display system.

Principal components were calculated before ground truth area selection. The first component explained 93 percent of the variance of all bands while the second explained 5 percent. Pixel values of ground truth seedling stands were selected on monitor with a cursor and statistics (means and covariances) were calculated. The means were also marked on two cross tabulations. One cross tabulation was made from MSS bands 5 and 7 and the other from the first two principal components. Three classes for regeneration areas were delineated on cross tabulations: 1) deciduous trees and shrubs harmless (referred to as "harmless") 2) "possibly harmful" and 3) "harmful". The spectral boundaries of classes were found according to the field contents of ground truth areas.

For maximum likelihood classification the Bhattacharyya-distances or B-distances (Fukunaga 1972) between ground truth areas were calculated from means of MSS bands and covariances between bands. These distances were then grouped and plotted as a graphic dendrogram. In the dendrogram the stands combine according to their mutual B-distance. By means of grouping one could find the classes corresponding to the parallelepiped classification. The pixel values of ground truth areas within a spectral class were combined and new statistics were calculated. Thus each class had statistically sufficient amount of pixels. All of the hundred ground truth areas (field checked and not field checked) were included in the grouping.

Classification

The Landsat image was rectified to the base map coordinate system prior to classification and resampled to a 50 m x 50 m pixel size. For test classifications the Regional Forestry Board of Pirkka-Häme sent map coordinates of 50 regeneration stands which had the same area and dimension restrictions as ground truth areas, and coordinates of 50 regeneration areas with no restrictions.

Test stands were selected according to the base map coordinates from rectified Landsat imagery. A computer program picked up windows of 15 x 15 pixels in side with the test stand in the middle. It stored the stands one after another to a file. This file, referred to as window file, was then classified and the results were plotted with a Versatec grey tone plotter to scale 1 : 20 000.

Test stands were delineated on aerial photographs in scale 1 : 60 000. Altogether 67 test stands were field checked. Of those stands 43 were from the group with minimum area restriction and 24 from the group with no restrictions. From test stands information was collected corresponding to that from ground truth areas.

RESULTS AND DISCUSSION

Spectral classes

The classes had wider variation in reflected red light (band 5) in maximum likelihood classification than in parallelepiped classification of band 5 and 7 (figure 2). Band 5 does not seem to separate deciduous tree classes but it is useful in separating the regeneration areas from their surroundings. On the contrary both principal component bands separate deciduous shrub classes (figure 3).

Band 7/5 ratio was also calculated from means of maximum likelihood classes. They showed that band 7 alone separates the deciduous tree classes much better than the IR/red ratio. The IR/red ratio may measure more the total biomass than the biomass of deciduous trees alone.

Test stands

If only a single pixel had been classified to the class "harmful" the condition of seedling stand regarded as unsatisfactory. From this starting point all the classifications in figure 4 are equally good although they differ in details. The examples show how great a deal of surroundings was classified in seedling stand classes in maximum likelihood classification. It was due to the wide range of spectral values in band 5 and made difficult the exact delineation of the stand. The cautiousness of the band 5 and 7 parallelepiped classification can also be seen. The class "possibly harmful" encompasses a great proportion of the

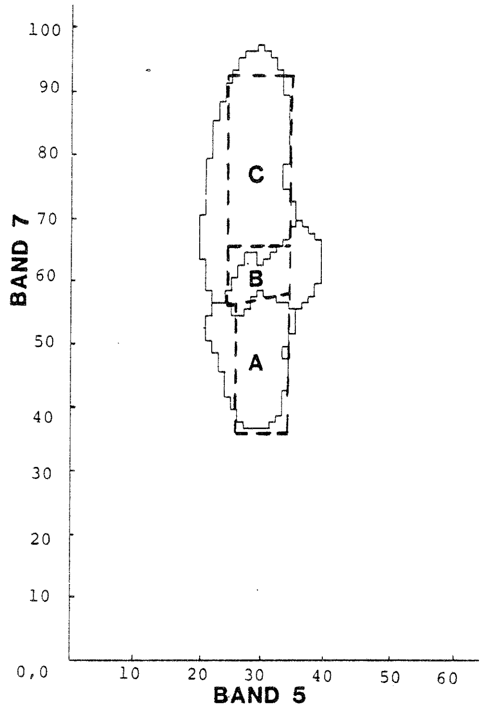


Figure 2. Boundaries of parallelepiped classification from MSS bands 5 and 7 - broken line and the boundaries of maximum likelihood classification - continuous line (if only two bands had been used). Deciduous shrubs: A - harmless, B - possibly harmful, C - harmful.

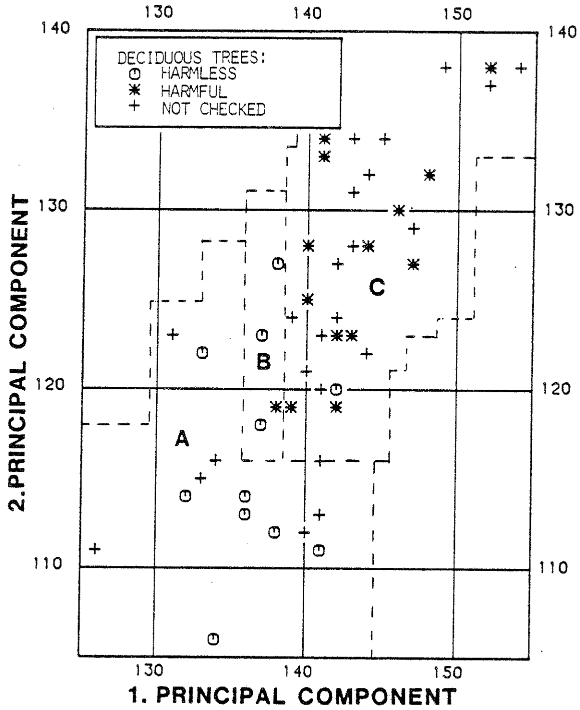
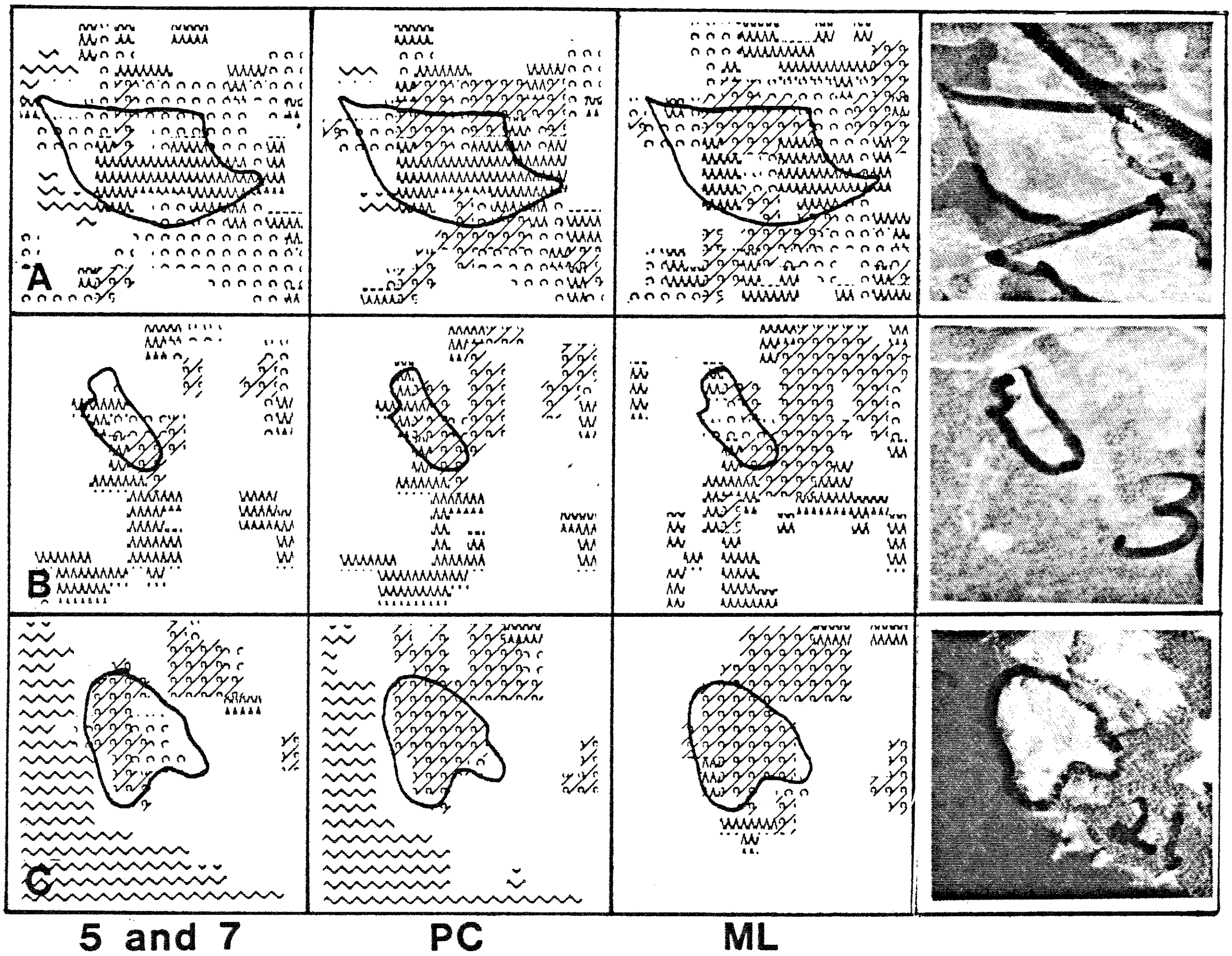


Figure 3. Boundaries of parallelepiped classification from principal components and the means of ground truth areas. Deciduous shrubs: A - harmless, B - possibly harmful, C - harmful. 5

area. This class was chosen wider in band 5 and 7 classification than in principal component classification. The differences between those two classifications can be caused more by the subjective choosing of class boundaries than by the differences in input data.

Similar field and Landsat classification results cover about 80 percent of the seedling stands observed (figure 5). The highest overall accuracy has been achieved with maximum likelihood classification and the lowest with band 5 and 7 parallelepiped classification. Maximum likelihood classification has registered deciduous trees most sensitively. This has also caused that seedling stands in good condition have been classified "harmful" (FIELD OK, S NOT OK in figure 5). About 10 percent of test stands could not be localized exactly or were rejected for other reasons.

The shape and the internal variation of the seedling stand was distinguished better in parallelepiped classifications, especially in principal component classification, than in maximum likelihood classification. The successful use of maximum likelihood classification would need digitized boundaries of seedling stands and spectral classes for surroundings of stands, too. It may be complicated for operational use.



Deciduous trees:

Harmless

Possibly harmful

Harmful

Water (not registered in maximum likelihood classification)

Figure 4. Examples of classification results. Field observations: A) Southern part of seedling stand rocky, northern part richer site type with harmful deciduous shrubs. B) Rocky stand with a lot of deciduous shrubs and peat formation. C) Deciduous shrubs harmful. Boundaries of stands drawn manually. Scale 1 : 20 000.

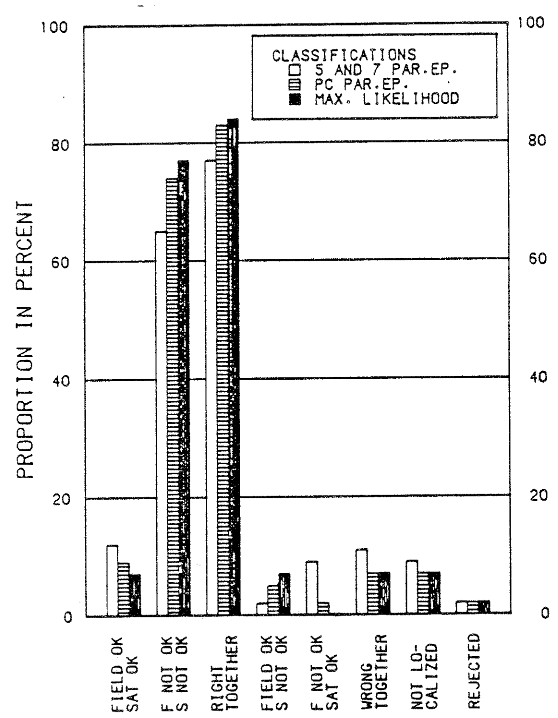


Figure 5. Proportion of correct and incorrect classifications by 43 test stands. FIELD OK -deciduous shrubs harmless in field observation, SAT OK - deciduous shrubs harmless in Landsat classification, F NOT OK - deciduous shrubs harmful in field observation, S NOT OK - deciduous shrubs harmful in Landsat classification. RIGHT TOGETHER - correct Landsat classifications together, WRONG TOGETHER - incorrect Landsat classifications together.

On poorer sites, particularly if they were stony and rocky, the amount of deciduous trees and shrubs was often underestimated (stand B in figure 4). Rock has a high red reflectance but low near infrared reflectance. The lesser vegetation on barren sites, e.g. Calluna vulgaris L. and Vaccinium vitis-idaea L. twigs and lichens such as Cladonia spp., also has quite high red reflectance and low near infrared reflectance. The lesser vegetation on barren sites, rock, and deciduous shrubs altogether cause radiation similar to stands without deciduous shrubs, although the shrubs can be harmful.

On richer sites, the typical vegetation is dominated by grasses such as Deschampsia spp. and Calamagrostis spp. They seem to have higher red and lower near infrared reflectance than deciduous trees particularly in late summer when they are partly red brownish in color. The reflectance is, however, more similar to deciduous trees than the reflectance of twigs and lichens.

The proportion of correct classifications was some 20 percent lower by the test stands which had no minimum area restrictions. That was due to the considerable proportion of small stands (about one hectare). The mixed pixels occasioned a stand with harmful amount of deciduous shrubs to be classified to the class "harmless".

In general, the best results were obtained with parallelepiped classification of the first two principal components. The original MSS bands would have been as good in parallelepiped classification if the spectral boundaries had been chosen otherwise. An operational method can be based on these results but practical forestry needs better spatial resolution. Stands under two hectares must be correctly classified. New images (like Thematic

Mapper) make possible the application of spatial classification programs, which will be useful in delineating seedling stands from their surroundings.

FRAMEWORK FOR AN OPERATIONAL METHOD

The Regional Forestry Board makes a file of the map coordinates of seedling stands to be checked. Some administrative alpha-numerical data is also included in the same file. The interpretation has the same phases than in this study. Parallelepiped classification of principal components is used. The spectral boundaries of classes are delineated according to the pixel values of ground truth areas. The window file which has the stand to be checked in the middle of every window is created and classified. It is plotted with administrative data by a matrix plotter in scale 1 : 20 000.

A photomap for field checking is made from the red light band. The red light band of the area of the Regional Forestry Board is rectified. The classified stands are marked digitally on the image. The image is plotted with a film scanner to negatives. Negatives are magnified to copies in scale 1 : 50 000. The testing of Landsat classification follows the principles of sequential sampling (Loetsch and Haller 1973). First, all seedling stands are checked. If the field checkings show that the classification of satellite imagery can diverge e.g. stands with harmful deciduous shrubs, one leaves out stands with this class from later checkings.

REFERENCES

Ajai, Kamat, D. S. Chatuvedi, G. S. Singh, A. K. & Sinha, S. K. 1983. Spectral Assessment of Leaf Area Index, Clorophyll Content, and Biomass of Chickpea. Photogramm. Eng. Remote Sensing 49(12), pp. 1721 - 1727.

Bryant, E., Dodge, A. G. Jr. & Warren S. 1980. Landsat for Practical Forest Type Mapping: A Test Case. Photogramm. Eng. Remote Sensing 46(12), pp. 1575 - 1584.

Fukunaga, K. 1972. Introduction to Statistical Pattern Recognition. Academic Press. 369 p.

Hildebrant, G. 1976. Die Spektralen Reflexionseigenschaften der Vegetation. XIV IUFRO World Congress, Subject Group 6.05. Oslo 20.6. - 2.7. 1976. Oslo. Pp. 9 - 22.

Jaakkola, S. & Saukkola, P. 1980. Spectral Signatures of Field Layers and Canopies of Pine Forest Stands in Northern Finland. International Society of Photogrammetry, 14th Congress, Hamburg 13. - 25.7. 1980. International Archives of Photogrammetry 23(B7), Commission VII. Pp. 567 - 579.

Kalensky, Z. & Wilson D. A. 1975. Spectral Signatures of Forest Trees. Third Canadian Symposium on Remote Sensing, Edmonton, Alberta 22. - 24.9. 1975. 18 p.

Kharin, N. G. 1973 Spectral Reflectance Characteristics of the U.S.S.R. Main Tree Species. Proc. Symp. IUFRO S. Freiburg. 20 p.

Loetsch, S. & Haller, K. E. 1973. Forest Inventory I. Muenchen. 436 p.

Mayer, K. E. 1981. Identification of Conifer Species Groupings from Landsat Digital Classifications. Photogramm. Eng. Remote Sensing 48(11), pp. 1607 - 1614.

Shimabukuro, Y. E., Hernandez Filho, P., Koffler, N. F. & Chen, S. C. 1980. Automatic Classification of Reforested Pine and Eucalyptus Using Landsat Data. Photogramm. Eng. Remote Sensing 46(2), pp. 209 - 216.

Tucker, C. J. 1979. Red and Photographic Infrared Linear Combinations for Monitoring Vegetation. Remote Sensing of Env. 8, pp. 127 - 150.

Tucker, C. J., Miller, L. D. & Pearson, R. L. 1975. Shortgrass Prairie Spectral Measurements. Photogramm. Eng. Remote Sensing 41(9), pp. 1157 - 1162.