Use of Airborne MSS and Landsat-TM Data for Monitoring and Forest Decline Inventory

A. Kadro
Abt. Luftbildmessung und Fernerkundung der
Universität Freiburg
Werderring 6
D-7800 Freiburg

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Abstract

TM-simulation data were acquired from different altitudes within the scope of a project for forest damage inventory in the Black Forest in Germany. The evaluation of the TM-simulation data will be the base for the analysis and the computer aided classification of Landsat-TM data. Different investigations of the spectral signatures, computer aided classification (supervised) and ratio image analysis on different TM bands have been carried out. Thereby it was possible to classify different degrees of forest decline and also different types of vegetations. Ground truth and the results of IRC photo interpretation were the basis for the verification of the results of the computer aided classification.

1- Introduction

Since the forest decline has been increasing for the last ten years in Middle and Western Europe, the need for detailed information on the actual situation of the forest in Germany has proved to be of vital interest. Therefore remote sensing appears to be the most convenient tool for the monitoring and quantification of the forest decline. Ground and aerial survey methods are time-consuming and expensive. That is why a project started at the Department of photo interpretation and Remote Sensing at the University of Freiburg to evaluate multispectral data for forest damage inventory. This project ist dealing with research as regards the application of the Landsat-TM data for the monitoring and survey of forest decline after encouraging results achieved through TM simulation (Hildebrandt, Kadro et al. 1987; Kadro et al. 1986).

2- Test Sites

The same test sites already covered by TM simulation during the ongoing project conducted at the department, have also remained the subject of analysis with TM-data. These test sites are located in the Black Forest (South-West-Germany).

They differ in morphology, forest types and the degree of the actual forest damage to simulate all possible survey problems. The sites contain mostly coniferous trees (spruce mixed with fir) and some smaller stands of deceduous trees (mostly beech). The main interest in this project is the monitoring of coniferous trees. The damage classes differ according to age, altitude exposure in the different test strips. The damage symptoms mainly consist in needle loss and chlorosis, at times both symptoms appear together. According to the percentage of the needle loss the damage classes are beeing determined in the following classes (tab. 1)

Tab.1

healthy	D0 = 0 - 10%	needle loss
sickly	D1 = 10 - 25%	" "
damaged	D2 = 26 - 60%	" "
severely damaged	D3 = > 60%	" "

3 - Available Basic Information

The data and informations available about the test strips are the following:

3.1 - TM-Simulation Data were acquired in July 1984 and August 1985 from different altitudes; 300; 1000 and 3000 meters above ground. The Landsat-TM data (scene 195/27, 12.09.85) were acquired at approximately the same time as the TM-simulation.

The differences as to the dates of acquisition between the data obtained being so slight a comparison between TM-Simulation and Landsat-TM data is made possible. The different altitudes have the following ground resolution (pixel size) tab.2.

Tab.2:

at 300m	altitude	0.75x0.75m	(aircraft TMS)
at 1000m	altitude	2.5 x2.5 m	"
at 3000m	altitude	7.5 x7.5 m	"
at 705km	altitude	30 x 30 m	(Landsat 5)

3.2 - Ground Truth

A lot of test areas have been established alongside the test strips (photo 5). The respective size of each test area is between 2 and 40 ha. Information on the vitality of the trees in each test area has been collected through ground check by means of line samples along the test area.

3.3 - IRC Photo Interpretation

IRC photography in scale 1:5000 was also available for the test strips; these photographs were taken at approximately the same time as TM-simulation and Landsat-TM data. The vitality of the trees in each test area has also been determined by photointerpretation and also by means of line samples. An interpretation key has been developped for the photo interpretation.

4 - Results of Spectral Signature Analysis

The advantage of the TM data is that they have additional to the other bands in the visible and near Infrared two spectral bands in the middle Infrared. Till now they have not been investigated and proved to analyse the spectral signature of different forest damage classes.

Fig.1 illustrates clearly that not only in the near Infrared, but also in the middle Infrared there are information about the reflection properties of different vegetation types. This could be an additional advantage for the computer-aided classification.

For the selection of a certain TM band for computer classification certain investigations should be carried out in an two-dimensional feature. Fig. 2-3 show such kinds of investigation. Each cluster in the figures contains the middle grey value and the standard deviation for different vegetation types.

The reflection intensity in the visible bands is too small for all levels, but on the other hand the different vegetation types have a low reflection in the visible bands (Kadro 1981, Kadro 1986, HILDEBRANDT and KADRO et al. 1987, WASTENSON et al. 1987).

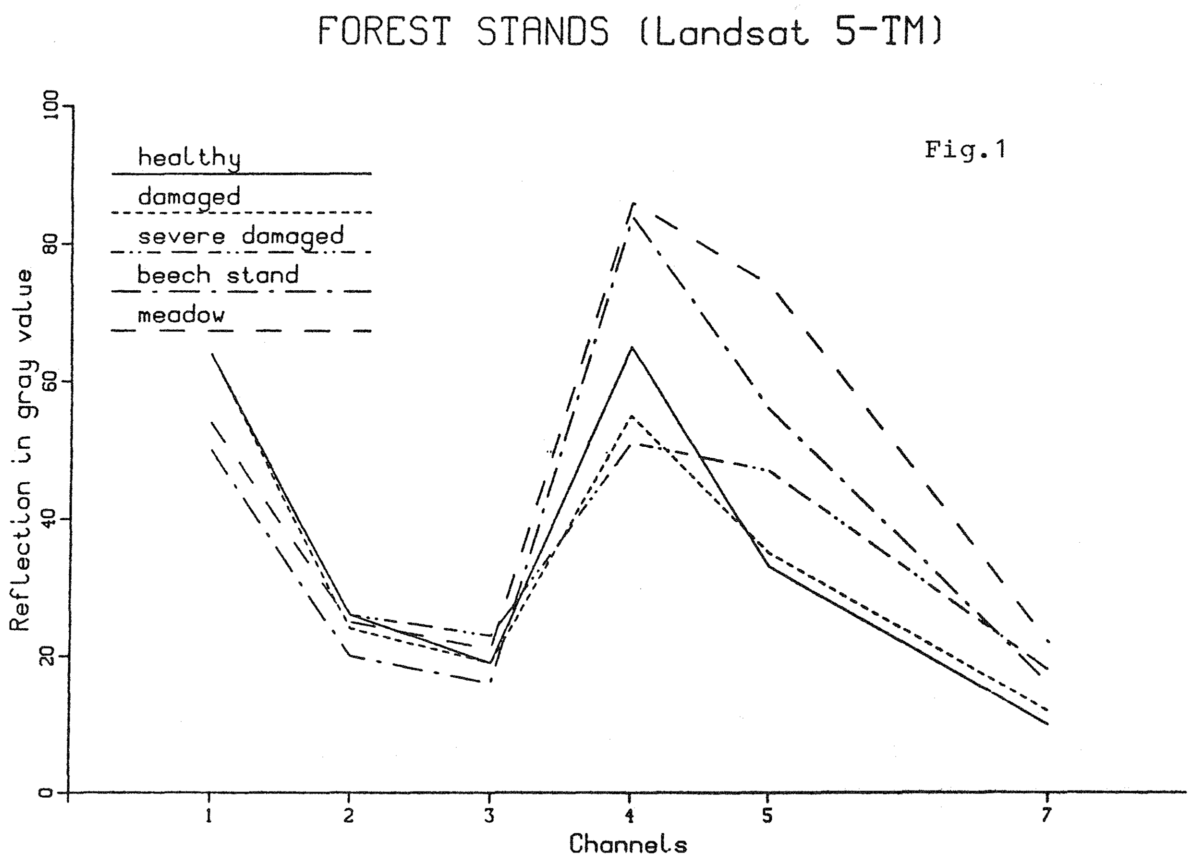


Fig.1

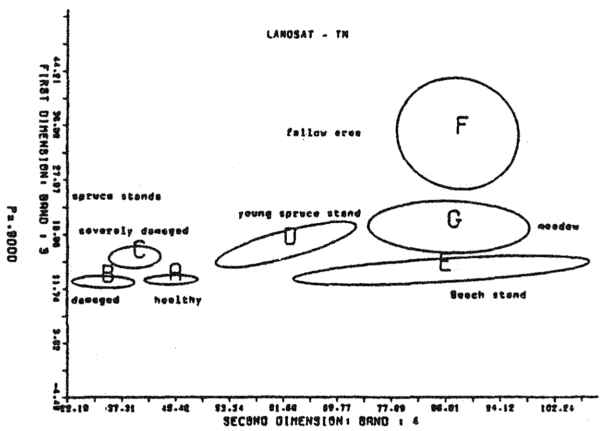


Fig.2

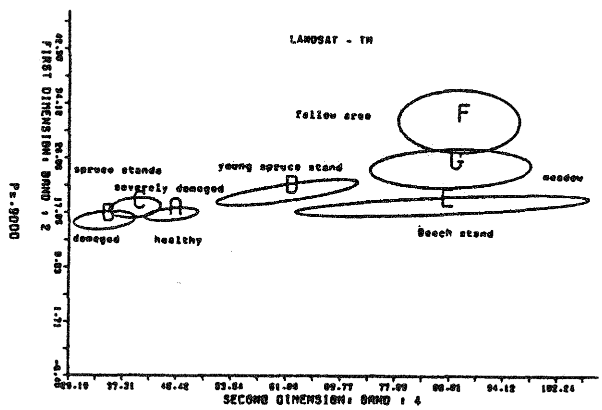


Fig.3

5 - Results of Computer-aided Classification

TM-Simulation data and Landsat-TM data were evaluated simultaneously in this pilot project in order to test the practicability of these data for forest decline survey. The data having been acquired during ideal weather conditions they consequently haven't been atmospherically corrected.

The main difference between the data acquired is the pixel size (ground resolution) tab.2. It is only possible to investigate single trees from low altitudes; but data from other altitudes allow for the investigation of groups of trees or stands. As a consequence the greyvalue of the pixel does not present a single crown, but represents the reflection of all the components in the pixel size; thus resulting in the formation of mixed signatures. It is decisive for computer-aided classification which component is dominant in a pixel, thus determining the allocation of the pixels.

The spectral properties of the stands are being influenced by the following aspects (Kadro 1981):

- the phenological and physiological situation of the trees
- the vertical structure of the canopy and the relation between illuminated and unilluminated portions of the crowns
- species composition
- crown density and ground cover

The problem with the mixed pixel is obvious at Landsat-TM data; although Landsat-TM has a high ground resolution each pixel covers an area of 900m². In this case only large areas can be investigated and sensed. To achieve an appropriate computer-aided classification the area to be classified should be homogenuous. For the more inhomogenuous the reflection characteristics of an area may be, the more difficult will be the unequivocal allocation to a specific class by the computer.

5.1 - Determination of the Training Area for the Supervised Classification

Determination of the training area on the digital images occur by the user and with already available information through ground truth, IRC photo interpretation and the interpretation of the color Composition directly on the screen. Determination of the training area for deciduous trees, Coniferuous trees, grass land, water surface etc... is not so difficult, but to determine the training area for different damage classes among the Coniferuous trees is not so easy for the user.

The experience and the knowledge of the spectral signatures, interpretation of the digital images of the different forest types and damage levels by the user is a basic essential for the handling with digital image analysis in remote sensing.

5.2 - Results of the Ratio Image Analysis

The first simple handling of the TM Bands for the reconnaissance of the damaged area is the analysis of the ratio TM5/TM4. By this method it is possible to separate the damaged areas from non damaged ones because the damaged areas have a high grey value in this Ratio, due to a higher reflection in TM5 and lower reflection in TM4 than the healthy ones (photo 7).

This kind of ratio does not differentiate between the damage levels, but at least differentiates between healthy and damaged in addition to severely damaged stands. The advantage of this method is that it is easy and not time-consuming, presenting and indicating in general the distribution of the decline.

Apart from the method already described there is still another ratio, and that is the ratio of the vegetation index. This will be obtained through ratio TM4/TM3 (photo 6).

This ratio allows not only for the separation of vegetation areas from non-vegetation areas, but for the distinction even between deceduous and coniferuous trees, gras land or agricultural areas.

It is possible to use this vegetation index ratio as an auxiliary band in addition to the Landsat-TM band set. In this case there is a facility to do a computer-aided classification with different TM bands, but in dependence on the auxiliary bands (ratio of vegetation index) and on certain vegetation types. In this way the misclassified pixels could be reduced by this method.

5.3 - Results of the Supervised Classification

The main evaluation method in this project is a supervised classification according to the maximum likelihood method. All investigated data sets from different altitudes have been classified with this methodology. The most important step in this method is to determine an exact training area for forest damage levels and to select different spectral TM bands for the calculation with the computer; at the evaluation of different data sets the fact has been taken into consideration that the data sets should cover the same area. Therefore the comparison of the data from different altitudes is made possible.

The main task of the user was to classify the different forest damage levels among the coniferuous trees but other classes in the data sets have also been classified such as decedious trees, roads, bar soil etc. in order to render it possible for the forest departments to compare with their own available forest maps. The photos (2,3,4,8) illustrate the results of examples of one test sites which have been classified through a supervised computer-aided classification method.

5.4 Analysis of the Results of the Supervised Computer Aided Classification

The results obtained from different data sets have been analysed by comparison with information obtained through ground truth or with results of IRC photo interpretation. All the trees in each test area have been counted according to different damage levels, and their respective numbers in percentage have been calculated (results of IRC photo interpretation and grand truth).

As regards the case of the classified data sets however, the pixels have also been counted in each test area also according to different damage classes, and their respective numbers in percentage have been calculated. Both figures of percentage (photo interpretation and classification results) have been set off agains and compared with each other. The verification of the computer classified results is illustrated for some test areas in form of histogrammes (fig.4,5). Actually that is respective to the distribution of damage degrees and different data sets according to the differring acquisition of the data sets from different altitudes.

Photo 1

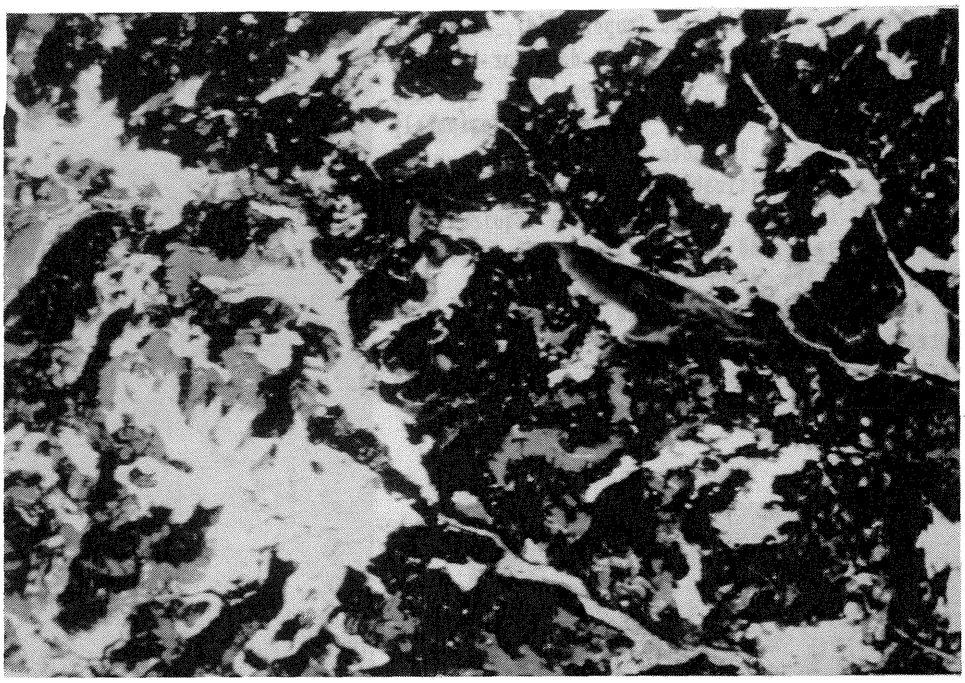


Photo 2

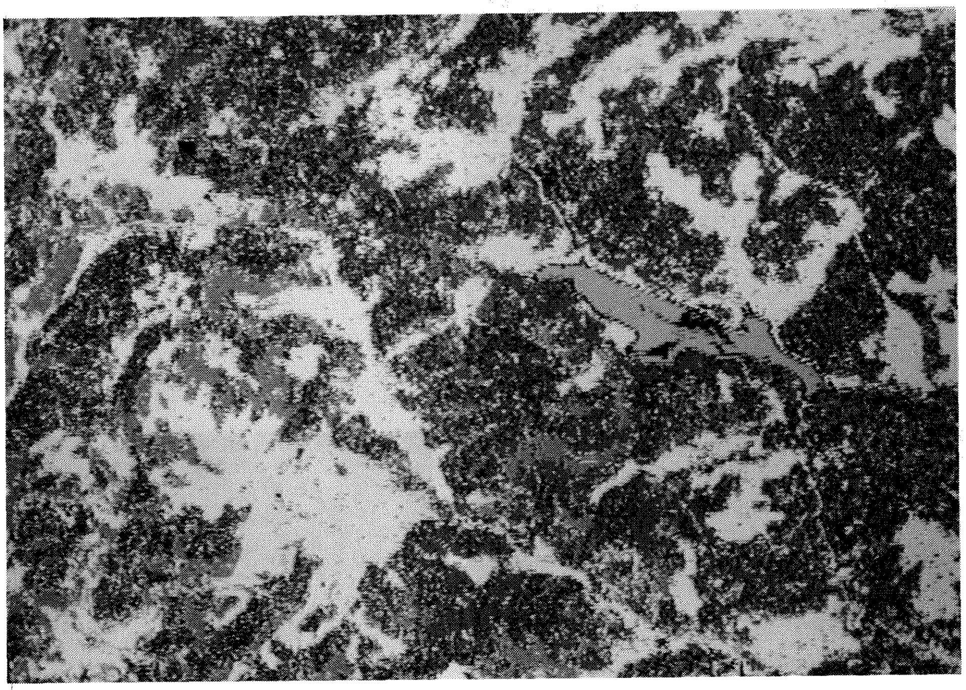


Photo 1: Landsat-TM imagery, IR Color composite from band 2,3 and 4, showing the test site St. Blasien - South Black Forest, acquired on September 12th 1985, covering approximately 15x21km.

Photo 2: Computer-classification of the area in photo 1 (supervised classification, bands 2,3,4,5 have been used).

Identification key (Photo 2)

color	vegetation/terrain type
green:	healthy conifer
dark blue:	damaged conifer
red:	severely damaged forest
orange:	deciduous forest
light blue:	water surface
white:	meadow, agriculture, roads

Photo 3: Computer classification (supervised), Thematic Mapper simulator (TMS) aircraft scanner data for the test site St. Blasien, data are acquired from 1000m altitude above ground on Aug. 22nd 1985, covering approximately 1.75x5km, color coding as in photo 2.

Photo 4: Computer classification (supervised), TMS data also for the test site St. Blasien. Data are acquired from 3000m altitude above ground on Aug. 22nd 1985, covering approximately 4.5x4.5km, color coding as in photo 2.

Photo 5: shows the test areas on the IR color composite. The information in these test areas will be used for the verification of the computer classification results (see chapter 3.2).

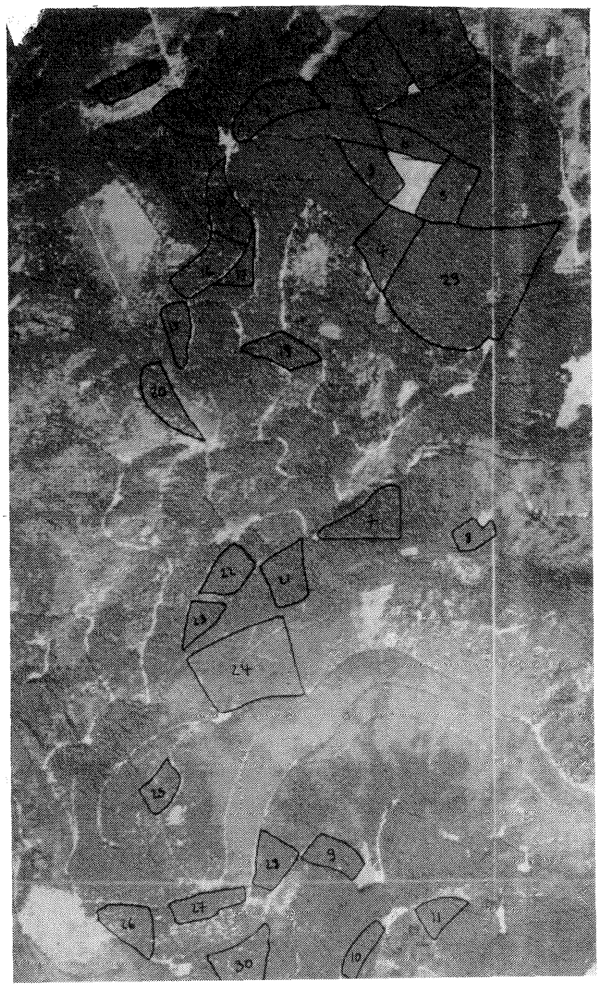
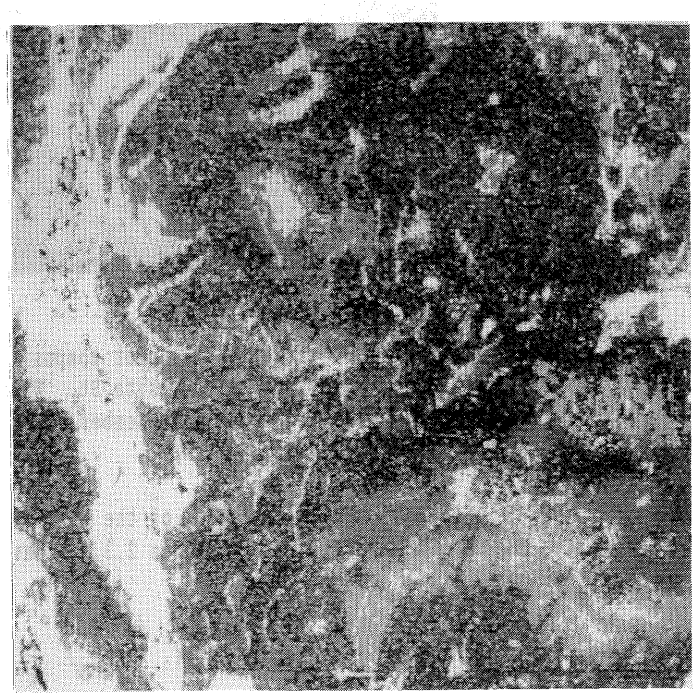


Photo 5

Photo 3

Photo 4



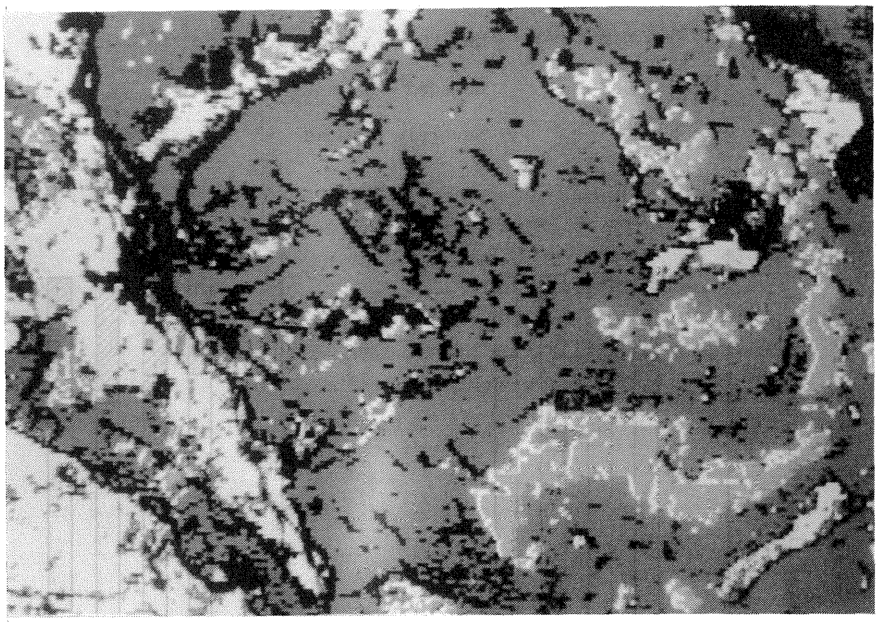


Photo 6: Landsat-TM image from the middle in photo 1, show a ratio image TM4/TM3 near IR band/red band (vegetation index).

Identification key

color	vegetation type
green:	conifer forest
dark blue:	deciduous forest
light blue:	agricultural/grasland

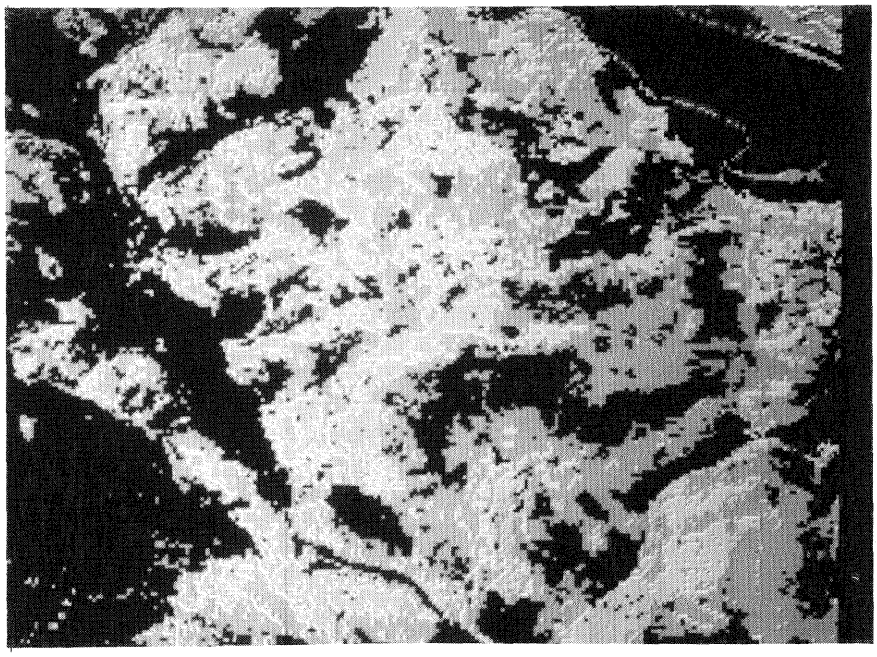


Photo 7: Landsat-TM Ratio image B5/B4 for the area in photo 6

Identification key:

color	vegetation type
green:	healthy conifer forest
red:	damaged conifer forest
black:	non conifer forest area

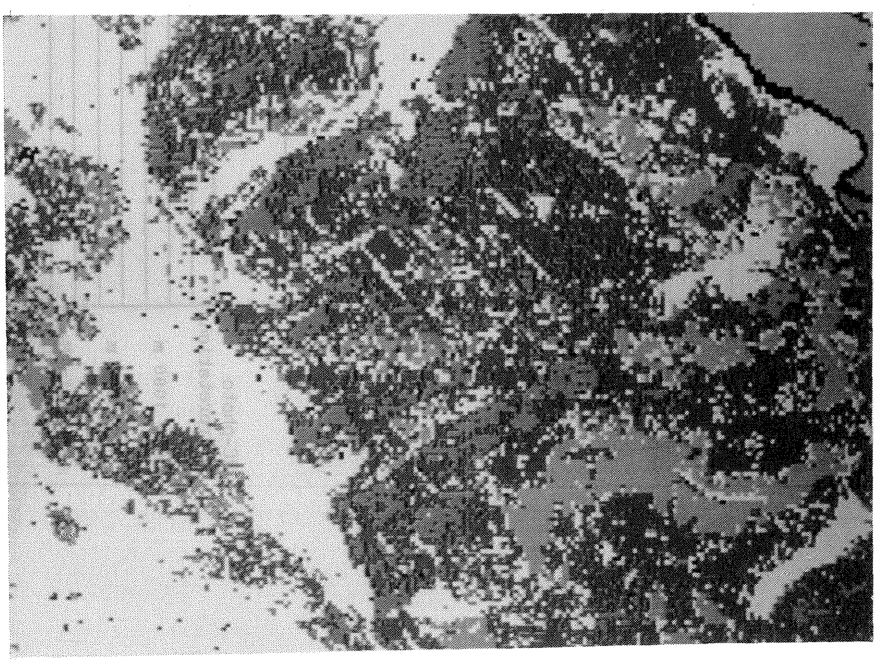


Photo 8: Computer classification (supervised) of Landsat TM data for St. Blasien test site, band 2,3,4 and 5 have been used. The area is the same as photo 6 and 7 and covering the area in photo 3 and 4.

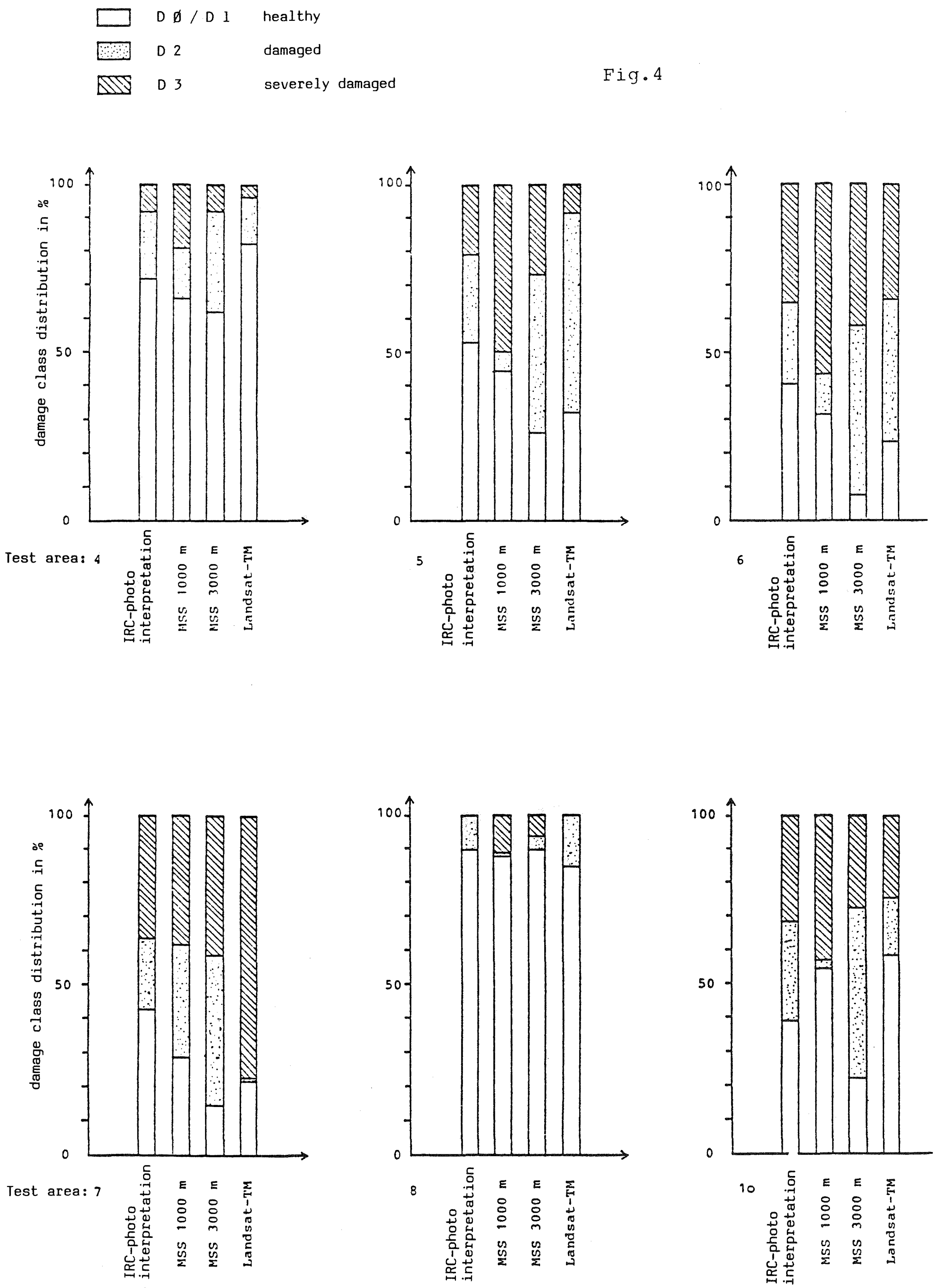
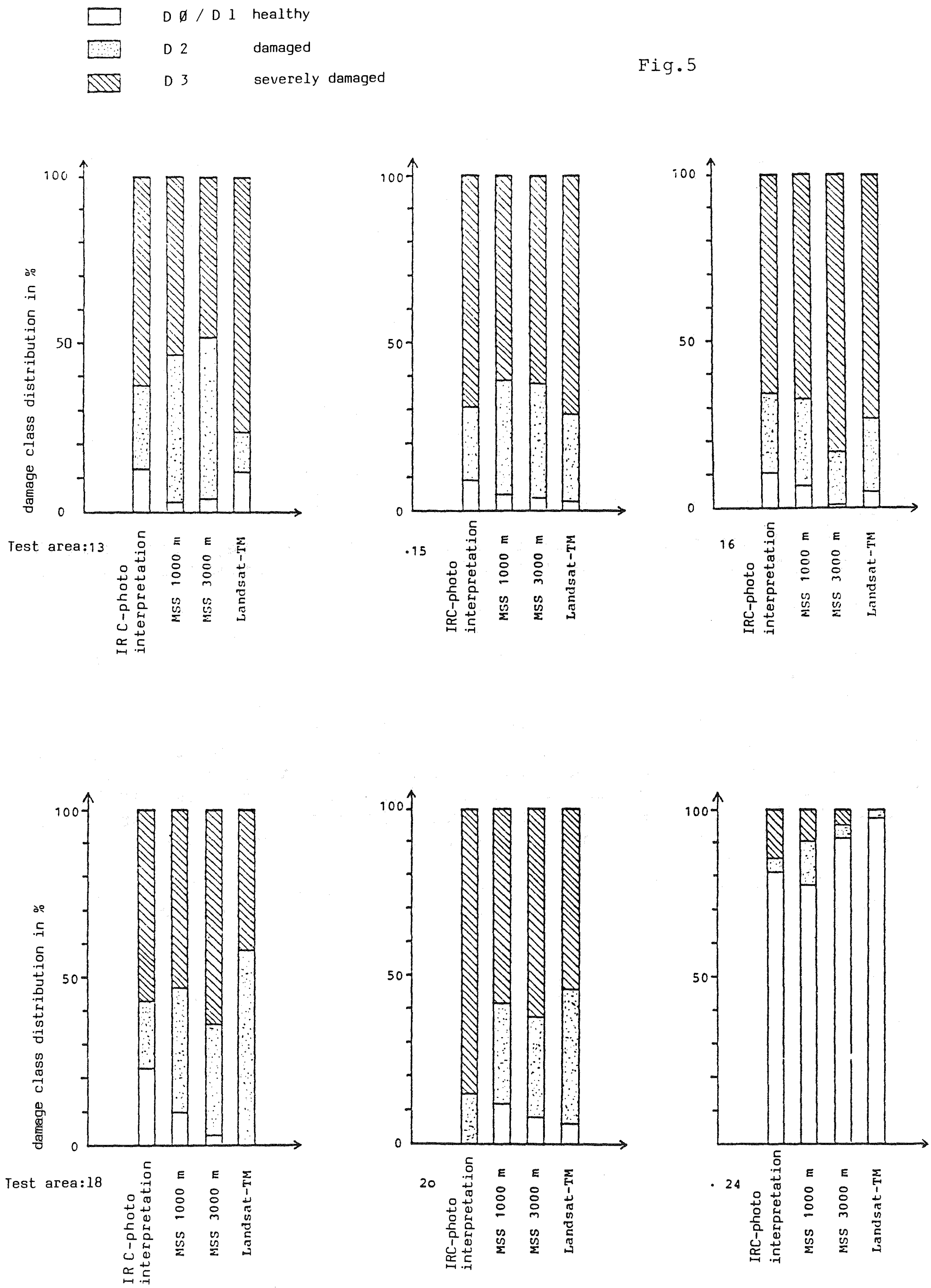

D Ø / D 1 healthy
D 2 damaged
D 3 severely damaged
damage class distribution in %
0
50
100
Test area: 4
5
6
Test area: 7
8
10
IRC-photo interpretation
MSS 1000 m
MSS 3000 m
Landsat-TM

Fig.4


D Ø / D 1 healthy
D 2 damaged
D 3 severely damaged
Fig.5
damage class distribution in %
0
50
100
Test area:13
·15
16
Test area:18
2o
· 24
IR C-photo interpretation
IRC-photo interpretation
MSS 1000 m
MSS 3000 m
Landsat-TM

6. Discussion of the Computer Aided Classification

On the basis of the results achieved by means of the evaluation of Landsat-TM data sets, it has been possible to come to a decision as regards the use of Landsat-TM for the monitoring and survey of the forest decline. It can be concluded that it will only be possible to identify and quantify forest decline for three damage levels (D0-1, D2, D3: healthy/slightly damaged, damaged and severely damaged stands)on the TMS and TM data images.The following remarks will illustrate the potential and the difficulties of the Landsat-TM data as a tool for forest damage survey:

1. homogenious canopies can be classified and distinguished without any restriction.
2. vigorious stands with a low density of trees will be classified in dependence of the ground cover type. Green vegetation between the trees promote the classification of the pixels to the low damage class. Dry vegetation ground cover favours the shift of the pixels to the highly damaged class.
3. Generally the shadows between the trees in the old stands, independent of the dominant class, favour the classification of the pixels into a highly damaged class.
4. It is difficult to classify stands on a steep western slope because of the shadows cast during the flight of Landsat in the morning.
5. Use of Landsat-TM data is practicable to survey the forest decline in different levels only for large stands due to the ground resolution (pixel size).
6. Before the application of results achieved with TM-data, a confirmation of the result should be carried out by another survey method like ground truth or IR photo interpretation, before any operational steps will be taken.
7. Finally it is important for the forest Department to have information about the location of the damages and therefore it is not necessary to know whether one single tree or small group of trees in the stands have been correctly classified or not.
8. Simultaneously to the classification of the damage levels in one test site the distribution, quantification and monitoring of other classes should also be classified to achieve a high utility of the TMS and TM data.
9. Landsat-TM data can be obtained regularly and continuously for different purposes for monitorung and surveillance of forest developments.
10. Structure and texture parameters of the level of forest decline cannot be investigated and determined on TM-Data due to the pixel size.In this situation a detailed investigation of the spectral signatures of different decline levels is a fundamental step for the analysis and application of the Landsat-TM data for forest monitoring as an important tool for remote sensing.

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