Commission VII

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ASPECTS OF COUNTRYWIDE INVENTORY AND MONITORING OF ACTUAL
FOREST DAMAGES IN GERMANY

Abstract:

The paper informs on the situation concerning forest disease,
mainly caused by airpollution and acid rain in Central Europe.
It describes the information requirements of the forest service
and the various activities to inventory and monitor these disease.

During 1983 in addition to field sampling large areas have been
inventoried by aerial photo interpretation. The applied methods,
some results and experiences of this remote sensing operation
including methodological problems which arose during the work
are discussed.

Beside the conventional photointerpretation also experiments
with computer assisted classification using multispectral scanner
data, have been started. First results are presented in the
paper.

1. The actual situation and the resulting need to inventory the
forests damages

In the last decade also in Central Europe - for instance in the
Erzgebirge and the Isergebirge - thousands of hectares have
been destroyed in the environment of emission sources by sulfur
emission. Such extreme but mostly local forest damages are
known since the beginning of the industrialization. Their inven-
tory - also by means of remote sensing - isn't very difficult
because entire areas are affected and mostly complete destructed.

Since a few years, however, a new type of stress occured in many
forest regions of Central Europe - independent from site condi-
tions and of the distance to industrialized areas. The symptoms
are different but they point also to airpollution. SO₂ and NOx,
partly in combination with ozon and peroxydants and with acid
rain are discussed as the main causes. Neither insects, fungus or
virus disease nor climatic effects could be found as primary rea-
son for the suffering and dying of many trees and forests.

The inventory and monitoring of these new type of damage is
much more difficult because the reaction of the trees within a
forest is not uniform and the proceeding of the damages within
each stand and whole forest regions is different.

Main symptoms of the damages are: progressive loss of needles,
partly discoloration and/or stunted growth of needles or lea-
ves, dying parts of tree crowns and - esp. in the case of old
firs - deformation of the crowns. Decreasing vigour makes the
afflicted trees prone to biotic as well as climatic effects.
Furthermore remarkable decrease of timber increment can be observed.

An actual inventory (1983) indicated that in the Federal Republik of Germany one third and in the southern german states Baden-Württemberg and Bayern the half of all forests are affected by the new type of damage. Old conifers are most damaged; much more than the younger ones and deciduous trees (see table 1 as an example).

<table>
<thead>
<tr>
<th>Forest type (species)</th>
<th>Federal Republic of Germany</th>
<th>State Baden-Württemberg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area classification</td>
<td>Area classification</td>
</tr>
<tr>
<td></td>
<td>Mill. ha</td>
<td>%</td>
</tr>
<tr>
<td>All forests</td>
<td>7.41</td>
<td>66</td>
</tr>
<tr>
<td>fir</td>
<td>0.18</td>
<td>24</td>
</tr>
<tr>
<td>spruce</td>
<td>2.95</td>
<td>59</td>
</tr>
<tr>
<td>pine</td>
<td>1.46</td>
<td>57</td>
</tr>
<tr>
<td>other conifers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>beech</td>
<td>1.25</td>
<td>74</td>
</tr>
<tr>
<td>oak</td>
<td>0.62</td>
<td>85</td>
</tr>
<tr>
<td>other hardw.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

o = healthy 1= less vigorous, sickly 2= clearly affected, diseased 3= heavy diseased, dying


How the development of the damage have proceeded can be shown by fig. 1 and 2. Both present the results of the exact tree by tree inventory of the health condition of fir and spruce trees in permanent test sites in Baden-Württemberg (Southwest-Germany). The test sites are spread over the entire state area, each of them is 0.25 ha in size and have been measured since 1979 twice a year.

The tremendous and rapid worsening can be seen from fig. 1 and 2
- fir: In autumn 1980 still 67% of the fir trees within the test sites could be classified as healthy. Three years later no tree could be classified as healthy but 98% must be rated as diseased, heavy diseased or dead.
- spruce: this species was more or less healthy up to fall 1981. Then a very fast worsening happened. End of 1983 the number of healthy trees was zero.
27 test sites with 1675 firs

27 test sites with 556 spruces

classification:

healthy  sickly  diseased  heavy  diseased  dead

loss of needles 0-10%  11-20%  21-60%  61-99%  100%

Fig. 1 and 2 Conditions of fir and spruce trees on permanent test sites in Baden-Württemberg. Development between fall 1980 and fall 1983 (from Schroeter 1983 and additional personal information).
This critical and alarming situation induces the forest services in Germany to inventory and monitor the extend and gravity of the damages. A first rough estimate for the entire Federal Republic of Germany by an inquiry in 1982 was followed in 1983 by an improved estimate and in several states (in the FRG forestry is a matter of the states) by well prepared damage inventories either for the entire forest area or for the present restricted to specific regions. These assessments have been done by fieldwork and remote sensing. In all cases the inventories 1983 should be the beginning of monitoring the state of the forest's health, resp. the development of the damages.

2. The principal decisions how to use remote sensing for the inventories.

Concerning remote sensing the country-wide or regional damage assessment was a great challenge. This especially considering the required and expected information on

- a classification according to the loss and discoloration of leaves into four classes

  -- 0 = healthy, vigorous          loss of leaves 0 - 10\%
  -- 1 = less vigorous, sickly     loss of leaves 11 - 25\%
  -- 2 = clearly affected, diseased loss of leaves 26 - 60\%
  -- 3 = heavy diseased, dying     loss of leaves > 60\%

- the local distribution (damage pattern)
- and all together distinguished between the main tree species

First - for 1983 - the decision had to be made wether the inventory (and later monitoring) should resp. can be done

- by visual aerial-photo interpretation or computer aided classification using multispectral scanner data or any other remotely sensed data (thermal IR, microwave data),

- by complete classification covering the entire area or by some kind of sampling

- by using a tree by tree approach or an area (=standwise) classification

- for all forest types or only for certain "indicator"-types.

The unanimous opinion of all German experts dealing with remote sensing in forestry led to the decision to use large scale infra-red-color aerial photographs and visual interpretation by experts for the inventories in 1983.

This opinion was based on the results of own systematic experiments since the sixtieth (i.e. Hildebrandt u. Kenneweg 1968, Kenneweg 1972), the experiences gathered during many practical damage inventories in the seventies (see the summarizing papers by Hildebrandt 1980, Masumy 1983 and the complete discussion of the matter by Kenneweg 1980) but also on successful damage appraisal by other European and Northamerican experts (i.e. Heller 1971, Murtha 1972, 1980, 1982).
In view of the information requirements and the diversified forest types in Germany computer aided approaches using either digitized data from aerial photos or multispectral scanner data have been judged as not yet operational for that purpose.

Also uniform was the decision in all states of the FRG to classify, if possible, tree by tree. This means, that each tree within the inventory units - may it be a stand or a sample plot - or a number of selected trees within a stand or around a sample point has to be classified. For young stands or in some cases also for deciduous stands the classification was (or must) done for areas of the stands or of the photo-sample plots.

However, depending on the special situation of the damages or certain requirements in the individual federal states the inventory by remote sensing was done either for the entire forest area of the state or for particular regions or only for a few, single forest districts or estates. Considering these different approaches table 2 is showing the various activities concerning forest damage assessment by remote sensing in the Federal Republic of Germany.

<table>
<thead>
<tr>
<th>Federal State 1)</th>
<th>USING Film / Scale 2)</th>
<th>entire forest area</th>
<th>forest of regions</th>
<th>single districts or estates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baden-Württemberg</td>
<td>IRC 1:5000</td>
<td>Ss</td>
<td>Ss</td>
<td>Cc/s</td>
</tr>
<tr>
<td>Bayern</td>
<td>IRC 1:3000</td>
<td></td>
<td>Ss</td>
<td>Cc/s</td>
</tr>
<tr>
<td>Hessen</td>
<td>IRC 1:5000</td>
<td></td>
<td>Ss</td>
<td>Cc/s</td>
</tr>
<tr>
<td>Niedersachsen</td>
<td>IRC 1:6000</td>
<td>Ss</td>
<td></td>
<td>Cc/s</td>
</tr>
<tr>
<td>Nordrhein-Westfalen</td>
<td>IRC 1:5000</td>
<td></td>
<td></td>
<td>Cc/s</td>
</tr>
<tr>
<td>Rheinland-Pfalz</td>
<td>IRC 1:6000</td>
<td>nothing reported so far</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saarland</td>
<td>IRC 1:16000</td>
<td>Ss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schleswig-Holstein</td>
<td>IRC 1:6000</td>
<td>Ss</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) without the "town-states" Berlin, Hamburg, Bremen
2) prevailing scale

Tab. 2 Forest damage inventories in the Federal Republic of Germany 1982/83 by remote sensing.

S = Aerial photography taken from sample strips
s = Interpretation on photo-sample plots
C = Complete coverage by aerial photography
c = Photointerpretation for (all) forest stands
3. The inventory of forest damages in Baden-Württemberg 1983

3.1 The task and objectives

As an example, the statewide inventory 1983 of Baden-Württemberg will be described in more detail.

The decision of the forest service to carry out a forest damage inventory for the entire forest area of the state (=1 303 000 ha) was taken in February 1983. The objectives of the inventory have been:

- the quantification of the actual damages "July 83" in the entire forests of the state, the various regions and the forest districts, classified into the main species and four damage classes (see above)

- the investigation of the occurrence of the damage relating to certain site conditions (elevation, aspect, slope) and to certain characteristics of the forest (age, density, stand type)

- the investigation of the occurrence of the damage-distribution within the country and its regions

- the investigation of the burden of the forests concerning immissions (measurement of deposits of S,F, heavy metals in the soil and in leaves)

- the documentation of the conditions in summer 1983 by aerial photographs in addition to statistical data.

3.2 The applied method as far as remote sensing is concerned

The survey was carried out by two independ inventories: a field sampling using a 4 x 4 km grid and a photosampling based on aerial photographs taken along sample strips. Both, the field sample grid and the photosample strips were orientated by the Gauss-Krüger-geodetic net.

The field inventory will not be discussed in this paper. A detailed description is given by Schöpfer and Hradetzky (1983). The results of the field inventory are meanwhile published by the Forstliche Versuchs- und Forschungsanstalt Freiburg (MELUF 1983)

The base of the photosampling were infrared-color aerial photographs 1:5000 taken with metric cameras 3o/23 from sample strips. These strips run north-south along Gauss-Krüger-lines in distances of 8 km (fig. 3). Overlapping on the lines was 60% to ensure complete stereoscopic coverage. For economic reasons no photographs were taken over areas without or with less than 10% forest coverage (see the dashed line-sections in fig. 3). Over the remaining 3723 km along the linear 8400 aerial photographs were shot.
Fig. 3. Map of Baden-Württemberg with flight lines of the forest damage inventory 1984

- solid line sections: aerial photos taken
- dashed line sections: photos are not taken because of less forest lands

The division lines within the state are the borders of forest districts.
6 privat companies were involved in the aerial photography. The order was to do the photography not before July 20th and not later than September 10th. This advise was given concerning phenological facts. In that period namely, the leaves and young needles grown in the current year are in the forests of Baden-Württemberg fully developed but don't yet show any autumnal tints.

To avoid to much shadows within the (rough) canopies of the forests resp. to much shaded parts of the tree tops, the forest service gave the order to take the photographs only in the noon time and permitted a sun elevation of 45 degrees as the minimum.

Due to a period of cloudfree days all photographs could be taken during one week end of July. The quality of the photographs was alltogether good and allowed the necessary very detailed interpretation. However, the photographs from the individual companies, had different color tones and hue (as usual). Therefore individual interpretation keys must be developed for each photoserie to ensure a reliable interpretation of the four damage classes and each species.

Considering the geometry of the original aerial photos and the fact, that each sample point should be reestablished some time later for monitoring, it was suggested (Hildebrandt 1983) to define first the coordinates of systematically distributed sample points and then to transfer these to the aerial photographs by photogrammetric means. This procedure results in distorted grids (fig.4a) which are adapted to the image geometry and avoid systematic sampling errors in mountainious inventory areas. It was first proposed by Kölbl and Trachslcr (1978, 1980, see also Kölbl 1982) for the national Swiss area statistic. It was also successfully used by Schade (1980) for a forest inventory test in the German Black Forest.

Unfortunately economic and logistic reasons but also some difficulties in the timely providing of reliable controll points (6-8 controll points are necessary for each stereomodell) stopped the production of the distorted grids. Therefore conventional regular grids were used (fig.4b), but the option to introduce distorted grids for subsequent inventories is left open.

The grid - containing 25 sample points together with a surrounding circel and spider lines, both to facilitate the interpretation - is printed on a transparency. It was overlaid on each third photo. 6 to 9 photo points were applied as samples. This resulted in alltogether more than 16000 samples for the entire country. The option to multiply this number, esp. for local investigations is left open.

At each selected sample point
- either 20 conifer trees, nearest to the point
- or in the case of young conifer or of deciduous stands a defined area of the stand
Fig. 4a Distorted sample point grid (adapted to the geometry of a given aerial photo (see text))

Fig. 4b Regular sample point grid.
have been interpreted and classified into four classes as described earlier.

According to the four classes as described earlier, but independent from tree species and certain color differences between some of the photos, the following "general" key was applied

- to the tree-wise classification:

  **class 0** the crown doesn't show any occurrences of damage or disease; full color, good shape

  **class 1** slight or beginning discoloration of the entire crown or perceptible discoloration of single parts of the tree top, first signs of deformation of the crown or single branches.

  **class 2** the crowns show clear damages; obvious discoloration of the entire crown or larger parts of it; the crowns appear very often "marbled"; crown deformation is esp. by fir recognizable

  **class 3** complete and extreme discoloration or/and deformations of the crown; signs of disintegration of the tree top to final stages; also trees-skeletons belong to this class.

- to the standwise classification:

  **class 0** no occurrences of damage or disease within the stand area or any tree

  **class 1** within the stand as many as 10% of the trees or the area show perceptible damages seen as discolorations, marbled appearances, skeletons....

  **class 2** within the stand are 11-30% of the trees or the area recognizable damaged seen as in class 1

  **class 3** within the stand more than 30% of the trees or the area are damaged, seen as in class 1

Loss of trees, decreased density and small clearings are described and registered as such but not classified as damaged diseased area.

Along with the classification for each sample point a series of other parameters have been registered, namely: the elevation (taken from a topographic map), slope and aspect, the geomorphological situation of the point, age class and density of the stand, forest type and location of the sample point within the stand.

Furthermore the geological site and the climatic region as well as the belonging to the (administrative) forest district was known and registered for each sample point.

After the development of the interpretation keys by their own the interpreters get within a short time very sure, competent, and efficient in the interpretation. Nevertheless a systematic control of the classification has been carried out to avoid misclassification and to adjust the results of the seven interpreters.
3.3 Some remarks to the performance

Closing to the short description of the statewide forest damage inventory by remote sensing in Baden-Württemberg a few remarks concerning its performance should be given. A more detailed report including experiences and considerations for further improvements are presently published.

It was mentioned earlier in this paper, that the entire inventory included a field inventory and a remote sensing assessment. The concept of the field inventory was developed by Prof. Dr. Schöpf er and Dr. Hradetzky. The approach for the remote sensing inventory was proposed by Prof. Dr. Hildebrandt and finally developed in cooperation with Prof. Dr. Schöpf er, Dr. Hradetzky and Dr. Sieder, who were responsible for the performance of both, the field and the remote sensing inventory.

Concerning the remote sensing inventory, furthermore Dr. Tzschupke, Dr. Masumy, Ofr. Oberfell, Prof. Dr. Kenneweg, Prof. Dr. Kölbl, and the interpreters have been involved in the discussions of the best or practical way to carry out particular parts of the work.

The inventory of the forest damages in Baden-Württemberg by remote sensing in 1983 took up the following operating times:

- 1 week development of the inventory approach in February 1983, later on during the first phase of the interpretation followed by
- 1 week adaptation of the methodology to the prevailing conditions
- 1 week aerial photography by 6 privat companies
- 2 weeks training of the seven interpreters
- 6 weeks photographic processing, production of additional hard copies, clearence, preparation of the photographs, done by the companies
- 3 weeks development of the "individual" interpretation keys by each interpreter; in the same time preparation of the regular grids by a privat company
- 20 weeks photo interpretation including control by 6 - 7 interpreters.
- 3 weeks evaluation and analysis of the (main) results.

The interpreter were young, academically trained foresters, experienced in forestry and especially very good familiar with the actual forest damage situation.

The results and first analysis of the inventory are just published by the Forest Research Institute of the Forest Service of Baden-Württemberg.
4. Can computer aided classification contribute to the damage inventory? First results of spectral signature analysis

4.1 Introduction

The visual interpretation by experts is timeconsuming, very trying to the eyes and in a certain extent subjective. The first two facts are clearly disadvantages, the third however, implies disadvantages as well as advantages. The last because the experience and knowledges of the experts are very useful inputs to a qualified interpretation and nothing can completely substitute the human (the expert's) ability to associate objects and occurrences, symptoms and phenomena.

The question is: can computer aided classification using multispectral scanner data as input contribute to the inventory of the actual forest damages? To answer this question it is necessary to know the spectral reflectance of healthy and affected trees and forest stands and how far different spectral signatures can be registered by multispectral sensorsystems.

Fig. 5 reminds of the typical "normal" spectral reflectance characteristic of healthy, green leaves and the dominant factors which influence this reflectance.

![Spectral Reflectance Diagram]

Fig. 5 Reflectance characteristic of healthy, green leaves (derived from Hoffer and Johannsen 1969). It applies in the shape of the curve also for trees with full, green foliage and for dense canopies of healthy forests stands.
4.2 General remarks for a conducted signature analysis

Some first results of detailed spectral signature analysis using airborne multispectral scanner data will be presented in 4.3. They were elaborated under the advice of the author by Kadro in Freiburg and partly in cooperation with Kritikos and Kübler in Oberpfaffenhofen.

The objects are spruces and firs growing in the Black Forest (Southwest-Germany) and representou trees and stands of the dif-
ferent "damage-classes" as mentioned in chapter 2 of this paper.

The spectral signature analysis is based on data taken with a Bendix M'S scanner, which was modified by the DFVLR for simu-
lation of TM data. Table 3 is showing the channels.

| band | $\lambda$ | $\Delta \lambda$ | band | $\lambda$ | $\Delta \lambda$
<table>
<thead>
<tr>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>nm</td>
<td></td>
<td>No</td>
<td>nm</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>465</td>
<td>50</td>
<td>8</td>
<td>720</td>
<td>40</td>
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<td>600</td>
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</tr>
<tr>
<td>6</td>
<td>640</td>
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<td>(10)</td>
<td>2210</td>
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<tr>
<td>7</td>
<td>680</td>
<td>40</td>
<td>11</td>
<td>11000</td>
<td>6000</td>
</tr>
</tbody>
</table>

Tab. 3 Position and width of the spectral bands of the applied scanner.
Radiance values of bands 1 and 10, located in the middle
infrared, were not available for all investigations.

The data were taken from 300 m and 1000 m above ground. Thus the
ground resolution of the pixels in the nadir is 0.75 x 0.75 m
and 2.5 x 2.5 m, respectively.

Using data from
300 m flight hight
the single crowns of old firs were covered by 45 - 108 pixels
the single crowns of spruces were covered by 14 - 25 pixels
the stand areas of fir were covered by 588 - 1132 pixels
the stand areas of spruces were covered by 99 - 225 pixels

1000 m flight hight
the selected spruce stands were covered by 1200 - 9200 pixels

The results of the analysis are presented in fig. 6-11 and 13-20 based on
radiance values, which were not calibrated. This doesn't effect the
comparison between healthy and damaged trees or stands in the
various bands. However the shape of the curvew in fig. 6 - 10, the
positions on the frequency graphs of the single lines of fig.
13 - 16 and the position of the clusters (not their extend) in
fig. 17 - 20 will change after calibration.
fig. 6 - 9 Spectral reflectance characteristics expressed by Q over λ (see text) for:
crowns of 120 year old firs (fig. 6)
crowns of 80 year old spruces (fig. 7)
stand areas of 120 year old firs (fig. 8)
stand areas of 80 year old spruces (fig. 9)
base: scanner data taken from 300 m above ground

- healthy
- sickly
- damaged
- severe damaged
- dead
To characterize the spectral reflectance the spectral reflectance factor $R(\%)$ could not be used in this stage of the research. Therefore in fig. 6-10 the quotient of the mean of radiance (uncalibrated) in the resp. band divided by the overall mean of radiance values of the tree or stand was calculated and drawn over the wavelength $\lambda$.

### 4.3 Result of a spectral signature analysis

The results of the signature analysis can be summarized as follows. For more detailed information it is referred to forthcoming publications of the authors mentioned above.

1) **In the visible part** of the spectrum the reflectance of stressed and damaged trees increase compared with the reflectance of healthy trees. The increase is the more as the damage increase. This is true for both species and for single crowns as well as for stand areas (fig. 6 - 9) and can be observed for stand areas in the data taken from 300 m and 1000 m (compare fig. 9 and 10).

![Diagram showing spectral reflectance characteristics](image)

**fig. 10** Spectral reflectance characteristics expressed by $Q$ over $\lambda$ (see text) for 60 - 80 year old spruce stands of different damage. Base: scanner data, taken from 1000 m above ground.

This reaction concerning the reflectance properties in the visible can be explained by increasing defoliation and (if appearing) by increasing destruction or changing of leaf pigments. Both result in less absorption of the incoming radiance and therefore in the measured increase of reflection. In this context it should be reminded that the reflectance characteristic of healthy leaves is in the visible particular affected by the large absorption and esp. the absorption bands in the blue and red parts of the visible (fig. 5).
(2) In the near infrared of the spectrum the reflectance of stressed and damaged trees decrease compared with the reflectance of the healthy ones. The decrease is the more as the damage increase. This is true for both species and for single crowns as well as for stand areas (fig. 6-9). It can be observed for stand areas in the data taken from 300 m and 1000 m (compare fig. 9 and 10).

The reaction in the near infrared can be explained by the fact, that healthy foliage doesn't absorb in this part of the spectrum very much but does reflect a lot (fig. 5). Thus decreasing foliage means the loss of material, which reflect very much in the near infrared. Vice versa material, which reflect only a little in the near infrared increase. Such materials are branches, the trunk, shaded parts within the crown, soil which is shining through the sparse crown. All this together result in the observed decrease of reflectance in correspondence to the increasing damages.

(3) In the middle infrared again a reversal can be observed. It is not supported by a figure in this paper but by meanwhile available results of the investigations. In this part of the spectrum the healthy trees and stands have the least reflectance. Corresponding to the decrease of damage the reflectance increase. It could be investigated only in the data taken from 1000 m above ground.

In this part of the spectrum the water content of the reflecting material determine the reflectance very much. Less leaves - with their great water content - and more branches and other wooden parts - with their less water content result logically in more reflectance resp. less absorption. Furthermore it can be assumed (but must be investigated) that also the remaining leaves of diseased trees have a lower water content as the foliage of healthy, vigorous trees.

Fig. 11 Reflectance spectra for controlled and different ozone damaged cantaloupe-leaves. (from Gaussman 1978)

water content in leaves:
control = 90,3%
very severe damaged = 82,6%
Fig. 11 shows how changing leaf water content influences the spectral reflectance in the middle infrared. Comparable investigations for tree-leaves are not available, therefore the results of an experiment with cantaloupe (Cucumis melo L.) are used to demonstrate this effect.

(4) The differences in the signatures between healthy and in a different degree damaged trees are more distinct than the differences which can observed for stand areas.

This could be expected because within all stand areas a certain variety of other objects (shadows, soil, soil cover vegetation, mixed species) participate in the reflectance. This more or less independent of the health conditions of the forest trees. It lead obviously to smaller differences of the radiance means in the various bands as well as to broader frequency distributions and variations of the data.

(5) Frequency distribution and variance of spectral data increase in correspondence with increasing damages, both in the case of single crowns (fig. 13,14,17,18) and stand areas (fig.15,16,19,20). This point to differences in the texture, which possibly can be used for classification purposes.

Concerning the variance of the reflectance within each class attention must be drawn also to the different quantities of reflection in dependence on the direction of reflection resp. the direction of observation (see fig. 12 a/b).

![Graphs showing spectral reflectance](image)

Fig. 12 a/b Dependence of spectral reflectance factors from the direction of reflection. Example: young spruce stand. (from Kadro and Hildebrandt 80)

(6) The differences in the signature between healthy and in different degree damaged stand areas in the scanner data, taken from 300 m as well as 1000 m, are very similar (compare fig.9 and 10, as well as fig. 19 and 20) The variances within each damage class don’t allow a clear discrimination by spectral data alone. The overlapping of the clusters in the two- and more-dimensional space are about the same in the data taken from 300 m and 1000 m (fig. 19 and 20).

These statements are true also for other band combinations.
fig. 13 Frequency distribution of reflectance values (densities) of a healthy fir crown

fig. 14 Frequency distribution of reflectance values (densities) of a severe damaged fir crown

fig. 15 Frequency distribution of reflectance values (densities) of a healthy fir stand

fig. 16 Frequency distribution of reflectance values (density) of a severe damaged fir stand

All data taken from 300 m above ground. Channels see tab.3
fig. 17-20 spectral reflectance signatures of healthy and different damaged crowns and stand areas shown as clusters in a two dimensional feature space (band 5 vs 9) $p = 0.6$

1 = healthy  
2 = sickly  
3 = damaged  
4 = severe damaged  
5 = dead

fig. 17-19 data taken from 300 m
fig. 20 data taken from 1000 m

fig. 17 signatures of fir crowns.
scale: 12.5 gray-values/cm

fig. 18 signatures of spruce crowns
scale 12.5 gray-values/cm

fig. 19 signatures of spruce stands
scale 5.4 gray-values/cm

fig. 20 signatures of spruce stands
scale 4.4 gray-values/cm
Recent attempts to classify the actual damages in relative homogenous spruce and fir forests by Kritikos, Kübler and Koch (presented in a DFVLR workshop 1983) as well as Kadro, Kritikos and Kübler (last personal communication) using multispectral scanner data and computer aided classification lead to promising results.

Former computer aided classifications of forests which were damaged by airpollution have been done before in Austria and Germany by Zirm (1980), Kritikos, Kübler and Dörfel (1983).

In addition to the classification tests mentioned above, it should be pointed to tests using infrared aerial photography and approaches of color separation for damage classification either by digitizing the photos or by a method called "isochromography" (Helbig 1983, Rose 1984, Lohse 1984 all not yet published papers but presented in meetings 1983 and 1984). It was reported that these tests lead to good results in more or less homogenous forest stands.

4.4 Conclusion of chapter 4

The first results of spectral signature analysis of the actual forest damages in Central Europe as well as some first tests of computer aided classification are promising. However they have been done for conifers only and for more a less homogenous stands. Considering - on the one hand - the heterogenous silvicultural conditions in many European forests with regard to species, mixture of species, structure, density and age but also topographic matter like illuminated and shaded slopes in mountainuous areas and - on the other hand - the diversity of symptoms of the actual damages, as mentioned at the beginning of this paper, one is faced with a lot of still unsolved problems when using computer aided or other automatic classification.

The necessary intensive and systematic research in this field and the development of inventory models, suitable for operational application must be done in close cooperation with public or privat forest services to meet their information requirements and to avoid disappointments. One should be aware that these requirements are very high concerning the reliability of the results, the classification also of early stages of the damages and even the differentiation of the damages with regard to their causes.

5. Literature cited

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