Commission VII

GERD HILDEBRANDT

Universität Freiburg, Fed. Rep. of Germany

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 forest 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 f mination. Such extreme but mostly local forest damages are known since the beginning of the industrialization. Their inventory - 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 conditions and of the distance to industrialized areas. The symptoms are different but they point also to airpollution. SO_2 and No_x, 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 reason 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 leaves, 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).

Forest type (species)	Federal Republic of Germany Area	classification				State Baden-Württemberg Area	classification			
		o	1	2	3		o	1	2	3
	Mill.ha	%				Mill.ha	%			
All forests	7.41	66	25	8	1	1.3o	51	31	17	1
fir	o.18	24	27	42	7	o.12	23	26	48	3
spruce	2.95	59	3o	1o	1	o.59	5o	34	16	o
pine	1.46	57	32	1o	1	o.12	3o	38	34	2
other conifers						o.o5	61	25	13	1
beech	1.25	74	22	4	o	o.25	67	28	5	o
oak	o.62	85	13	2	o	o.o7	63	32	5	o
other hardw.						o.1o	7o	22	8	o

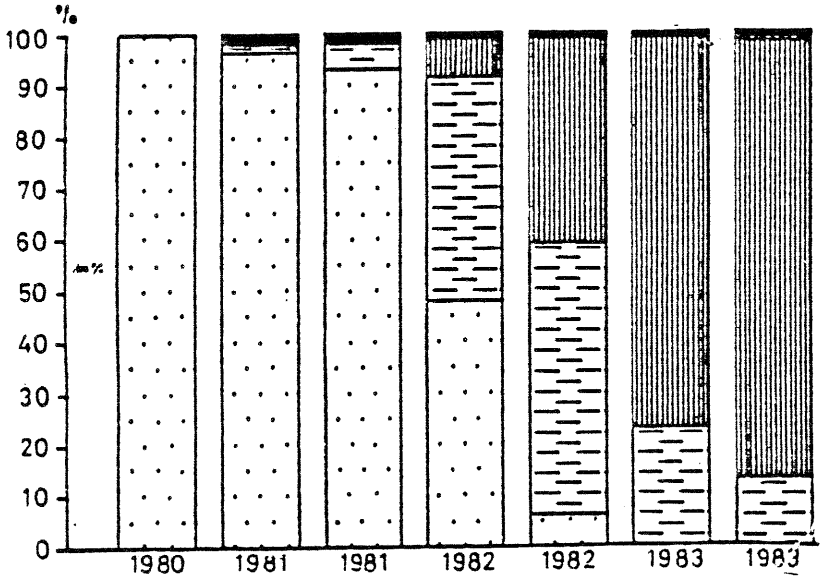
o = healthy 1= less vigorous, sickly 2= clearly affected, diseased 3= heavy diseased, dying

Tab. 1 Condition of forests in the Fed. Rep. of Germany and the State of Baden-Württemberg, Summer 1983 (Sources: BELF Bonn 1983; MELUF, Stuttgart 1983)

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 o,25 ha in size and have been measured since 1979 twice a year.

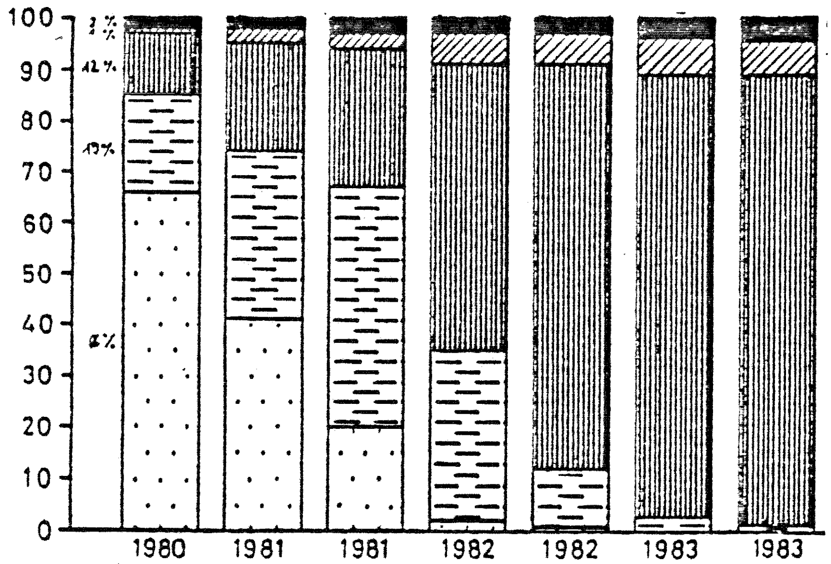
The tremendous and rapid worsening can be seen from fig. 1 and 2

- fir: In autumn 198o 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

F S F S F S F F = fall
S = spring



27 test sites
with 556 spruces

F S F S F S F F = fall
S = spring

classification:	healthy	sickly	diesased	heavy diseased	dead
loss of needles	o-1o%	11-2o%	21-6o%	61-99%	1oo%

Fig. 1 and 2 Conditions of fir and spruce trees on permanent test sites in Baden-Württemberg.Development between fall 198o 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 o - 1o%
-- 1 = less vigorous, sickly	loss of leaves 11 - 25%
-- 2 = clearly affected, diseased	loss of leaves 26 - 6o%
-- 3 = heavy diseased, dying	loss of leaves > 6o%

- 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 remotly 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 infrared-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 summerizing papers by Hildebrandt 198o, Masumy 1983 and the complete discussion of the matter by Kenneweg 198o) but also on successful damage appraisal by other European and Northamerican experts (i.e. Heller 1971, Murtha 1972, 198o,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.

	The inventory and assessment by remote sensing was done			
Federal State[1]	USING	FOR		
	Film / Scale[2]	entire forest area	forests of regions	single districts or estates
Baden-Württemberg	IRC 1:5000	Ss		Cc/s
Bayern	IRC 1:3000 1:5000		Ss	Cc/s
Hessen	IRC 1:6000		Ss	Cc/s
Niedersachsen	IRC 1:6000	Ss		Cc/s
Nordrhein-Westfalen	IRC 1:5000			Cc/s
Rheinland-Pfalz		nothing reported so far		
Saarland	IRC 1:16000	Ss		
Schleswig-Holstein	IRC 1:6000		Ss	

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

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

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

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 3o3 ooo ha) was taken in February 1983. The objectives of the inventory have been:

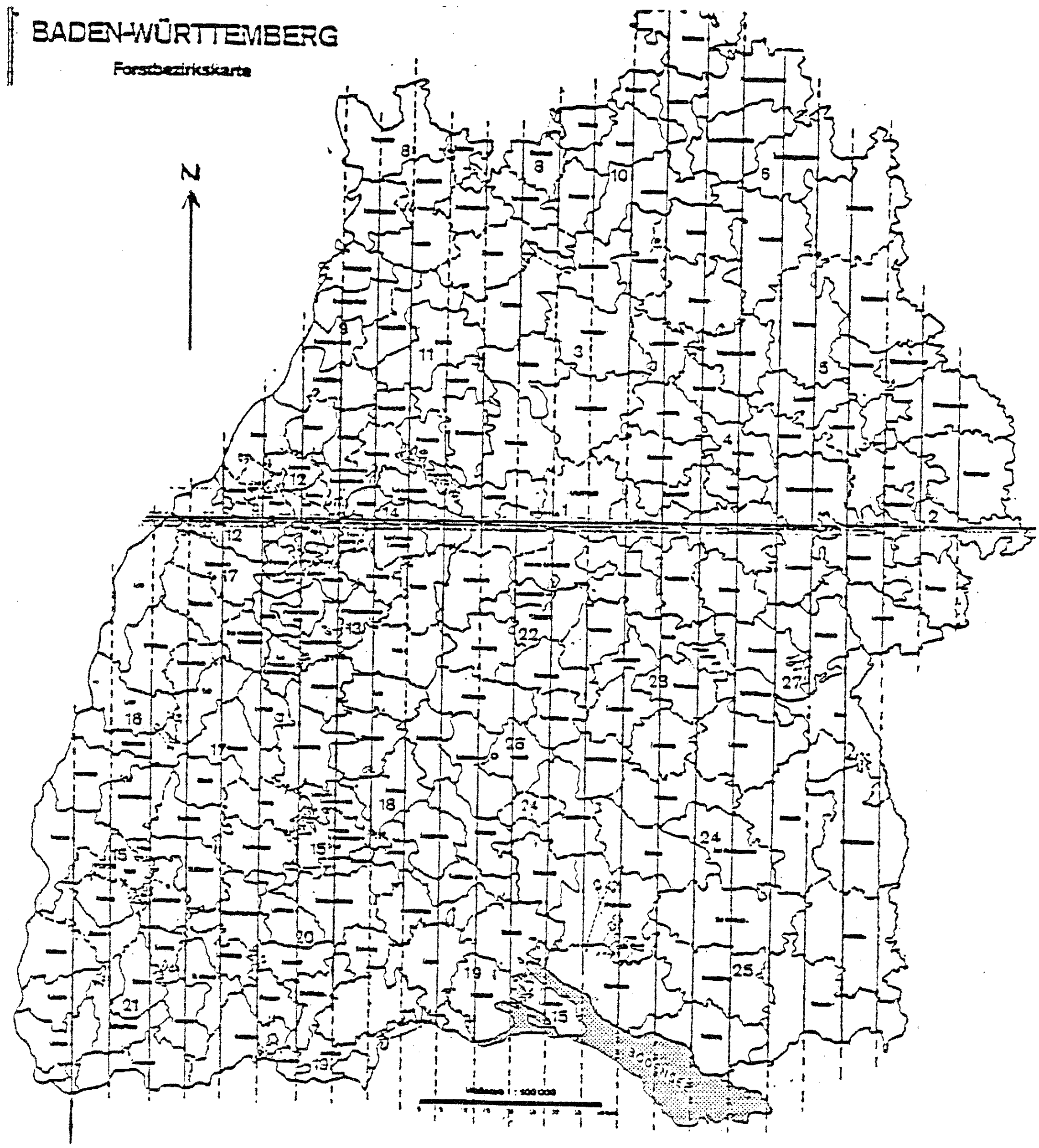
- the quantification of the actual damages "July 83" in the entire forests of the state, the various regions and the forest districts, classified into the main species and four damage classes (see above)
- the investigation of the occurrence of the damage relating to certain site conditions (elevation, 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 1:5ooo 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 6o% to ensure complete stereoscopic coverage. For economic reasons no photographs were taken over areas without or with less than 1o% forest coverage (see the dashed line-sections in fig. 3). Over the remaining 3723 km along the lines 84oo aerial photographs were shot.



Gauss - Krüger lines

34o4 3596

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 2oth and not later than September 1oth. 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 Trachsler (1978, 198o, see also Kölbl 1982) for the national Swiss area statistic. It was also successfully used by Schade (198o) for a forest inventory test in the German Black Forest.

Unfortunatly 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 sorrounding 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 2o conifer trees, nearest to the point
- or in the case of young conifer or of deciduous stands a defined area of the stand

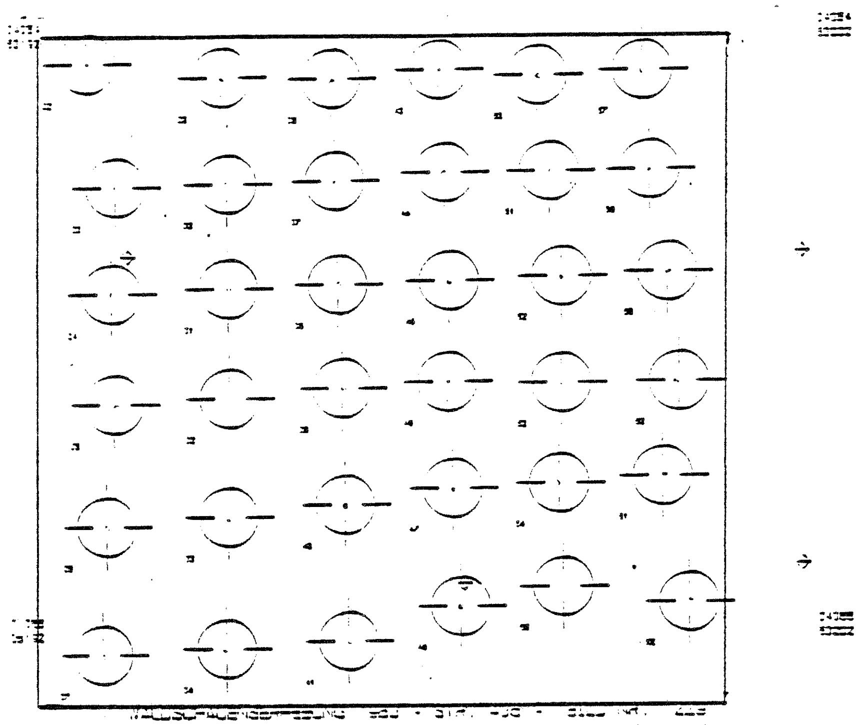


Fig. 4a Distorted sample point grid (adapted to the geometry of a given aerial photo (see text)

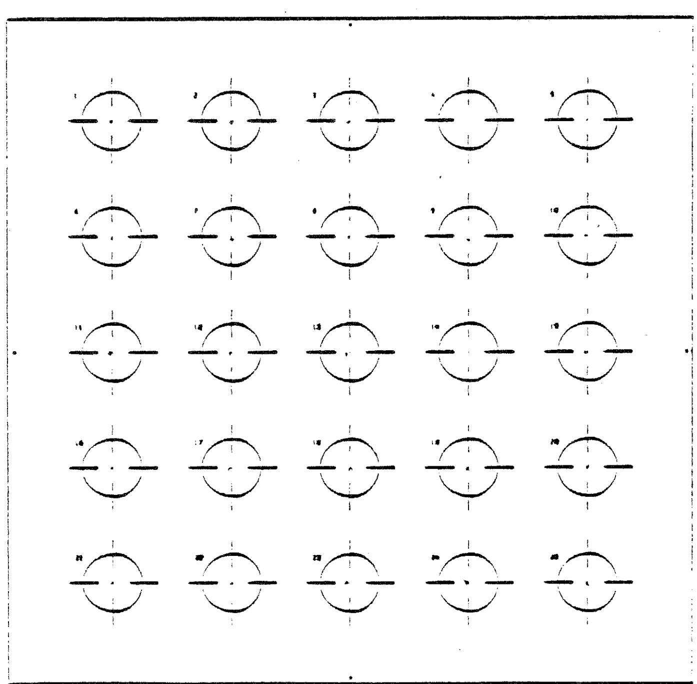


Fig. 4b Regular sample point grid.

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 occurences of damage or disease; full color, good shape
class 1	slight or beginning discoloration of the entire crown or perciptible 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 tree-sceletons belong to this class.

- to the standwise classification:

class 0	no occurences of damage or disease within the stand area or any tree
class 1	within the stand as many as 1o% of the trees or the area show perceptible damages seen as discolorations, marbled appearences, sceletons....
class 2	within the stand are 11-3o% of the trees or the area recognizable damaged seen as in class 1
class 3	within the stand more than 3o% 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 serie of other parameters have been registered, namely: the elevation (taken from a topographic map), slope and aspect, the geomorphological situation of the point, ageclass 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 beloging 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 controll 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. Schöpfer and Dr. Hradetzky. The approach for the remote sensing inventory was proposed by Prof. Dr. Hildebrandt and finally developed in cooperation with Prof. Dr. Schöpfer, 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. Obergfell, 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
- 2o 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 completly substitute the human (the expert's) ability to associate objects and occurences, 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.

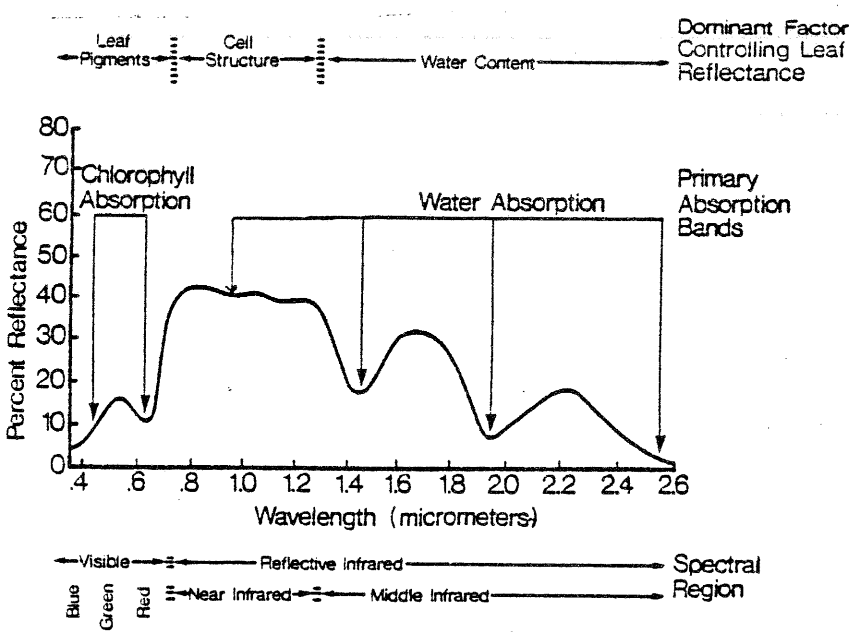


Fig. 5 Reflectance characteristic of healthy, green leaves (derived from Hoffer and Johannsen 1969). It applies in the shape of the curve also for trees with full, green foliage and for dense canopies of healthy forests stands.

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 (Sothwest-Germany) and representou trees and stands of the different "damage-classes" as mentioned in chapter 2 of this paper.

The spectral signature analysis is based on data taken with a Bendix M^2S scanner, which was modified by the DFVLR for simulation of TM data. Table 3 is showing the channels.

band	λ	$\Delta\lambda$	band	λ	$\Delta\lambda$
N°	nm		N°	nm	
2	465	5o	8	72o	4o
3	515	4o	9	815	9o
4	56o	4o			
5	6oo	4o	(1)	165o	2oo
6	64o	4o	(1o)	221o	27o
7	68o	4o	11	11ooo	6ooo

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

The data were taken from 3oo m and 1ooo m above ground. Thus the ground resolution of the pixels in the nadir is o.75 x o.75 m and 2.5 x 2.5 m, respectively.

Using data from

3oo m flight hight

the single crowns of old firs were covered by 45 - 1o8 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 coverd by 99 - 225 pixels

1ooo m flight hight

the selected spruce stands were covered by 12oo -92oo pixels

The results of the analysis are presented in fig.6-11 and 13-2o 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 courves in fig. 6 - 1o, 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 - 2o will change after calibration.

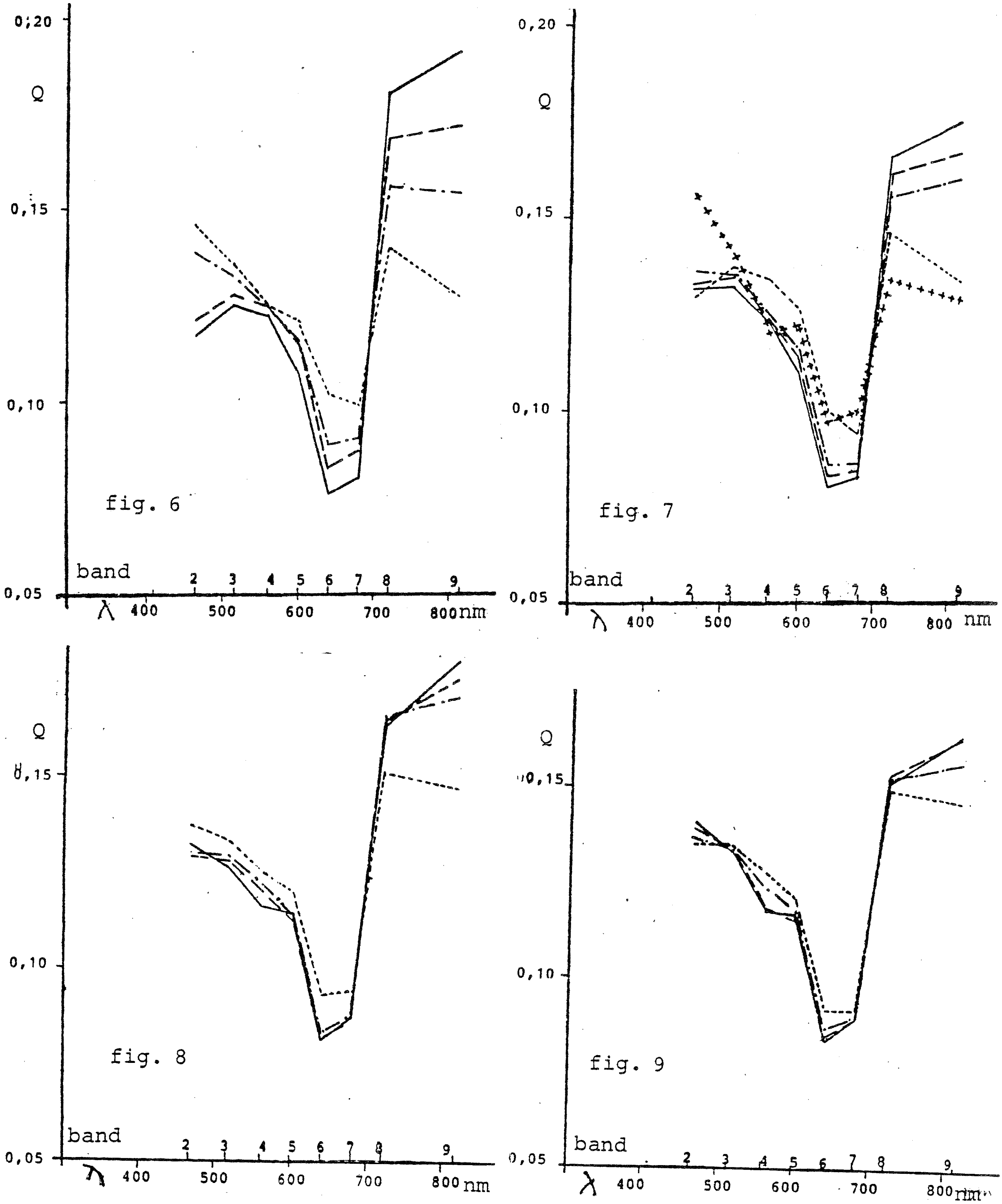


fig. 6 - 9 Spectral reflectance characteristics expressed by Q over λ (see text) for:
crowns of 12o year old firs (fig. 6)
crowns of 8o year old spruces (fig. 7)
stand areas of 12o year old firs (fig.8)
stand areas of 8o year old spruces (fig.9)
base: scanner data taken from 3oo m above ground

healthy
sickly
damages
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. 6-1o 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 λ .

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 refered 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 relfectance 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 3oo m and 1ooo m (compare fig. 9 and 1o).

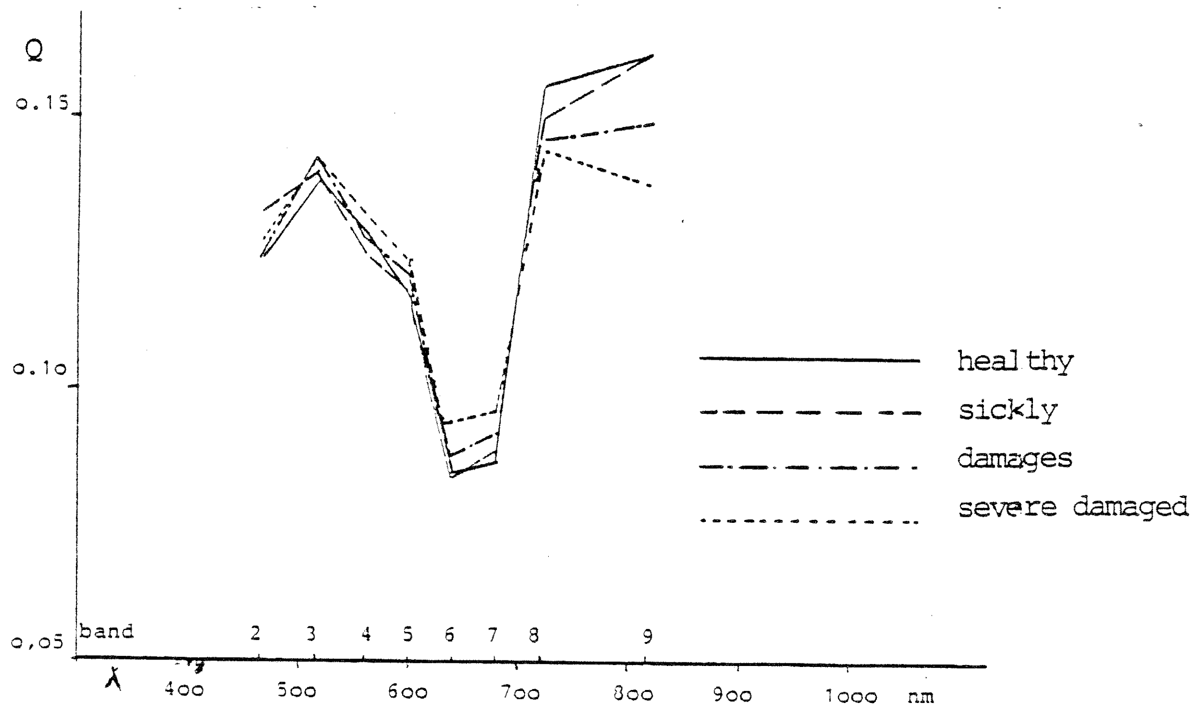


fig. 1o Spectral reflectance characteristics expressed by Q over (see text) for 6o - 8o year old spruce stands of different damage. Base: scanner data, taken from 1ooo m above ground.

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 3oo m and 1ooo m (compare fig. 9 and 1o).

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 relfectance 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 1ooo 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.

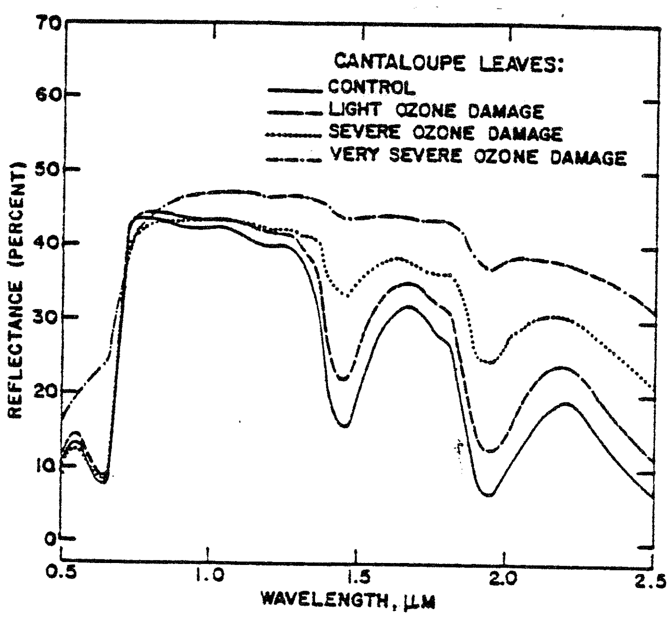


Fig. 11 Reflectance spectra for controled and different ozon damaged cantaloupe-leaves.
(from Gaussman 1978)

water content in leaves:

control = 9o,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 independ 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.15,16,19,2o). Thispoint 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 dependance on the direction of reflection resp. the direction of observation (see fig. 12 a/b).

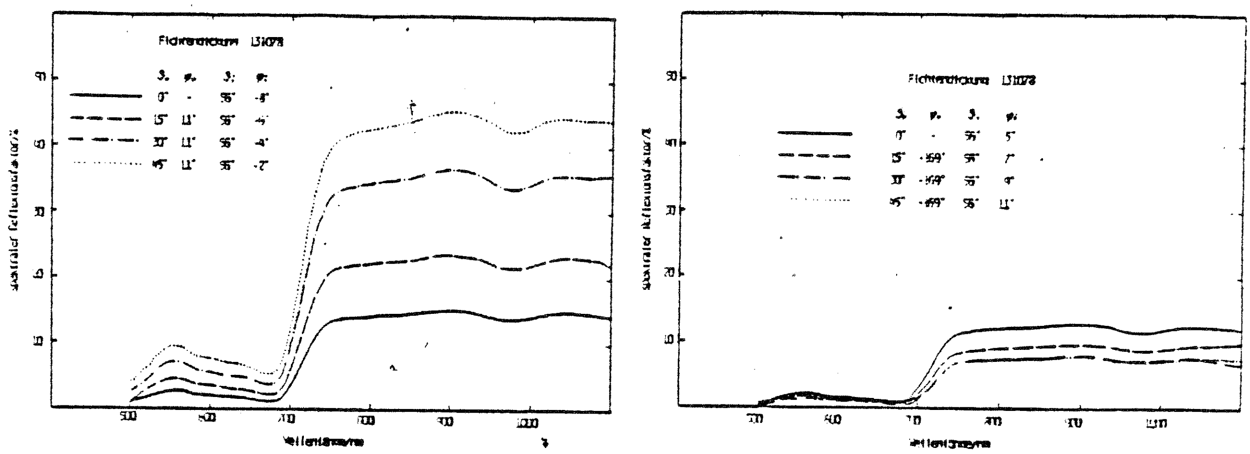


Fig. 12 a/b Dependance of spectral reflectance factors from the direction of reflection. Example: young spruce stand. (from Kadro and Hildebrandt 8o)

(6) The differences in the signature between healthy and in different degree damaged stand areas in the scanner data, taken from 3oo m as well as 1ooo m, are very similar (compare fig.9 and 1o, as well as fig. 19 and 2o) 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 3oo m and 1ooo m (fig. 19 and 2o).
These statements are true also for other band combinations.

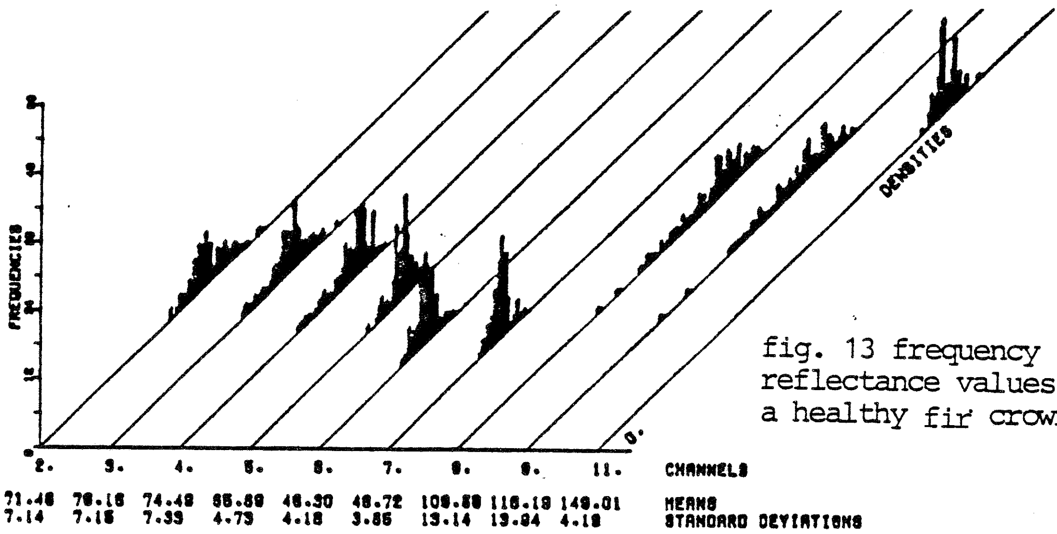


fig. 13 frequency distribution of reflectance values (densities) of a healthy fir crown

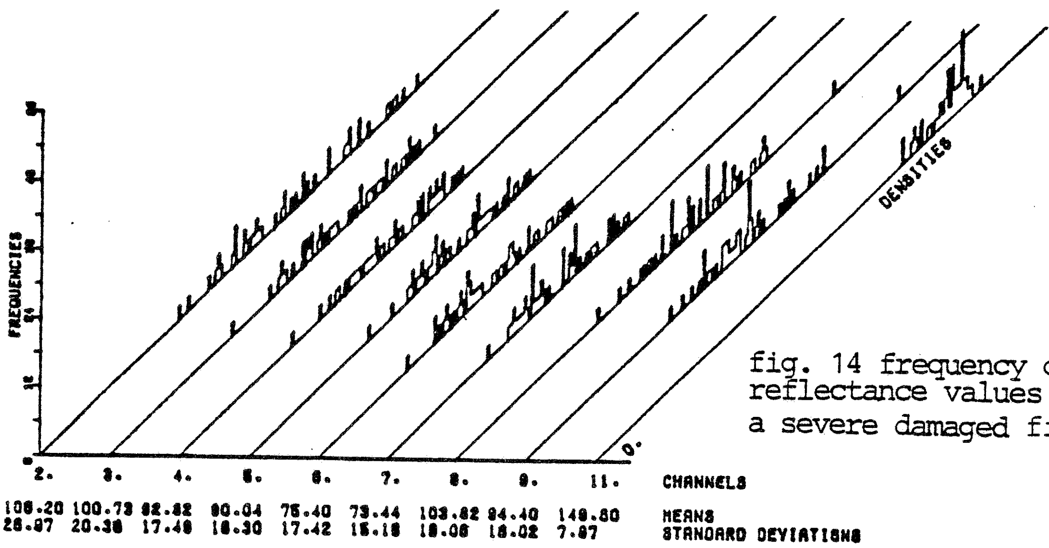


fig. 14 frequency distribution of reflectance values (densities) of a severe damaged fir crown

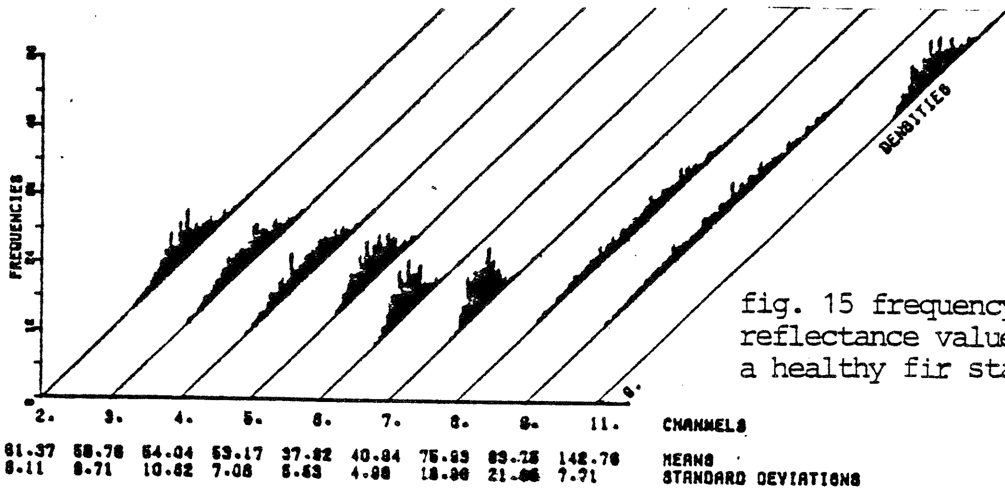


fig. 15 frequency distribution of reflectance values (densieties) of a healthy fir stand

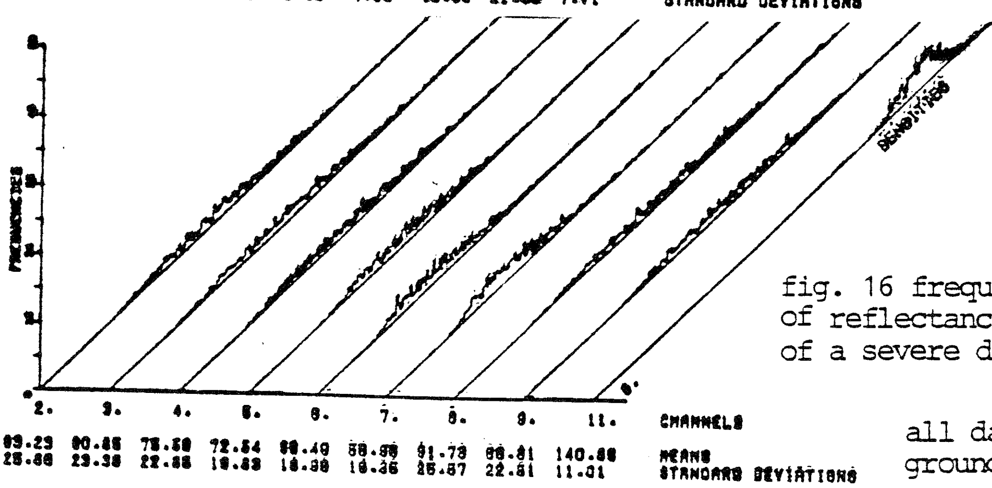


fig. 16 frequency distribution of reflectance values (density) of a severe damaged fir stand

all data taken from 3oo m above ground. Channels see tab.3

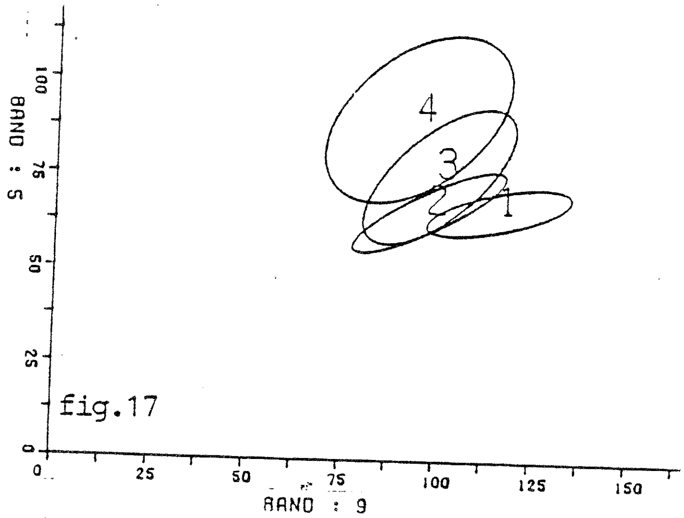


fig.17

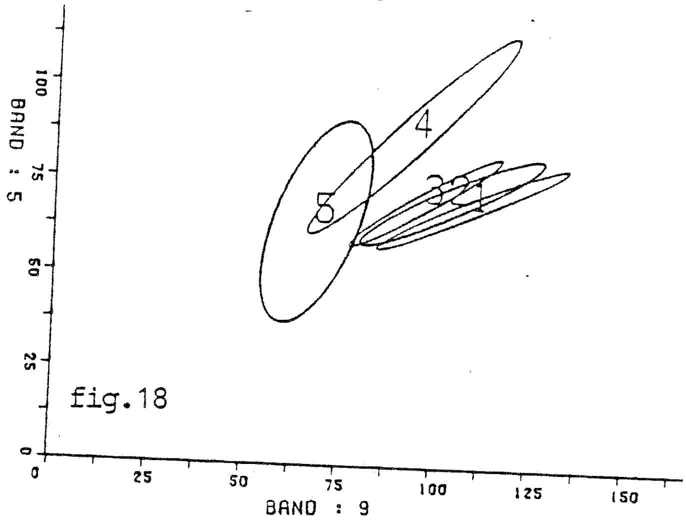


fig.18

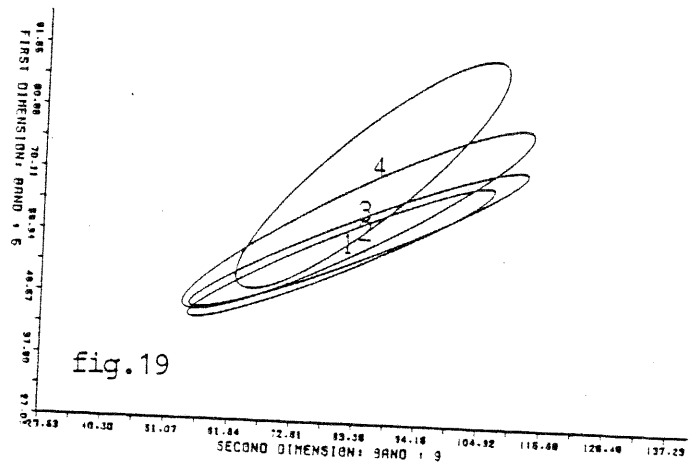


fig.19

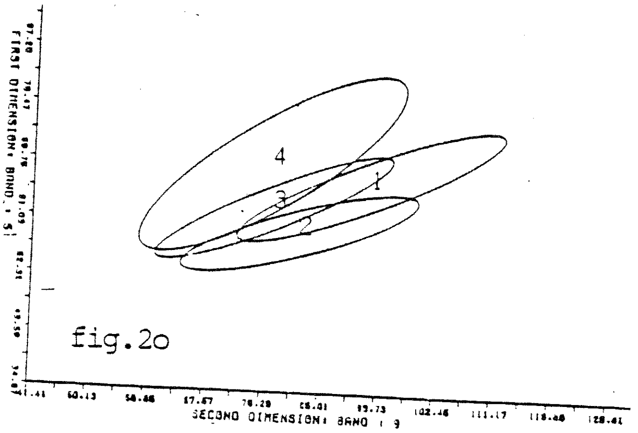


fig.2o

fig. 17-2o 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 = o.6

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

fig. 17-19 data taken from 3oo m
fig. 2o data taken from 1ooo m

fig. 17signatures 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. 2o signatures of spruce stands
scale 4.4 gray-values/cm

Recent attempts to classify the actual damages in relative homogenuous 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 (198o), 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 homogenuous 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 homogenuous stands. Considering - on the one hand - the heterogenuous 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

BELF (Bundesministerium für Ernährung, Landwirtschaft und Forsten) 1983 : Bericht des Bundesministers für Ernährung, Landwirtschaft und Forsten, anläßlich der Waldschadenserhebung 1983 Bonn, 18.1o.1983

Gaussman H.W. et.al. 1978: Effects of stress, succulence and pubescence on plant leaf and canopy reflectance. Proc. Int. Symp. on Remote Sensing for observation and Inventory of Earth Resources and the Endangered Environment. Vol I pp. 719-75o Freiburg 1978

Heller R.C. 1971: Color and false color photography; its growing use in forestry. In: Application of remote sensors in Forestry IUFRO Sect. 25 report, Freiburg 1971

Hildebrandt G., Kenneweg H.1968: Einige Anwendungsmöglichkeiten der Falschfarbenphotographie im forstlichen Luftbildwesen. Allg. Forst- und Jagdzeitung. 1968 pp. 2o5 - 212

Hildebrandt G. 198o: Voraussetzungen und Praxis der Inventur von Vegetationsschäden durch Fernerkundung. Allg. Forstzeitung 198o pp. 72o-723

Hildebrandt G. 1983: Studie zur Durchführung einer landesweiten Inventur zur Erfassung und Beobachtung der Waldschäden in Baden-Württemberg. (type written report Febr. 1983) Freiburg 1983

Hildebrandt G. 1984: Die Luftbildinventur der Waldschadenserhebung 1983 in Baden-Württemberg. In: Schriftenreihe der Forstwirtschaftlichen Fakultät, Universität Freiburg 1984 (in print)

Hoffer R.M., Johannsen C.J. 1969: Ecological potentials in spectral signature analysis. In: Remote Sensing in Ecology. Athens, USA 1969, pp 1-16

Kadro A. Hildebrandt G.198o Beobachtungen über das spektrale Reflexionsverhalten von Kiefern- und Fichtenbeständen. Int. Arch. Photogramm. Vol XXIII B 7, pp. 487-496

Kenneweg H. 1972: Die Verwendung von Farb- und Infrarot Farb-Luftbildern für Zwecke der forstlichen Photointerpretation unter besonderer Berücksichtigung der Erkennung und Abgrenzung von Kronenschäden in Fichtenbeständen. Diss. Freiburg 1972

Kenneweg H. 198o: Luftbildinterpretation und die Bestimmung von Belastung und Schäden in vitalitätsgeminderten Wald- und Baumbeständen. Schriftenreihe der Forstl. Fak. Göttingen Bd.62 198o

Kölbl O. Trachsler H. 1978: Großräumige Landnutzungserhebungen mittels stichprobenweiser Auswertungen von Luftbildern. ORL-Institut ETH Zürich, DISP.Nr. 51, Zürich 1978

Kölbl O, Trachsler H. 198o: Regional landuse survey based on point sampling on aerial photographs. Int. Arch. Photogramm. Vol. XXIII B 1o pp. 536-549. ISPRS Congress Hamburg 198o

Kölbl O. 1982: Stichprobenweise Luftbildauswertung zur Erneuerung der Arealstatistik. In. Nouvelle Statistique de la Superficie en Sui sse Publ. No. 19 Lausanne 1982.

Kadro A. 1981: Untersuchung der spektralen Reflexionseigenschaften verschiedener Vegetationsbestände.Diss. Freiburg 1981 Universität Freiburg.

Kritikos, Kübler, Dörfel 1983: Untersuchung der Eignung von SPOT-Simulationsdaten zur Erfassung von Waldschäden. Type written report DFVLR and Abt. Luftbildmessung und Fernerkundung Universität Freiburg 1983

Masumy S.A. 1983: Infrarot-Farbluftbilder als Grundlage zur Inventur der großräumigen Waldschäden. Allg. Forstzeitung 1983 pp. 125o -1251

MELUF (Min. für Ernährung, Landwirtschaft, Umwelt und Forsten Baden-Württemberg). Endauswertung der terrestrischen Waldschadensinventur Baden-Württemberg 1983, Stuttgart 12.12.1983

Murtha P.A. 1972: A guide to air photo interpretation of forest damage in Canada. Can. Env., Can. For. Serv. Publ. 1292, 1972

Murtha P.A. 198o, Modelling tree damagetype patterns for photo interpretation of SO_2 injury. Int. Arch. Photogramm. Vol XXIII B 8, pp. 667-679. ISPRS Congress Hamburg 198o

Murtha P.A. 1982: Detection and analyses of vegetation stress. In: Uses of remote sensing in forestpest damage appraisal.North. For. Res. Centre Edmonton, Inf. Rep. NOR-X-238

Schade J. 198o:Ein mehrphasiges Stichprobesystem für forstliche Großrauminventuren, gestützt auf Landsat-MSS-Daten, Luftbilder 1:5o ooo und ergänzende terrestrische Messungen. Diss. Freiburg 198o

Schöpfer W., 1983: Arbeitsanweisung für die terrestrische Waldschadensinventur Baden-Württemberg 1983, FVA, Freiburg 1983

Schröter H. 1983: Krankheitsentwicklung von Tannen und Fichten auf Beobachtungsflächen der FVA in Baden-Württemberg. Allg. Forst- und Jagdzeitung 1983, 123-131

Zirm K.L. 198o: Erfahrungen bei der Klassifikation geschädigter Vegetation mit Hilfe von multispektralen Scannerbildern. Int. Arch. Photogramm. Vol. XXIII, B8 pp 979-987. ISPRS-Congress Hamburg 198o