LARGE AREA OPERATIONAL EXPERIMENT FOR FOREST DAMAGE MONITORING IN EUROPE USING SATELLITE REMOTE SENSING - RESULTS OF THE TECHNICAL WORKING GROUP

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ABSTRACT: In January 1992, UNEP called the first Advisory Board meeting in Prague to launch the **"Large Area Operational Experiment for Forest Damage Monitoring in Europe Using Satellite Remote Sensing" (LAOE).** The Czech Republic, Poland and Germany agreed to participate by providing their relevant ongoing research projects as contributions to the experiment. The Czech Republic was nominated to be the lead country, and UNEP offered to provide co-ordination and secretarial services. The Advisory Board of the project appointed a Technical Working Group (TWG), with scientists from the Czech Republic, Poland, Finland and Germany to develop a methodology and prepare guidelines for the harmonisation of the various classification approaches for regional applications. The results and the recommendations of the TWG will be introduced in this paper.

1. INTRODUCTION

In the 1970's, a widespread deterioration in forest health was observed, first for the European fir and, subsequently, also for many other tree species. Now a large proportion of the forests in Europe is affected by forest decline to varying degrees. Intense research on the causes of this decline has been performed from that time on with the result that the decline can not be attributed to one single causal factor but rather is thought to be the result of a multitude of adverse environmental conditions (Hildebrandt, 1992; Skelly and Innes, 1994). Besides the fundamental research work a great variety of damage assessment methods have been developed, and numerous inventories have been carried out. In order to obtain reliable and comparable results on national and international level it has become necessary to monitor the forest damage by applying standardised inventory methods.

Based on the Convention on Long Range-Transboundary Air Pollution of 1979, the "International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests" (ICP-Forest) was established in 1985 by the Executive Body of the Convention. The work is based upon national monitoring inputs using terrestrial damage evaluation methods on sample points. The European governments are provided with statistics on forest condition on annual basis. This programme was funded by UNEP during 1985-1990. Since 1991, the countries finance the inventories themselves.

Besides the statistics obtained through this national and transnational surveys, more detailed data is often required locally. Especially, there is a lack of spatial information of the damage distribution within the European Countries. The mapping of forest condition, displaying the spatial distribution of damage at national and regional level, would be useful for determining the causes of forest decline and in improving the visualisation of damage statistics.

Mapping of forest condition by the means of satellite remote sensing is a technology that should be considered as an additional tool for the ongoing work under the Convention. In various studies satellite remote sensing has been shown to improve the quality of forest change monitoring, and especially its reporting. Today the methodology is ready for large scale operational experiments, but not fully tested for regional damage monitoring.

2. BACKGROUND

The necessity to perform forest damage inventories arose with the occurrence of the first forest decline symptoms in large areas. The individual countries, participating in the LAOE, started from the beginning with research work and the establishment of damage assessment methods. These traditional methods are based on terrestrial sample surveys and partly accompanied by the interpretation of aerial photography. The approaches of the inventories, the area coverage and most of all the definition of damage classes varies widely among the countries. Despite of the immense costs and the lacks in providing maps, the biggest deficit is the inability to compare the results of these different damage assessments.

The analysis of the literature shows that satellite remote sensing has been applied successfully in various forest decline mapping studies. Affected trees are characterised most conspicuously by discoloration and foliage loss, accompanied by leaf pigment, morphological and water content changes. It is generally acknowledged that these factors influence the spectral reflectance and that this can be registered by multi-spectral scanner systems. For spruce and fir stands the spectral properties are highly correlated with the severity of the damage, measured by terrestrial means or aerial photography. This has been demonstrated in numerous investigations (Rock et al., 1986; Khorram et al., 1990; Brockhaus et al., 1993; Ekstrand, 1990; Lambert et al. 1993; Kenneweg et al. 1993; Schardt et al. 1995 and others). Several authors have shown that it is possible to distinguish 3 to 4 damage levels (Kadro, 1990; Förster, 1989; Häusler, 1991). The basis for the separation of distinct levels relies on the traditional classification scheme, with few exceptions. Therefore, these studies lack in the ability to compare the classification results in terms of damage class definitions. Satellite remote sensing, on the other hand, focuses on stands or groups of trees as the basic object and has the advantage to detect deforestation and opening-up of stands as an additional damage symptom. Therefore there is a strong demand in the development of new standardised damage levels, which can reliably be derived from spectral information and which can easily be compared.

In conclusion, although the use of satellite remote sensing in forest decline mapping has been demonstrated in a number of studies, it has proven to be operational only in specific cases, in restricted areas and with certain assumptions. It has never been tested for large areas with a harmonised classification scheme. In the participating countries, investigations on forest damage assessment by satellite remote sensing have been carried out since several years but only on locally limited areas. Due to the individual methods applied and the different definitions of damage classes, the comparison of the results is still impossible. Therefore, special emphasis has to be given to the development of a harmonised classification system and the definition of comparable damage classes on a regional level, which implies the need for further operational tests.

3. OBJECTIVE OF THE STUDY

The aim of the project "Large Area Operational Experiment for Forest Damage Monitoring Using Satellite Remote Sensing" was to propose, develop and test methods and systems for classifying forest damages for large areas in Europe. For the purpose of this experiment, forest damage is defined by destruction of forest canopy and forest decline.

The main interest was to identify damage levels which can be reliably classified by the means of satellite remote sensing and to propose a standardised mapping system as a complement to ongoing European damage monitoring programmes.

Specifically, the project goals were:

- to provide additional spatial information on heavily damaged mountain forests in Central Europe
- to develop damage classifications based upon field observations and satellite image
- to evaluate and verify the accuracy of the methods applied.

4. TEST SITES

For this investigation such test sites were chosen where national projects for forest damage classification with remote sensing are already in progress of being carried out. The work to be performed was closely related to the investigations of the national projects. The experiences gathered from there could be incorporated into the LAOE.

The Advisory Board agreed to restrict the work to the most endangered low-mountain ranges of the participating countries. The following areas were selected as test sites:

1. Sudety Mountains (Polish project)
2. Ore Mountains (Czech project: Krušné Hory; German project: Erzgebirge)
3. Šumava Mountains (Czech project)
4. Krkonoše Mountains (Czech project)
5. Harz (German project)
6. Fichtelgebirge (German project)

5. THE PARTICIPATING RESEARCH TEAMS

The work for the Czech test sites was performed by **the Czech Forest Management Institute, LESPROJEKT**, in Brandys nad Labem under the contracts No. G/CON/94/19UNEP and G/CON/95/02-UNEP as part of the UNEP Programme in Europe. The project was carried out in close co-operation with the firm **Stoklasa Tech.**

The Polish experiment was performed within the contracts G/CON/94/18-UNEP and G/CON/95/01-UNEP by the **Remote Sensing and Spatial Information Centre, OPOLIS**, of the Institute of Geodesy and Cartography. IGiK, in Warsaw.

The German Harz Mountains were investigated by the research team of the **Institut für Landschafts und Freiraumplanung of the Technical University, TU Berlin.** The research project was funded by the Federal Ministry for Research and Technology, BMFT, under the project no. 0339347A.

The project team for the German test sites Fichtelgegirge and Erzgebirge consists of the partners **Company for Applied Remote Sensing, GAF Ltd. - Munich, the Bavarian and Saxon State Institutes of Forestry, LWF-Freising and LAF-Graupa**, respectively. The project is financed by the German Space Agency, DARA, and the Bavarian and Saxon Forest Ministries under the project no. E-50K9207-ZA.

All the investigations were carried out in close co-operation with research groups from Sweden, Finland, France and the USA.

6. METHODOLOGY

The Advisory Board appointed a Technical Working Group (TWG), with scientists from the Czech Republic, Poland, Finland and Germany to develop a methodology and prepare guidelines for the harmonisation of the various classification approaches for regional applications. Their meetings took place in Harz (Germany), in Brandýs (Czech Republic) and in Warsaw (Poland). The elaboration of the standardised methodology was based on the exchange of experiences obtained from national projects within the TWG meetings.

For the operational part of the project only the damage on spruce were considered since this tree species is the most-investigated so far.

The classification of forest damage on beech (Fagus sylvatica) and Scots pine (Pinus sylvestris) is also of great interest, because damages on these tree species were observed increasingly. Since the investigations are still in a research phase, the mapping of these tree species were excluded from the experiment until the study results within the national projects will lead to operational damage classification procedures.

The recommendations of the TWG were structured according the following issues:

- choice of the appropriate remote sensing data
- problems of damage classification and role of ancillary data
- harmonisation of damage class definitions according to
- proposals of damage class definition to be applied in the test sites
- classification of the satellite data
- verification of the results

Following these guidelines and recommendations, the standardised methods had to be tested in smaller, yet representative areas within the national projects. One important factor that had to be considered in this procedure was the feasibility to transfer the classification methods to larger forest areas. The results had to be presented in standardised maps with a harmonised legend.

7. HARMONISED APPROACH FOR THE EXPERIMENT

The following section describes the results of the discussions of the Technical Working Group (TWG). Based on the findings of other research studies and the experience from their own national projects, the members of the TWG developed guidelines for the harmonisation of the various damage classification approaches for the regional application. In the following, recommendations for a standardised methodology for applying satellite data for forest damage assessment are presented.

7. 1 Remote Sensing Data

Due to the large area to be covered and the spectral complexity of forest damage classification, Landsat TM data were recommended by the TWG in this particular experiment. The spectral resolution of these data has been proven to be useful for forest damage classification in various studies and the main damage areas can be covered at reasonable costs. Since the sensor shows a spatial resolution of 30 * 30 metres, a mapping scale of 1:50,000 can be provided accurately. More detailed inventories on local level by means of infrared aerial photographs or feasibility studies with other satellite sensor data can be performed within the national projects and are not an element of the LAOE.

Infrared aerial photographs are explicitly recommended for supporting the determination of suitable training areas for the digital classification and for verification. The application of the AFL interpretation key ensures the standardised evaluation of damage levels by visual photo-interpretation. For financial reasons, infrared aerial photographs should only be taken for relatively small forest areas, giving a representative survey of different degrees of damages, types of forest management and topographic conditions.

7.2 Problems of Classification and Ancillary Information

Forest damage is only one of a number of factors influencing the spectral response of stands. If the separation of damage classes is not possible by relying on spectral signatures only, ancillary information, if available, is needed for obtaining a more precise classification result. Particularly, in classifying different forest-damage levels whose spectral characteristics differ only marginally, the overlapping of object-typical (damage typical) spectral information by other parameters might be so severe that a satisfactory classification into many different damage classes without ancillary data is very difficult. Because of the diverging data in the different countries, it can not be assumed that the availability and quality of ancillary information is homogeneous among the participating countries. This fact was not seen as a major problem by the TWG as long as different kinds of ancillary data do not inevitably lead to results which are no longer comparable.

The TWG came to the conclusion that the incorporation of ancillary information is quite helpful in improving the classification accuracy but only those ancillary data should be used, that are already available in digital format. Digitising large amounts of data, just for the purpose of optimising satellite classification, is too time-consuming and thus not feasible for small-scale classifications.

7.2.1 Seperation of Forest and Non-Forest

Basically, a separation of closed forest and non-forest using TM data is possible. However, using the signatures only, it is not possible to separate areas with severe or total deforestation with vital and lush grass vegetation from some agricultural areas, like grassland. Therefore, ancillary information regarding the forest distribution is advantageous in order to support the separation of forest and non-forest.

7.2.2 Pre-Stratification of Tree Species

Associated tree species in spruce stands may result in a confusion of damage classes. For example, the spectral behaviour of undamaged pine stands is similar to particular damage classes of spruce stands. If both tree species occur in the investigated areas, a pre-stratification is necessary in order to avoid a mis-classification. This could be done by incorporating ancillary information on the distribution of tree species.

Mixed forest stands consisting of spruce or beech should not be included in the classification. A spectral stratification of pure spruce stands from spruce/beech mixed stands is only possible with a percentage of beech exceeding 20%. Digitised forest maps were available only for small parts of the test sites, except in the Harz. Consequently, stands with a deciduous mixture below 20% and pine stands are included in the classification.

Because of the expenditure of work, it was not recommended to digitise forest maps for large areas, in order to optimise the classification. If spruce is mixed with pine in the investigated area and no digital forest map is available, it must be specified in the classification results that the mapping is only valid for the tree species "spruce".

7.2.3 Elimination of Negative Topographical Influences

Topography strongly influences the reflection of forest stands. Miss-classifications have to be expected and thus, the separation of damage levels may therefore be more difficult in mountainous areas. The differences in illumination can be taken into account by modelling and subsequent correction of the disturbing effects by using digital elevation models (DEM). But the availability, resolution and accuracy of digital elevation models differs widely within the participating countries. For example in the Czech Republic no DEM is available and in Poland only the forest maps give details on topographic parameters. Digitised forest maps are available only for a restricted area, but since in this project methods for damage classification of large forest areas are to be developed, the integration of forest maps is unrealistic at the moment. For some parts of Germany digital height models at a resolution of 80 m * 80 m are available.

It was not recommended by the TWG to generate DEM for larger forest areas, because this would be too cost- and labour-intensive. An alternative would be to make use of the synergetic effects of band ratioing for minimising illumination differences in the data set (Crippen, 1987; Crippen et al., 1988; Häusler 1991).

7.2.4 Summarising

The availability of ancillary information differs widely in the participating countries. This means that the harmonisation of classification procedures is neither possible nor really necessary as long as the use of differing data does not impede the harmonisation of damage-level definitions. However, with ancillary data of differing precision or scope of details, the precision degree of the classification must be indicated separately for the respective country or even for individual areas.

7.3 Harmonisation of Damage Classes

The most important point of discussion was the definition of harmonised damage classes which should correspond both to the requirements of satellite remote sensing and to the needs of the forest administration for forest damage inventories. Remote sensing means measurement of spectral signatures, which in forest stands are mainly influenced by the amount of needle biomass per pixel. In damaged forest stands this parameter results from stand density, the average degree of defoliation of the remaining trees and the occurrence and composition of ground vegetation. Stand density as a (possible) damage symptom is completely neglected by field-sampling methods, whereas with remote sensing methods it can and must be taken into account. The parameters "needle loss" and "deforestation" were given special consideration by the members of the TWG. The results of the discussion can be summarised as follows.

7.3.1 Classification of Defoliation

Satellite classifications of forest damage using Thematic Mapper data cannot give any information on the defoliation stages of single trees because from picture elements with a spatial resolution of 30 m * 30 m only an integrated information on approximately 10 to 50 trees (dependent on tree age) can be derived. Because of the heterogeneous spatial distribution of defoliation stages most of the pixels integrate trees that belong to different defoliation classes. Therefore it was examined whether these stages must be assigned to categories according to their respective portion of different defoliation classes or to categories containing a single defoliation class. The latter class definition is only possible if defoliation classes are distributed homogeneously so that mainly one defoliation class occurs within one pixel. The damage class defionition which was chosen for different types of damage classes will be discussed below.

7.3.1.1 Damage Class Definition According to Needle Loss of Single Trees

A common damage-class definition based on the needle loss of single trees was established by a working group for aerial photo interpretation (AFL, 1988, or VDI, 1990) and is by now accepted as an international standard for forest damage assessment by the means of aerial photo interpretation (table 1). In order to obtain damage classes which are compatible with forest damage inventories based on ground measurements and aerial photo interpretations this definition was suggested by the TWG as base for the standwise damage class.

Damage degree	Description	Needle loss
S0	not defoliated	0-10%
S1	slight defoliation	10-25%
S2	moderate defoliation	25-60%
S3	severe defoliation	> 60%
S4	dead	

Tab. 1: Damage class definition according to AFL interpretation key

7.3.1.2 Damage Class Definition According to Needle Loss of stands or pixles

It was the consistent opinion of the members of the technical group that the damage cannot be defined as one single damage class, because of the unhomogeneous distribution of damages within stands or picture elements of the satellite data. The classes must rather be defined as the portion of differently damaged trees. There are different possibilities to describe the damage of stands or pixels, which are all based on definitions describing the damages of single trees (7.3.1.1). After intensive discussions, the TWG decided to accept Förster's damage-class definition for determining standwise needle loss (Förster, 1989). This class definition which is shown in table 2 was developed in the first phase of the German Harz project. In this definition the defoliation categories are defined as the portion of strongly damaged trees belonging to the defoliation classes S2, S3 and S4 (AFL, 1988).

Defoliation class	Indication
C0	0-10% of strongly damaged trees (S2+,S2-,S3, and S4, AFL)
C1	11-33% of strongly damaged trees (S2+,S2-,S3, and S4, AFL)
C2	34-66% of strongly damaged trees (S2+,S2-,S3, and S4, AFL)
C3	67-100% of strongly damaged trees (S2+,S2-,S3, and S4, AFL)

Tab. 2: Standwise needle loss categories

The advantages of this damage class definition is, that all potential damage conditions in the stand are included. It is not optimised for one region and thus can be applied universally. This advantage is of special importance for small-scale forest-damage mapping not limited to a single country, as it is the case in this project. Apart from that the definition is easy to be understood by everyone.

7.3.2 Classification of deforestation / crown density

The question of the necessity and practicability of integrating deforestation stages as a damage symptom into the classification was also discussed intensively in the TWG. The members of the TWG decided to integrate this parameter into the damage-class definition.

It was suggested that deforestation due to decreasing crown density can be defined as the percentage of crown cover. It was decided to test the following combined damage class definition, that integrates standwise damage classes (see table 2), and deforestation symptoms.

Crown closure more than 60 %	Classification into Defoliation Classes C0, C1, C2, C3+/-
Crown closure 41-60%	Deforestation class 1
Crown closure 21-40%	Deforestation class 2
Crown closure below 20%	Deforestaion class 3

Tab. 3: Damage class definition by combination of standwise needle loss and deforestation

By this definition, damages with a crown closure of more than 60% are classified exclusively according to needle loss as proposed by the TU Berlin (C0 to C3). Those with a crown closure below 60% are classified exclusively according to deforestation symptoms expressed by the canopy density. The advantages and the disadvantages were also discussed intensively.

Advantages of the damage class definition:

The term 'deforestation' is appropriate for a canopy density below 60%, since the stability of stands below this range is no longer guaranteed, and only a few silvicultural procedures are intended to operate at such a low canopy density.

As in former forest-damage inventories, the important information on needle loss of single trees in terms of the portions of different damage classes (S2-S4) will be integrated.

The very important information of the stand density which indicates the stability of a stand will also be considered. For a correct interpretation of these new damage classes, knowledge of the classified area must be taken into account, or digitised forest maps must be superimposed on the classification results in order to know which state the stand is supposed to be in.

There is a consensus among the members of the working group that a classification according to needle loss categories of stands with a crown closure of below

60% is either not possible at all or only with an unsatisfying degree of precision. One of the reasons for this is that the potential differences in reflection caused by needle loss are superimposed by the reflection of the ground vegetation, which strongly influences the signature in open stands. However, it can be assumed that these stands show strong damages and thus belong predominantly to the category C3 (damaged trees more than 66%). It can be assumed that C3+ will often be find in the deforestation class 1 (solution of damage degree "improvement" after damaged trees are taken out) and C3- in the deforestation class 2. Thus a subdivision into different needle-loss categories is not necessary.

Disadvantages of the damage class definition

As mentioned above, it is not possible to isolate the defoliation symptoms from picture elements integrating defoliation as well as deforestation features. A precise separation of defoliation categories is only possible with the classification within one deforestation stage. Unfortunately, these both effects may superimpose each other and thus lead to a less satisfying classification result of the needle loss.

The problem of recognising damages caused by air pollution among clearcuts, windthrow areas or other damages leading to a decreasing crown density cannot be solved if information on regular cutting operations and on disaster (storm, snow, ice, insect attacks etc.) is not available.

A decreasing canopy density leads to an increasing influence of ground vegetation on the reflection of forest stands. The typical reflection characteristic of forest stands can be modified strongly by different types and phenological stages of ground vegetation. Detailed field information and knowledge about the reflection characteristic of the forest floor is necessary to estimate the influence of ground vegetation on the classification accuracy.

7.4 Classification

In the final phase of the project the damage-class definition had to be tested. It must be made sure that only those methods are applied which are also operational for small-scale classifications (total test area), since the classifications in the pilot studies were carried out for smaller investigation areas only. This is particularly important for the integration of ancillary information available for smaller test areas but not covering the entire region.

It is not necessary to use the same classification algorithm for all the test areas as long as it is ensured that the classification of forest damages is carried out according to the damage classes mentioned above.

7.5 Verification

The verification of the classification result must be directed towards the "Ground Truth" available for the test area (e.g. aerial photographs or field experiments). Methods therefore cannot be standardised.

Irrespective of the method applied, it must be ensured that for all the verification areas in the entire test region the damage symptoms "needle loss categories in percentage" are recorded and "crown density" according to the percentage of canopy density. Only then there can be a guarantee that the classification of the damage class definition described above can be verified. One of the verification results is to be the analysis of the causes of mis-classifications so that the classification results can be analysed in detail by the user.

8. RESULTS OF THE STUDIES IN THE TEST SITES

The final image classification and the presentation of its results was performed in all test sites following the common methodology approved by the Advisory Board of the Large Area Experiment for Forest Damage Monitoring in Europe using Satellite Remote Sensing. This methodology was based on the suggestions of the TWG.

The results of the forest damage classification were printed on coloured maps in scale of 1:100,000 (Polish Sudety Mountains, Krusne Hory, Harz) and 1:200.000 (Fichtel- and Erzgebirge). The results of the particular projects are summarized below. Detailed information on the investigations in the test areas can be derived from Henzlik, 1995; Zawila-Niedzwiecki, 1994; Reuter & Akgöz, 1995 and Schardt et al, 1995:

Necessity of ancillary information

The investigations in pilot studies showed that the integration of a DEM and forest stand parameters derived from digital forest maps increased the classification accuracy only slightly. The digitisation of forest maps is very time consuming. Digitising large amounts of these data just for the purpose of optimising satellite classification is not advisable and thus not feasible for small scale classifications. The thamatic information of forest maps should only be integrated into the classification process if it is already available in digital format.

However, the integration of additional information is necessary in order to seperate forest from non forest (open stands <20% crown closure). This can be derived either by using the digital forest layer of topographic maps or by classifying a forest mask through multi-temporal classification of Landsat-data.

Signature analysis

All pilot studies stated that the influence of stand density on the spectral signature of Landsat TM data is high. The influence of different needle loss symptoms on the spectral signal is generally lower and is masked by the influence of varying stand densities. The influence of tree age and illumination is significant in each band. But by using synergetic effects of band 4 and 5 this influence can be reduced.

The separation of different neddle loss categories is not possible in stands with crown closure less than 60%. Crown closure below 60% is mostly caused by forest damage and exeptionally a result of regular forest management. Therefore, the damage class definition used in the LAOE is very suitable for describing the whole range of damage symptoms (opening up and needle loss).

Classification accuracy

The verification of the results was carried out with differing methods among the projects. Terrestrical ground data and aerial photo interpretation was used for the assessment of accuracy. In the Harz project for example the accuracy of the classification of the 4 standwise needle loss classes is about 70%. The combination of the classes C0, C1 and C2, C3 gave an accuracy of 84%. In the other test sites the average accuracy of the needle loss classification was above 89%. The classification of the three openening up classes can be performed with an accuracy of over 90%.

Collection of ground truth

It has been shown that the methodology of the definition of representative training areas for the damage classes is the most crucial point which influencing the classification result. It is necessary to collect the ground truth data in such a manner that the stands or training areas can be directly categorised into the harmonised damage classes. Harmonisation must already be started by collecting the ground truth data. The verification areas have to be defined with the same procedure.

The interpretation of aerial photos is best suite for a precise definition of ground truth.

9. CONCLUSIONS AND RECOMMENDATIONS

Recent and realistic forest damage maps with harmonised forest damage classes did not exist at regional scales until now. The presented project has demonstrated the value of satellite based remote sensing data for forest monitoring, in particular for assessing forest damage areas, where rapid changes in stand conditions occur.

The satellite based remote sensed data is usable for forest health status detection. It has been demonstrated in all the individual investigations of the LAOE that the reflected radiation recorded by the sensor of Landsat-TM is affected by changes of forest health status. Satellite remote sensing has been proven as an appropriate tool for monitoring forest condition by measuring the spectral characteristics associated with changes in vegetation health and destruction of forest canopy.

So the classification results can be used as a first phase of small scale inventories. Additional investigations by the means of aerial photos or field measurements can be performed in order to obtain more detailed information on the level of forest damage. The satellite classification can provide information for the selection of areas, in which those detailed inventories have to be carried out.

The digital data sets and maps elaborated in the course of the LAOE can serve as basis for future change detection studies and for the installation of a long-term monitoring system. The results of the project are comparable among the countries and provide planners at national and regional level with relevant data for their decisions. Especially valuable is the ability to control the effects of already initiated counter measures against the enormous pollution problems.

With the remote sensing methodology developed in this project it is generally possible to complement terrestrial and aerial photography damage assessments. In the Czech Republic the method is also used operationally for providing foresters with information they need. on local level.

The advantages of using satellite data include:

- large area coverage that allows mapping of the spatial extent of forest damages,
- extended spectral coverage improves measurement capabilities for assessing the health status of vegetation,
- archived data sets allow change-over-time studies of forest stand conditions.

The remote sensing methodology developed in the project should be brought to the consideration of all European bodies dealing with the assessment of forest condition, as a complement to current methodologies.

The methodology should be brought to the attention of the bodies monitoring the implementation of and in compliance with the Convention on Biological Diversity as well as the UNCED Forest Principles, as a complement to current methodologies.

The results of the project should be brought to the attention of the governments of Central and Eastern Europe, the progress of Ministerial Conferences on the Protection of Forests in Europe, the task force for the implementation of the Pan-European Biological and Landscape Diversity Strategy, the CSD International Panel on Forests and the scientific community dealing with global change.

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