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The health condition of the Dutch forests in 1984

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Summary

In the Netherlands, as in many other European countries, forests are showing signs of decreasing vitality due to the effects of various kinds of air pollution, possibly combined with other effects. In 1983 a first national survey about the health condition of the Dutch forests showed a critical situation. A more extensive second survey carried out in 1984 covering 2800 sample points indicated that 40 % of all trees had to be qualified as less vital, 8 % as hardly vital or sick and 1.5 % as dying or already dead. All tree species were affected with 57 % of coniferous species showing signs of reduced vitality against 33 % of broad-leaved species. Abiotic causes of such reduced vitality in the form of damage caused by harvest or wind could only be ascertained in a small amount of the samples. Young stands were less affected than old stands. Generally forest vitality showed a slight deterioration since 1983. The most alarming situation is found in the provinces of Overijssel, Utrecht, Noord Brabant and Gelderland, where over 50 % of all trees show signs of decreased vitality. The forests in the provinces of Groningen, Zeeland, Noord Holland and Zuid Holland and the IJsselmeer polders generally can still be qualified as vital.

Introduction

During the past few years several investigations have showed a decline of the health condition of forests in several Central European countries such as Germany, Austria, Switzerland and Luxembourg (Bucher et al., 1984; Lammel, 1984). Still earlier, data from Scandinavia drew the attention to the hazards of acidification of lakes.

Generally, these processes have been attributed to the effects of acid deposition and air pollution of SO_2 and NO_x produced by industry and traffic. An additional source of air pollution in the Netherlands is also ammonia produced by intensive practices of animal husbandry (van Breemen et al., 1982; Belois et al., 1984; Buysman, 1984; Roelofs et al., 1985).

The effects of air pollution upon plants and trees and the interaction between several air pollutants have already been described and discussed extensively in many publications (e.g. Anon., 1983; Ulrich & Pankrath, 1983; Keller, 1984). It is evident that air pollutants often effect the growth of trees. However, the physiological processes involved are still only partly understood (e.g. Mooi, 1981; Materna, 1983; Garsed & Rutten, 1984).

In order to assess the extent of the decline of forest health in the Netherlands, in 1983 the Dutch National Forest Service carried out a special survey. This survey was a first effort to describe the vitality of the Dutch forests in quantitative terms. The results showed that the condition of many forest stands had to be qualified as being critical (Staatsbosbeheer, 1983). Based on the experiences of this survey, in 1984 a second survey was carried out, which investigated the situation in more detail. This paper describes the methodology and results of the 1984 survey. This investigation had laid a firm foundation on which further research on several aspects of the diminished vitality of the Dutch forests can be based. Such research is at present being carried out by various research institutes.

Research methodology

The purpose of the survey was to obtain comparative quantitative data on the vitality of the Dutch forests in various regions and for various species. The survey covered a total area of 280 000 ha of forest lands out of the total area of Dutch forests of 330 000 ha. Only forest stands older than 5 years of age were included; furthermore, coppice stands were excluded.

On the basis of topographic maps at a scale of 1:25 000 the area under investigation was divided in blocks of 1 km × 1 km. In each block an observation site was chosen where 25 trees were examined. Consequently, the survey involved 2800 sample sites and 70 000 trees. Of the sample sites 200 were similar to the sites used in the 1983 survey, which enabled to compare the results of the 1984 survey with those from 1983.

At each sampling site a transect was laid out from the southern edge of the stand to the farthest opposite site. Starting from the southern edge 5 trees were examined at four 20-metre intervals. Only dominant trees were assessed, and oppressed or dominated trees were not taken into consideration. Only the main tree species in the stand was examined. At each site 2 or 3 persons were involved in assessing the health condition of the trees in order to obtain as high a degree of objectivity as possible.

The assessment of the vitality of trees was based on the principle that each tree manifests certain definite characteristics according to its stage of vitality. These characteristics are

- the number of year-classes of needles or leaf occupation
- the colour of needles or leaves
- the growth pattern
- the transparency of the crown
- the number of water sprouts or temporary shoots
- the time when leaves or needles fall off
- the number of dead branches in the top.

The vitality of trees can be judged by comparing these characteristics between healthy trees and others. In the present survey the health condition was primarily assessed based on the amount or lack of leaves or needles and by the degree of their yellow discolouration (Anon., 1983). The other characteristics may also indicate a reduced vitality, but they are not as consistent. Therefore they were only used to support or reinforce the primary assessment.

Based on a classification system developed by the EEC working group on 'Effects of air pollution on forests' the vitality characteristics were used to classify stands as either vital, less vital, hardly vital or non-vital. This classification system is based not only on the present health condition of the stand, but also on the perspective for its future development. Less vital stands show initital signs of decreased vitality, but it is uncertain how their future development will be affected. The hardly vital stands are more seriously ill and there is not much possibility that they will recover. The non-vital stands are dying or already dead.

In addition to the characteristics indicating vitality, also several environmental factors which may affect vitality were recorded. These included the degree of exposure, soil type, fertility and moisture conditions. These factors were scored as being either favourable, satisfactory or unfavourable for the stand being assessed. In this manner a relative comparison of the site quality was obtained, which was used as an environmental index against which forest vitality could be judged.

Results

The general condition of the forests

The general conclusion of the survey was that in the Netherlands 49.5 % of all forest trees are showing signs of decreased vitality. 40 % of all trees are less vital, 8 % hardly vital or sick and 1.5 % are dying or already dead. In other words, this means that every second tree is more or less affected, two out of five trees are less vital and one out of sixty trees is dying. This last percentage is only low because these trees are generally quickly harvested and removed in order to prevent them from becoming breeding-places for insects. Furthermore, shortly before or after death these trees can still be used for commercial purposes. As a result, in contrast to the situation in Belgium, Germany and Switserland it has not yet been necesary in the Netherlands to start an intensive programme of control against secondary insects that attack less vital trees.

The health condition of stands varies with age. Less than 30 % of young stands under 20 years of age and very old stands over 120 years of age showed signs of decreased vitality. In contrast, more than 55 % of stands at an age between 40 to 100 years displayed characteristics of declining health. It is not clear whether this difference is caused by differences in forest structure, provenances used or that it is a definite effect of age.

As to species, generally coniferous species are showing more signs of decreased vitality than broad-leaved species with coniferous species scoring higher in all categories of decreased vitality (Table 1). For both groups most of the stands with decreased vitality belong to the category of less vital stands.

Of all species Scots pine (*Pinus sylvestris*) has the worst condition. All other coni-

Table 1. Vitality of different tree species

	Area (ha)	Vital (healthy) (%)	Less vital (initial symptoms) (%)	Hardly vital (ill) (%)	Not vital (dying or dead) (%)
Alle tree species	281 350	50.5	40	8	1.5
Coniferous species	181 940	43.5	44	11	1.5
Pinus sylvestris	113 400	34	51	12	3
P. nigra	15 860	57	34	8	1
Pseudotsuga	15 530	50	39	9	2
Picea abies	13 120	62	28	7	3
Others	24 030	62	32	4	2
Broad-leaved species	99 410	67	28.3	3.7	1
Quercus	43.850	57	38	4.5	0.5
Fagus sylvatica	8 550	71	24	4	1
Others	47 010	74	23	2.5	0.5

ferous species are less affected (Table 1). These data were obtained in spite of the fact that the original classification system for vitality was somewhat modified for the Scots pine. According to the EEC classification system Scots pine with less than three year-classes of needles belongs to the category of less vital trees. However in the Netherlands, as well as in Nordrhein-Westfalen in Germany, local foresters are accustomed to Scots pine with only one or two year-classes of needles. Only old stands do normally have three year-classes. This situation may result from the fact that many Dutch pine forests consist of first-generation plantations on formerly degraded sites. Both the provenances used and the stand composition may not be optimal for these sites. Consequently, the vitality characteristics on these sites may vary somewhat from those of well-established pine forests elsewhere in Europe. In the present survey, this local experience was used as a base for the vitality classification of Scots pine, and trees with 1½ to 2 year-classes of needles were still classified as vital.

Among the broad-leaved species, oak (*Quercus* spp.) is more affected than beech (*Fagus sylvatica*) and other species such as ash (*Fraxinus excelsa*) and maple (*Acer pseudoplatanus*).

Regional variation in forest vitality

Considerable variation in forest vitality occurs between various regions. Areas with a high degree of seriously affected stands are found in the provinces of Overijssel (75 % of the stands show a reduced vitality), Utrecht (60 %), Friesland (58 %), Noord Brabant (52 %) and Gelderland (52 %). In contrast, in the provinces of Groningen (6 %), Zeeland (1 %) and the IJsselmeer polders (9 %) stands are generally healthy. The situation in Limburg (39 %) and Drenthe (35 %) is more or less intermediate (Fig. 1). Within the provinces important differences can still occur.

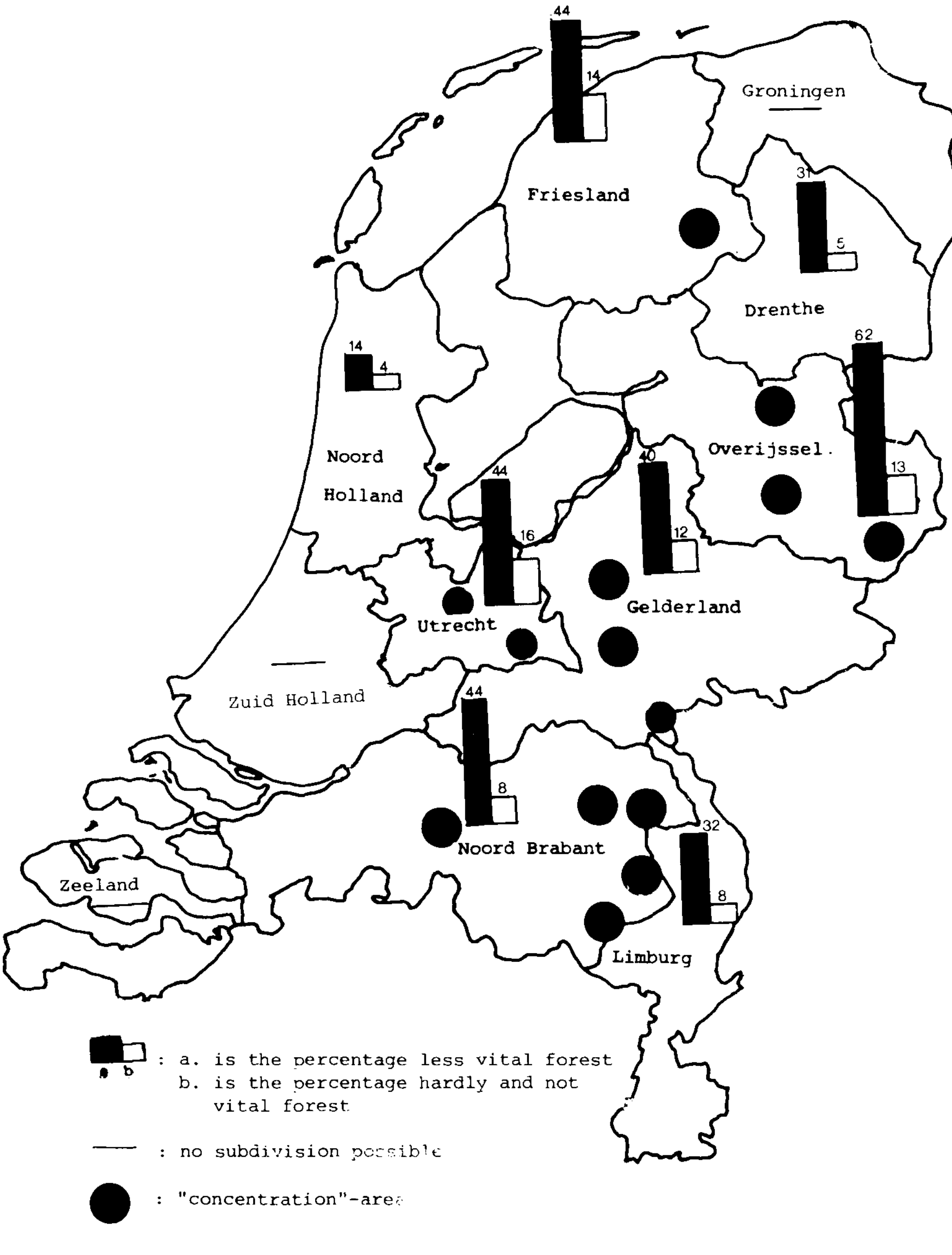

Fig. 1. Regional distribution of health condition of Dutch forests.

Stands with decreased vitality are concentrated in the southeast of Friesland, the east of Brabant as well as in certain parts of Overijssel, Utrecht and the Veluwe in Gelderland. Still favourable is the health condition of forests in the dune areas of western Netherlands (except in the neighbourhood of the steel industry of Velzen), western Noord Brabant, the northern parts of Limburg, and most of the central part of Drenthe and the IJsselmeer polders.

Development of forest health condition

From all stands showing signs of reduced vitality most belong to the category of less vital trees. The perspective for the development of these stands is still uncertain. On the one hand stands belonging to this category could still recover if a definite improvement of some environmental conditions (e.g. improved water supply) takes place in the coming years. On the other hand, the stands may have lost their ability to recover and their vitality may decline further.

Because the present survey was the first of its kind in the Netherlands, it is not yet possible to distinguish any precise trends in the health condition of the forests. However, some 220 sites examined in 1984 were also assessed in the much smaller preliminary 1983 survey. The results of the 1983 survey gave rise to anxiety about the condition of the forests. In some of the re-examined stands a recovery of health conditions could be observed in 1984, but in a greater number of stands the situation had deteriorated. In particular the process of declining vitality manifests itself in stands of Scots pine and Douglas fir (*Pseudotsuga menzisii*).

These findings indicate that the lack of vitality in many Dutch forests is not just a temporary effect caused by the summer droughts of 1982 and 1983, but that more long-term changes in environmental conditions are primarily responsible for this process. In order to monitor the future developments of the health conditions of the forests, the 220 stands examined both in 1983 and 1984 have now been established as permanent sample sites for assessing vitality.

Possible causes for reduced vitality

Various environmental factors may influence the decline in forest health, either acting separately or, more likely, in combination. Although the survey was not designed to evaluate each of the possible candidates for causing the deterioration in detail, correlation between the vitality stands with their environmental characteristics provided some general indications about possible relations.

Abiotic causes of reduced vitality in the form of damage caused by wind, frost, snow or harvest damage could only be ascertained in a small number of the sample stands. Attacks by insects or fungi were also found to be of minor importance. In less than 10 % of the stands effects of fungi or physical damage occurred. Insect damage was observed in about 40 % of the stands. Generally both the damage caused by fungi and insects was relatively slight and cannot be held responsible for the decline in vitality. Only in stands where less than 20 % of the trees were still vital a frequent occurrence of insects was noticed. Apparently this concerns a secondary effect of declined vitality, but not the cause. A similar situation was found in relation to the presence of a fungus disease caused by *Sphaeropsis sapinea* (= *Diplodia pinea*). This disease was observed for the first time in the Netherlands in 1982, but is has now spread over the whole country. Its main occurrence is found in the regions with lowest forest vitality.

In relation to soil conditions it was found that stands with reduced vitality often occur on soils which are susceptible to acidification or on soils with unfavourable moisture availability. The first observation is in accordance with the hypotheses of Ulrich (1983) about the effect of air pollutants on soil conditions and tree health. The second observation indicates that a role may also be played by the relatively dry weather of the past years. However, also on places with a good moisture regime stands with reduced vitality may be present. Together with the observation that forest vitality did not improve after the favourable weather between the 1983 and 1984 surveys, this indicates that drought is probably only to a minor extent responsible for the decline in forest health.

Conclusion

The results of the 1984 survey indicate that, although several climatic, biotic and site factors certainly affect the vitality of forest stands to some degree, generally the examined factors do not seem to offer a satisfactory explanation for the serious deterioration in forest vitality. An additional factor of major importance is thought to be present, of which air pollution is the most likely candidate. From the present data no conclusions can be drawn about the single or combined effect of various air pollutants such as SO_2, NO_x, ozone or ammonia. However, it is interesting to note that the pattern of regional variation in the health condition of forests does most closely resemble the pattern of regional variation in ammonia concentration (Buijsman, 1984) and much less the variation in SO_2, NO_x or ozone concentration. This observation gives further credit to the hypothesis that in the Netherlands a special form of air pollution caused by intensive forms of stockbreeding is at least partially responsible for the decline in forest health. The air-borne ammonia reacts with sulphur dioxide from the atmosphere, causing deposition of large amounts of ammonium sulphate. In trees this may result in an exchange between ammonium and other cations in needles, resulting in potassium and/or magnesium deficiencies (Roelofs et al., 1985). In the soil the pH may decrease due to nitrification of the ammonium (van Breemen et al., 1982).

References

Anonymous, 1983. Zum Erkennen von Immissionsschäden an Waldbäumen 1983. *Allgemeine Forst Zeitschrift* (Farbbild-Heft 1983) 38: 1387-1402.

Belois, H. de, M. de Bode & R. Brinksma, 1984. De verspreiding van stikstofverbindingen, in het bijzonder van ammoniak uit drijfmest en de effecten hiervan op de ecosystemen. Agricultural University, Wageningen, Netherlands, 121 pp.

Boer, W. M. J. den & H. Bastiaens, 1984. Verzuring door atmosferische depositie - vegetatie. Publicatiereeks Milieubeheer, Ministerie van Landbouw en Visserij & Ministerie van Volksgezondheid, Ruimtelijke Ordening en Milieu, The Hague, Netherlands, 82 pp.

Breemen, N. van, P. A. Burrough, E. J. Veldhorst, H. F. van Dobben, T. de Wit, T. B. Ridder & H. F. R. Reinders, 1982. Soil acidification from atmospheric ammonium sulphate in forest canopy throughfall. *Nature* 299: 548-550.

Bucher, J. B., E. Kaufmann & W. Landolt, 1984. Waldschäden in der Schweiz -1983. 1. Interpretation der Sanasilva-Umfrage und der Fichtennadelanalysen aus der Sicht des forstlichen Immissionsschutzes. *Schweizerische Zeitschrift für Forstwesen* 135 (4): 271-287.

Buijsman, E., 1984. Emissie van ammoniak in Nederland. Publikatiereeks lucht No. 22, Ministerie Volksgezondheid, Ruimtelijke Ordening en Milieu, The Hague, Netherlands.

Garsed, S. G. & A. J. Rutter, 1984. The effects of fluctuating concentrations of sulphur dioxide on the growth of *Pinus sylvestris* L. and *Picea sitchensis* (Bong) Carr. The New Phytologist 97(2): 175-195.

Keller, T., 1984. Die Auswirking von Immissionen auf Waldbäume. Berichte Eidgenössische Anstalt für forstliche Versuchswesen, Birmensdorf, No 255, 23 pp.

Lammel, R., 1984. Endgültige Ergebnisse und Bundesweite Kartierung der Waldschadenserhebung 1983. *Allgemeine Forst Zeitschrift* 39: 340-344.

Materna, J., 1983. The objectives, sources and possibilities of the prognosis of the effect of air pollution on forests and forestry. *Lesnictvi* 29(8): 649-657.

Mooi, J., 1981. Influence of ozone and sulphur dioxide on defoliation and growth of poplars. *Mitteilungen der Forstlichen Bundesversuchsanstalt Wien* 137: 47-51.

Roelofs, J. G. M., A. J. Kempers, A. L. F. M. Houdijk & J. Jansen, 1985. The effect of air-borne ammonium sulphate on *Pinus nigra* var. *maritima* in the Netherlands. *Plant and Soil* 84: 45-56.

Staatsbosbeheer, 1983. Kort verslag van het vitaliteitsonderzoek door Staatsbosbeheer. Staatsbosbeheer, Utrecht, Netherlands, 6 pp. & app.

Staatsbosbeheer, 1984. Verslag van het landelijk onderzoek naar de vitaliteit van het Nederlandse bos. Rapport No 26, Afd. Bosontwikkeling, Staatsbosbeheer, Utrecht, Netherlands, 24 pp. & app.

Ulrich, B., 1983. Soil acidity and its relation to acid deposition. In: B. Ulrich & J. Pankrath (Eds.), Effects of accumulation of air pollutants in forest ecosystems, pp. 127-146. D. Reidel, Dordrecht.

Ulrich, B. & J. Pankrath (Eds.), 1983. Effects of accumulation of air pollutants in forest ecosystems. Proceedings of a workshop held at Göttingen, West Germany, 16-18 May, 1982. D. Reidel, Dordrecht, 389 pp.