European Forest Decline Problems in Assessing and Monitoring Health

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Problems in Assessing and Monitoring Health

by

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Abstract

At the beginning of the 1980's the major species began to display a rapid deterioration in crown appearance over large areas of Europe. Consequently, crown condition has since then been subjected to annual observation in national surveys in many countries. In the past few years not only the leaf or needle loss but also the degree of discoloration has remained fairly stable. Subjective influences, which cannot be excluded even with the most careful planning and execution or systematic checking, have so far precluded more exact conclusions as to the changes in the appearance of the tree crowns.

Nevertheless, increment has not decreased during the 1980's; in some regions and particular species it has even increased. In other words, the two major indicators of the health of the forest have developed as if they were completely independent of each other. On the other hand, national inventories and many local studies reveal a more or less significant relationship between foliage loss and increment within a particular stand or sample area. This relationship exists also between the increment occurring before 10, 20, or more years and the recent foliage loss.

At first glance, these findings appear contradictory, but they must and can be explained. The question as to whether decrease in increment was due to foliage loss or perhaps other factors is basic for both the interpretation of what has happened and the future monitoring of forest health.

Previous Indices of Injury in Europe

Injury due to pollutants has increased over the past forty years and research on the subject has become more and more intensive. In the past, injuries were generally limited to particular localities or regions and it was possible to establish a direct relationship with definite emission sources, so that the identification of causes was relatively simple. The greatest and most obvious injuries occurred in industrial areas using brown coal as their energy source. The major pollutant in these areas was undoubtedly sulfur dioxide. In other areas fluorides were found to be responsible.

The first large-scale type of forest damage was termed silver fir decline. Over the past thirty years it has been observed from France to Poland in trees more than about 70 years old. Its symptoms are reduction of the height and increment growth rate and, in particular, thinning of the crown, especially in the middle and lower parts. Eventually, the affected trees die. This syndrome was patchily distributed: severely damaged stands were found next to apparently healthy ones, regions with much damage of this type bordered on others where the phenomenon was completely unknown. In no case was it possible to attribute the differences to site factors. Increment losses were later traced back to the fifties. The causes of silver fir decline have never yet been clarified, though in some cases local emissions of fluorides or chlorides were clearly responsible (Schmid-Haas 1989).

In the seventies much research was conducted on the effects of acid rain, especially in northern Europe. In areas with an acidic bedrock acid precipitation exerted a definite influence on lacustrine life and contributed to the extinction of some fish. In general, no increment losses or other types of damage to forests were established. Nevertheless these studies led foresters to pay more attention to air and soil pollution.

Large-scale leaf and needle loss

In the early eighties conspicuous needle loss in Norway spruce (*Picea abies* Karst.) was observed. Over large areas most spruces were seen to be losing an abnormal proportion of their needles while their crowns were becoming increasingly sparse. As spruce is by far the most important species both in terms of frequency and economic importance, that was alarming. At the same time, extensive new needle loss was observed in silver fir (*Abies alba* Mill.), even in those areas in which the firs had previously appeared healthy. Pines (*Pinus silvestris* L.) also suffered conspicuous needle loss, though not for the first time. The appearance of many broadleaf trees, too, deteriorated considerably. Consequently, more and more countries have begun to scrutinize tree crowns in the past few years, usually employing permanent systematic sampling. Sampling grids of 16 x 16 km are usual; in Switzerland a 4 x 4 km grid is used. In most national damage inventories the statistical design is simple and sound.

The forest damage map of Europe (Fig. 1, Sanasilva 1988) shows that injury is widely distributed and also clearly reveals that by no means are all results comparable. The major damage area stretches from eastern France to Poland and from the Alps to the Baltic.

Unfortunately, the symptoms in all species studied so far are very vague and cannot be directly attributed to specific causes. In spruce and fir the crown becomes transparent because old and shaded needles fall, while the young shoots grow relatively normally and bear more or less the normal number of needles (Fig. 2). In certain restricted areas, however, a characteristic yellowing has been observed; this has been attributed to magnesium or potassium deficiency. In Switzerland it has been only moderate. Pines also exhibit very sparse crowns; this impression is sometimes enhanced by the effect of flowering. Another difficulty in estimating the density of needles in pine is that old needles become brown in summer, precisely when inventories are conducted. In broadleaves the sparsity of the crowns is equally evident; in some cases the leaves are conspicuously small, and in localized areas there is a premature yellowing of the upper crown, which may begin as early as July. The expression "leaf loss" is
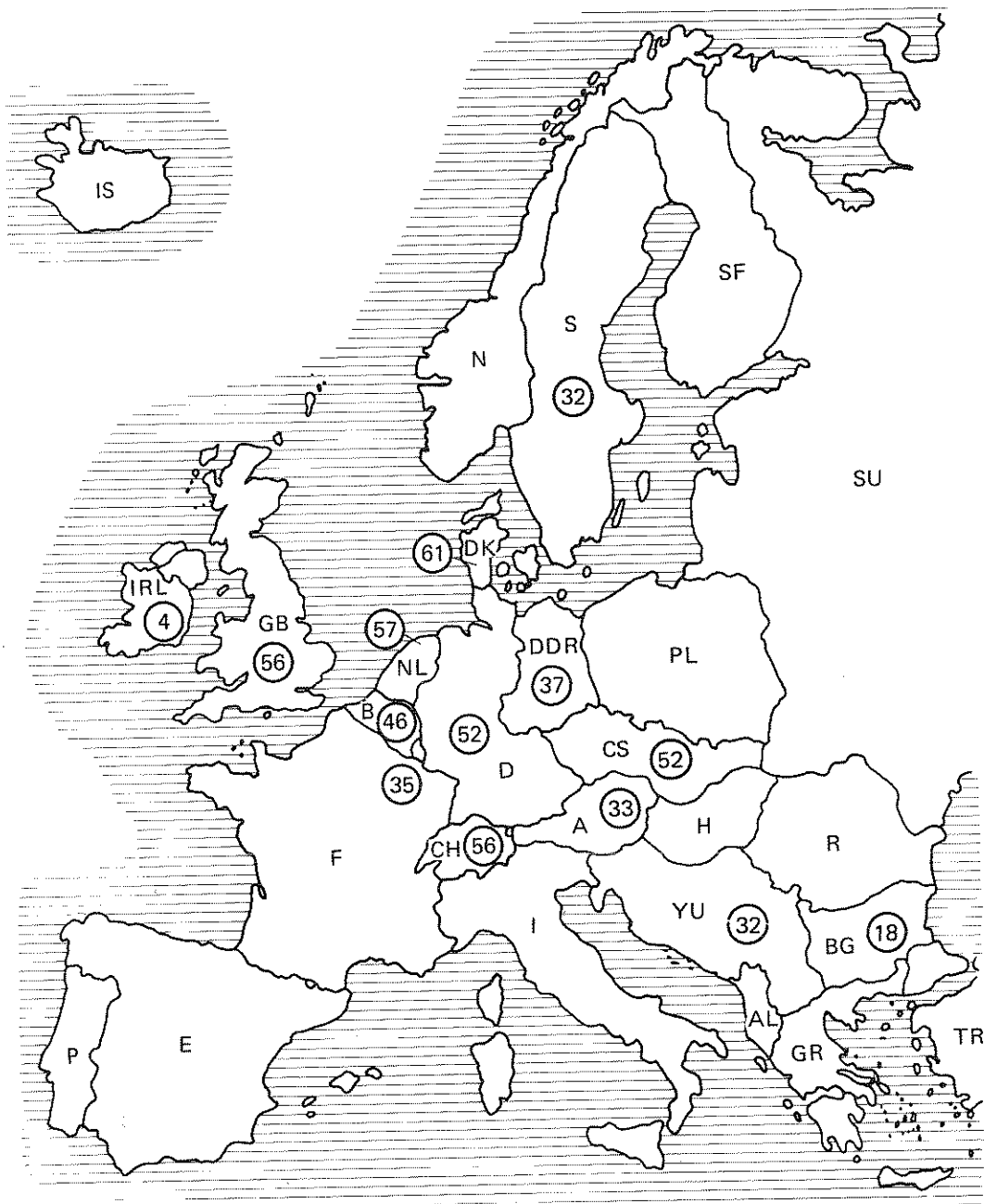
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Fig. 1:
Percentage of trees with more than 10% foliage loss registered in national forest damage inventories of 1987 (Sanasilva 1988).
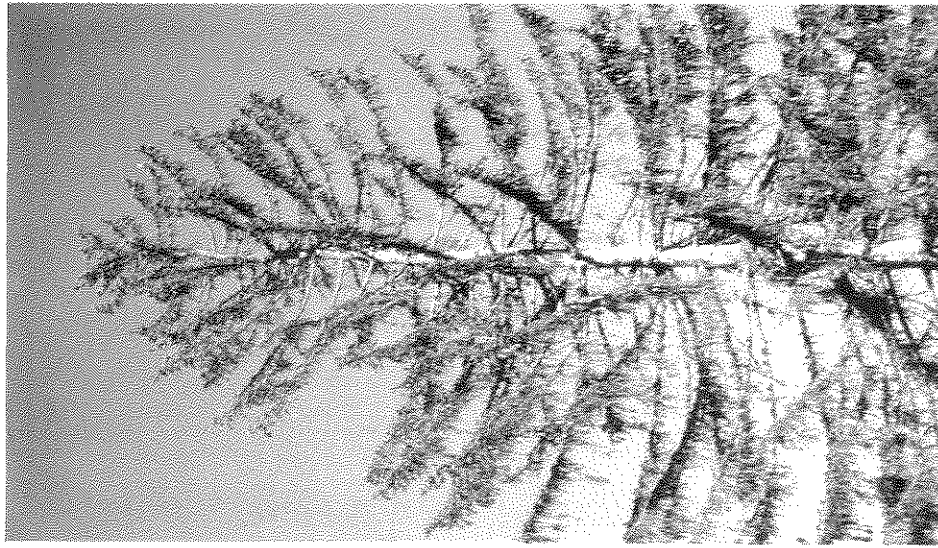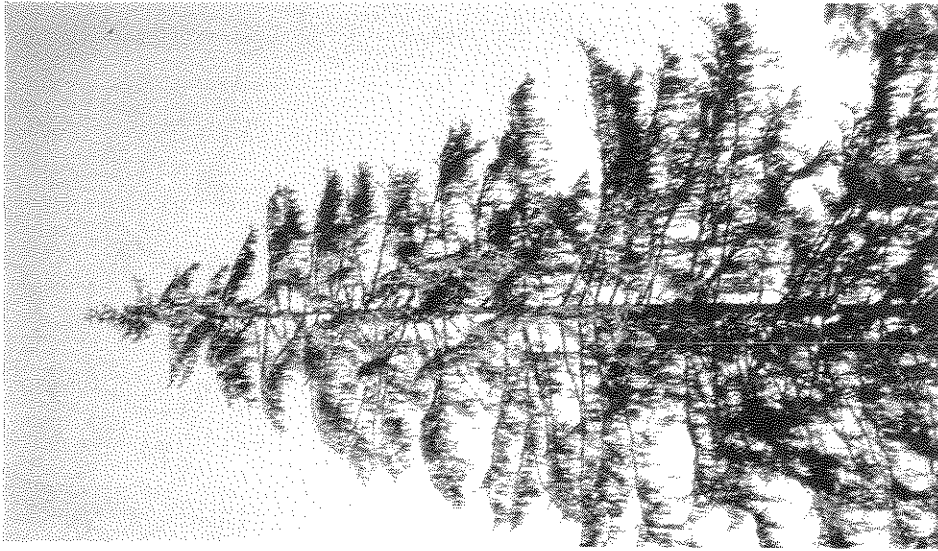
Fig. 2a:
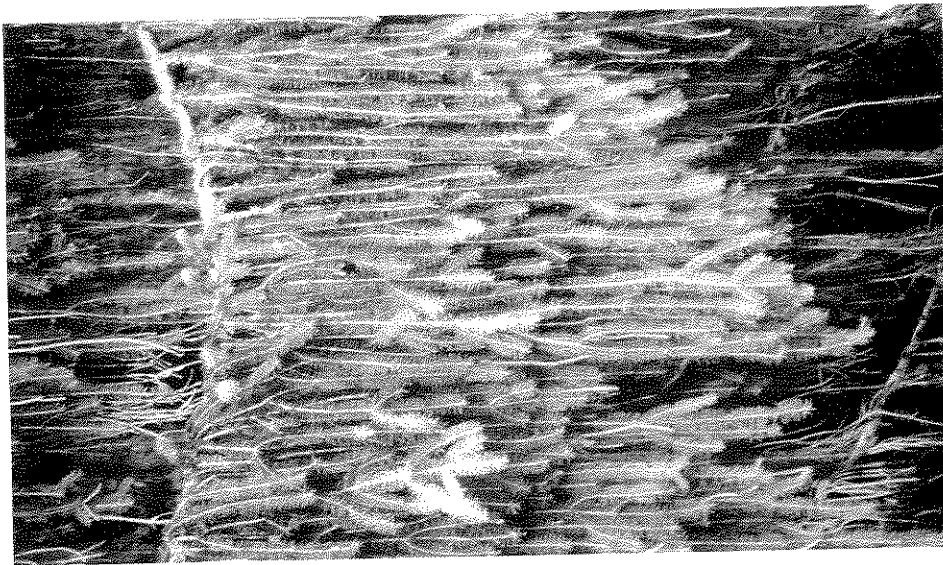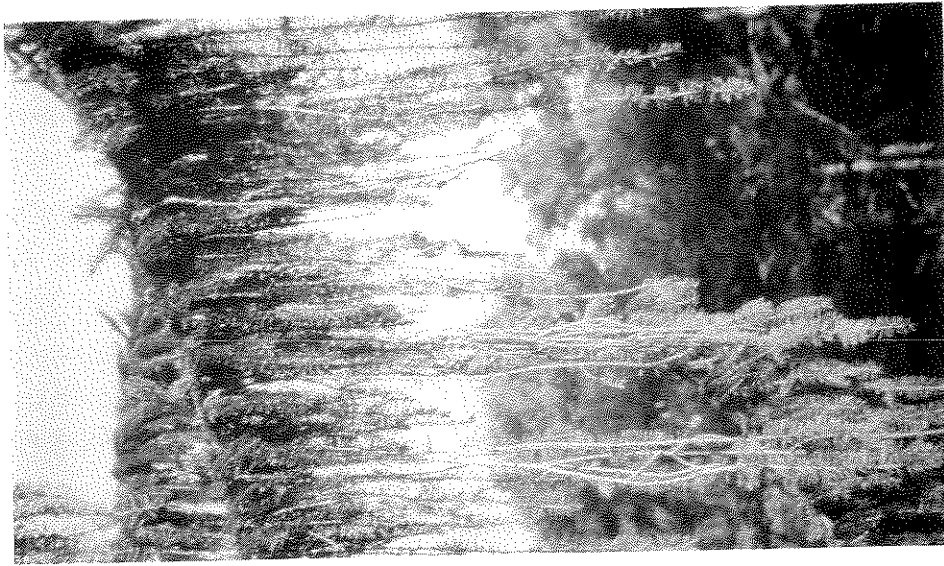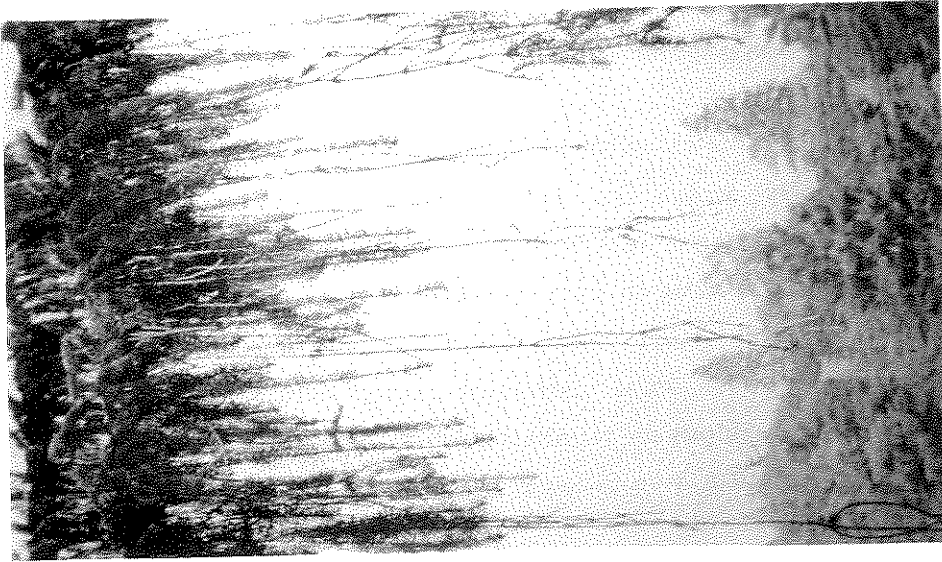Tree crowns of Norway spruce with 5%, 50% and 70% needle loss.

Fig. 2b:
Branches of Norway spruce with 5%, 50% and 70% needle loss.

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used in analogy to "needle loss", although the deficit in the total leaf mass is only partly due to premature leaf fall.

In the inventories with which I am personally familiar, the assessment is always very carefully made. The survey teams are thoroughly trained in centralized instruction courses making full use of binoculars. Tree crowns are assessed, either from all sides or from the same side every time. The work is regularly checked by supervisory teams. This means that the assessments within one country are comparable. Joint instruction courses held by several countries together and many discussions on coordination have achieved quite a lot towards the comparability of results from different countries.

The major discrepancies arise from differences of opinion, and are consequently not easily resolved. Some researchers regard the part of the crown most exposed to sunlight as most important, arguing that it contributes a great deal to biosynthesis and its appearance is characteristic for the state of health of the tree. Others maintain that all parts of the crown must be taken into account, since observed needle loss occurs mainly in the lower and inner sections and needles in shady parts can at least partially substitute for lost needles from sunny parts. Some would like to determine the total deficit in foliage mass, while others seek to define as far as possible the foliage loss due to pests, disease, or site conditions in order to estimate separately what is termed the "new type of forest damage" or "forest damage with no known cause". In general, certainly, efforts are no longer being made to assess damage due to pollution.

There is much discussion on the threshold above which a tree should be considered as damaged. In some cases, trees with a foliage loss of 10% or less are classified as "without signs of damage", in other cases this threshold is set much higher. As yet, little is known about physiological relationships in connection with the new type of forest damage. Statistical studies show that significant differences in increment can sometimes be detected between trees with 0% foliage loss and those with 5% foliage loss (Fig. 10), while in other cases where the foliage loss is much greater no differences in increment are found. Until more is known there is little point in discussing a threshold, as every one used is arbitrary. The main point is that the terminology is precisely

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defined and that a given threshold, once chosen, should be applied as long as possible, so that developments in the forest can be accurately traced. Often, it is better not to use thresholds at all but to examine instead the entire frequency distribution of foliage loss or its mean.

The course of needle and leaf loss

In Germany and Switzerland as well as in some other countries the course of needle loss has followed a similar pattern (Fig. 3). In the two first named countries the losses increased greatly at first and then remained more or less constant at a high level. By the time the initial sharp increase occurred in Switzerland, losses in neighbouring southern Germany had already reached the constant, high level; otherwise the pattern is similar. In Poland, for instance, the phenomenon had already begun 2 or 3 years earlier.

Unfortunately there is great uncertainty about the immense increase in Germany between 1982 and 1983, because the 1982 survey is not comparable with later ones. In Switzerland it was possible to observe this phase somewhat more accurately because it commenced a little later. Admittedly, the first survey in Switzerland, in 1983, comprised only a questionnaire circulated among local forest services which gave an estimate of 13% slightly damaged trees. From its very nature, such a decentralized inventory can only produce uncertain results. However, the survey teams of the Swiss National Forest Inventory used the same definitions in assessing conifer crowns in permanent, systematically distributed sample plots over one third of the country. In the following year this classification was compared with the estimates of needle and leaf loss introduced in the forest damage inventory. The 24 appraisers of the National Forest Inventory and the 16 of the forest damage inventory assessed the same sixty trees with their own methods (a total of two thousand four hundred assessments). Comparison of results showed that the National Forest Inventory class "no damage" corresponded fairly accurately with an estimated loss of up to 10 percent (Fig. 4). This agreement was valid for all species investigated. Consequently, it was possible to compare validly the results from 1983 with those of 1984, at least for one third of Switzerland.
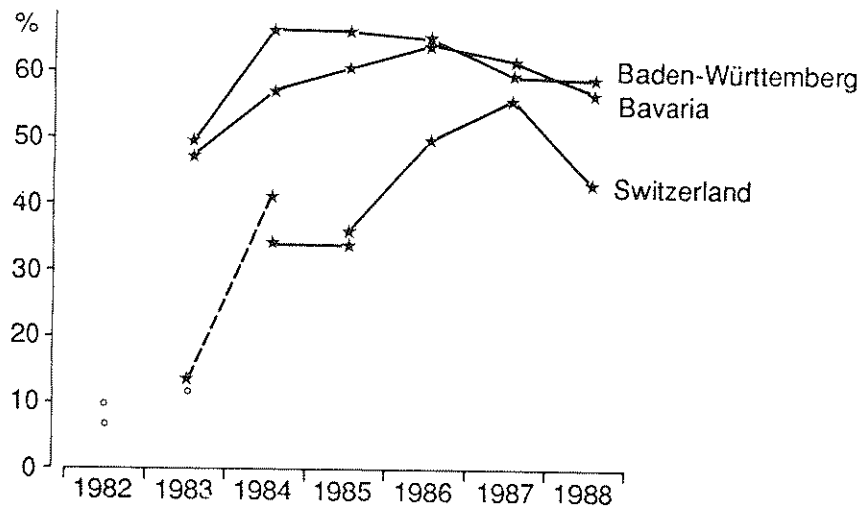

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Fig. 3:
Development in the percentage of trees (>20 cm) with more than 10%
foliage loss recorded in Baden-Württemberg, Bavaria and Switzerland
1982-1988.
∘ surveys by questionnaires
★ inventories by representative sampling
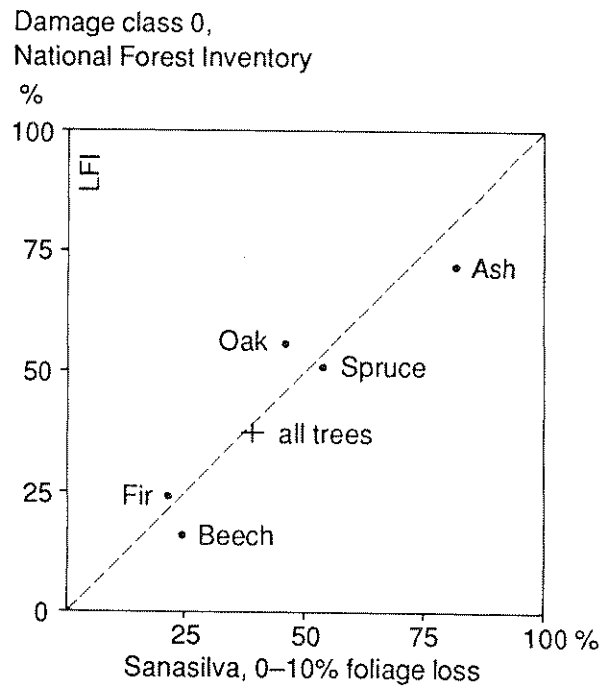

Fig. 4:
In order to compare foliage loss as defined in the Sanasilva instructions
with the damage classes defined in the Swiss National Forest Inventory,
60 trees were assessed with both methods by the relevant experts (2400
assessments in all). The graph shows that the damage class 0 of the
National Forest Inventory coincides with the interval 010% of the
Sanasilva survey.

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1983 was a dry year in Switzerland, so the sharp increase in needle loss can be at least partly attributed to the weather. In fact, the summer of 1983 was relatively dry and also fairly hot. Comparison with the period 1942 to 1950, however, shows that the weather in 1983 was by no means extreme. This is best shown by a model of annual drought maxima (Fig. 5).

Looking back, there are various reasons for questioning the findings:

— because after the first rapid increase leaf and needle loss has stagnated at the same level for some years, and the observed damage has remained at a constantly high level, bearing in mind that pessimists had already forecast a rapid advance in damage and the death of the forests, while optimists hoped for a quick recovery in wetter years;

— because, as will be shown later, increment suffered no corresponding loss, even after a lapse of several years;

— because all attempts to find the cause of this sudden change have so far been unsuccessful.

There have always been trees with more or less needle loss. Postcards from earlier times show that such losses were relatively common, at least in marginal or solitary trees (Schweingruber 1989).

Uncertainties may have been the reason for systematic trends in assessment in the early years. Debates on environmental policy may have lead to a more critical assessment of tree crowns and a greater influencing of not only the instructors but each and every appraiser. On the other hand, once the appearance of most trees has changed, survey staff may become accustomed to sparse crowns and consequently underestimate leaf or needle loss.

Unfortunately, it is not possible to measure crown thinning; despite all efforts to improve assessment and to conduct quantitative measurements, it remains a question of visual appraisal. It will not be possible to check developments registered in the past, and in particular, it is no longer possible to
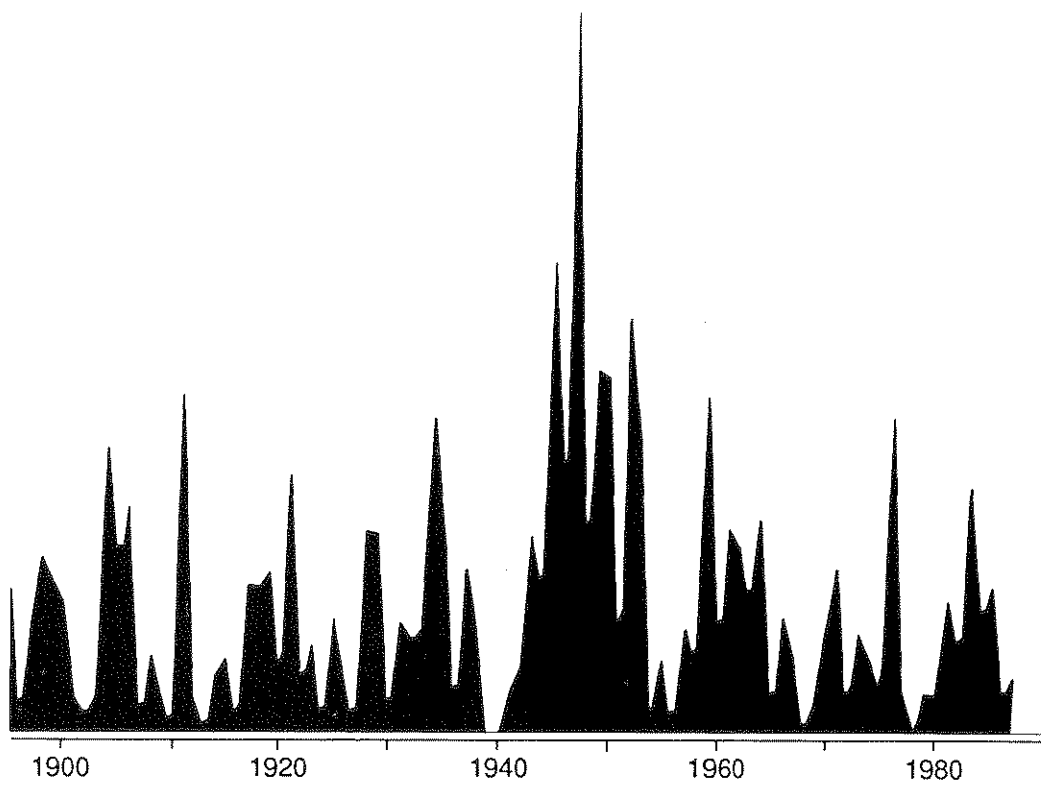
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Fig. 5:
Annual drought maxima (Zurich) (Sanasilva 1988).

establish how far the current or future state of the forest has deviated from the normal.

Are we really sure that there is a new type of forest damage, or that the current foliage loss is not in fact absolutely normal? There are three arguments which are, in our opinion, convincing.

(1)   When it all began, obvious changes in the tree crowns were observed, lots of needles fell, even green ones, and therefore the assessment was started. The results of the first inventories corresponded to what we had observed anyway, and the enormous changes from one year to the other agreed with our everyday observations, so that hardly anyone doubted their veracity.

(2)   The differences detected in the first years were so great that they could not be explained through changes in assessment. All the trees estimated in 1986 as displaying a needle loss of up to 25% must have been assessed in 1983 as having a loss of at most 10% if the apparent changes during this period were due to systematic methodological shifts. One can do better than that.

(3)   What has actually happened can be better established through intensive observation of particular areas than through large-scale national inventories. Especially informative are the areas in Baden-Württemberg observed by Schröter (Fig. 6). The findings reveal that in many areas the deterioration occurred within one or two years and the condition then stagnated, but that this pattern may have occurred in different areas in different years and that within the same plot spruces usually lost their needles one or more years later than firs. Such differences do not seem attributable to subjectivity in observation (Schröter and Aldinger, 1985).

The corresponding surveys conducted in yield research plots in Switzerland, unfortunately only beginning in 1985, support these findings (Keller and Imhof 1987). In these plots needle loss in both spruce and fir was found without exception to have increased between 1985 and 1987.
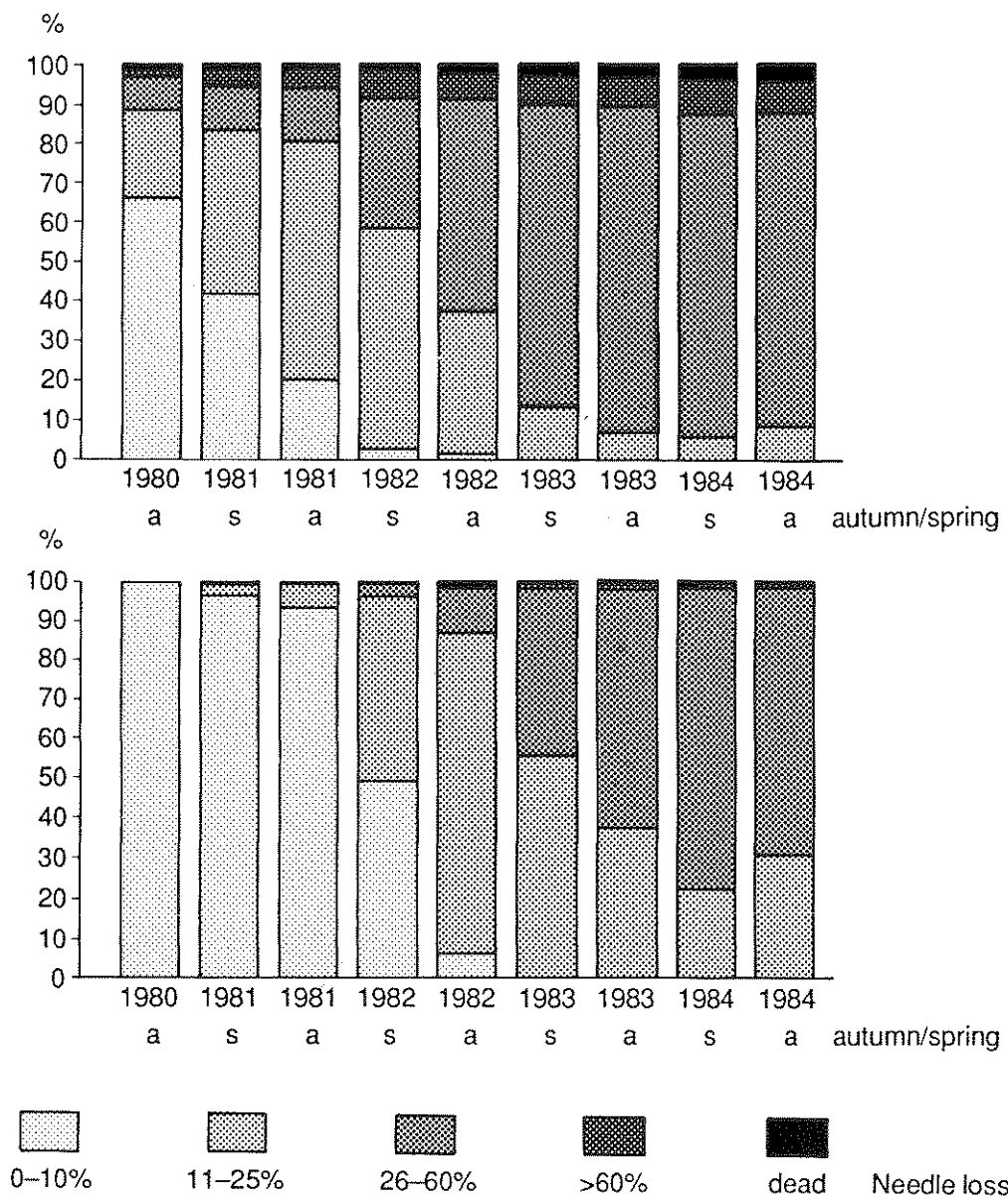
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Fig. 6:
Development of the health condition of 1675 silver firs (top) and 556 Norway spruces (bottom) on 27 fir observation plots (Schröter et al. 1985).

Thus it is certainly clear that needle loss was much smaller than it is today, but it is no longer possible to establish what is actually normal. The opportunity has been lost, because tree crowns were never assessed or photographed with sufficient accuracy before the abrupt changes occurred.

Even in the future it will only be possible to evidence changes with certainty and sufficient accuracy if enough attention is at last given to the avoidance of systematic trends in assessment. Obviously, that in turn demands that the same tree collectives are repeatedly surveyed with exactly the same criteria. This is practically only feasible if the survey teams are instructed partially by means of photographs of many tree crowns. That would necessarily involve a certain reduction in refinement of assessment methods. The booklet by E. Müller (1986), with pictures of crowns with differing degrees of crown thinning and data on estimated leaf or needle loss comprises a step in the right direction. In contrast, a more careful assessment of individual tree crowns or an even more precise checking and homogenization of surveys of the various groups is valuable but does not contribute to the improvement of the constancy of estimation over time.

These problems were foreseen by acknowledged experts at an early stage (Schöpfer 1984, Schläpfer 1985, Pollanschütz 1985), but have not yet received the necessary attention. Even now, national inventories to determine leaf or needle loss are carried out every year with methods which either give the impression of relatively great changes from one year to another or fail to establish any at all, but in any case provide no definite proof either way.

Unfortunately, infra-red aerial photographs cannot easily be used for subsequent scrutiny of past developments, because the hues on the photos depend on the production series of the film, storage conditions, and the way in which each film is developed. Consequently, hues in earlier photographs are only comparable with those in more recent ones to a limited extent. Even the exposure of color tables for calibration — a step which has usually been omitted — would only partly help in solving this problem. Periodically measured values of the reflected radiation, especially by satellites, might be somewhat less problematic in this respect.

The course of increment growth

Naturally, many inventories have sought to determine other characteristic changes in the appearance of the tree crowns. Apart from premature yellowing, foliage loss still seems to be the only feature to have undergone a dramatic change. Many characteristics are of little importance in regional or national inventories, if only because they cannot be observed easily enough from the ground. Whether anomalies in branching as described by Roloff (1985) and Westman and Lesinsky (1985) and others, or anomalies in flowering furnish a useful criterion for inventories remains to be seen.

Mortality and compulsory felling have presumably increased somewhat. They have, however, not been objectively and precisely enough determined to allow a definite increase to be shown.

In tall trees the growth of apical or lateral shoots cannot always be easily observed. It is even more difficult to assess root growth. Since the root system is very heterogeneous and it is not at all easy to obtain information on the growth or death of roots, it is out of the question to include this field of investigation in large-scale inventories. Consequently, one of the few parameters that can provide useful information on tree vitality is increment in diameter.

In the Swiss forest damage inventory of 1984 one increment core was taken from each sample plot. In the results of the study by Bräker and Z'Graggen (1989), the influence of tree age on the average radial increment has been eliminated (Fig. 7).

In the Swiss Alps, average radial increment in spruce has been constant over the past 80 years. There is clearly no systematic trend at all. In the Swiss Mittelland the radial increment of spruce behaves differently. Over the past thirty years the increments have averaged about 10% more than before, but vary around a constant average for this period. The change occurring in the fifties
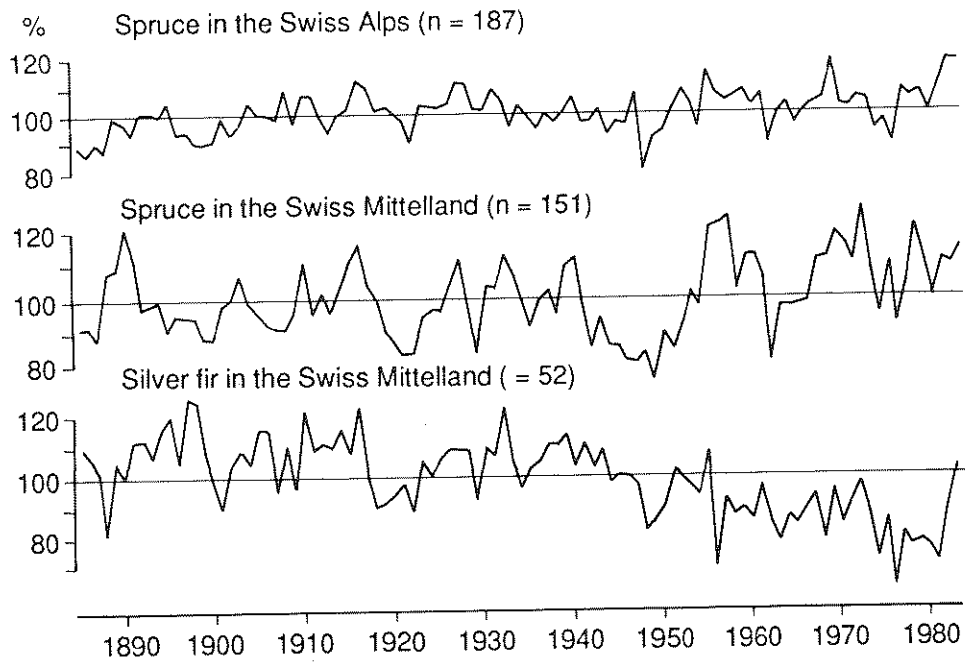
Fig. 7:
Relative radial increments 1885–1983, average age influences compensated (Bräker, Zgraggen 1989).
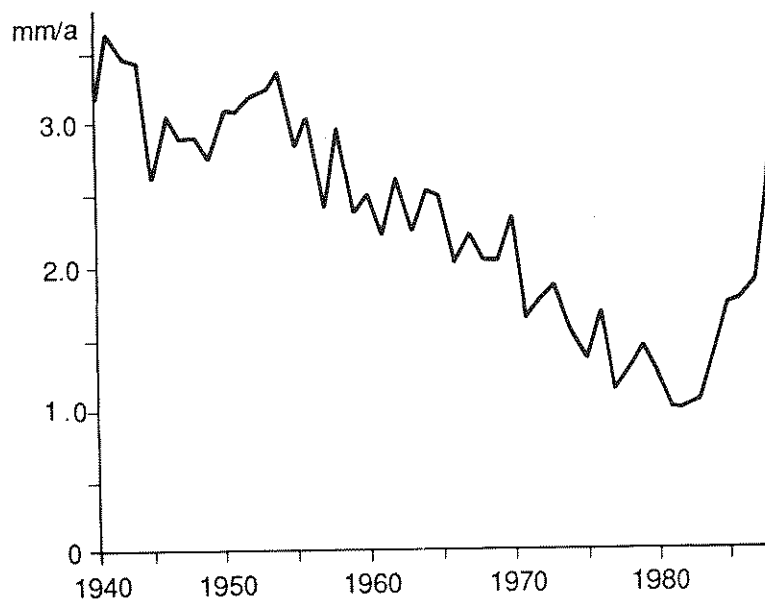

Fig. 8:
Average radial increments in a stand with silver fir decline (n = 49).

cannot be explained through weather conditions: it must be due to anthropogenic influences.

In silver fir, radial increment decreased by about 20% between 1950 and 1980, and increased to some extent in the early years of the present decade. This is due to silver fir decline in some parts of the country.

In most other species, however, increment has not diminished. Even in very recent years increment has been found to be rather high in all studies that I know of, though little has so far been published on increments between 1984 and 1989.

In Germany the volume increment per area has been observed in many yield research plots through repeated surveys on a long-term scale. The course of increment growth is, in many places, characterized by a marked peak between the mid-fifties and the seventies, which in some places has sustained to the present. This high can be seen in all age classes; only in areas with severe crown damage does increment display considerable reduction (Franz 1988). The results from Baden-Württemberg (Kenk 1988) and the relatively sparse findings from study areas in Switzerland support this conclusion.

Mean growth ring width is greatly dependent on silvicultural treatment: diameter growth is naturally greater when a tree has room to expand than when it is constricted. Consequently, ring widths are influenced not only by changes in the age distribution (taken into account in the illustrations) and the weather but also by overall changes in thinning patterns. The influence of these factors is probably superimposed by the effect of pollutants or epidemics.

Needle loss and increment

Increase in diameter is a measure of the biosynthesis of a tree, even when time lags due to changes in the crown and root zones or in the reserves occur. Great foliage loss must lead to impairment of biosynthesis and eventually of growth in diameter, but as long as it is mainly the old and shaded leaves or needles which are falling, the effects on the tree are not clear. Old and shaded

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foliage often respire more than they photosynthesize, and it has been experimentally shown that, at least in young Norway spruces, removal of the lowermost green branches does not result in any decrease in increment (Keller, Pfäffli 1987). On the other hand, more susceptible trees with greater foliage may also suffer a greater decrease in the productivity of the remaining needles. Consequently, it is not possible to explain physiologically whether the observed foliage loss is necessarily connected with considerable decrease in increment or not.

Taken over whole countries, changes in increment do not correspond to those in needle loss. Detailed observations of particular regions or stands showed in many cases that increment had not changed at the same time as needle loss. In comparable areas, increased needle loss often runs parallel with a more or less constant increment. These two parameters may even run contradictorily. An extreme example is a carefully investigated stand of fir, which had recovered from a long period of growth depression and which displayed a diameter increase of more than 250% between 1983 and 1987 (Fig. 8), while between 1985 and 1987 its needle loss showed yet another great increase.

On the other hand it has been found in almost every case that spruces and firs with fairly large needle loss display somewhat smaller growth in diameter than trees with little needle loss in the same stand or sample plot. Dong and Kramer (1985) even suggest a very close relationship between the growth of individual spruces and firs and the needle mass, as long as the needle mass is very accurately determined and increment refers to the crown surface area. The correlation between increment and needle loss varies greatly. The differences are doubtless to some extent due to variations in precision of assessment or measurement, but also arise from differences between populations.

In yield research plots in selection forests, with periodical measurement of diameter, the correlations between needle loss in 1985 and diameter increment over the preceding measurement period were significant in most cases for fir but only in one third of the stands for spruce (Fig. 9, Keller and Imhof, 1987). Where needle loss correlated with increment over the preceding measurement period, it generally also correlated with increment in earlier measurement periods, sometimes as far back as twenty to forty years; in one high altitude
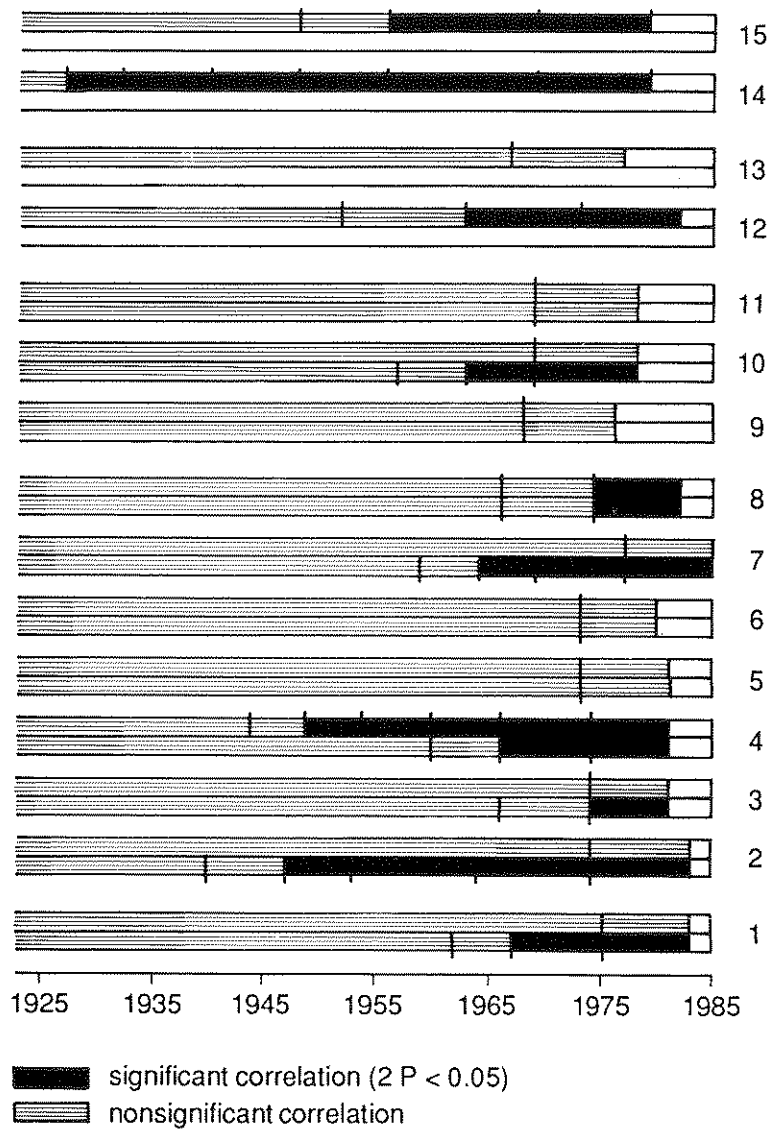
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Fig. 9:
Significance of correlation coefficients between needle loss 1985 and increment in previous periods in 15 selection forests. Norway spruce (upper bars) and silver fir (lower bars).

spruce selection forest even back to 1930. That means that the increment pattern of trees now displaying varying degrees of needle loss has long varied. It has not so far been possible to determine whether these differences are due to specific site factors or conditions of competition. Quite a few dendrochronological studies show similar results for evenaged forests.

Also in local inventories with permanent sample plots the correlation between increment and needle loss in spruce and fir varies greatly. Only stands at least sixty years old were assessed, since needle loss in younger stands is often almost negligible. In spruce and fir an increase in needle loss from zero to thirty percent corresponded to an increment loss of thirty-five percent in Liestal and sixty percent in Bremgarten (Fig. 10). As regards other species, neither larch, oak, or pine in Bremgarten displayed any statistical correlation between foliage loss and increment (Fig. 11), while beech exhibited only a slight correlation. One might expect that increment in species showing a close correlation with needle loss would be particularly low. But that is not so. Spruce and fir even display a relatively high mean increment compared to other species and to the values in yield tables. In Bremgarten, needle loss in spruce and fir was almost as closely correlated with the increment of more than ten years ago.

Let us sum up: the course of increment over the past few decades has certainly not been normal and cannot be explained through weather alone; nevertheless it followed a completely different pattern than that to be expected from the observed rapid decrease in crown density.

On the other hand, most stands display a significant negative correlation between needle loss and increment in individual spruces and firs (Spelsberg 1988). This correlation often remains where the increment of twenty, thirty, or even more years ago is considered rather than that of recent times.

These findings furnish only a confusing picture and can be only partially explained:

The deviations from the expected course of total increment may be explained through the positive, superimposed fertilizing effect of pollutants (in
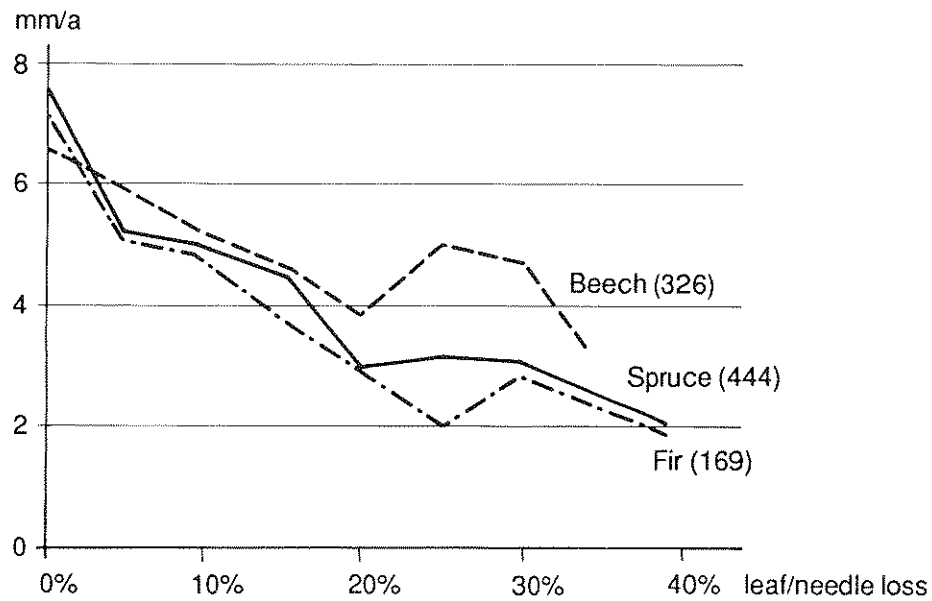
Fig. 10:
Diameter increments 1977–1986 in relation to needle or leaf loss of individual trees in 167 sample plots (age >60 years, D >20 cm). Bremgarten.
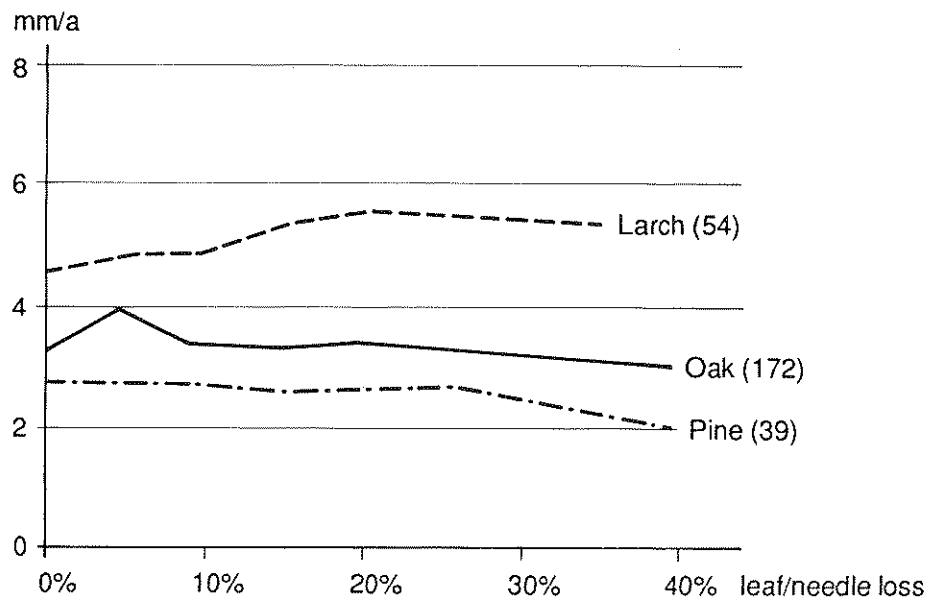

Fig. 11:
Diameter increments 1977–1986 in relation to needle or leaf loss of individual trees in167 sample plots (age > 60 years, D > 20 cm). Bremgarten.

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particular nitrogen and carbon dioxide) and the negative effects of unrecognized epidemics or harmful emissions. Here it must be borne in mind that unbalanced fertilizing may lead to injury or at least to an increase in susceptibility.

The abrupt increases in crown thinning may be explained through an unrecognized epidemic or through a new kind of emission, but may equally be due to the influence of the weather if the trees had actually become much more susceptible.

Yield research trials have long shown that total increment rapidly returns to its original level after moderate thinning, in other words that the remaining trees are able to compensate for the felled ones because of the decrease in competition. Equally, the increment decrease in trees with much crown thinning can obviously be compensated through increased growth in less affected trees, due to their improved conditions of competition, at least as long as needle loss is not too great. Consequently, there is as yet no reason to infer overall increment loss from varying degrees of crown thinning within the stands.

Where, within one stand, trees with varying needle densities have displayed varying degrees of increment for decades, the implication may be that the differences in crown density have, at least in part, persisted over decades, but it may also be that the differences in increment are not the result of varying crown density but rather that individual trees of differing vitality have reacted differently to stress. If that were so, the less vital trees, which have long displayed slow growth because of genetic composition, site conditions, or their situation in competition, would have had a greater needle loss than more vital trees, and the statistical relationship would have thus been explained. However, as the most vital trees tend to become dominant, these ought to have by far the lowest needle loss. Yet this is not the case. Dominant trees often have even more needle loss than others, possibly because their crowns are more exposed.

Conclusions

The forest in Europe is not dying. Nevertheless, what has happened must be regarded as an express warning — perhaps the last we shall have.

It can only be established that great crown thinning occurred over large parts of Europe some years ago and that since then the condition of the trees has neither greatly deteriorated nor improved. The crown thinning has not led to any provable overall increment loss over large areas, except in major pollution zones; and its causes remain unclear.

The methods of assessing and monitoring health must be founded on a sounder basis, and research on causes must be intensified, epidemiologically as well as experimentally.

Translation M.J. Sieber

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