SOIL ACIDIFICATION BY ATMOSPHERIC POLLUTION AND FOREST GROWTH

BENGT JONSSON, Royal College of Forestry, S-104 05 Stockholm 50, Sweden.

ABSTRACT

In recent years concern has been expressed about the danger of harmful pollution deposits which affect areas at great distances from the emission sources.

The investigation was so designed that a possible reaction in growth resulting from a supposed acidification could be observed as far as possible. A poorer growth development was observed in regions, which are suspected of being more susceptible to acidification than those regions which are presumed to be less susceptible in this respect. We have found no good reason for attributing the reduction in growth to any cause other than acidification.

1. GENERAL

It has long been known that smoke fumes from industries may damage surrounding vegetation. Forests around such local pollution sources often have reduced growth, and may in extreme cases be completely destroyed.

In recent years concern has been expressed about the danger of harmful pollution deposits which affect areas at great distances from the emission sources. In this respect the sulfur compounds have attracted most attention. It appears to be quite clear from observations during the past few decades that a general acidification is taking place in our environment. The sulfur emitted into the atmosphere is brought down to the surface of the earth by rainfall, in the form of sulfuric acid, and causes acidification, which amongst other things, is clearly expressed in the increased acidification of lakes and rivers. Soils are also exposed to sulfuric acid, and it may be suspected that as a result, a longterm impoverishment of the soil will ensue. On soils which are more susceptible to acidification, this results in an accelerated impoverishment which in its turn may result in a lower growth rate as compared with less susceptible regions. *This hypothetical difference in growth between regions of different susceptibility to acidification is the object of study in this investigation.*

2. MATERIAL

The investigation is limited to Sweden south of 61°N (essentially Svealand and Götaland), i.e. to about 40 percent of the country's productive forest land by area, or about 50 percent of the production.

In this part of the country, two types of region have been selected, primarily on the basis of soil and water chemical conditions (see Section 3), viz. those regions, which are suspected of being *more susceptible* to acidification, as a result of sulfur deposition, than other regions; and those regions which are presumed to be *less susceptible* in this respect. It is possible that these latter regions have remained substantially unaffected by the deposited sulfur.

For the sake of simplicity the more susceptible regions are designated as A regions (acid), and the less susceptible as B regions (basic). The remaining regions, which fall between A and B, have not been utilized in the analysis of the growth reduction.

Growth data are derived from observations carried out by the Department of Forest Survey at the Royal College of Forestry in Sweden. This department collects annually various types of forest information according to a systematic sampling procedure. From some sample trees increment cores are taken (at breast height), i.e. a continuous wood sample from the bark to the pith. On these cores the annual ring widths can be measured, giving a series for each tree of annual increments well defined in time, each one the result of a biological process with many interacting growth factors. The question is whether the deposited sulfur has so far directly or indirectly affected this process, and hence also growth.

The growth comparison according to the above, between the two susceptible types of region, is carried out for everyone of the four groups of material in table 1.

The total number of sample trees processed was 4269. These trees are derived from the sample tree material for the years 1966-1969, and are so selected that they have a breast height diameter over bark of 20-40 cm, and 50-120 annual rings.

Table 1. The material groups

Tree species	Site quality classes according to Jonson [within parentheses: the annual average yield in m^3 (total volume on bark) per hectare during 100 years]	
Scots pine Pinus silvestris	II-III (8-6)	IV-VI (4.5-2.5)
Norway spruce Picea abies	I-II (10.5-8)	III-V (6-3.4)

3. THE BASIS FOR DELIMITATION OF REGIONS DIFFERING IN SUSCEPTIBILITY

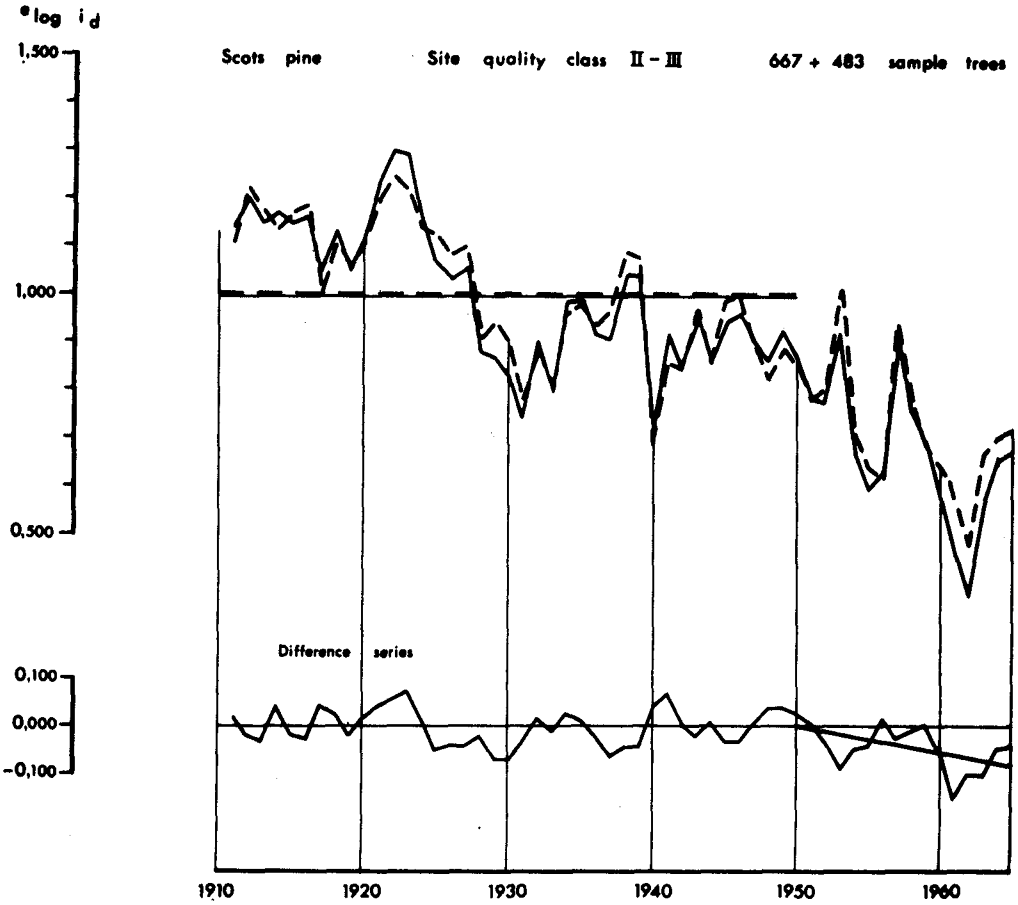
The criteria of selection for regions, which can be suspected to be more or less susceptible to acidification, have been the magnitude of the acid fallout over the country (the average pH value of the precipitation) and information about pH values and ion composition in Scandinavian lakes and rivers in 1965 and 1970 and finally information about the distribution of soil types.

The main emphasis has been laid on the last-mentioned criteria. If, for example, a region consists of precambrian tills of low base status or of glacifluvial sand deposits, and the surface water within the region has both a low pH value and a low cation value, the region has been regarded as more susceptible to atmospheric chemical influence. No numerical ranking into susceptibility classes has been carried out.

The various regions have been delimited and classified by Professor S. Odén.

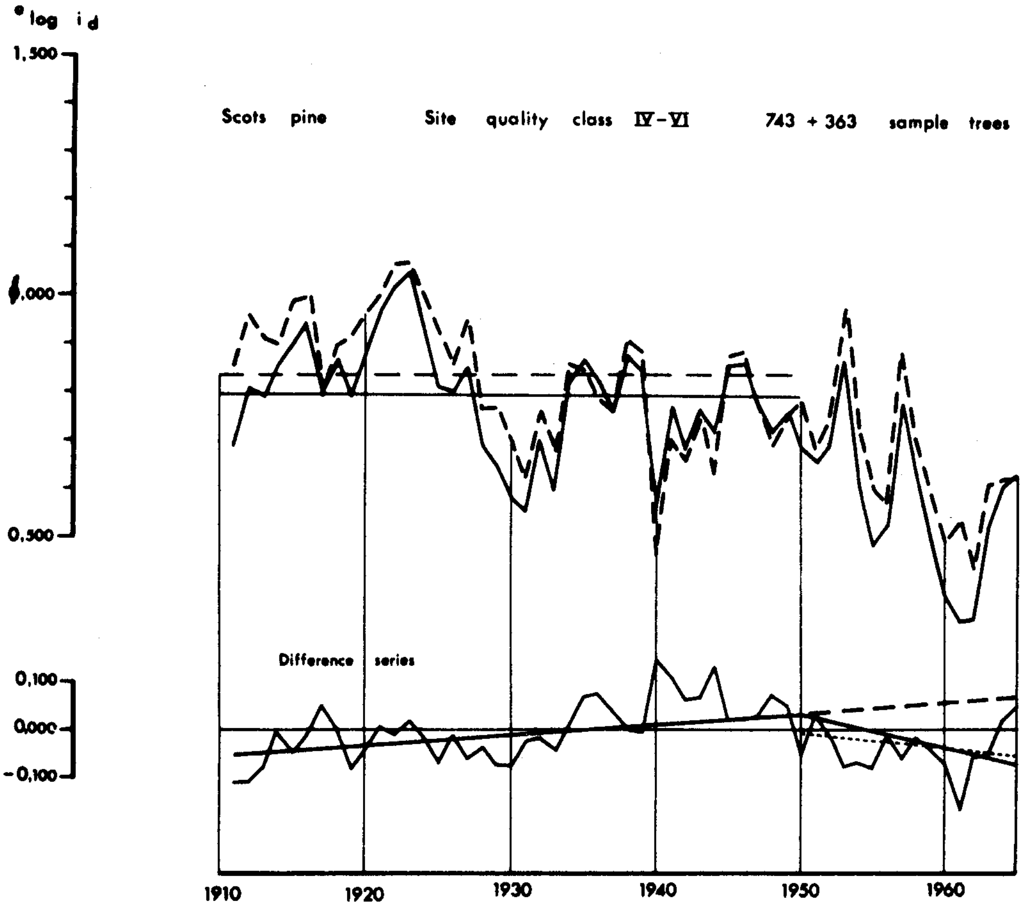
4. STATISTICAL MODELS, CALCULATIONS AND RESULTS

A statistical model was introduced for the annual growth of a tree. This model led to the consideration of averages of logarithmized annual growths, the averages being based on the sample trees from each region and also on the combined region groups (A and B, respectively). The annual difference between the A and B averages was considered as a statistical time series with a trend function. This trend function was represented by a broken linear function composed by one time-linear



Figures 1a and b. Averages of logarithmized double annual ring widths (in mm) for the more susceptible (full line) and less susceptible (dashed line) regions, repectively, and difference series of these average series. The average level during the period 1911-1950 is shown for each series. Two linear trends of the difference series are also drawn. The trend of the acidification component is represented under the two assumptions of individual (full line) and common (dotted line) rate of ageing, repectively, discussed in the text.

The figures before "sample trees" represent the number of sample trees; the first one from the more susceptible regions and the second from the less susceptible regions.



trend, representing the differences in growth level and in rate of ageing, and another time-linear trend starting at a year t_0, representing the possible increasing difference between the two groups of regions in acidification effect on growth. If the regions in group B have not been affected by acidification, the slope of the latter trend component is a measure of the average acidification effect on growth in region group A.

The slope of this acidification component was estimated by the method of least squares, and the standard error of the estimate was estimated (by two methods). As concerns the rate of ageing, each region was given its own rate in the main model, but calculations were also performed under the assumption of a common rate of ageing, the latter implying a time-constant trend component up to the year t_0 in the difference series.

The estimated acidification trends were compared with the estimated standard errors in an assessment of the statistical significance. This led to the following statement: *The observed difference in trends between more susceptible and less susceptible regions could hardly be interpreted as reflecting the statistical uncertainty in the estimates.*

5. CONCLUSIONS

When casual conclusions are to be drawn on the basis of an analysis of non-experimental observations, a situation arises in which no good methods are available.

The risk is that an erroneous explanation will be given of a course of events, even though the facts have been carefully scrutinized.

This investigation was so designed that a possible reaction in growth resulting from a supposed acidification could be observed as far as possible. A poorer growth development was observed in more susceptible regions than in less susceptible. We have found no good reason for attributing the reduction in growth to any cause other than acidification.

The conclusion must therefore be that *acidification cannot be excluded as a possible cause of the poorer growth development, but may be suspected to have had an unfavorable effect on growth within the more susceptible regions.*

The investigation gives only an impression of the order of magnitude of the average annual reduction during the period 1951-1955, for the more susceptible regions in relation to the less susceptible. The values 0.3 and 0.6 per cent have been proposed, in an example, as a reasonable approximation to this relative reduction. The investigation gives no information about the absolute level of the reduction for the two groups, nor about the reduction during a certain year. A difference is assumed between site quality classes, but it could not be statistically established.

In this connection it should be pointed out that during the period 1945-1965, the productivity of the Swedish forests as a whole increased considerably, principally because of more efficient forest management.

REFERENCES

Jonsson, B. & R. Sundberg. 1972. Has the Acidification by Atmospheric Pollution Caused a Growth Reduction in Swedish Forests? A Comparison of Growth between Regions with Different Soil Properties. Research Note No. 20, Department of Forest Yield Research, The Royal College of Forestry, S-104 05 Stockholm 50, Sweden.