WORKING PAPER

ECONOMIC EFFECTS OF FOREST DECLINE DUE TO AIR POLLUTION. STUDY OF THE LITERATURE CONCERNING METHODS AND RESULTS

Aino-Marjatta Metz

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About the Author

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Preface

One of the greatest potential economic effects of air pollution and regional acidification is that on forests. The Regional Acidification INformation and Simulation (RAINS) model developed by this Project has submodels dealing with the acidification of forest soil and of direct effects of SO_2 on forest vegetation. This literature survey, financed primarily by HAPRO, the Finnish Research Project on Acidification, takes an important first step in examining the methodologies for evaluating the economic effects of air pollution on forests, and gives some preliminary estimate for three European countries. It is possible that, in the future, predictions of biochemical effets by environmental models such as RAINS will be linked with economic data to give predictions of the economic effects of regional air pollution.

Roderick W. Shaw
Leader
Acid Rain Project

Executive Summary

The first discussions about man's disturbance of the environment were made in the 1950's. Some national economists point out that the crises in forestry also demonstrates a crises of the economy in that the high value of our ecological resources have not been taken into account by mankind. The reawakened interest of the national economists with regard to forestry and timber economics as a part of the environmental economy is a welcome and important development. However, it is sometimes difficult for the national economists and the foresters to understand each other. The national economists are used to thinking in the larger context of the total economy. In contrast, the foresters often concentrate on problems of their individual enterprises. However, the crisis of forestry damage demands that the disciplines of forestry and national economy both become more involved with each other, especially in dealing with the problems due to novel forest decline from air pollution. Political decisions should be based not only on forest economic factors but also on national economic factors.

In the 1980's, many studies in the European countries have been published about the economic effects in forestry due to air pollution. They can be divided from the economic point of view into three categories:

1. National economic studies in different countries;
2. Forest economic studies for individual enterprises; and
3. Timber economic studies.

The national economic studies vary due to the different national structure of forestry in each country. For example, in the Federal Republic of Germany, the recreation function has a high value. In Switzerland, the protection function against mountain torrents and avalanches gives rise to large estimates of the costs of forest decline, and in Austria tourism and timber production are especially important.

Table I summarizes the estimated total costs (in round numbers) of forest decline due to air pollution, divided in use-sectors in FRG and Switzerland. In the Federal Republic of Germany (Ewers *et al.*, 1986), the total monetary damage was evaluated for a time period of 77 years (1983–2060), and the additional residual damage taking into account recovery was calculated for an equal time period resulting after 2060. The damage in the FRG was divided into three subsections. The forestry subsection includes, for example, an estimate of the loss of growing stock, difference in stand value, costs due to culture and conversion, management and fertilizing costs. The recreation subsection includes, for example, loss of use by local and distant visitors, loss of optimal utilization and income loss in the tourism economy. In the water and soil subsection, changes due to forest damage in the extent, in temporal distribution and quality of the run-off from forested catchment areas; in addition, possible damage in the area of soil erosion and increased avalanche danger has to be considered.

Table I. Estimated total monetary damage in the Federal Republic of Germany (2% discount rate, from Trend-Scenario to Status-quo-Scenario; and in Switzerland in DM per total forest area and DM per inhabitant. (All data rounded.)

	DM/ha			*DM/inhabitant*		
Federal Republic of Germany	***Trend[1] Scenario***		***Status-quo[2] Scenario***	***Trend[1] Scenario***		***Status-quo[2] Scenario***
Forestry	11000	–	16000	1400	–	1900
Recreation & leisure	15000	–	30000	1800	–	3500
Water & soil	1500	–	2500	180	–	300
Total	28000	–	50000	3000	–	6000

Switzerland	DM/ha	DM/inhabitant
Forestry	13000	2200
Protection (against mountain torrents and avalanches)	20000	3300
Additional damages	15000	2600
Total	48000	8000

1. Trend scenario. Reduction of SO_2 with 40% and NO_x with 30% until 1991. From 1991 to 2060 emissions will reach 25% SO_2 or 35% NO_x to the level at the beginning of 1980's.

2. Status-quo scenario. A level of emissions was assumed which corresponds to the level at the beginning of 1980's.

In Switzerland (Basler *et al.*, 1986), on one hand, the total direct costs due to forest decline are calculated for a time period from 20 to 40 years. On the other hand, costs for measures and adaption concerning different economic sectors and inhabitants will result from increased natural dangers. These costs are described in a form of employment and factor income losses, which will mainly be taken care of by enterprises and private persons. The income losses in different economic sectors cannot be directly compared with the damage costs mentioned above because of a limited time period of interpretation. The income losses can only partly be understood as a negative effects affecting the different branches or regions. In Switzerland, the direct costs of forest damage are described in the subsections for forestry, protection against natural danger and additional costs like damages to people and buildings due to increased natural danger.

In Austria, only annual total monetary damages could be calculated. In the first published study in Austria (Schönstein and Schörner, 1985) the monetary damage due to air pollution includes that on forestry involving, for example, loss of growing stock , additional costs in conversion and cultural measures, management and fertilizing costs, etc. The possible costs of protection against mountain torrents and avalanches are also included. Loss of tax income is also estimated, but the importance of the recreation function has not been evaluated. In a more recent national economic study in Austria (Puwein, 1987) the value of tourism and recreation is included resulting in higher costs due to forest decline than was calculated in the early study of Schönstein and Schörner (1985).

In Austria, the total evaluated annual monetary damage would be around 0.64 milliard DM according to the 1985 study and about 3 milliard DM in the 1987 study. In Switzerland, the annual damage varies from 2.2 to 1.5 milliard DM. In the Federal Republic of Germany, the annual monetary damage varies from 5.5 to 8.8 milliard DM under the assumption of a discount rate of 2%. Expressed in percentage of total gross national product the estimated monetary damages vary in these three countries from 0.3 to 1.5%; an average of 0.6 to 0.7%.

The total monetary damage depends on the assumed discount rate. In Switzerland, the authors used 0%. In this case the residual damage was not added. In the Federal Republic of Germany, discount rates in the range of 0, 1, 2 and 3% were used. In this case the choice of the discount rate and the assumption of the monetary damage was left open also to the decision-makers. Using a discount rate the time component of forest decline will be considered. The costs of forest damage in different years will be determined with a rate of interest set down. Ewers *et al.* (1986) mentioned as realistic the so-called real discount rate in an amount of 2%; real discount rate means the difference between the nominal interest and the inflation rate. However, in the case of severe environmental damage a discount rate of 0% should be applied, since the value of the environment in the future is to be valued to be as high as the present.

Although the national economic effect of forest decline would not be catastrophic, the effects of forest decline on small enterprises can be devastating. The growing stock and the annual growth increment of trees will be reduced. The increase of costs in forestry and forest management will be considerable. The public will be more obligated to support the forestry.

The development of the timber market cannot be predicted for a long period. All studies predict an increased timber supply and a fall in timber price in the near future as a result of the damaged timber. However, a slight restructuring in the field of export-import would result.

Although the monetary evaluation of environmental and especially forest damages has began, there are a number of theoretical, methodological and practical problems to solve. In the near future it will be essential to emphasize the importance of the benefit of protecting our environment.

Acknowledgments

In a number of European countries since 1980 the monetary evaluation of environmental damages have enjoyed an increasing interest by national and forest economists. In order to summarize and compare the methods and results of these publications this study, owing to P. Kauppi's initiative and with financial support of HAPRO (the Acidification Project of the Ministry of Environment in Finland) was undertaken. For this reason the author would like to thank P. Kauppi for his initiative and helpful attitude. The author is obligated to HAPRO for financing this project. The author is also grateful to K. Kuusela, and S. Nilsson for their expert comments and especially to P. Duinker and R. Shaw who carefully reviewed the paper. The author also expresses her thanks to L. Cornelio and V. Hsiung who provided great help in typing the paper.

Table of Contents

Economic Effects of Forest Decline Due to Air Pollution. Study of the Literature Concerning Methods and Results.

Aino-Marjatta Metz

1. Introduction

Man has been forced to accept that he has endangered his own existence through his excessive demands on nature. The shortage of natural resources forces him to make difficult choices. Clean water has become scarcer. Air pollution causes human illnesses which, in turn, causes increased costs for national economies. The situation with trees and the forests is similar.

The monetarisation of benefits of nature, which up to now have been assumed to be free, has now begun. New methods of evaluation have been developed. Studies have been carried out on how the damage due to pollution can be evaluated in terms of forestry and forest economics and their different functions.

In the opinion of Schulz (1987) there has been too much discussion in the past only about the costs of environmental maintenance. This is the wrong way of looking at the problem. The real point is the advantages that can be gained from protection of the environment. In the light of the damage to nature and property which can be avoided, environmental protection can yield benefits for our national economy. Environmental economists do not demand that all emissions should be avoided but that a measure of avoidance be exercised in which the cost of the avoidance of the last unit of harmful substance is just compensated for by the benefit of the avoidance. The advantage of a reduction in emissions is that the damage resulting from emissions can be avoided (Ewers *et al.*, 1986). This attitude of a basic denominator of use instead of the earlier one of cost is a new one and puts the evaluation of the measures enacted for the protection of the environment into a completely different light.

National economists have, for a long time, worked on the assumption that natural ecosystems are stable (Thoroe, 1984). Furthermore, forest economists were far from a comprehensive economic attitude and were intensively engaged with their management problems. They thus failed to consider the numerous external effects outside their business. A stronger cooperation is required between national and forest economists since forest decline is an consequence of the modern economic processes and is contingent on economic considerations. Accordingly, political decisions must have a basis in forestry and economics (Bonus, 1984). This requires, however, new ways of thinking to evaluate all the consequential costs to the forest economy. Only in this way can a basis be found for justification of the benefits of conservational measures.

This study concentrates on the published literature of three central European countries. In the Federal Republic of Germany, Austria and Switzerland, separate national economic evaluations of the extent of forest damage have been made. It is intended to look at the problem of economic environmental evaluation on the basis of published materials. Ethical principles and the development of man's attitude to ecology will be discussed. The relationship between ecology and economy will also be looked at on the basis of published literature. Finally reference will be made to forest decline and its significance for the national economies of some central European countries. Mention will also be made of the significance of forest decline to individual enterprises and to the timber economy, based on published materials. The studies of the monetary evaluation of forest decline as a result of air pollution will be summarised in order to be able to present a concise picture.

1.1. Development of the forest decline situation

Different types of forest disease have been known since antiquity. Damage to the trees and forests was first described in specialist forest literature in 1845 (Rettstadt cit. by Wentzel, 1985; 1987). About 140 years ago Rettstadt described the 'sulfurous' acid and metal dust as the cause of the poisoning of forests, people and animals. Smoke damage was first dealt with in the textbook 'Der Forstschutz' 1878 by Professor Richard Heß. In addition, the book 'Damage to vegetation by smoke and the Upper Harz hut smoke damage' by Professor Julius von Schröder and chief forest officer Carl Reuß was published in Berlin 1883. The authors investigated 4500 hectares of damaged forest, of which many hundreds of hectares were totally bare on the basis of visual evidence of the stock and on chemical needle analysis divided into three categories of damage. As a result of this investigation detailed maps of damage were produced. The authors stressed the major importance of avoiding pollution of the air. They categorically rejected the immediate construction of higher chimney stacks with the observation that, 'in mountainous areas the smoke masses not only reached to the forest stands on the mountain slopes, but also into the valleys where they mix with the low cloud and thus damage both areas' (Wentzel, 1985).

Ten years later there were further publications in which, among other things, Reuß (cit. by Wentzel, 1985) showed that a chronic emissions effect produced a stronger susceptibility of the forest to natural dangers. Thus, approximately 100 years ago the interaction of weather conditions and parasitic disease was established. His observations concerning mining and industry were however legally challenged, and Reuß lost his case in the courts. In the 90 years following 1880, approximately 20 further monographs and textbooks dealt with the problem of emission damage. As early as 1872, a textbook entitled 'Acid Rain' by Professor Robert August Smith appeared in London (Wentzel, 1987), giving birth to the well known environmental term.

In more mountainous countries such as Austria and Switzerland, catastrophies and forest destruction have been experienced for many years. Reports from Tirol claim that between 1750 and 1830 the forest destruction due to anthropogenic causes was very high. On top of the damage caused by water run-off, which was out of control, there was damage caused by avalanches. If 70% of the avalanches recorded in the land register break away below the natural treeline, their triggering moment will mean an anthropogenically caused destruction of the forest in the protection forest area (Jobst and Karl, 1984).

According to Stolz (1988) the present state of forests cannot be explained without reference to historical facts. In his opinion it is quite possible that the laymen can easily learn from positive or negative prior experience. In Switzerland the floods of the 1830's made no significant improvement in the learning process concerning the protection of forest; however, the flood catastrophe of 1868 gave rise to a public concern which finally gave birth to federal legislation on forestry. Stolz's calculations show that the damage of 1868 amounted to 2.2% of the net national product. The causes were no surprise to the experts who had much earlier drawn attention to the connection between the overexploitation of forests and the dangers of runoff.

The over-exploitation in Swiss forests was followed by afforestation and conservation, and a trend to manage forests on too small a scale. Just as this trend began to change as a result of a change in forest policy, and the forestry problems seemed to be solved, the forest economy began to be threatened by forest damage due to pollutant emissions. This 'sudden' appearance is seen by Stolz rather more as insidious; the analysis of the annual rings led to the assumption that the level of harmful substances had, in the 1950's, already exceeded those limits beyond which the trees began to suffer damage.

The expression 'novel forest damage' has been introduced in the Federal Republic of Germany. According to the Forest Decline/Air Pollution Research Advisory Board to the Federal Ministry for Research and Technology, 'novel' describes the geographically widespread nature of the symptoms of damage to individual types of trees which almost simultaneously (i.e., within only a few years) appear on many types of trees, as well as the rapid spread and chronic nature of the disease. In contrast, Wentzel (1987) maintains that the widespread nature of the damage is, however, only new in the western part of the large central European area. Research has revealed this simultaneous appearance on many species of trees for over 100 years, and the chronic nature of such decline has been known even longer as characteristic of forest decline due to emissions. The following section briefly discusses further possible causes of novel forest decline.

1.2. Possible causes of novel forest decline

It is widely recognized that harmful substances in the air are the main cause of novel forest decline. The externally identifiable damage is so manifold and confusing that it is difficult to form a complete picture of the phenomena. They vary according to the type of emission, weather, humidity, exposure, solar intensity, type of soil, altitude, tree species, etc. Articles about the possible causes of forest decline have, for example, been published by Prinz (1987) and Krause *et al.* (1986). According to Gesellschaft für Strahlen- und Umweltforschung (GSF) (Anon., 1987) one can distinguish, for example, between the following hypotheses, which have been only partly confirmed:

1) acidification of the soil
2) photo-oxidants
3) leaching
4) nitrogen
5) stress hypothesis
6) radioactivity
7) triethyllead
8) halogenised hydrocarbons
9) other organic compounds.

1) The acidification hypothesis is maintained most strongly at the University of Göttingen in the FRG (Ulrich, 1981, 1983; Matzner *et al.*, 1985). The extent of soil acidification depends upon the one hand on soil buffering capacity and on the other hand on the deposition of acid from the atmosphere. This leads to the mobili-

sation of nutrients which, due to reduced root mass, are unavailable to plants and are washed out. Toxic aluminum ions are mobilised. This hypothesis appears to be valid for weakly buffered soils.

2) Photo-oxidant damage means direct damage to the part of the plant above the ground surface by gaseous or dissolved peroxide, whereby ozone acts as the indicator substance. Other peroxides are peroxyacetylnitrate (PAN) or H_2O_2. Membrane damage and even necrotic spots lead to stronger washing out of the nutrient elements from the needles and leaves. The photo-oxidant hypothesis has gained in importance and is maintained for example by Krapfenbauer (1988a, b) and Prinz (1985). In order to come to grips with this particularly difficult aspect of air chemistry, a project group set up by the Bavaria State Ministry to research the effects of substances harmful to the environment (PBWU) has developed the concept for the Alpine Research Center on Mountain Wank (Bayer. Staatsforstverwaltung, 1987). The photo-oxidants hypothesis was intensively examined in laboratory and open-top chamber experiments. A clear conclusion is still pending. This hypothesis seems to be pertinent to the higher elevations of the central mountains and the Alps (Anon., 1987).

3) Not only acidic precipitation, but also SO_2, ozone and other peroxides, damages the outer wax layer of the needles and leads to membrane damage as well as damage in the stoma. This gives rise to disturbance of transpiration, foodstuff losses and increased photosensitivity. This hypothesis is supported, for example, by Zöttl (1987) and Hüttl (1987). On acidic soil poor in nutrients, this especially leads to calcium and magnesium deficiency, the older needles turning yellow and finally dropping off. This hypothesis can be combined with the previous one.

4) The nitrogen hypothesis is based on the fertilization effect of constantly increasing NO_x emissions. As a consequence there is a noticeable increased-growth effect in the trees; however, on the other hand, deficiencies develop in other nutrients such as calcium, magnesium and phosphorous. Susceptibility to insects increases and the trees become more prone to frost damage (e.g., Rehfuss, 1983). Changes in the nitrogen conversion in the ground can lead to acidification and more serious washing out of elements. In particular NO_x can be damaging to plants in two different ways in connection with other substances: (1) when together with SO_2 the synergistic damaging effect is increased; (2) NO_x are necessary initial products in the formation of ozones (Nießlein and Voss, 1985). Conclusive experimental evidence has not yet been produced for this thesis.

5) The stress hypothesis attempts to show that the different levels of harmful substances in the air provide the basis for the reduction in photosynthesis performance and assimilate transportation in the roots. Thus, the whole energy balance is changed and there is also a reduced production of protective substances by the plants. The susceptibility to further stress factors is raised.

6) According to some reports, forest areas near nuclear power stations display a higher grade of damage than stocks located at a greater distance. However, the role of radioactivity has not been proven in any case (Bundesamt für Ernährung und Forstwirtschaft, 1987). This hypothesis has also been refuted in the studies of Hüttermann (1987) and Schöpfer (1987).

7) Tetraethyllead is mixed into leaded petrol as an anti-knock agent. It is converted through the burning process or via U.V. light into triethyllead which is toxic to plants. Since the concentration of triethyllead remains below the limits of toxicity, there is no proof of accumulation in plants.

8) The hypothesis concerning the effects through halogenised hydrocarbons has also not yet been confirmed.

9) Organic chemicals are emitted in large quantities. It is suspected that among these substances there are some compounds which are damaging to plants. This hypothesis is undergoing intensive investigation, for example, in Bavaria.

The causal agents of forest decline can be further divided into direct and indirect. To the former belongs air pollution in the form of SO_2, NO_x, photo-oxidants, acidic precipitation, heavy metals, and organic compounds. Also to be included in the direct agents are the increasingly influential fluorohydrogens, and the cumulative effects of different air pollutants (Bundesamt für Ernährung und Forstwirtschaft, 1987). Under the indirect influences we can find effects above the ground, changed element content in the organs of the plant, and fine structural changes in the needles and leaves. To these we must also add the changed factors for natural regeneration such as susceptibility to stress. Other influences damaging to the forest are to be seen in the biotic, climatic, and silvicultural influences. To the last-mentioned belong the overstocking and over-aging of forest growing stocks, which are partly to be seen as a problem of the central European forests (on this subject *see* Kuusela, 1987a, b).

In Austria, discussions have been held on the subject of the possible causes of forest decline within the framework of FIW (Research initiative against forest decline). It has been established that the symptoms of forest decline are correlated with a multiplicity of anthropogenic influences, ecosystemic reorganisation processes and natural environmental stresses. Investigations have revealed that the observed occurrences are not the same in every location, but rather that the form of the occurrence of forest decline as well as its intensity are strongly dependent on local circumstances. A number of pre-stresses are also mentioned, including removal of forest litter, forest pasturing, and stress due to hooved game. The influence of forest use, building of forest roads, and the vast building during the post-war years is also cited (Glatzel, 1987a, b). Weather stress is cited as a cause of forest decline in Austria whereby it is has been shown that, in the last 30 years on the whole, dry years have been more predominant than in the previous 30 years (Richter, 1987). In summarising one can say that main cause for the occurrence of the novel forest decline has not yet been identified. It is to be hoped that this fact will be considered with the appropriate care as long as measures to restore damaged forest stock and to prevent new forest damage are being sought.

1.3. Present state of forest decline

Table 1 presents basic data such as total area, forest area, structure of ownership and percent division of coniferous and deciduous trees in some central European countries. The gross national product per inhabitant is also featured. *Table 2* presents the extent of damage per hectare shown in classes of damage (slight, moderate, and dying or dead) in some central European countries according to Kuusela (1987a). It can be seen from this information that in 1986 54% of the forest area in Federal Republic of Germany, 10% in Austria, and 48% in Switzerland was damaged. Altogether in these countries 4,412 million hectares were damaged of which some 134,000 hectares were dying or dead.

Nilsson and Duinker (1987) have calculated the volume of damaged stands in cubic meters according to degree of damage of coniferous or deciduous growing stock for central European countries. The authors have also calculated the relationship between the decline and the growing stock and decline and the annual felling ratio. They have also shown that particularly in Switzerland, Austria, and the Federal Republic of Germany the relationship of the decline to the growing stock

Table 1. Basic data of the Federal Republic of Germany, Austria and Switzerland.

	F.R.G.	*Austria*	*Switzerland*
Total area (million ha)	24.9	8.4	4.1
Forest area (million ha)	7.4	3.8	1.1
Inhabitants (million)	61.1	7.6	6.5
Forest area (ha/inhabitant)	0.12	0.5	0.17
State owned forest (%)	31.3	15.4	6.0
Corporation owned forest (%)	25.3	17.5	67.0
Private forest (%)	43.4	67.1	27.0
Coniferous (%)	70	81	80
Deciduous (%)	30	19	20
G.N.P. 1986 (DM/inhabitant)	31900	27105	47385

Table 2. Extent of forest damage due to air pollution in the Federal Republic of Germany, Austria and Switzerland (Source: Kuusela, 1987a).

	Damage class (in 1000 ha)				*Proportion of total exploitable closed forest*
Country	*Light*	*Moderate*	*Dying or dead*	*Total*	*%*
F.R.G.	2424	1163	111	3698	54
Austria	240	80	10	330	10
Switzerland	295	76	13	384	48
Total	2959	1319	134	4412	

is higher than the average in Europe. This also applies to the relationship of decline to the annual fellings in the countries mentioned. The diverse methods of keeping records in the different countries made a comparison between the countries rather tennous and led in some cases to an under-estimation and in other cases to an overestimation of the damage situation.

2. Evaluation of the Decline of the Environment

2.1. The need for a more broadly-based anthropogenic environmental ethic

Many scientists have concerned themselves with our anthropocentric conception of the world. The opinion has recently been voiced more and more that we must begin to think in more complex interconnections and that our pattern of thinking must change, i.e., we must effect a paradigm change (Capra, 1983 cit. by Bucher, 1984; Capra, 1986). Albert Schweizer formulated, quite radically, the independent right of Nature. 'Ethic is the responsibility of unlimited extent for everything that lives'. This radical ethic supercedes any rational thinking of the industrial society; there is no economic imperative which has priority over nature's right to life. Nature's right to life is only then able to evolve when mankind develops a new intellectual relationship to the universe to conclude an inner peace with nature (Reiche *et al.*, 1987). Kafka (1988) was also concerned with the symptoms of decline of our world in his essay 'The law of ascent' wherein, however, he sees no reason to give up the struggle against decline completely. According to him it will be possible with insight and judgment to influence this decline. Bucher (1984) was of the same opinion. He stated that forest decline could be one of the signs of the high level of instability of our complex social system. This instability does not necessarily have to develop into chaos, but it could and must lead to a change in our approach. In the opinion of Reiche *et al.* (1987) an economically based environmental protection plan would be morally strong, but would remain politically weak since it could not prevail in a conflict with anthropocentrically based interests. A more widely-defined self-critical anthropocentrism would provide more effectiveness to an environmental policy. In the eyes of Fähser (1987) further 'progress' is only justified when, in the sense of 'doctrine of budgeting', it serves in the broadest sense mankind, the environment, the present generation, and the following generation better than previously. Our technical potential seems clearly to be rushing way ahead of our cultural, social and moral abilities.

2.2. Ecology and economy

One of the first oracles of the threatening rise in social costs and the disturbance of the environment was Kapp (1979) in the year 1950. Present experiences point to the fact that we need new concepts and solutions in order to stave ecological destruction, economic regression and social decline. Even in a liberal society where, according to Samuelson's maxim 'individuals preferences are to count', there is a duty to provide for future generations (cit. by Hampicke, 1987). The obligations to nature and the environment only find their limit where the costs are so high that, in the light of the norms of inter-generational justice, they become an unreasonable expectation of the present generation (Hampicke, 1987). The concerted action of economy and ecology and vice-versa in the field of primary production in economic and ecological systems have an especially great significance for the practical economy. Although as foresters we are used to treating nature and the forest as one ecological totality, because of the unsatisfactory knowledge of the infinitely complex network of connections and because of unrealistic, deterministic linear empirical methods, we are surprised again and again by the exceeding of limits, and sudden collapse of equilibrium. In contrast the economic viewpoint concentrates on the rationale of economic principle. The compatibility with nature depends strongly on whether the models for explanation and decision-making that are used correctly portray the connections with and within nature, and whether the economic aims respect ecological limits (Fähser, 1987).

In the opinion of Bonus (1984) the forest crisis demonstrates a crisis of the economy. He concludes that mankind has managed its ecological capital very inefficiently, and has squandered it because it failed to take into account the high value of ecological resources. It is not that too much economy has ruined our forests, but rather too little; the same applies to our ecosystems: 'our industrial system is embedded in a natural ecosystem, its own existence depends on it and this fact should have had its influence on every single everyday economic decision'.

In order to understand the connection between economy and ecology and vice-versa, one must briefly consider the two definitions. Economy refers to a system of rules (nomus) which have been developed for expedient housekeeping (oikos = house). Ecology is the science (logos) of the relationships in Nature's household. To achieve the necessary integration of the two terms one must try to find a general housekeeping/ budgetary doctrine (Fähser, 1987). The forgetfulness about Nature in the field of ecology, and on the other hand the economic naivety in natural science, must be eliminated. Thus, in the interest of forest economy, an ecological market economy could arise from the forest crisis, an economy in which the tension from economy and ecology are no longer suppressed, but is liberated and made economically productive (Bonus, 1984).

If one combines the two definitions of economy and ecology to form a characterization of budgeting, then it transpires that the budgetary doctrine has the aim of making use of materials, energy, information, and life so that man's requirements can be satisfied, whilst maintaining the conditions of natural existence of the environment, the present generation, and future generations. In mathematical terms this would be a task of optimisation (Fähser, 1987), which would be compatible with our anthropocentric conception of the world. However, as has already been said, the new ethic would require that the independent rights of nature be set as a prediction. This would lead to a simpler new definition of budgeting; 'The budgeting doctrine has the aim of arranging material, energy, information and life in such a way that the natural existence of the whole living community is permanently ensured'. This, in turn, means that the test criteria of economic efficiency, environmental and social compatibility, and international acceptability will have a stronger role to play in environmental and forest policy (Fähser, 1987). Hjerppe (1988) also draw attention to the international nature of environmental problems and their solution within the environmental economy.

2.3. Forest economy and national economy

Nobel prize-winner Samuelson (1976) observed over ten years ago that 'ecologists know that soil erosion and atmospheric quality at one spot on the globe may be significantly affected by whether or not trees are being grown at some distance away. To the degree this is so, the simple Faustmann calculus and the bouncing's of the futures contracts for plywood on the organised exchanges need to be altered in the interests of the public'. The interests of national economists in questions of forestry and timber economics as part of the environmental economy is a welcome development. However, sometimes there are difficulties for the two parties to understand each other. The national economists, who are used to thinking in larger contexts of the total economy, have ignored environmental problems for a long time. They assumed that natural ecosystems were stable (Thoroe, 1984). On the other hand, forest economists have also laboured under false assumptions that they could quietly continue to solve their individual enterprise problems with their customary long-standing methods, also with the observation that the national economists would hardly appreciate the many-sided nature of the individual managerial and specialised problems. Thoroe (1985) found the reasons for the division between the national and forest economists in their economic analysis and evaluation to be that; 'in the eyes of the national economist it is the attitude of concentration on the forest which led to a large extent to an ignorance of alternatives outside the forest sector and also to economically incorrect conclusions in forest economy analysis. In the eyes of the forest economist it is especially the narrow economic attitude which was responsible for the reduction of the problem situation to a purely economic level and principles which made it appear irrelevant or insignificant to national economic analysis based on competitive models of market economy'.

What changes would it make if national economists turned their attention to the subject of forest decline? Bonus (1984) says that the forest crisis demands that both the disciplines of forestry and national economy become more involved with each other than they have been up to now, especially since forest decline is an (unintended and unforeseen) incidental consequence of modern economic processes and is also conditional on economic factors; and for this reason political conclusions should not only be based on forest economic factors but also on national economic factors. In the opinion of Wiebecke (1983), the national economies of all the countries affected in all their parts are concerned with the influence of forest damage. According to him forest policy is required as a part of the national economy. On this subject Thoroe (1985) made the suggestion in the form of a licence solution. He says the state has to decide politically, first of all, how large the minimum size of the forest area should be, and which protectional and recreational functions it should perform. The state should not, however, force the forest owner to provide these services. Instead of this, appropriate promissory documents would be issued which would impose on the owner the operation of particular forest areas, or, requiring their availability for protection or recreational purposes. The forest owners could buy or sell these licences according to the extent of their intended activities. However, in the opinion of some forest economists this is not a very realistic suggestion to solve the difficult problems in forestry.

The stronger consideration which is given to the forest economy by the national economy is characterised by two factors: on the one hand the profit of the forest is moved more and more from the private to the public sector, and thus becomes external. An ever-increasing part of the national economic revenue from the forest is for the benefit of the community as a whole. On the other hand, following the trend of rising salaries, the growing costs have to be carried solely by the forest economy (Bonus, 1984). These external effects of timber production, from the point of view of the whole economy, must be included in the calculations for any decision. From the point of view of the national economy these external effects should be clearly shown in models for forest economy decision-making (Thoroe, 1985).

In the light of questionnaire research in which it was shown that the population of the Federal Republic of Germany considered the extra economic performance of the forest to be four and a half times more important than timber production (Nießlein, 1983 cit. by Thoroe, 1985), the national economists question whether the analyses and the models for decision-making for timber production can still form a basis for forest policy. In the context of forest damage the forest economy is faced with a problem of the lasting changes in growth of the forest which they must allow for in their analyses and models. This also applies to the changes in the behaviour of forest owners (Thoroe, 1985).

In the opinion of Fähser (1987) a judgement about the rationality of economic management cannot be made because, to date, there is hardly any data about ecological, social, and to a certain extent also economic costs which ensue, but which are not covered by the classical perception of costs of independent enterprises.

In his opinion these missing costs are costs as a consequence of management. These consequential costs can be sub-divided into four categories (Leipert, 1984, cit. by Fähser, 1987):

1) defensive expenditure for removal, reduction or prevention of the damage,
2) consequential charges due to additional payments to insurers,
3) direct loss of production, income and assets,
4) real damage to human health, to the animal and plant world and to ecosystems, etc.

According to Müller-Wenk (1978), in order to internalise the consequential costs, an 'ecological accounting' is required. This should be accompanied by a comprehensive, interconnecting, dynamic, and multidimensional concept. Such concepts were presented, for example, by Vester (1985, 1987). In his calculations he showed, on the basis of the value of a tree and of a bird, how subjective economic evaluation can be. The average timber value of a tree in the FRG, for example, is put at 270 DM. In his comprehensive evaluation, a 50-year-old tree achieves an output value of 264,000 DM, without taking interest into account. The value of a bird was equally vividly presented.

In Fähser's (1987) opinion it is possible today to slowly extend the classical tools of business management with ecological and social information when the environmental compatibility (e.g., of pesticides) and the special compatibility of operational measures is closely examined. To this end the Council of the European Community has provided guidelines for the examination of environmental compatibility. Forest economy activity also has a regular influence on the environment. For the analysis of the ecological effect of projects the Council for Nature Conservation and Care of the Countryside at the Ministry for Agriculture and Forestry suggests various methods such as Delphi method, scenarios, graphic processes, tables of order of priority, utility-value analyses, and mathematical processes (Fähser, 1987). These processes have been increasingly used recently in order to be able to estimate the economic consequences of forest decline in terms of national, industrial and timber economies. In the next chapters we will look at methods and presentation of results achieved in estimation of the economic consequences of forest decline in the above-mentioned areas.

3. Evaluation of Forest Decline

American economists laid the foundation for economic evaluation in the 1970s. At that time extensive estimations were made concerning costs of damage due to air pollution. The monetary emphasis of the examination, however, then lay on the damage to human health. Damage to vegetation was considered monetarily only in last place after damage to buildings and materials. The same thing happened in the FRG. One of the first studies estimated in the year 1977 the damage to materials, works of art, and buildings at an amount of 3.2 to 4.2 milliard DM (Heinz, 1979 cit. by Thoroe, 1984). The damage to vegetation was estimated at 0.4 milliard DM. In a study in 1980 the damage due to air pollution to buildings and materials was estimated at 3.35 milliard DM, the damage to health was set at 4.5 milliard DM, and to vegetation at 0.2 milliard DM (Glück *et al.*, 1982, cit. by Thoroe, 1984).

In recent years in the FRG, pioneer studies of the evaluation of environmental damage have been carried out. In Austria and Switzerland, extensive economic investigations have also been carried out. The structure of the forest economy in these three countries is somewhat different. This leads to some differences in the national economic evaluation in each country. For this reason the spheres of interest which have committed themselves to an evaluation of the forest damage are very diverse, and the translation of the studies into forest policy will be motivated very differently. The purpose of recreation and tourism are, in conjunction with the utility function, extremely important in these three countries. The protective function of the forest is equally significant in these three mountainous countries (in the FRG in the southern part). It is a question of diversified and complicated problems of forestry and society of which the evaluation and solution of new ways must be sought. In other European countries, as in Poland (Owczarzak *et al.*, 1987) and in Czechoslovakia (Stoklasa and Duinker, 1988), a beginning is also being made on the evaluation of forest damage. In the USA also (Callaway *et al.*, 1986a, b) and in Canada (Crocker and Forster, 1986) forest damage has been monetarily evaluated. In the last mentioned study account was taken not only of the increment loss but also of the importance of the wildlife and recreational functions.

3.1. Monetary evaluations of forest decline in the Federal Republic of Germany

As in the American and OECD studies in the 1970's, vegetation damage including forest damage is rated much lower than damage in other areas (Thoroe, 1984; Environment and Economics, Vol. II, OECD 1984 cit. by Juhasz, 1986). In addition, the statistics concerning the forest have little scientific foundation. As a result, the forest economy has a strong need for in a correct economic evaluation, especially as one can only make claims of damage with soundly based knowledge. Also, with substantiated knowledge the urgency of the environmental and forest policy measures can then be emphasised more strongly. However, there are diverse and difficult problems in conducting the evaluation. The multiplicity of forest diseases, the long turnover times, the complexity of ecosystems and the lack of knowledge about the development of diseases are problematic enough. On the other hand, economists demand an answer to at least two questions: how high are the increment losses due to air pollution, and how severe is the damage to the forest stock in terms of future utility? (Thoroe, 1984). Since one can refer to the timber price as a basis for the evaluation of damage, it will be possible in this case to make at least initial approximations of the losses to be expressed in monetary terms.

It is a different case when we consider the protection, social welfare (in Austria) and recreational functions, especially when one wishes to evaluate the soil, fauna and flora affected by ecosystem damage. The climatic and water budgets are also influenced by advancing forest decline. Finally, the forest has a cultural and ethical value, too. A system of evaluation of forest damage due to air pollution had been worked out by a working group in the FRG (Brandl and Matthies, 1984). A model was designed in tabular form with a diagram of damage and damage components. The former includes total or partial loss of stands as well as increment loss. The latter is divided into four main components. These are (a) individual forest stands, (b) soil, (c) total forest utilities, and (d) national economy.

Another working group studied the social function of the forest (Matthies, 1985). The following theoretically possible evaluations were considered: (1) from the point of view of the supply: expense and return, and (2) from the point of view of demand: cost and benefit. This latter refers to utility for the general public. The possibilities mentioned were (a) reproduction and social costs, (b) replacement costs, (c) loss of use costs, and (d) utility value analysis based on data using a non-monetary scale.

In the FRG extensive studies have been carried out in the last few years to evaluate the utility of measures to improve the environment, some of which were commissioned by the Ministry for the Environment (Heinz, 1980; Ewers and Schulz, 1982; Schulz (ed.), 1986; Schulz, 1987; Ewers *et al.*, 1986). The study of Ewers and Schulz (1982) is a work with a pioneering method about the monetary utility of measures to improve water quality. The method already developed for evaluation of the use of measures to improve the environment was systematised and, more important, its practical application was tested on a concrete example, the Tegeler Lake in Berlin. Two new methods to evaluate leisure and recreational use were developed. The authors see the general results of the study to be that:

- measures to improve water quality can be justified in the same way as other infrastructural activities of the state,
- this monetary justification of the use for leisure and recreational activities as well as drinking water utilization will be of a higher and growing significance in the future,
- contrary to a widely held attitude, the main problem of a monetary evaluation of measures to improve the environment lies less in the economic base data for evaluations of determinable effects than in the quantitative forecast of the effects themselves (development of water quality with or without measures, development of water utilization in dependence on the water quality).

Wicke (1986) provides five arguments for a monetarisation of forest damage:

a) Rational environmental policy requires, in his opinion, the balancing of the accounts of all advantages and disadvantages of environmental protection. The supporters of less environmental protection, with their knowledge of the costs of environmental protection, can convince the opposite side.

b) In Wicke's (1986) opinion it is understandable that economic cost estimations showing the socio-political dimensions of forest decline are presented to the public.

c) Wicke sees it as part of man's nature that he only becomes careful with his belongings when he has to pay an appropriate price for their use.

d) The money available for environmental protection must be used effectively so that the highest benefit can be achieved.

e) In the context of disturbance of the environment, the gross national product gives a misleading picture of a very high standard of living. It is hoped to replace this through an extended national economic calculation which takes into account environmental damage and damage to health. This can only be the case when environmental damage can be measured in terms of money.

Wicke (1986) was the first to make a systematic estimation of all environment damage in the FRG. He presented a detailed 'Report on Ecological Damage in the FRG' based on new sound research from home and to an extent from abroad which is really a conservative interim balance sheet. The amount of the damage calculated (including forest damage) constitutes more than 6% of the GNP of 1985. The sum in monetary terms is at least 103.5 milliard DM/year (Wicke, 1986). This means an oft-quoted OECD estimation from the 1970's of 3–5% does not even reflect the lowest level of the environmental damage in the FRG (Schulz and Wicke, 1987). Or, to put it in other words, in the FRG in 1984 the economy and the state make expenses of, on average, approximately 20 milliard DM per year available for the prevention of damage to the environment to meet requirements of over 100 milliard DM per year (Schulz and Wicke, 1988).

3.1.1. National economic evaluation of forest decline in the FRG

A study on this subject has been published by Ewers *et al.* (1986). This work has been referred to in many publications (Ewers, 1986; Brabänder, 1987; Wicke, 1986; Schulz and Wicke, 1987, 1988; Anon., 1986).

Premises of value and evaluation methods

According to Ewers *et al.* (1986) the basic individual prejudice of the social welfare economy purports that it is the individual citizens who decide the relevant values of their own trade and order in society. This assumption means that, for every monetary evaluation of environmental damage, the social evaluation is the sum of individual evaluations. Many different arguments have been presented against this, including information problems, representation problems, neglect of future generations, and distribution problems (distribution of available income). This also gives rise to the problem of whether the individual evaluation is interpreted as a 'willingness to pay' or 'willingness to sell'. Politically one should decide between willingness to pay and willingness to sell as a basis for monetary evaluation. Willingness to pay would mean that you implicitly accord all environmental rights to the instigator of damage. Willingness to sell would mean that you accord all environmental rights to the damaged party which would correspond with the causation principle. Accepting the status quo of our environment as a basic point, the concept of willingness to pay can only be seen in the sense of the causation principle, should it be a question of measures which imply a improvement of the status-quo of our environment. In this case the people concerned should, in fact, be questioned about the willingness to pay, or the willingness to pay should be estimated indirectly. Should it, however, be a question of measures which imply a deterioration of the status quo, then, in the sense of the causation principle, the willingness to sell must be the basis of the evaluation (Ewers *et al.*, 1986).

The choice of the appropriate method of evaluation depends not only on the level of information held by the population concerning the relevant damage, but also on the time and the costs which are available for the evaluation. It must be mentioned in this context that an excellent compilation of the systematology of the methods for monetary evaluation was presented by Ewers and Schulz (1982). This systematology is given in ***Figure 1***. On the basis of the social welfare economy, the level of the willingness to pay and the willingness to sell must be made known to the party affected. This can be done directly (questioning) or indirectly (estimation). The direct investigation requires a satisfactory level of information on the part of the person questioned. Indirect investigation processes avoid any expenditure involved with the questioning; however, they often considerably under estimate the social welfare losses. Indirect investigation processes must also, as far as possible, ensure that consideration is taken of the preferences expressed by those affected by environmental damage. Whereas in the case of direct loss of income this can be assumed, the relationship especially to basic data for evaluation calculated with aggregated avoidance costs must be carefully furnished with proof in every single case. According to Ewers *et al.* (1986) this must be considered in a study about the monetary evaluation of forest damage.

In every monetary evaluation there are three steps to be taken:

- marshalling and quantifying of the subject matter to be evaluated,
- monetarising of the facts measured in physical dimensions,
- production of contemporary comparison for the facts which accrue at different times due to discounting.

According to Ewers *et al.* (1986) this can, with the choice of appropriate monetarising method in view of the present state of science, be largely regarded as solved. The same can be said for discounting. The time component of forest damage will be considered by a use of a discount rate, although the damage occurs in a longer time period. According to Wicke (1986), the use of a discount rate of 3% in a year means that the total damage will count in the next 10, 50 or 100 years only a reduced share of 75, 20 or 5%. Lower discount rates will be chosen the more long-term the public measures are. The individual, according to Pigou (cit. Bonus, 1984), is to a certain extent short-sighted where the future is concerned, and finds it more difficult to judge long-term phenomena correctly. The social discount rate – that is to say the socially correct discount factor – must therefore be lower than the current interest rate (Bonus, 1984). In the study of Ewers *et al.* (1986), discount rates between 0 and 3% were used, but the authors pointed that the use of a so-caled real discount rate of 2% would be realistic. Real discount rate means the difference between the nominal interest rate and the inflation rate.

In the case of environmental damage, as has been mentioned before, it is a question of external effect. Simple damage is described, according to the Civil Code, by three criteria: (1) it is possible to identify one or more parties responsible for the damage, (2) it is possible to prove a connection between one or more damaging actions and the occurring damage, and (3) the damage can be limited in terms of time or subject matter. These criteria are not present in the case of forest decline and accordingly all attempts to claim damages from the state are doomed to failure.

Since it requires such a long time before the complexity of the cause-effect connection can be fully explained, solutions to the present problems concerning forest decline are being demanded. Such methods to evaluate effects of forest decline have been worked out preferably with the help of three processes or a combination of these processes:

1. Use of probability distribution or subjective point probability to connect the unknown causal connections.
2. Drawing up of scenarios, i.e., plausible 'if-then' consequences to delimit the range of possibility of future development.
3. Use of the Delphi process of questioning experts in order to exploit present (incomplete) knowledge quickly and effectively.

Heuristic methods do not aim to eliminate the present uncertainty in relation to the causal connections, but to try to give help in practical decision-making, despite this uncertainty. With this method the studies try to develop an effective model, whose as-yet unknown parameters are set by values of probability distribution or the opinion of experts. At a more advanced stage the improvised parameters could be replaced by proven values. In the study mentioned, a combination of expert opinions obtained according to the Delphi method and the scenario technique was used. An available simulation model for spruce was used as a basis (Möhring, 1984, 1986). The spruce species occupying 40% of the forest area has a high replacement share in the forest economy of the FRG, and so influences the picture decisively in terms of value. The study restricts itself to a global ascertainment of damage, without differentiating between growing area or harmful substances. The authors point out that what is described in the study as forest damage is to be seen as a result of the sum of all influences from anthropogenic and non-anthropogenic factors, which have had over the past decades, and will probably have for a long time to come, an effect on the forest. The individual fields of forest and timber economy, leisure and recreation as well as water and soil are dealt with. Climate and deposition protection by the forest stands, the cultural function of the forest, and the forest from the point of view of hunting, are not considered.

Scenarios

The term scenario is one which has been borrowed from the realm of theatre. The method of writing scenarios was made popular in 1967 by the book from Kahn and Wiener, 'The Year 2000'. In the opinion of Gundermann and Mergner (1984) we can find here a basic definition of the term: 'scenarios are hypothetical consequences of events, constructed with the purpose of drawing attention to the causal processes and the decisional dilemmas. They answer two kinds of questions:

- how can a hypothetical situation come about step by step? and
- what alternatives are available to each participant at each stage to enable him to prevent continuation of the process, to turn it in another direction or to support it?'

Or according to Bechmann (cit. Ewers *et al.*, 1986): scenarios are speculative, but in themselves ***plausible*** sequences of imaginable future developments under alternative presumptions. They are not forecasts. Scenarios are necessary when answers are required at short notice to questions with a high degree of complexity. This is the case with forest damage. Here the fixation of a period of observation is a problem – the temporal variability and the temporal development have a role to play. In Ewers *et al.*'s (1986) study a period of 77 years, i.e., from 1984 to 2060, was chosen.

Three scenarios were drawn up. Presumptions were made on the most important harmful substances according to the present state of scientific knowledge, namely SO_2 and NO_x. The presumptions were based on the ideas that (a) the development of the population in the FRG will decline (from 61 million inhabitants in 1984 to approximately 50 million inhabitants in the year 2030), (b) the real gross national product is expected to increase at a rate of 2% until year 2000, thereafter at a rate of 1.1%, and (c) a decline in the primary energy consumption of 375 million tons of hard coal units in the year 2000 to 360 million tons hard coal units in the year 2030. Thereafter the development is expected to be stable.

At present 3.2 million tons of SO_2 and 3.3 million tons NO_x are emitted in the FRG. It is expected that 50% of the SO_2 produced in the FRG is exported; however, the same quantity is imported (Ewers *et al.*, 1986). With respect to the development of these emissions the following scenario was developed.

Trend-Scenario (Low Emissions=LES): Until the beginning of the next decade it is expected that the SO_2 emissions will decrease by 40% and the NO_x-emissions by 30%. For the following period, from 1991 to 2060 it is assumed that the SO_2 emissions will reach 25% and the NO_x 35% of the 1980 level. It is also pointed out that the environmental policy measures taken up to now have not been sufficient to achieve these reductions. A particular problem here is posed by foreign emissions.

Status-quo-Scenario (High Emissions=HES): A level of emissions was assumed which corresponds to the present level. In the period of the simulation and under these conditions, an annual emission of 3.2 million tons of sulfur dioxide and 3.3 million tons of nitrogen oxide is expected. No changes are expected in the level of emissions affecting forests.

Reference-Scenario (RES): Harmful substance emissions and chimney stack heights are assumed similar to those in the 1930s. This variant serves to describe each development which has taken place in the last 30 years without effecting a change. This time was chosen because the level of air pollution corresponds to that which prevailed at the time of construction of the yield tables of Wiedemann (Wiedemann, 1936/42 cit. by Ewers *et al.*, 1986). The fertilizing effect of the air pollution was also thereby taken into account.

Delphi technique

The basis for the scenarios was a questioning of experts organised according to the Delphi technique. This is a process of obtaining and approximating opinions of a group of chosen experts. The technique was developed in the 1950's. The process is characterised by three features:

- questioning of a group of experts
- anonymity of the experts
- questioning in many rounds and feedback of all results. A dynamic simulation model of spruce served as a basis. Three rounds of questioning was required.

3.1.2. Results of the scenarios

Forestry and timber economics

In the Reference Scenario the forest area in the FRG will increase slightly from the present 7.4 million hectares and will remain the same in all other variants. The share of economic forest will change according to the picture of damage and the area shares of the individual tree species.

In the Trend Scenario (low emissions) the economic high-level forest area will be reduced by the year 2060 by 0.8 million hectares from 6.3 million to 5.5 million. In the Status-quo Scenario (high emissions) the economic forest area will decline from 6.3 million hectares to 4.3 million hectares. In addition there are noticeable changes in the tree-species composition in favour of other deciduous species excluding beech.

In *Figure 2* one can see the development of the timber volume of spruce in the three scenarios. In the RES, due to the present shortage of old wood, a slight increase of stock is to be expected, which would later recede. The development in the LES indicates a rapid decrease in stock in the next 20 years. This would be followed by a slow restoration of stands. The long-lasting restoration would mean that the forest enterprises would have hardly any prospect of economic surpluses. The development of stocks in the HES indicates a collapse of common forestry. In *Figure 3* can been seen the temporal development of spruce area in economic forestry divided up into 20-year age groups (1 = 0–20, 2 = 21–40,..., 7 = 120+ years). The age structure of the LES and HES displays considerably more change than that of the RES. The LES already shows that there would be practically no stands in the age class 6–7 from the year 2010 onwards. Only at the end do the age groups begin to be restored. In the HES there are no stands in the age groups 5–7 from the 2010. Age group 4 will be considerably decimated for many years.

In *Table 3* the calculated damage to the forest economy is presented in millions of DM. The evaluations are made on the basis of actual costs. The greatest economic damage shows up in the loss of yield. The small damages in the HES are a result of the decrease in spruce area. Accordingly, the silvicultural, administration and fertilization costs are considerably higher than in the LES. It is hardly possible today to give a right answer to the question of the amount of restoration costs. The reforestation program in the Harz area of the FRG could be taken as an example. Due to forest damage and dead trees it is necessary to carry out planting work over an area of some 6,200 hectares. For the costs achievement of this afforestation project with different silvicultural concepts, a sum in the range of 65 million DM will be necessary until the year 1992 (Anon., 1988). In Bavaria, people are thinking in terms of costs of half a million DM per hectare for renovation of the forest areas used for protection (not including mountain torrent and avalanche constructions). According to Brabänder (1987), Ulrich assumes that the whole forest area must be treated, with thorough working and fertilizing a prerequisite. Normal treatment with lime costs about 500 DM per hectare. In connection with conversion, however, soil treatment at a cost of approximately 5000 DM is being calculated.

The subject of fertilizing is as complicated as it is controversial. It should, nonetheless, be mentioned that in central European countries completely different opinions exist about the subject of fertilizing (Glatzel, 1987a; Glatzel (ed.), 1987b; Hüttl, 1987; Isermann, 1987; Schweizer Bundesamt für Forstwesen und Landschaftsschutz, 1987; Greminger, 1985; Bayer. Forstl. V-u.FA 1987; Gussone, 1987).

Table 3. Monetary consequences in forestry due to forest decline in million DM. LES = low emissions (Trend-Scenario), HES = high emissions (Status-quo-Scenario). (Source: Ewers *et al.*, 1986.)

Species / *Type of damage*		*Spruce* *LES*	*Spruce* *HES*	*Other Species* *LES*	*Other Species* *HES*
1. Loss of yield Net value	0	59,527	54,586	32,440	29,944
	1	37,310	34,185	19,066	17,638
	2	24,038	21,951	11,441	10,572
	3	15,905	14,465	6,966	6,424
Annual value	0	774	708	421	369
	1	697	638	357	330
	2	615	561	292	270
	3	532	484	233	215
2. Difference in stand value Net value	0	25,645	31,242	17,097	20,828
	1	12,039	14,666	8,026	9,777
	2	5,694	6,936	3,796	4,624
	3	2,713	3,305	1,808	2,203
Annual value	0	333	406	222	270
	1	225	274	150	183
	2	146	177	97	118
	3	90	110	60	74
3. Costs of cultures due to conversion Net value	0	10,164	22,869	14,058	31,630
	1	7,135	16,054	9,544	21,474
	2	5,267	11,850	6,769	15,230
	3	4,067	9,150	4,995	11,239
Annual value	0	132	297	183	411
	1	133	300	178	401
	2	135	303	173	389
	3	136	306	167	376
4. Administrative expenses due to conversion areas Net value	0	5,150	11,587	7,685	17,291
	1	3,152	7,092	4,690	10,553
	2	2,007	4,515	2,973	6,690
	3	1,330	2,992	1,959	4,407
Annual value	0	67	150	100	225
	1	59	133	88	197
	2	51	115	76	171
	3	44	100	65	147
5. Fertilizing costs Net value	0	5,070	10,010	7,605	13,650
	1	4,223	7,027	5,967	9,216
	2	3,567	5,187	4,751	6,493
	3	3,054	4,005	3,837	4,756
Annual value	0	66	130	99	177
	1	79	131	111	172
	2	91	133	121	166
	3	102	134	128	159
6. Residual damage Net value	0	105,656	130,234	78,885	113,343
	1	29,978	37,069	22,211	32,231
	2	9,008	11,198	6,601	9,682
	3	2,863	3,587	2,069	3,070
Annual value	0	1,372	1,691	1,024	1,472
	1	560	693	415	602
	2	230	266	169	248
	3	96	120	69	103
7. Total damage Net value	0	211,312	260,468	157,770	226,686
	1	93,837	116,033	69,524	100,889
	2	49,581	61,637	38,331	53,291
	3	29,932	37,504	21,634	32,099
Annual value	0	2,744	3,382	2,048	2,944
	1	1,753	2,168	1,299	1,885
	2	1,267	1,575	1,052	1,363
	3	1,001	1,264	723	1,074

Note: 0, 1, 2 and 3 refer to discount rate in %.

In the work of Ewers *et al.* (1986) a basic assumption is made that an equally long time is necessary for the renovation and regeneration of the forests as was necessary for the examination to be made (i.e., 77 years). For this reason a residual value is calculated that is as high as the amount of loss. Thus the resulting total damage for the spruce in the LES is approximately 211 milliard DM, and in the HES approximately 260 milliard DM. These figures do not include the damage not monetarised at the time, i.e., such damage as losses expected by the forest economy due to a fall in prices on the timber market which in the context of the time in question could easily amount to a sum of 500 million DM annually (Brabänder, 1987). One problem is posed by the discount rate. In the case of this severe damage a discount rate of 0% would apply, since the future is to be valued as high as the present. However, in the study mentioned the choice of the discount rate was left open to the decision-maker. Therefore, different discount rates were between 0% and 3%. Incidentally, Callaway *et al.* (1986b), in their study for the period of damage 1985–2030 in the USA, used a discount rate of 10%.

In the field of timber economy the authors (Ewers et al., 1986) restricted themselves in the estimation of the probable surplus or shortage situation on the domestic market to the basis of constant fixed parameters of behaviour until year 2000. In *Figure 4* the production and utilization of timber in the FRG in the year 1983 are laid out. Since the question of the development of the timber market is to be looked at later, we will restrict ourselves here to a brief summary of the results.

In the section about timber economy, the timber requirement development for the most important sectors of the timber economy was econometrically calculated in the time periods until the year 2000. This timber requirement according to 'normal conditions' was compared to the results of the simulation model for spruce (in consideration of the other coniferous species). This showed in what situation and when, according to the development in the spruce model, drastic adjustments by the timber-processing sector would be necessary or expected. These indications are however more of a qualitative than of a quantitative character (Ewers *et al.*, 1986). An internal or intercompany storage of roundwood as well as legal or economic measures of forest policy were not taken into account. Whereas in the Reference Scenario a very balanced development of timber supply and timber demand was expected, in the Trend Scenario and more strongly in the Status-quo Scenario, there were serious supply surpluses until the year 2000. Until this date the only impairments of the timber-economy sector to be expected are in shortages in some individual timber assortments. According to the simulation, the requirement for coniferous wood will increase from 14 million cubic meters in 1980 to 15.4 million cubic meters, of which the sawmills will take 13 million cubic meters. As with coniferous roundwood, no strong increase in demand is expected in coniferous industrial wood. The requirement in industrial residual wood is estimated at 6.9 million cubic meters in the year 2000 in comparison with the requirement in 1982 of 4.3 million cubic meters. Here the strongest growth in demand is expected. Following the decline in the domestic wood reserve, a period of shortage will occur (see comparison *Figures 5a-5e*). This could hardly be balanced out by precautionary storage of the timber or by import.

Leisure and recreation

In the field of leisure and recreation in connection with forest damage, five utility components in monetary evaluation have been taken into consideration. These are:

- loss of use by local visitors
- loss of use from long distances visitors
- loss of optional utilization
- loss of income in the tourist economy
- residual damage at the end of the period of study

The calculations are based on the empirically certified observation that the advance of forest damage will cause a reduction in the number of forest visitors. A number of variations were calculated in the study. The evaluation of forest visitors and the changes in their numbers was made using a time-utility-value method (Ewers and Schulz, 1982), according to which an evaluation sum of 4.87 DM was calculated per forest-visit hour. The evaluation of optional uses was, on the basis of questioning, cautiously set at 7.50 DM per year per head of the working population. It was, however, assumed that only 62% of the working population would pay this sum. The loss of income in the tourist industry was estimated on the basis of a regional income multiplication factor of 1.5. Residual damage was added to this as in the forest economy. The resulting figures are set out in *Table 4*. In this case the Trend Scenario arrives at a total damage figure, at a discount rate of 0%, of 487 milliard DM, and the Status-quo Scenario at the value of some 871 milliard DM.

Water and soil

For water and soil, changes due to forest damage in the extent, temporal distribution and quality of the runoff from forested catchment areas had to be checked in addition to possible damage in the area of soil erosion and increased avalanche danger. Considerations of the evaluation of reduction of the soil protection performance of the forest, with a practical example, were published by Moog and Püttmann, (1986). In their calculations of soil protection performance of forests, they arrived at a sum of 1938 DM and 3972 DM per hectare. It was shown in the Trend Scenario (LES) as well as in the Status-quo Scenario (HES) that forest damage would lead to an increase in the total annual runoff. Moreover, an increase in the low discharge by surface near-ground water flow is linked to a risk of deterioration of water quality. The expected increase in total runoff also causes an increase of the maximum discharge. Maintenance of maximum discharge would involve costs of 5 milliard DM according to the LES and in the case of the HES of some 8 milliard DM. In addition to the maintenance of maximum discharge, investment costs for stream and avalanche constructions and soil-erosion protection in the Alps will be necessary. Here one can refer back to earlier studies made in the Bavarian Alps (Ewers *et al.*, 1986). From these extrapolations, the LES arrived at costs to the amount of 6.5 milliard DM and the HES at costs of 7 milliard DM. The authors had difficulty in evaluating the deterioration of water quality. The quality risk with drinking water was calculated on the basis of a cautious rough estimate with a value of 2 pfennigs per cubic meter in the LES and 4 pfennigs in the case of the HES (time period 2021–2060). The total damage in the area of water and soil was given a monetary value of some 885 milliard DM in the LES, and some 1407 milliard DM in the HES (discount rate 0%).

In *Table 5* the total monetarised damage is summarised with different branches and discount rates. When one takes a total result at a discount rate of 2%, one can see that the total damage in the LES stands at 211 milliard DM, and in the HES at 344 milliard DM. This gives annual damage in the amount of 5.5 milliard DM in the LES and 8.8 milliard DM in the HES. According to the authors these calculations are conservative and thus show the lowest limits. If the emissions and depositions

Table 4. Monetary consequences in leisure and recreational activities due to forest decline in million DM. LES = low emissions (Trend-Scenario), HES = high emissions (Status-quo-Scenario). (Source: Ewers *et al.*, 1986.)

Scenario *Components of the use*		*LES*	*HES*
1.Loss of use by	0	106,770	193,175
neighbourhood-recreation	1	65,160	119,850
Net value	2	41,025	76,855
	3	26,630	50,910
Annual value	0	1,387	2,508
	1	1,218	2,240
	2	1,049	1,965
	3	891	1,702
2. Loss of use by	0	15,325	27,765
distant recreation	1	9,355	17,225
Net value	2	5,890	11,050
	3	3,825	7,315
Annual value	0	199	361
	1	175	322
	2	151	283
	3	128	245
3. Loss of use of	0	2,270	4,010
optimal utilization	1	1,385	2,495
Net value	2	870	1,600
	3	570	1,060
Annual value	0	30	53
	1	26	47
	2	22	41
	3	19	36
4. Loss of income due	0	119,200	210,735
to tourism	1	72,795	130,790
Net value	2	45,875	83,925
	3	29,810	55,630
Annual value	0	1,548	2,737
	1	1,360	2,444
	2	1,173	2,146
	3	997	1,860
5. Residual damage	0	243,565	435,690
Net value	1	69,804	126,916
	2	20,784	38,504
	3	6,434	12,156
Annual value	0	3,164	11,317
	1	1,305	2,372
	2	532	984
	3	216	407
6. Total damage	0	487,130	871,375
Net value	1	218,499	397,276
	2	114,445	211,934
	3	67,269	127,071
Annual value	0	6,327	11,317
	1	4,083	7,423
	2	2,926	5,418
	3	2,250	4,249

Note: 0, 1, 2 and 3 refer to discount rate in %.

are not reduced, then the picture of the damage given in the LES must be seen as an underestimation.

Table 5. Total monetary damage due to forest decline in million DM. LES = low emissions (Trend-Scenario), HES = high emissions (Status-quo-Scenario). (Source: Ewers *et al.*, 1986.)

Scenario *Components of damage*		*LES*	*HES*
1. Damage in forestry:	0	369,082	487,154
Net value	1	163,361	216,922
	2	85,912	114,928
	3	51,566	69,603
Annual value	0	4,792	6,326
	1	3,052	4,053
	2	2,320	2,938
	3	1,724	2,328
2. Recreation and tourism:	0	487,130	1,254,340
Net value	1	218,499	571,451
	2	114,445	304,512
	3	67,269	182,309
Annual value	0	6,327	16,290
	1	4,083	10,677
	2	2,926	7,784
	3	2,250	6,096
3. Water conservation:	0	28,800	48,200
Net value	1	16,375	26,525
	2	11,042	17,414
	3	8,395	12,965
Annual value	0	374	616
	1	306	495
	2	282	446
	3	281	433
4. Total monetarized damage:	0	885,012	1,406,729
Net value	1	398,235	640,723
	2	211,399	344,226
	3	127,230	209,639
Annual value	0	11,493	18,258
	1	7,441	11,971
	2	5,528	8,802
	3	4,255	7,010

Note: 0, 1, 2 and 3 refer to discount rate in %.

3.1.3. Further publications of forest decline in the FRG

Bavaria

One of the first works of 'evaluation of forest damage' in the FRG was the article of the same name by Kroth (1985). As input for a global evaluation in Bavaria due to increment loss in spruce, the following factors were used:

- proportion of degree of damage per age class from the forest inventories in 1983 and 1984;
- increment performance in percent of a normal increment performance following initial estimations by Franz (see also Franz *et al.*, 1985, 1987) for the stands from the fifth age class according to degree of damage. No increment loss was assumed for the first two age classes, and the increment losses for the third and fourth age classes was arrived at by interpolation, and
- income excluding harvesting costs from pre- and final felling in the age classes calculated according to Hap structure forecasts (timber yield forecasts) from Franz and an assortment program from Bartelheimer (Kroth, 1985). In the evaluation of increment losses, the relationship to loss in value is noteworthy. The economic damage of an increment reduction in terms of percent is always higher than the loss in rough wood volume (over 7 cm diameter). For a normal forest model with spruce, yield class II (Wiedemann moderate thinnings) with a rotation of 100 years, using 1984 prices and costs with an decrease of rough wood increment of 10%, there is a loss in value of 12% with an unchanged stem number. However, if the development of the stem number is accorded an appropriately low site-quality class, then the loss in value is 25% (Kroth and Bartelheimer, 1984). In a more recent study, model calculations carried out for working circles are also graphically presented (Kroth and Bartelheimer, 1987).

Using the above mentioned basis, Kroth (1985) calculated an increment loss for spruce in Bavaria for the year 1984 of 19%. This is equivalent to an income excluding harvesting costs of about 166 million DM. Increment reductions were calculated for other tree species in a way similar way to that for the spruce.

In addition to the increment loss, Kroth also calculated the damage due to extraordinary yield. Not taken into account in this study was the damage due to the effects of forest decline on protectional and recreational functions.

On the basis of yield statistics from the Bavarian State Forest Administration, Kroth analysed the necessarily premature utilization of diseased trees. According to this analysis, the proportion of sanitation fellings constituted 5.8% of the timber harvest, a further 7.7% was affected by insect damage, and 3.2% affected by other forms of damage. Altogether 10% of the timber harvest was seen as utilization attributable to pollutant depositions. For the global evaluation, 10 DM/cubic meter was estimated for the extra cost due to the dispersed nature of the occurrences. The same sum was fixed as lost income. On this basis the total damage in Bavaria amounts to a sum of 20 million DM.

The earlier enforced utilization of parts of the growing stock or stands which are not yet mature means damage due to immature felling. For unstocked stands there is a compensatory soil rent. In his study Kroth calculated immature surface areas of 3,500 hectares for spruce and 2,615 hectares for pine. This produced an average loss of 55 million DM.

In addition, increased forest protection, culture, and amelioration costs were expected. Bark-beetle control alone involved costs of 6 DM per hectare for the Bavarian State Forest Administration. Extra administration, culture, and amelioration costs were set at 10 DM/hectare. This would result in damage for Bavaria amounting to 25 million DM. The following *Table 6* shows Kroth's calculation of the possible damage once again.

Table 6. Evaluated monetary damage in Bavaria. (Source: Korth, 1985.)

	1984 *million DM*
Spruce	166
Pine	18
Beech	13
Oak	5
Damage due to sanitation fellings	20
Damage due to premature utilisation	55
Increased forest protection, culture, and amelioration costs	25
Total damage in Bavaria in million DM	302

Total forest area in Bavaria = 2.4 million ha

Damage DM/ha in Bavaria = 126.- DM/ha

In order to estimate the possible consequences of forest decline in Bavaria, scenarios according to three different variants were worked out on the basis of the Bavarian complete state inventory 1970/71 and the adjusted timber yield recovery for Bavaria (cit. Encke, 1988). Changes in the assortments structure in Bavaria can be ascertained from *Figure 6*. The variants up to the year 2005, (optimistic, probable, and pessimistic) are presented according to Bartelheimer (cit. Encke, 1988). It is only the pessimistic variant which leads one to expect strongly increasing harvests over the whole time period [according to the pessimistic variant the proportion of the damage class diseased (2), severely diseased (3), and dead (4) will increase continuously until year 2005]. There a very slow continuous improvement is expected. The harvest in the year 2005 will be 8 million cubic meters higher than the situation in the equalisation year 1980 and more than 50% above the harvest according to timber yield forecasts. A dramatic change for the rough wood user is, however, not expected.

The effect of the increased harvest due to compulsory utilization cannot be predicted in the opinion of Kroth (cit. Encke, 1988). For this reason the present prices and costs have been used in the monetary evaluation of the expected damage. The following results were presented:

- the income, without the harvesting costs, from the utilizations is set at 145% of the timber yield forecast in the year 2005 in the pessimistic variant,
- the growing-stock capital in the year 2005 in comparison to the timber yield forecast of 48.4 milliard DM is expected to show a decrease of 4.2 milliard DM in the optimistic variant, 7.2 milliard DM in the probable variant, and 12 milliard DM in the pessimistic variant,

- the debit balance out of loss of wealth (capital) and excess proceeds resulting from over-utilization are set at 5 milliard DM in the pessimistic variant.

Suda and Pröbstl (cit. Encke, 1988) have made an estimation of the effects of forest damage on the protection and recreational functions of the forest. For replacement costs, reconstruction costs and loss of earnings, the variants showed values for avalanche constructions of 100 to 500 million DM and for tourism of 100 to 600 million DM.

In order to give practical figures, some 1983 costs due to forest decline in Bavaria State forests were given (Anon., 1983). The check on the damage in the form of an inventory cost approximately 500,000 DM. The planned large-surface inventory with air photographs was set at 1.5 million DM. Approximately 6,000 hectares of forest area are fertilized every year, involving costs of 2.3 million DM. In 1982 a sum of some 2.0 million DM was used for pest control. Silvicultural measures of the forests where stock had suffered damage cost 10,000 DM per hectare – for the state forest alone this amounted to 50 million DM since some 5,000 hectares required immediate support and regeneration.

Economic and political consequences of forest decline

In a treatise of the study on the subject of 'Economic and Political Consequences of Forest Decline – Analysis of Effects and Instruments for Political Action' (Nieβlein *et al.*, 1986) the different subject areas of forest and timber economy were discussed. Considerations and calculations concerning the quantitative consequences of forest decline relevant to the timber market were made. Timber-market political design measures to avoid disadvantageous consequences of a possible surplus situation were discussed. The economic and property policy limits of forest decline for private forest owners were also considered. An estimation was made of the expected consequences to the countryside ecology and of the possibilities of their evaluation. There was also discussion on the consequences of the recognisable trends in international environmental policy and finally joint and far-reaching political scientific considerations were made.

3.1.4. Evaluation of forest decline in relation to individual enterprises

Pattern models of damage to stands and to the rotation pattern form an essential basis for the evaluation of the monetary damage. This is also the case in the study of Ewers *et al.* (1986). In order to investigate the cost – benefit situation in the forest economy, data were collected from 80 forest enterprises with more than 250 hectares (Möhring, 1984). This provided information where already in 1983, emission damage had already a noticeable influence in the financial situation and thus also on the management operations of forestry enterprises. The damage data from individual enterprises varied between 0 DM and 225 DM per hectare of operational area, depending on the degree of the damage. The average damage was 29 DM per hectare. Changes of timber grades and spread fellings of the timber were also taken into account as well as the additional costs of timber harvest, fertilizing, tree species change, forest protection and others. The estimate does not include increment losses, premature felling, and other damage values.

There are two types of increment reduction:

- through physiological weakening, individual tree growth is reduced (in this context *see also* Athari *et al.*, 1984; Eckmüller and Sterba, 1987; Eckmüller, 1988); and
- because of the physiological weakening of individual trees the volume growth of stands is also reduced.

In order to estimate the influence of changes in basal area increment, height increment and individual tree mortality on the development of different timber grades within a stand, a pattern model is necessary (Möhring, 1984). Such a model, for reasons already mentioned, was developed for spruce. The yield tables of Wiedemann served as a growth norm.

Figure 7 shows the most important connections between different simulation models, whereby the growth process is exposed to various 'disturbances'. *Figure 7a* shows a normal development. The growth in value of the old stand is achieved especially by ingrowth in assortments. *Figure 7b* establishes a reduction of the basal area increment of the amount of 50% from the age of 50 onwards. The building up of the growing stock and the utility of the timber will be reduced, and the growth in value will be disproportionately affected. In *Figure 7c* the growth loss is supplemented to by a loss of 3% annually in the permanent growing increment over 50 years old; this causes a much steeper drop in the final yield of the felled stand, which in effect means a reduction in the productive timber stock. *Figure 8* shows that there is a close connection between the reduction in increment and the loss in value (Möhring, 1985). A reduction of 20% would therefore lead to a loss in value of 40%. It is also shown that an ideal-normal forest hardly reflects this in practice. In the lifetime of a stand a number of risks come into play, whereby, e.g., not every enterprise achieves the planned rotation time. It is considered quite normal today that in forestry the younger age classes are in stronger presence. When, however, severe damage, e.g., novel forest damage occurs, this means a higher utilization of the increasingly younger stock. This, in turn, raises the costs and brings decreasing yields and thus possible negative net balances. This simulation model for spruce was further developed (Möhring, 1985). In addition a dynamic simulation for the rotation in forestry for the most interesting questions about evaluation of emission damage in an individual forestry enterprise were used (Keuffel and Möhring, 1986). In order to produce a simulation model, a management program system (e.g., Framework, Javelin, Multiplan, etc.) was used on a microcomputer (Möhring, 1986). This program was also used in the computer supported analysis of key figures in a comparison of enterprise operations (Möhring, 1987).

On the subject of emission damage, a number of authors have provided statistical presentations of the economic effects. The records of a municipal forest enterprise were analyzed and this showed that indeed there had been additional expenditure because of forest damage (Härle, 1986). Further, it was possible, on the basis of old records, to establish that the unexpected fellings between 1927 and 1981 on average stood at 20% of total fellings. The felling plan for the year 1986 was based on 60% preplanned and 40% unexpected fellings comprising the timber yield. The removal of diseased and dying trees caused the incidental yields within the felling rate to rise sharply; in 1984, they were 52% and in 1985, 51% of the fellings. Of these 51%, 30% are from windfall, 8% due to emissions, 9% to reduction of stock, 2% to drought and also 2% to breakage by snow (Härle, 1986). Riederer von Paar (1984, 1985) published some thoughts and statistical records of the effect of forest decline on private enterprises from the point of view of a practitioner in a large enterprise in Bavaria. Geßmann-Böhm (1985) discussed the effects of damage due to air pollution on farmer-owned forest in the Black Forest. According to her, forest decline does not only mean material loss. It also means the slow destruction of a life-style which has existed throughout forest farming families for centuries. Netsch (1985) also examined the monetary effects of forest decline on farmer-owned forestry enterprises.

Speidel *et al.* (1985) estimated the economic consequences of forest decline for forest enterprises based on the example of a enterprise from the central Black Forest. The constant average damage according to calculations is about 395 DM per hectare (value 1985) net yield per year. It was emphasised that this value represents in fact the lowest limit of the true damage.

It is clear that the influence of novel decline should be taken into account in the evaluation of forest value. In this context the articles of Kato (1985, 1986), Berndt (1986) and also Kroth and Bartelheimer (1984, 1987) should be mentioned. An interesting publication was also made by Samuelson in 1976.

3.1.5. Timber economy

The possible developments in timber yield and timber consumption in the FRG until the year 2000 have been examined. Ollmann (1985) has made a forecast about the timber consumption. It is a function contingent on the development of gross national product. For the purposes of this study an effective rise of 2.5% in the GNP up to and including 1988 was expected, and thereafter a rise of 2%. In the Ewers *et al.* (1986) study a GNP of 2% was used as a guiding principle in the simultaneous econometric model for the simulation of yield and utilization of semi-finished timber goods. According to Ollmann it would be unlikely that total consumption would rise to 73.5 million cubic meters by the year 2000, that is to say a rise of 9 million cubic meters in relation to the 1980 level. For this variant an annual GNP of 3% was presumed. More likely is an increase of 6.5 million cubic meters (GNP of 1.5% from 1985). An increase of 6 million cubic meters is to be expected in paper production. In the case that a considerably greater yield of rough wood came on the market than before, as a result of the sanitation fellings as a consequence of novel forest damage, this quantity could certainly not be absorbed by a rising consumption of wood and wood products. This is on the precondition, according to Ollmann (1985), that goods which, up to now, have been imported would be eliminated from the domestic market.

In order to estimate the possible development of the state of the forests and the consequences for the forest economy until year 2000, Fähser (1985) used the scenario technique. ***Figure 9*** gives the annual timber yield dependent on emissions as a percentage of the normal felling rate. In the most favourable variant this would stand, in the year 2000, at 48% of the present normal felling rate (30 million cubic meters without bark). However, in the middle variant the timber yield dependent on emissions in the year 2000 would be 126% and in the unfavourable variant 202% of the normal felling rate. In the Ewers *et al.* (1986) LES variant, the peak among permanent spruce stock of felling due to emissions lies only just behind the total requirement of pine wood. According to the simulation the withheld utilization very quickly cumulates in a considerable mass of timber which at its peak nears 80 million cubic meters.

According to Fähser (1985) the annual timber yield due to emissions for the middle scenario variant including the normal felling rate in the year 1990 will be 150%, in 1995 159% and in the year 2000 156% of the normal felling rate. In the opinion of Fähser (1985) this surplus amount of 50% is likely, in a market economy, to have an effect on the timber price. It was also shown in the study of Ewers *et al.* (1986) that according to the simulation a withholding of wood in the interests of the market would no longer be possible. The simulation model results in the LES suggest that the shortage of timber will very quickly have an effect. According to the simulation, within 20 years the annual supply from coniferous timber will decrease from 21 million cubic meters to 8 million. The favourable expectations indicate a spruce timber supply of 2.5 million cubic meters in 30 years time instead of the present 11 million. In the case of the coniferous industrial wood the figures give a different picture. A change in the proportions of timber assortments leads only slowly and in the long term to a disparity between timber felling and timber requirement. Ewers *et al.* (1986) maintain that, on present evidence, there will be no shortage.

According to Fähser (1985) the average timber price per cubic meter will continually drop from 90 DM in the year 1985 to 60 DM in the year 1990. In *Figure 10* the timber yield and hypothetical timber price (without compensation for inflation) is graphically displayed. In the same period supply exceeds the normal volume by 30%. Only by a reduction in the increase of the apparent volumes will it be possible to bring the price back up to 75 DM in the year 2000. Pfleiderer (1984) presented scenarios developed from the point of view of the timber industry and timber economy, in order to find out what would happen if altogether over a quarter of the FRG area, at the same time and under calamitous conditions, fellings of double the amount of stemwood were necessary. The scenarios showed that the total coniferous felling would only rise by 5%. The surplus of roundwood for sawmills would be 11.5 million cubic meters. Thus a surplus production of 1 million cubic meters of sawn timber would be equivalent to 12%. The relation between industrial thin-wood and industrial residual wood would change by 5% in favour of the latter. New marketing possibilities were envisaged for the supplementary amount of stem and sawn-timber in (a) raising domestic timber consumption, (b) new large-scale industrial consumers, (c) long-term storage, and (d) import substitution and export of logs and sawn-timber. The lack of international competitiveness was mentioned as a problem.

Bergen (1987) examined the influence of forest damage on the supply of coniferous timber on the market. In his opinion forest damage would not directly influence the supply on the market, but indirectly via the cost-profit relation of forestry enterprises. This hypothesis was empirically tested during the period from 1980 to 1984. The progression of the surface area of forest damage according to time was taken from the federal forest damage inventory and covers the forest decline classes 1 to 4 for coniferous species (as a percentage of coniferous forest area). The result of the empirical test confirmed the theoretical expectations. The increase in forest damage raised the cost-profit relation such that forestry as a whole reacted with an increased supply of coniferous timber. Forestry would offer for sale a greater volume of coniferous timber whatever the production price. The calculations show that a 10% increase in the forest damage area would cause production prices to fall by 0.35%. However, a 10% increase in the forest-damage surface area would cause an increase of 14% in the volume on offer, whatever the production price. It was also possible to ascertain that an increase of 1% in the supply would require a drop in price of more than 1%. The marginal profit resulting from this supplementary supply is therefore negative. This would mean, according to Bergen (1987), that the behaviour of forest enterprises has contributed to a continued worsening of their own situation. Moog (1987) examined the supply behaviour of the regional forest administration of Baden-Württemberg on the roundwood market with the help of an econometric method.

Mantau (1987) has produced a 'simulation of increased felling yields as a consequence of novel forest damage and the economic consequences for the coniferous sawn-timber market' as a section of the report of the research project 'Consequences of Novel Forest Decline for the Timber Market in the Federal

Republic of Germany'. The assumption was made that, in the FRG, many successive years could lead to an annual total felling volume of timber of 10% to 20% more than the present level. The aim of the simulation was to analyse and quantify as accurately as possible the effect relationships of the individual sectors of the coniferous sawn-timber market. For this reason, it was not a future time period which was simulated but rather the effect of increased felling of coniferous timber in the years 1982 to 1984. The objective of the simulation was to provide a quantitative basis for decision-making, which rendered the economic consequences of novel forest damage calculable. Individual equations were developed for the price index for coniferous roundwood, for coniferous sawn-timber and for export development. The results of the simulation are to be found briefly summarised after Mantau (1987) in *Table 7*. The model is, according to the author, a pure supply model. That is to say, the demand side has no influence on the running of the model. Summarising, one can see that the export trade relations were clearly but not dramatically changed. This can also be said for Scenario II. The author was able to show similar changes in the coniferous sawn-timber trade in the framework of the SLIM-model (SLIM = Soft-wood Lumber Import Model) with a 10% reduction in the external value of the DM.

Table 7. Results of the simulations according to the Scenarios I and II in averages of the years 1982–1984. (Source: Mantau, 1987)

	*Absolute**		*Percentile*		*Safety-factor*
	I	*II*	*I*	*II*	
Roundwood-market					
Fellings	+1500	+3000	+12	+24	
Price indices					
1980 = 100	−5	−10	−5	−10	99.9
deflation	−2.5	−5	−3	−6	99.9
in US$	−6	−12	−9	−18	99.7
Export	+380	+760	+57	+114	93.9
Import	−130	−260	−17	−33	79.8
Timbermarket					
Price indices					
1980 = 100	−1.5	−3	−1.5	−3	99.9
in US$	−2	−4	−3	−6	99.8
Production	+180	+360	+2.5	+5	77.7
Export	+60	+120	+10	+20	84.7
Import					
Sweden	−55	−110	−5	−10	68.0
Finland	−45	−90	−7.5	−15	80.6
Austria	−90	−180	−16	−32	89.5
USSR	−10	−20	−2	−4	69.0
Canada	−15	−30	−14	−28	83.1
USA	−20	−40	−20	−40	68.6
ROW	−65	−130	−9	−18	85.6
Imports, total	−300	−600	−8	−16	

* In 1000 cbm, or in index-points.

Dysktra and Kallio (1986) in their timber market model in the 'Acid Rain' scenario also started from the assumption that between 1985 and 1995 the timber supply will increase because of sanitation fellings. It is expected that the annual increase in western Europe in the long term will recede by a third. No distinction was made between coniferous and deciduous timber, although Kauppi (1987) pointed out that differences between species are to be expected. It was also assumed that the timber quality would not be affected by the damage. Scenarios from Dysktra and Kallio (1986) show that a long-term reduction of increment would cause a decrease in the production of timber goods. The paper industry would hardly be affected. In the short term the excess supply of timber due to sanitation fellings would cause timber prices to fall. As a result, investment in the timber-processing industry would become more interesting. The authors concluded that increased felling due to forest damage in western Europe would certainly, in the short term, have its influence on the forest and timber economy. However, in the long term this influence would not be so significant.

The study of Voss (1987) is part of the same research project to which the study by Mantau (1987) also belongs. Voss studied the possibilities of 'soaking treatment of timber as a measure to relieve the market following forest calamities in the light of novel forest damage'. The storage ability and timber quality as well as the legal conditions and the practice of official approval were examined. On the basis of the results of consultation, an economic assessment of sawmills and forest enterprises was undertaken. Finally, timber policy aspects were also discussed.

3.2. The monetary evaluation of forest decline in Austria

Scenario techniques have also been used in Austria to evaluate the damage resulting from forest decline. Stemberger (1987) maintains, however, that the calculations made on the basis of scenarios are not to be described as evaluations or monetarisations, but as expert estimations of the order of magnitude to be expected. One advantage of the use of scenarios, according to Stemberger, is that the consciousness aroused by them of the threatening future due to forest decline increases the readiness to finance measures for the reduction of emissions as soon as possible, and also to set new priorities in the national economy and private households alike. It was also pointed out that, with respect to the timber market, scenarios could provoke undesirable reactions.

One of the earliest publications about the national economic significance of forest damage due to air pollution was commissioned in 1985 by the Federal Ministry for Health and Environmental Protection in Austria (Schönstein and Schörner, 1985). Among other things the ministry wished to have, on the basis of direct investigations and through secondary methods, a definition of the most seriously affected areas of damage. One of the tasks in the study was the elaboration of a national economic calculation of the measures necessary for the prevention of this damage.

As well as forestry, the sectors of timber economy, forest economy, secondary use, and also protection and performance relations in connection with the public welfare effect of forestry were all considered. The latter includes water economy, and regional and social parity. The study was carried out using the Brandl and Matthies (1984) assessment system already mentioned.

In order to quantify these increment losses, two scenarios were used. Scenario I was based on increment percentages of 0, 10, 20, and 50% for the decline classes healthy (0) ailing (1), diseased (2) and dead + dying (3). Corresponding percentages in Scenario II were 0, 10, 50, and 75%. The total Austrian productive forest of 3.165 million hectares, with an average increment of 6.2 cubic meters outside bark (Vorratsfestmeter) per year at an average round wood price of 950 Austrian Schillings (OS)/cubic meter (Erntefestmeter) (1983), would suffer a loss to the national economy of 449.2 million OS according to scenario I and 665.2 million OS according to scenario II.

The authors, similar to Nieβlein, assume that on the point of immaturity, more than half of the felling of spruce will be premature. This will lead to a reduced timber assortment yield. At a discounting of 4% over 20 years and a reduction in revenue of 20 DM/ cubic meter due to pollution, this would give a sum of 10 DM/cbm.

In the opinion of the authors, in addition to the deficiency in proceeds and the additional expenditure of harvesting, there is also a loss of bulk in the harvest, quality loss of the timber, mark-down in price because of the supply volume, loss in the assortment range, or timber sale at disadvantageous times. In a number of studies in the FRG, hardly any reduction in the wood quality could be ascertained as a consequence of forest decline (e.g., Schulz, H. 1985). In this case damage to the extent of 773 million OS (scenario I) and 1250 million OS (scenario II) were calculated. Swiss and FRG methods and data served as the basis for all the four scenarios. No account was taken of the reduction in value of the remaining stands.

On the basis of FRG studies, increased cultural costs were set at 37.9 OS per hectare. This represents an annual loss for the national economy of 6.33 million OS. Also based on FRG experience, the increased silvicultural costs were set at 5000 DM/hectare. In conformity with Nieβlein, a tripling of the forest protection costs from 3 DM to 9 DM per hectare was expected.

It was ascertained from the information about forest decline in the annual report on forestry 1982 (cit. by Schönstein and Schörner, 1985) that there had been 8,581 cubic meters of sanitation fellings over a damage area of 7,6512 hectares. From this one can calculate a damage figure of the amount of 58.8 million OS. In this study Schönstein and Schörner, 1985), increased risks and secondary forest uses, such as collection of seeds, hunting, or sale of fungi, were not quantified.

The restriction of the protectional and recreational functions is to be considered as very serious according to this study. In the opinion of Aulitzky (cit. Schönstein and Schörner, 1985), one must calculate average costs of 5 million OS (700,000 DM) for one hectare of avalanche constructions. Should it occur that, due only to the influence of air pollution, 0.1% of the Austrian protection forest had lost its ability to protect against avalanches and constructions were necessary, it would involve costs amounting to 4.1 milliard OS. If the area requiring sanitation was one percent, then the cost would climb to 41 milliard OS. According to a Swiss study which was not cited by Schönstein and Schörner, (1985), a loss of protectional function by 10% in the Swiss protection forest would cause costs of 50 milliard Sfr, that is, approximately 426 milliard OS. In this study the damage to the recreation and tourism functions was said to be unpredictable.

Two variants were calculated for fertilizing. In the first case, costs of 4,112 OS/hectare were calculated for a third of the severely damaged (decline classes 2 and 3) productive forest area. This gave a total sum of 280 million OS. In the second case it was assumed that liming at 3 tons per hectare would cost on average 3750 million OS. This meant costs of 766 million OS for the total severely damaged productive forest in Austria.

The experience in the FRG was also referred to in quantifying the increased costs of operational planning. Additional expense in the amount of 211 OS was expected for operational planning; this would mean a total sum of 109.5 million OS.

The shortfall in profits due to the reduction in assortments and excess supply of timber was calculated to be 1,100 million OS (scenario I) and 527 million OS (scenario II). The endangering of jobs was given a value in Scenario I of 1,076 million OS and in scenario II of 1,616 million OS. Finally, reduction in tax benefits for the forest economy was also calculated. This showed a reduction of tax benefits in the first case in the amount of 110 million OS and in the second case of 221 million OS. The cost of scientific research projects in connection with forest damage was given as 255.6 million OS. In this case the costs of the SANASILVA-project in Switzerland were adopted directly. Many other suitable areas of damage were mentioned verbally but they could not be quantified due to a lack of an appropriate method or for various other reasons.

The total national economic detriment as a result of forest damage due to air pollution amounts to an annual sum of 4,499.2 million OS. The authors of the study look upon this sum as representing a minimum amount.

A second study on the economic consequences of the forest damage in Austria was published by Puwein (1987, 1988). In Puwein's study (1988) the major economic factors such as production values and advance performances of forest economy, value of production in timber processing industry and tourism, investments in mountain-torrent and avalanche contractions, asset values of the forest owner, and the public welfare value of the countryside are all taken into account. These factors are all elements from different areas of the total national accounts.

Domestically produced goods and the output contributing to the gross domestic product (GDP) are to be found on the accrual side of the total national accounts. Forest damage will influence the forest economy's contribution to the GDP not only in terms of the final production but also in the advance performance. Increment damage in the long term reduces the timber volume to be harvest. Due to increased costs for soil amelioration and forest protection, the advance performance will rise.

To estimate the consequential effects of forest damage on the creation of wealth in forestry, the felling and yield scenarios of Frauendorfer (1987) were used. The monetary revenue was ascertained from a simulation using Austrian yield and assortment tables (price level 1986). This showed (a) that under conditions of undisturbed forest growth and retention of an approximately 120-year rotation, the creation of value in forestry would only change slightly. The forest economy contribution to the GDP, which was 0.7% in 1986, would decline to 0.5% in 1996, assuming a growth of 2%; (b) under conditions of moderate forest decline, the final production would first begin to fall significantly at the turn of the millenium. With rising advance performances the creation of value in the year 2026 will be almost a quarter lower than it would be with undisturbed growth; (c) in the case of a pessimistic scenario, the final production of forestry would, through increasing sanitation fellings, grow strongly in the next 20 years. Thereafter, however, there would be a decline and the creation of value in the forest economy in the year 2026 would only be half as high as it would be with undisturbed growth (Puwein, 1988). In this case the timber economy could no longer be supplied with domestic roundwood. The creation of value in the wood processing industry lay at 12.7 milliard OS in 1986, i.e., 0.9% of GDP. The GDP would therefore hardly be influenced by forest damage.

In contrast, the contribution of tourism to the GDP was 6.6% in 1986. Assuming that forest damage leads to recession in demand of 20% in the summer tourist traffic, there would be a reduction in the creation of wealth of 11 million OS (0.8% of GDP).

On the utilization side, forest decline could cause considerable investments. The protective constructions restraining avalanches and mountain torrents are largely public investments. In 1986 the Federal Government of Austria, the states, and the local authorities invested some 2.3 milliard OS in protective constructions. The repair of catastrophe damage in 1985 cost 522 milliard OS. The expenditure from catastrophe funds rose constantly and significantly, which indicates a deterioration in the state of protection forests. If one assumes that the real damage was four times as high as that covered by catastrophe fund expenditure, then the damage quota for 1985 was only 0.03%.

Puwein (1988) sees secondary effects with positive and negative influences for economic growth in the fields of the building economy and chemical industry, loss of income in the forest and timber economy, and regional economic consequences and burdens for consumers (e.g., catalytic converters for automobiles) and business. In this publication the accounting method with respect to damage due to forest decline is clearly shown. Novel forest decline would be ruinous for some sections of the economy, especially for forestry. It is shown, however, that in the present state of the total national accounts, the monetary damage would appear to be relatively slight. The author concludes from this that the public welfare effects are more relevant to the problem of forest decline, as had been discussed much earlier. Of the literature available, it is the publications of Puwein (1987, 1988) which show up most clearly the misleading nature of the present total national accounts.

3.3. Monetary evaluation of forest decline in Switzerland

In Switzerland, Altwegg-Artz (1987) has examined the method and significance of the estimation of the national economic costs of forest damage in alpine protection forests. A national economic study was made by a private company (Basler *et al.*, 1986) using scenario techniques. There were three different scenario elements which were based on each other. The consequential effects of forest decline were looked at in the framework of three scenario elements. These were: (a) the development of forest damage, (b) the development of natural dangers, and (c) the economic effects of forest decline. The scenario elements covered a time of altogether 20–40 years, divided into two phases of equal length of 10–20 years.

As well as the commercial function of forestry, the protection function will also be restricted by forest damage. It is assumed that developments must be combated with state measures. In the authors' opinion, it is necessary that the state obligates the forest owners to fulfill their legal responsibilities.

The protection function would bring with it various economic consequences. Particularly affected would be tourism, surface engineering, industry and agriculture. In comparison with the previous study, this investigation takes into account some new aspects.

The scenario is based on the assumptions that:

- as well as being dependent on local and climatic influences, the development of the health of the forest will essentially be dependent on air pollution,
- the legal provisions which are already in force will not be sharpened very much. It must be mentioned however that the new Swiss protection levels for harmful airborne substances are significantly lower than those in the FRG (Teufel, 1986),
- the acidification and toxification of the soil will continue,
- the state of the forest will continue to deteriorate and will only recover after a period of 20 to 40 years. In the mountains especially relatively large open areas will result,

- for reasons of forest sanitation, the dying trees will be felled and removed from the forest. Open areas will be reforested. It is expected, however, that part of the reforestation will fail,
- it is assumed that forest owners will no longer be capable of guaranteeing forest care from their own resources.

Four types of forest damage were defined. The timber perspectives of the scenarios were distinguished in two phases: the first phase with strong increase in forest damage and the second phase where the damage situation becomes more and more stable.

The Swiss forest area covers in total 11,000 square kilometers; with respect to the protection function, this surface was divided into three degrees of endangerment: I slight or decreasing endangerment, II existing endangerment, and III clear existing endangerment. This, in conjunction with the forest decline types (A, B, C, D), makes 12 surface categories. In a third step, assumptions were made as to how one can react, by means of measures of technical and organisational adaptation, to the increase in natural dangers and the changes in water balance. The total risk increased by natural dangers involves not only the costs of the measures but also the damage costs due to more frequent occurrence of such events. In order to cover a particular risk - or damage level, increased costs are necessary. Very low risk values can, to some extent, no longer be attained. Residual damage will also increase. The optimum in protection measures lies in the area where the sum of the damage costs as a consequence of residual risks and the cost of protection measures are at a minimum.

In ascertaining the economic consequences, the previously mentioned scenario elements are used as a basis. These effects are indirect consequences of forest disease. They are a result of:

- various measures against forest decline
- the financing of the measures by the economy and the population
- elementary damage, which is in fact, a consequence of the deteriorating protection function of the forest
- the increased objective and subjective residual risks.

Political measures, financing, policy towards dangers, and sensitivity were the most important influencing factors. The economic consequences of forest decline were diverted into a chain of effects specific to that branch and were expressed as costs. The financial situation of forestry was expressed in the form of business achievement and was compared with a fictitious healthy forest scenario. For this a number of different parameters were taken into account. These were: growth, utilization, increment, harvesting costs, remaining operational costs, and timber revenue. In addition, the loss of value of the forest stand was evaluated. The cost of the construction measures involved in the protection function was estimated. The costs included the outlay and the maintenance or renovation of the constructions. No account was taken of discounting. According to Basler *et al.* (1986) ignoring the discount would lead to an overestimation of the costs. Instead, the consequential costs (residual damage and consequential charges to forestry) occurring at the end of the scenario time period of 40 years were not taken into consideration. Compared with the study by Ewers *et al.* (1986) this fact, in the case of a discounting of 0%, would lead to a monetary underestimation of the damage in Switzerland.

In other areas of the economy, the increased residual risks, despite construction measures, would have an effect on production and employment in the long term. This would particularly be the case with avalanche risk. In this way the socioeconomic situation in mountain areas would be most strongly influenced or losses of jobs and income in the economic sectors affected.

Sensitivity to the increased residual risks would be transformed in every economic sector into a plausible reaction function. The effects in all branches in terms of changes in job availability and of changes in the factor income in this branch were estimated. These are to be seen in comparison with the increase or decrease in jobs and the factor income profit (of creation of value) or loss, which occurs as a result of public adaptation measures in the forest and building industry (Basler *et al.*, 1986).

Economic effects

To estimate the economic consequences for forestry, the following factors must be considered:

- as a consequence of enforced utilization, timber utilization increases in the short and middle term. In the longer term it will result, however, in a collapse of timber production:
- due to forest decline, timber increment will fall
- growing stock will decrease rapidly
- harvesting costs will rise
- other optional costs will increase steeply, especially as a result of reforestation
- timber supply will rapidly exceed timber demand.

It is to be expected that outside Europe, surpluses will also be produced. In the short and middle term this will lead to a drop in the timber price and the timber revenue. Inferior quality timber assortments will appear (Basler *et al.*, 1986). According to Zuber (1987), 20% of the total utilization volume in the Forestry Inspectorate of Graubünden in 1986 consisted of sanitation fellings due to forest damage. In recent years this proportion has risen constantly. In Switzerland, in order to combat the damage, individual enterprise planning has been employed (Schlaepfer *et al.*, 1986). The principle illustration of the influencing factors of business achievement can be found in ***Figure 11*** (Basler *et al.*, 1986).

Based on current prices, it can be ascertained that Swiss forestry can produce a revenue of approximately 600 million Sfr per year. In the face of this, there is an outlay of 530 million Sfr. The operating results are thus approximately 70 million Sfr/year.

In the forest-decline scenario, the outlay and revenue figures change considerably as time goes on. In Phase 1 the operating results show a negative balance of approximately 430 million Sfr/year. It is assumed that the public sector would provide the required financial means for necessary utilization, reforestation, and other silvicultural measures. This would give rise to a positive effect of job creation in the forest industry. In Phase 1 the creation of jobs would increase in proportion to utilization. However, it would probably prove difficult to obtain labour at the time required. About 7,600 extra jobs are calculated for forestry. The additional factor income in this Phase 1 is 230 million Sfr annually in mountain areas and 100 million Sfr in central areas.

In Phase 2 an increased requirement of manpower is also expected. At the beginning of this phase, enforced utilization and reforestation are most prominent. Towards the end of the phase, silvicultural measures for the care of the forests predominate. If one compares the operating results of the forest-decline scenarios with those of a undamaged forest, there would be supplementary outlay in Phase 1 of 500 million Sfr/year and in Phase 2 of 300 million Sfr/year, if the upkeeping the forest is to be maintained (Basler *et al.*, 1986).

The change in growing-stock value is to be seen in *Figure 12*. In Phase 2 the rising timber prices become positive. However, since the stand density is reduced, the growing-stock value of an undamaged forest is no longer able to be attained.

The timber economy would benefit from the falling timber prices in Phase 1. This would result in a positive job creating effect. Altogether 2,000 extra jobs are expected to be created. This would give a factor income of 120 million Sfr/year. In the second phase, however, the jobs would again be lost with 1,250 and the factor income would be set at a figure of minus 80 million Sfr/year.

The consequential effects of the protection measures against natural dangers would, in the both phases, be positive. Protection against avalanches, floods, and rock fall would cost 14,000 million Sfr in the first phase. In the second phase a sum of 4,000 million Sfr was calculated. In the construction business in both phases, a total of over 10,000 new jobs were created. The factor income in the construction business would amount to a total of 520 million Sfr/year. As a result of residual damage, further costs would be incurred despite protection measures. These costs would be 380 million Sfr/ year in Phase 1 and 555 million Sfr/year in Phase 2.

In the case of tourism, a recession of 20% in Phase 1 and of 30% in Phase 2 in the number of overnight bookings was expected. These serious drops would be accompanied by noticeable employment losses. The factor income in the hotel business and from secondary earnings was given in Phase 1 as 280 million Sfr/year and in Phase 2 as 430 million Sfr/year.

In surface engineering, jobs would also be lost. The factor income in Phase 1 would also be minus 70 million Sfr/year and the Phase 2 minus 110 million Sfr/year. In industry also there were negative results to be recorded. In both phases together 17,000 jobs would be lost. One must expect a negative factor income of 390 million Sfr/year in Phase 1 and 580 million Sfr/year in Phase 2.

In the field of agriculture, increasing natural danger was expected in mountain areas. In the long term, the closing down of 900 agricultural enterprises was calculated. The corresponding factor income losses were set at 35 and 45 million Sfr/year.

A continued drop in employment in the secondary and tertiary sector of 15,600 jobs, and an estimated reduction of the factor income in the amount of 700 million Sfr/year was presumed. The tax revenue in municipalities and cantons in mountain areas would be reduced by 90 million Sfr each in Phase 2. On the other hand, the municipalities would never be able financially to master the burdens which have arisen. In the following *Table 8* the costs of direct damage as a result of forest decline in Switzerland have been compiled for two phases of 15 years each.

The total costs amounting to 44 milliard Sfr are equivalent to a sixth of the annual gross national product of Switzerland. This sum will be reached if the costs accruing in the future are not discounted (discount rate of 0%). The average annual damage costs of forest decline, at 1–2 milliard Sfr, absorb 40 to 80 percent of the long-term real growth of the GNP which is approximately 1 percent. They are equivalent to 55 to 110 percent of the Federal expenditure on national defense or

Table 8. Direct costs of forest decline in Switzerland. (Source: Basler *et al.*, 1986.)

	Costs of damage		
	Cumulated million Sfr	*Phase 1*	*Phase 2*
		million Sfr/year	
Forestry	12000	500	300
Protection	18000	900	300
Additional damage	14000	380	530
Total damage milliard Sfr	to the nearest 44	1.8	1.2

for social welfare (Basler *et al.*, 1986). Looked at in this way the costs appear to be manageable but, according to the authors, this picture is deceptive, since it reflects only part of the costs. Not included here are those costs which cannot, or only with difficulty, be quantified, such as the costs concerning water balance, loss of the values of nature, or ethical questions.

In recent years subsidies for forestry measures have been considerably increased in Switzerland. In 1987, 35.5 million Sfr (+11 million Sfr) were granted for the remedying of forest damage and the care of mountain forests, and 37.1 million Sfr (+30.1 million Sfr) for avalanche constructions. In total, the Parliament granted 157.7 million Sfr for forestry measures in 1988. On top of this come 1.93 million Sfr for forest education and further training, and 7 million Sfr for investment loans. In comparison to the preceding year, this represents an increase of approximately 33.67 million Sfr or approximately 12%. State expenditure for forestry thus, at this time, re presents 2.5% of total state expenditure. At an average of approximately 150 Sfr/hectare the state expenditure for forestry has taken on proportions which would have been inconceivable 6 or 7 years ago. According to the budget plans of the Executive National Council, the financial allowance of the State should be increased by a further 50 million Sfr to approximately 200 million Sfr by 1991 (Zimmermann, 1988).

4. Conclusions

Since the beginning of the 1980's, novel forest decline has aroused the public interest and concern. This damage is very different from the previously known forest decline, especially in the light of the geographically widespread nature of the damage symptoms to different tree species, as well as the rapid advance and chronic nature of the disease. The cause of the damage has still not yet been unambiguously defined. However, air pollution is generally recognised to be a significant factor. Air pollution was long ago identified as a cause of to health and material things.

In order to quantify this damage scientists in America in the 1970's and later in Europe began to make monetary estimates of the environmental damage. The critical factor here is also to evaluate the utility of the environment, instead of only counting the cost of environmental protection measures.

Recently more serious discussions about the connections between ecology and economy have taken place. The crisis in the forestry sector not only manifest a crisis in economy, but it also indicates the instability of our complex social system. Criticism is often voiced about the anthropocentric behaviour of man. A new doctrine of management is required where an appropriate, compatible, and enduring existence must be assured for the whole living community. This doctrine requires a stronger commitment on the part of environmental and forest policy. On the one hand, the revenues from forestry have moved more and more from the private to the public sector. They have thus become external and serve the community as a whole. On the other hand, the costs in forestry have risen considerably. In the opinion of the national economists this external factor, in terms of the whole economy, should be included in decision-making calculations, and from the national economic point of view, should also be openly identified in forestry decision-making models. The question has been asked whether the evaluation methods used up to now in forestry can be really correct any more. Forest policy consequences should be based not only on forest economics but also on national economics. A closer cooperation between the disciplines of forestry and national economics is thus demanded. As in other environmental areas, consideration is being given to ways of encouraging forest owners to offer subsidiary services such as protection and recreational functions.

Public knowledge of the extent of the damage to forests has made the evaluation of the economic consequences of forest damage of current topical interest. The evaluation can be made in terms of operations or of economics. In the Federal Republic of Germany, Austria and Switzerland, separate national economic evaluations about the extent of forest decline have been made. For various reasons the importance of the forests in these countries is very high. In the Federal Republic of Germany the recreational function of the forest is very important, and in Switzerland and Austria tourism makes a very high contribution to the gross national product. The function of the forest in protection from avalanches and mountain torrents is also significant in the latter two countries. Finally, the differing rank position of importance of forestry and forest economy is governed in each of the individual countries by the structure of ownership. This is also of considerable importance to forest policy in each particular country.

When one compares the investigations and estimations for monetary evaluation made in the three countries, then one can see that the evaluations of damage were initiated at almost the same time. The first study was completed in Austria in 1985. In the same year a synopsis was also published in Bavaria. In 1986 national economic studies on the evaluation of forest damage appeared in the Federal Republic of Germany and in Switzerland. A purely national economic study was published in Austria in 1987. These studies all make use of the scenario technique. In addition, in the Federal Republic of Germany (UBA-study, Ewers *et al.*, 1986) the Delphi-Process was used to employ expert knowledge quickly and effectively. The subsections in the forest damage evaluation are partly the same and partly divergent. In the UBA study distinction was made between forestry and timber economy, leisure and recreation, and water and soil. In the first Austrian studies these sections were also considered, in addition to, for example, the reduction in taxation revenue. In Switzerland, consideration was also given to the positive effects of increased employment, as well as the evaluation of the damage, especially in avalanche and mountain stream construction work. These studies also dealt with the influence of forest decline on agriculture and industry as well as in the secondary sectors. In Austria, particular concentration was given in the purely national economic study to the influence of forest damage on the gross national product. A particular problem was posed by discounting. In the UBA study the final decision was left to the policymakers and calculations with different discount rates were presented. These varied from 0% to 3%. The evaluations with a discount rate of 2% were held to be realistic, although it was commented that these values of nature would be more correctly calculated with a discount rate of zero. In the UBA study, residual damage is also considered. In contrast the residual damage is not considered in the Swiss study but the calculations were made with a discount rate of zero. In both of the Austrian studies, only annual monetary damage was calculated. Thus one cannot compare the studies too directly or too strictly with each other. However, attempt will be made to make a comparative synopsis of the results of the works. *Table 9* should be helpful here.

In *Table 9*, the calculated total damage figures and the annual damage in the respective currencies of the countries can be seen. Also displayed are the gross national products (GNP; in Austria, the gross domestic product GDP) of the individual countries. In Austria, in fact, two different studies were published. In the first case total annual damage was estimated at 4,499.2 million OS (1983 price level). This would represent 0.3% of the GDP. In the publication by Puwein, annual damage amounting to a maximum of 1.5% of the GDP for in the next 30 years was mentioned. This would be roughly ca. 21.6 milliard OS. In the Swiss study total damage amounting to 44 milliard Sfr (17% of the GNP) was given. In the first 15-year phase an annual damage of 1.8 million Sfr was estimated, amounting to 0.7% of the GNP. In the Federal Republic of Germany different variants of the scenarios were worked out. Only in this UBA study is a connection clearly made between a reduction of emissions and the scenario. In the Trend Scenario (low emissions) a total damage of 211.4 milliard DM was calculated, that is 11% of the GNP; in the case of the Status-quo Scenario (high emissions) 344.2 milliard DM, or 18% of the GNP. The corresponding annual damage sums would be 5.5 milliard DM, i.e., 0.3% in the Trend Scenario and 8.8 milliard DM, i.e., 0.5% in the Status-quo Scenario (with a discount rate of 2% in all cases). One can then ascertain that with a total damage of 17% in Switzerland, and, using the Status-quo Scenario (high emissions) in the Federal Republic of Germany, these two countries show the highest values of calculated damage. If one calculates, with a certain caution, the damage in DM per forest area and per inhabitant in each country, one reaches the following conclusions: the total damage in DM per hectare would be highest in Switzerland with 48,500 DM, closely followed by the FRG, in the case of Status-quo Scenario (high emissions), with about 47,000 DM. The annual damage would be highest in Switzerland in the first phase with approximately 1,980 DM, and in FRG in the Status-Quo Scenario 1,205 DM. In Austria, annual damage would vary from 170 to 815 DM/ha forest area. If one looks at the calculated damage per capita in each country then one can see that the total damage in Switzerland is 8,200 DM/inhabitant, and in the FRG in the case of high emissions is 5,600 DM per inhabitant. The annual damage would

Table 9a. Total forest area, number of inhabitants and GNP in Austria (A), Switzerland (CH) and the Federal Republic of Germany (FRG).

Country	*Total forest Mio. ha*	*Inhabitants Mio.*	*GNP Mrd. DM * 1985 ***
A	3.8	7.6	206
CH	1.1	6.5	308
FRG	7.3	61.1	1949

* All data rounded
** Source: Fochler-Hauke, G. (Hrsg.) 1987.

Table 9b. Evaluated total monetary damage in Austria (A), Switzerland (CH) and the Federal Republic of Germany (FRG) evaluated monetary damage in % of the GNP, damage per total forest area (ha) and damage per inhabitant.

Country		*Damage Mrd. DM*	*Damage in % of GNP*	*Damage per total forest area DM/ha*	*Damage per inhabitant DM*
A	annual	0.64[1)]	0.3	170	85
	annual	3.09	max. 1.5[2)]	815	410
CH	Total[3)]	53.24	17.0	48500	8205
	I. Phase	2.18/yr	0.7	1985	335
	II. Phase	1.45/yr	0.5	1310	220
FRG[4)]	Total T	211.4	11.0	28960	3460
	Total S	344.2	18.0	47150	5635
	annual 2%T	5.5	0.3	755	90
	annual 2%S	8.8	0.5	1205	145
	(annual 0%T	11.5	0.6	1575	190
	annual 0%S	18.3	0.9	2510	300)

1) Schönstein and Schörner, 1985.
2) Puwein, 1987.
3) Basler *et al.*, 1986. Discount rate 0%, residual damage not accounted.
4) Ewers *et al.*, 1986. Discount rate 2%, residual damage accounted. T = Trend scenario, S = Status quo scenario.
* All data rounded

amounts to 340 DM per inhabitant in Switzerland, and 145 DM in FRG. The annual damage varies in Austria between 85 and 410 DM per inhabitant.

In the field of the timber economy, it is the same for all studies that the development of the timber market cannot be predicted. For this reason the models are restricted mostly to a shorter time period. All studies expect an increased timber supply in the near future as a result of the damaged timber. The ability of the timber-processing industry to absorb this supply is evaluated differently. A fall in price is expected in any case. A slight restructuring in the field of export trade is also expected. Domestic demand for wood should rise. In order to relieve the market, conservation of the timber and stronger export have been mentioned.

The effects of forest damage on small enterprises, according to a number of studies, can be devastating. The growing stock and the increment will be reduced as a result of novel forest damage. The increase of costs will be considerable for different reasons such as necessary silvicultural transformations, amelioration and more extensive and expensive administration. The savings-bank function of small forest property will also become insignificant. The public will be more and more obliged to support forestry. In order to solve all these problems it will be necessary to recognise the value of the forest and its functions. A start has been made, but it requires further thorough research to be able to solve the exceptionally difficult and complicated problem of the evaluation of damage to the forest and the environment.

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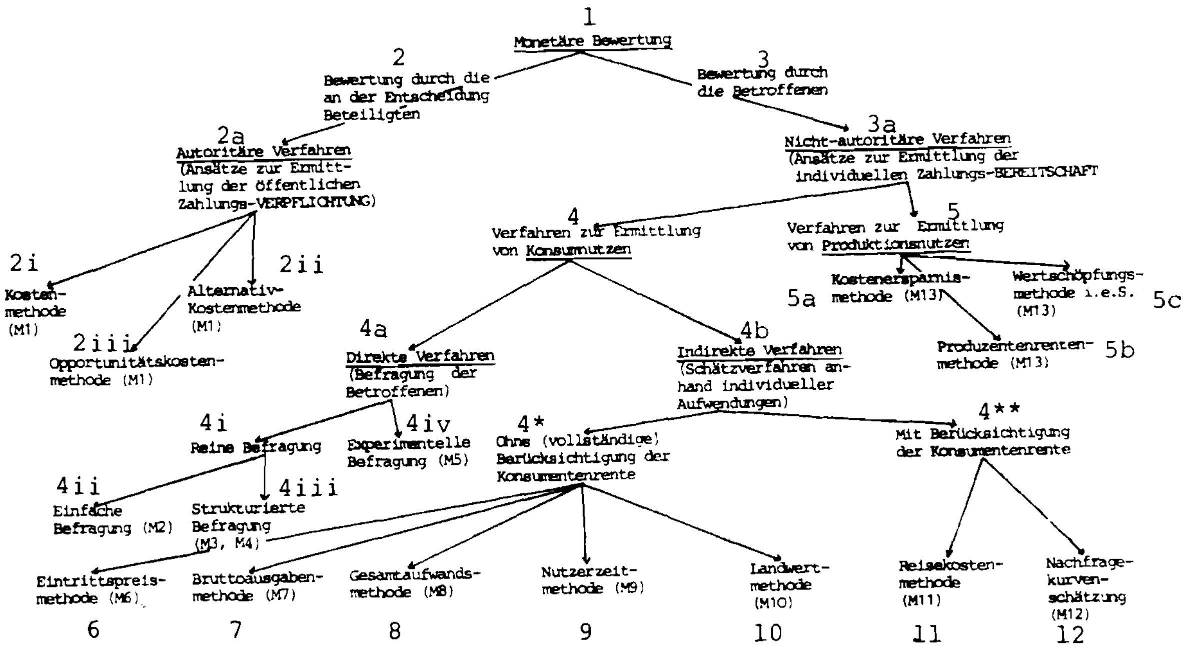
AFZ	=	Allgemeine Forstzeitschrift
Allg.Forst-u.J.-Ztg.	=	Allgemeine Forst- und Jagdzeitung
FA	=	Forstarchiv
FHW	=	Der Forst- und Holzwirt
Fw. Cbl.	=	Forstwissenschaftliches Centralblatt
FZ	=	Forschungszentrum
OF	=	Osterreichische Forstzeitung
Schweiz.Z.f.Forstw.	=	Schweizerische Zeitschrift für Forstwesen
UBA	=	Umweltbundesamt Berlin
W+H	=	Wald + Holz
ZfU	=	Die Zeitschrift für Umweltpolitik und Umweltrecht

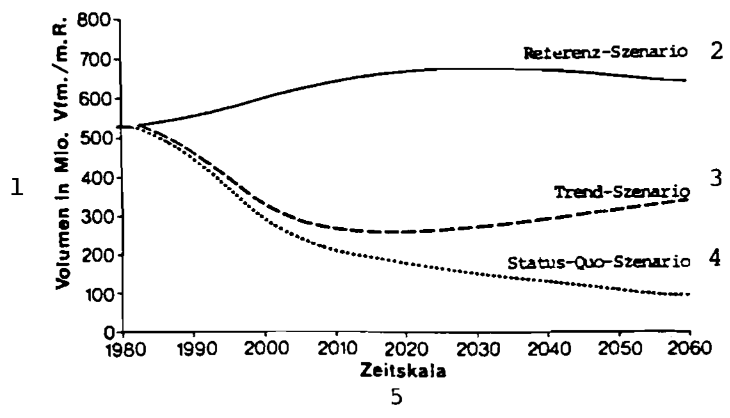
Figure 1. Systematology of methods for monetary evaluation of environmental values. (Source: Ewers and Schulz, 1982.)



Notes for Figure 1.

1. Monetary evaluation.
2. Evaluation by decision makers
   - 2a. Authoritarian method – public obligation to a payment
     - 2i. expenses method (M1)
     - 2ii. alternative expenses method (M1)
     - 2iii. time serving expenses method (M1)
3. Evaluation by persons concerned
   - 3a. Non-authoritarian method
4. Methods to evaluate the profit for consumption
   - 4a. Direct methods (questioning persons concerned)
     - 4i. pure questioning
     - 4ii. simple questioning (M2)
     - 4iii. structered questioning (M3, M4)
     - 4iv. priority-evaluator-method (M5)
   - 4b. Indirect methods
     - 4*. without consideration of the revenue for consumers
     - 4**. with consideration of the revenue for consumers
5. Methods to evaluate the profit for producers
   - 5a. Cost saving method (M13)
   - 5b. Producers revenoe method (M13)
   - 5c. Net product method (M13)
6. Entry price method (M6)
7. Gross-expenditure-method (M7)
8. Aggregate-expenditure-method (M8)
9. User time method (M9)
10. Land value method (M10)
11. Travel cost approach (M11)
12. Demand curve estimation (CCK method) (M12)

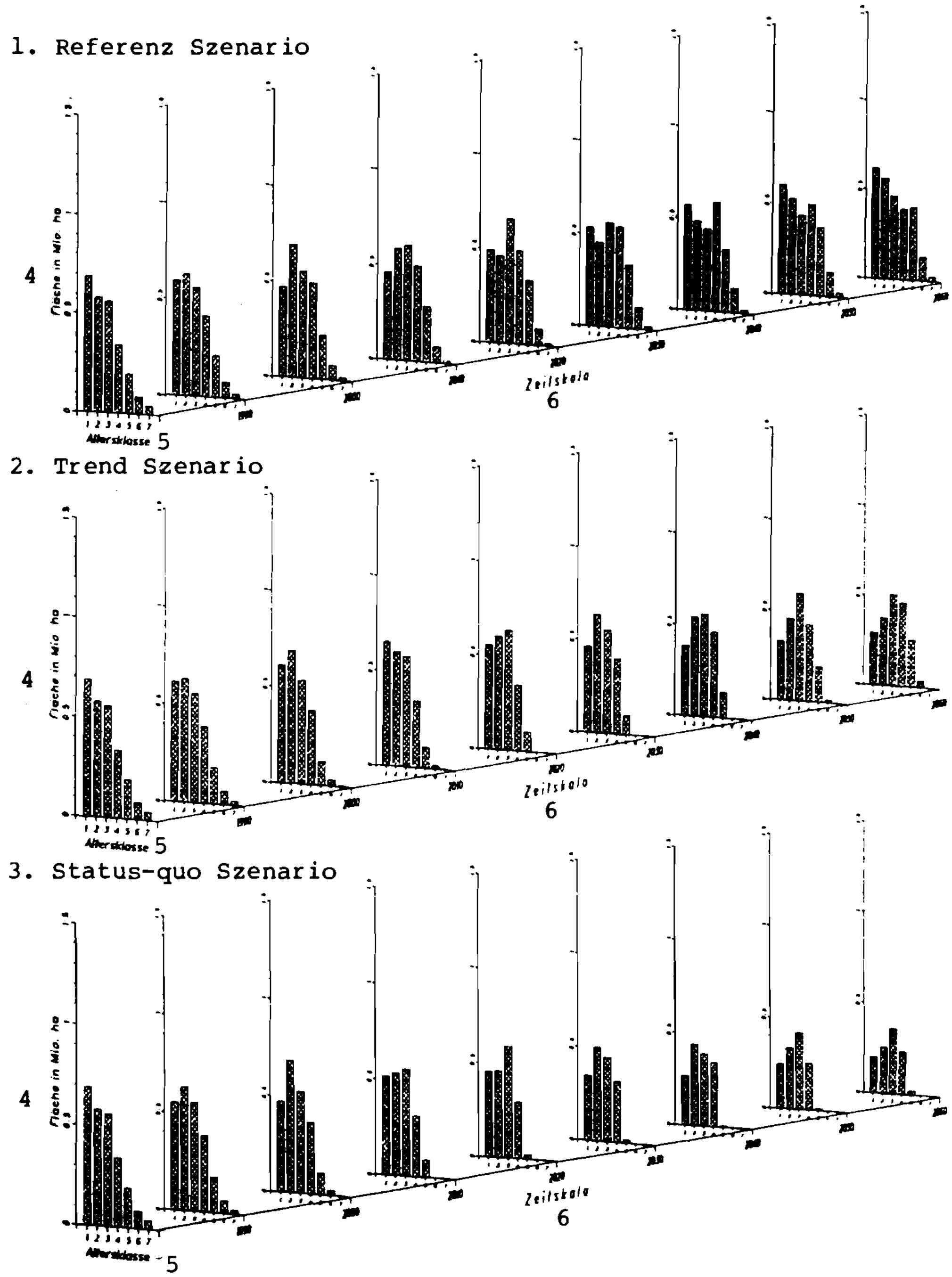
Figure 2. Development of growing stock of the spruce according to the scenarios in the Federal Republic of Germany. (Source: Ewers *et al.*, 1986.)



Notes for Figure 2:

1. Growing stock in million cubic meters outside bark.
2. Reference Scenario (RES)
3. Trend-Scenario (LES = low emissions)
4. Status-quo-Scenario (HES = high emissions)
5. Time scale

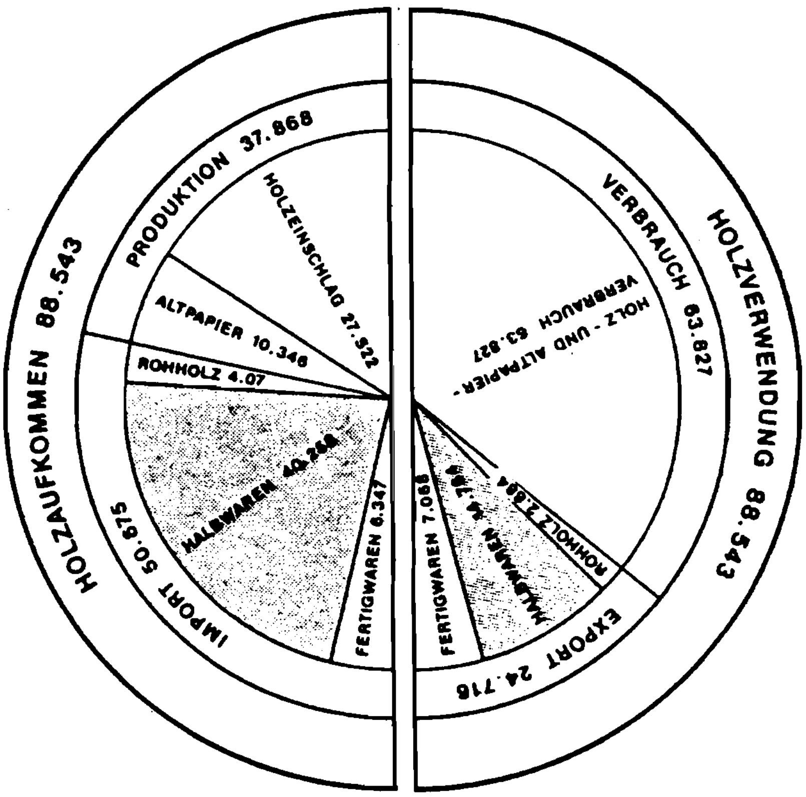
Figure 3. Temporal development of the spruce surface area in commercial forests, divided into age classes of 20 years according to the scenarios in the Federal Republic of Germany. (Source: Ewers *et al.*, 1986.)



Notes for Figure 3:

1. Reference-Scenario = RES
2. Trend-Scenario = LES (low emissions)
3. Status-quo-Scenario = HES (high emissions)
4. Forest area in million hectares
5. Age class
6. Time scale

Figure 4. Total production and utilization of wood in the FRG, in million m^3. (Source: Ewers *et al.*, 1986.)



Notes for Figure 4.

Total production of wood: 88.543

Production: fellings: 27.522, waste paper: 10.346

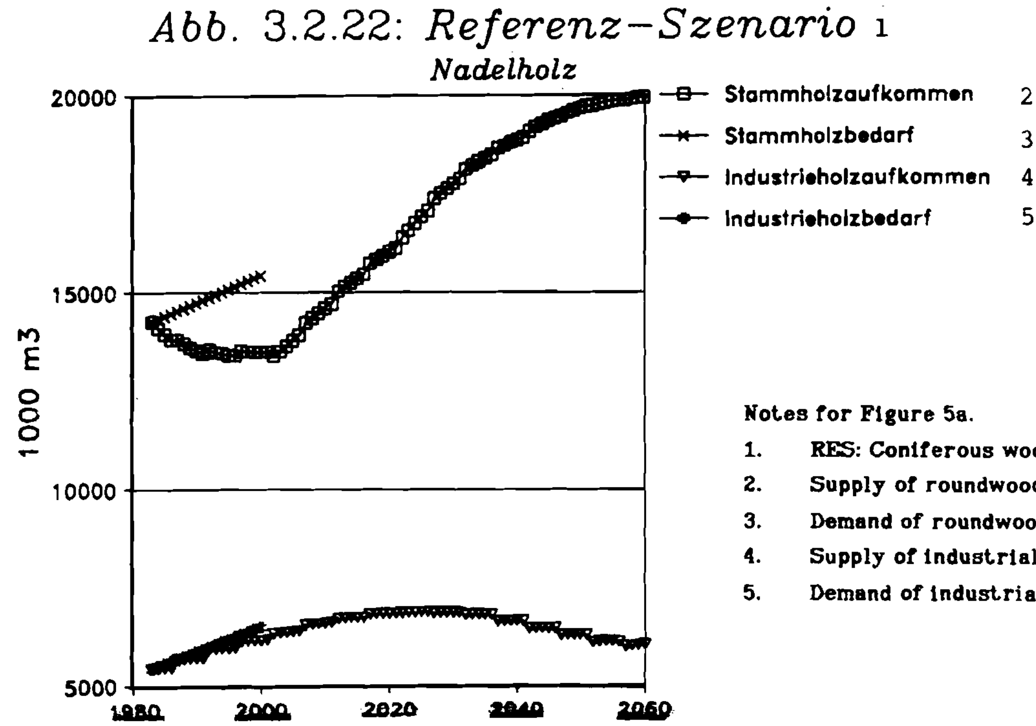
Import: 50.678; roundwood: 4.07, semi-factured articles: 40.258, manufactured goods: 6.347

Utilization of wood: 88.540

Consumption of wood: 63.827, consumption of wood and waste paper: 63.827

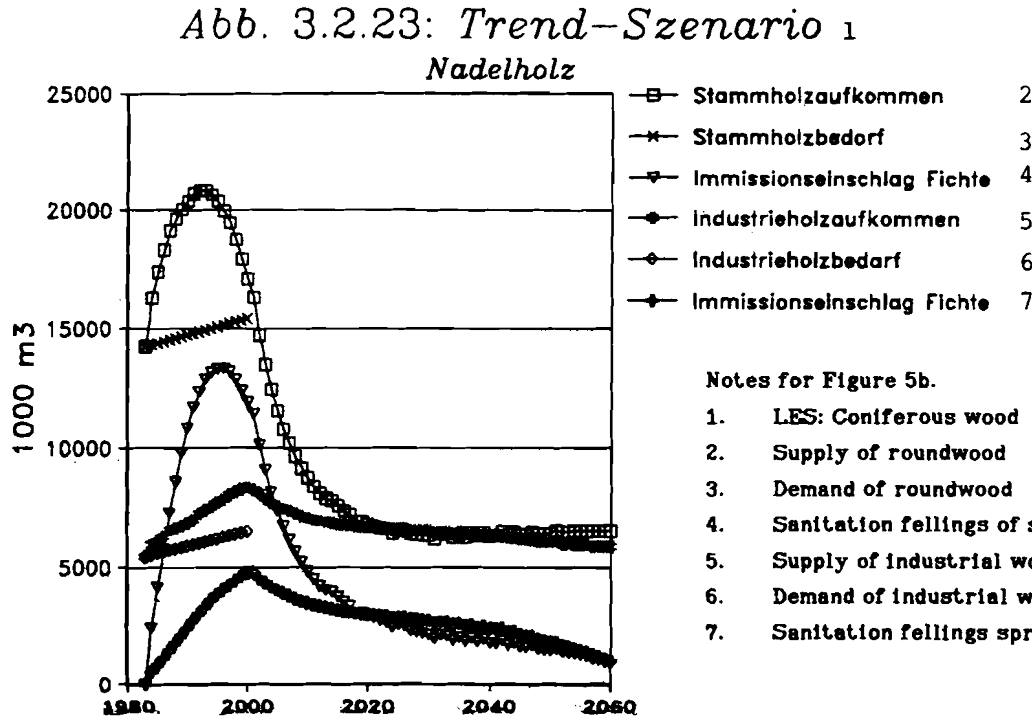
Export: 24.716; round wood: 2.864, semi-factured articles: 14.764, manufactured goods: 7.068

Figure 5. Comparison of timber demand and timber supply according to the different scenarios in the FRG. (Source: Ewers *et al.*, 1986.)



Notes for Figure 5a.

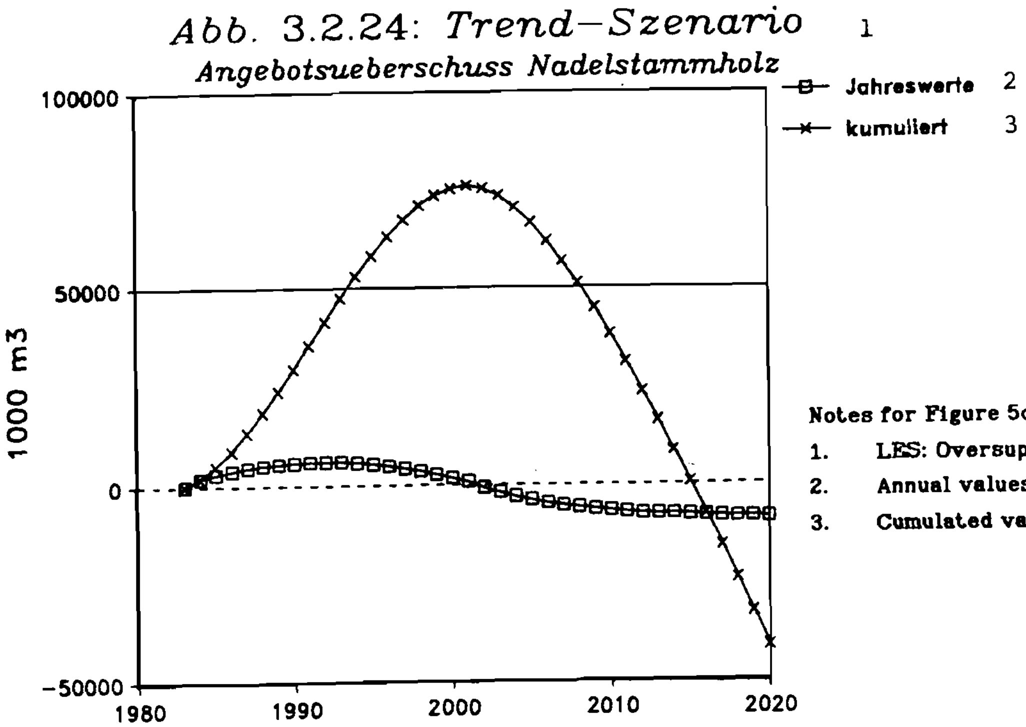
1. RES: Coniferous wood
2. Supply of roundwood
3. Demand of roundwood
4. Supply of industrial wood
5. Demand of industrial wood



Notes for Figure 5b.

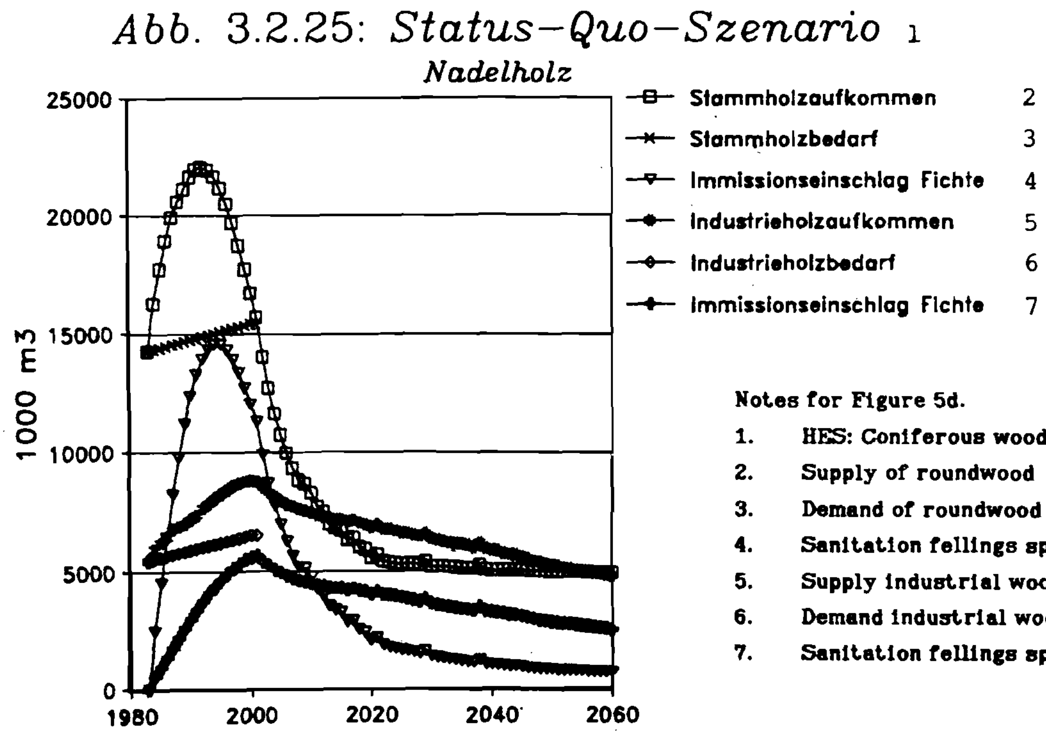
1. LES: Coniferous wood
2. Supply of roundwood
3. Demand of roundwood
4. Sanitation fellings of spruce
5. Supply of industrial wood
6. Demand of industrial wood
7. Sanitation fellings spruce

Figure 5 continued.



Notes for Figure 5c.

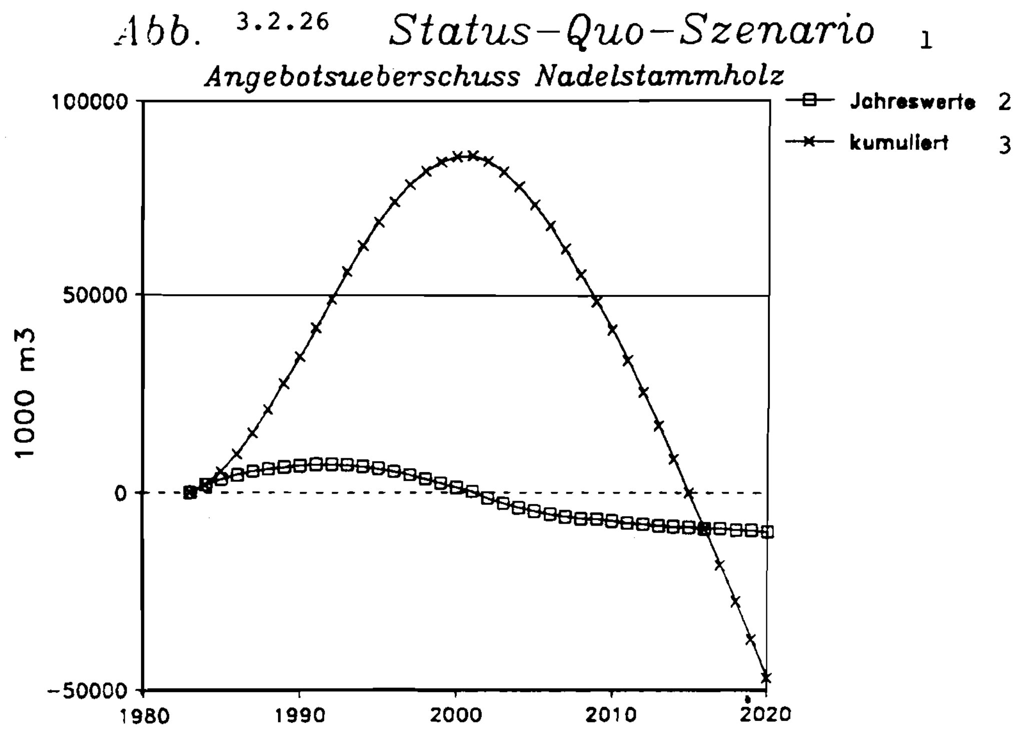
1. LES: Oversupply of coniferous wood
2. Annual values
3. Cumulated values



Notes for Figure 5d.

1. HES: Coniferous wood
2. Supply of roundwood
3. Demand of roundwood
4. Sanitation fellings spruce
5. Supply industrial wood
6. Demand industrial wood
7. Sanitation fellings spruce

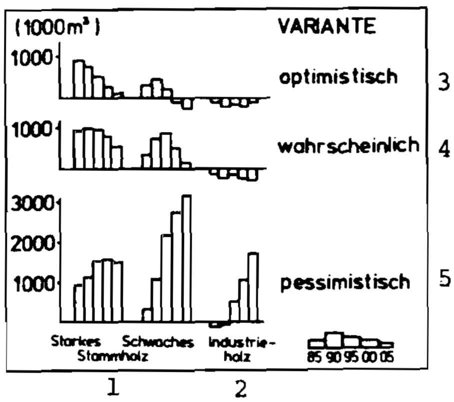
Figure 5 continued.



Notes for Figure 5e.

1. **HES: Oversupply coniferous roundwood**
2. **Annual values**
3. **Cumulated values**

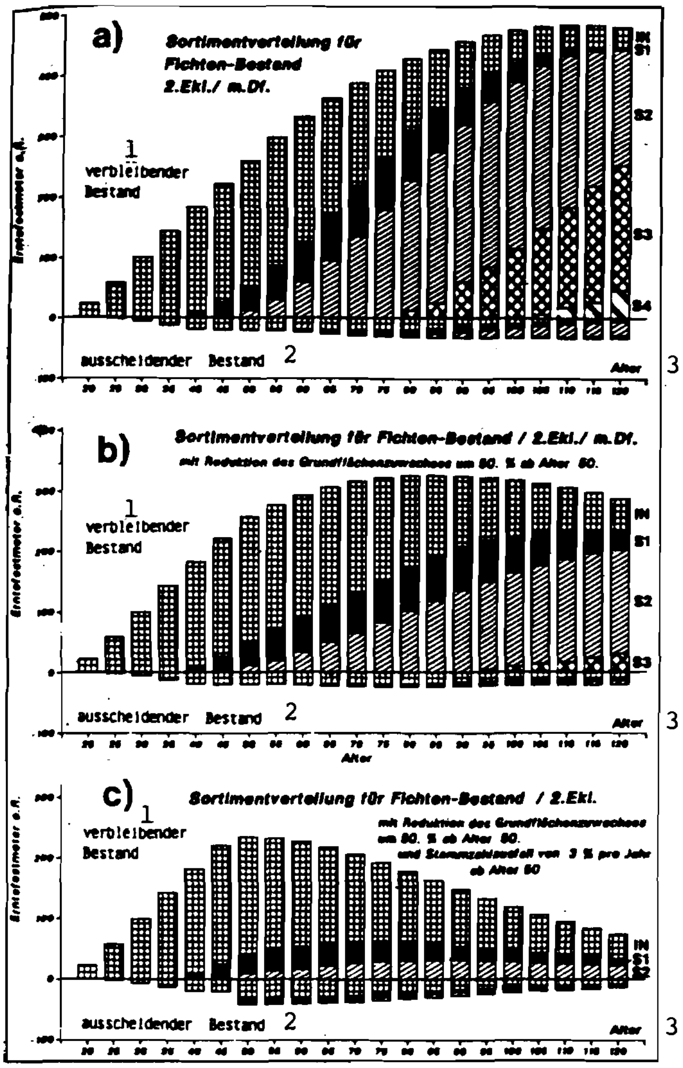
Figure 6. Derivations from the expected fellings according to the scenario-variants from the Reference Variant (all tree species) in Bavaria. (Source: Bartelheimer cit. Encke, 1988.)



Notes for Figure 6.

1. Heavy roundwood and small roundwood
2. Industrial wood
3. Optimistic
4. Probably
5. Pessimistic

Figure 7. Exemplary results of a simulation of assortment development for the spruce for the presentation of stand damage. (Source: Möhring, 1984.)



Notes for Figure 7a, 7b, and 7c.

(a) Timber assortment distribution for a spruce-stand, II yield class, moderate thinning

(b) Timber assortment distribution for a spruce-stand, II yield class, moderate thinning - including reduction of the basal area increment of 50% over an age of 50 years

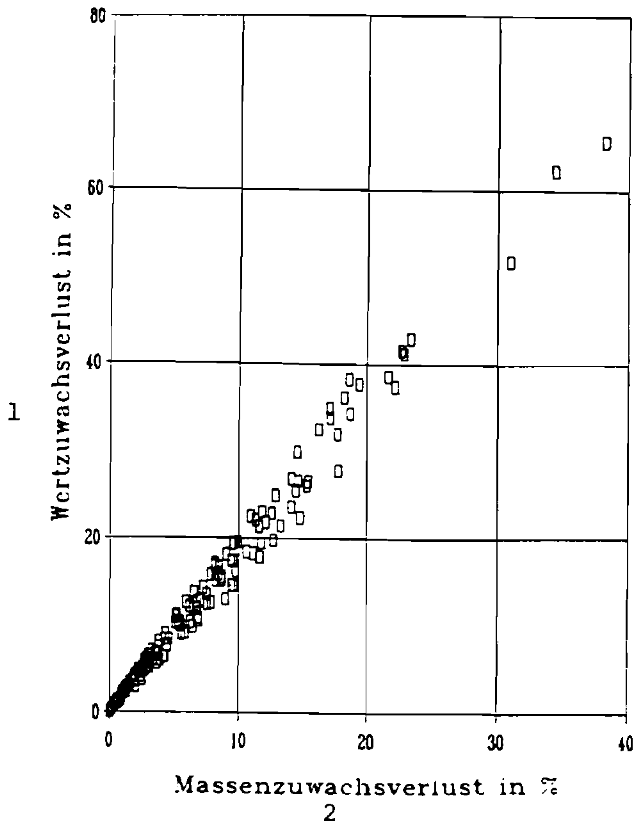
(c) Timber assortment distribution for a spruce-stand, II yield class, moderate thinning - including reduction of the basal area increment of 50% over an age of 50 years and reduction of a number of stems with 3% per year over an average of 50 years

1. main crop
2. thinnings
3. age

IN = industrial wood

S1–S4 = roundwood classes 1–4

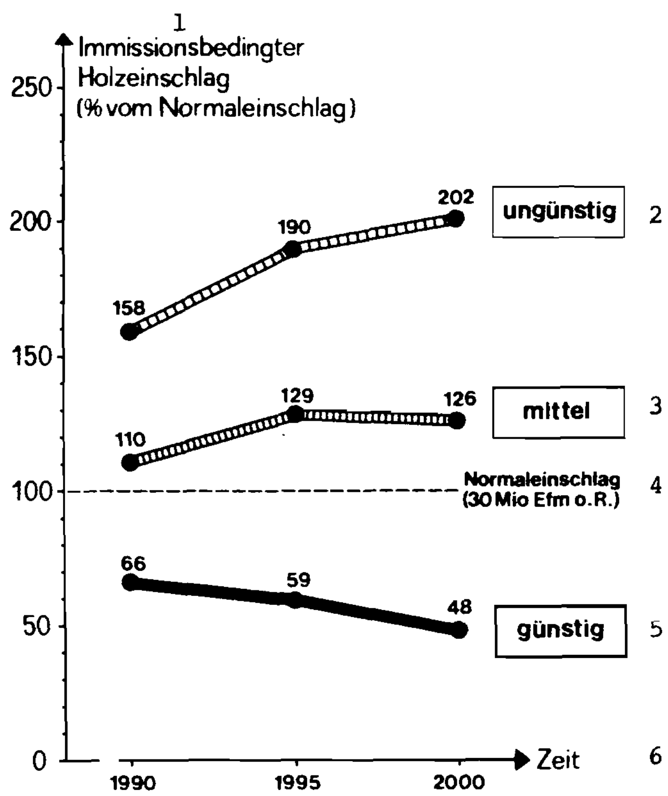
Figure 8. The mass-value-relation for the spruce, II yield class, moderate thinning (Wiedemann), rotation 100 years, taken from the increment reduction simulation model. (Source: Möhring, 1986.)



Notes for Figure 8.

1. **Loss of value in %**
2. **Loss of growth in %**

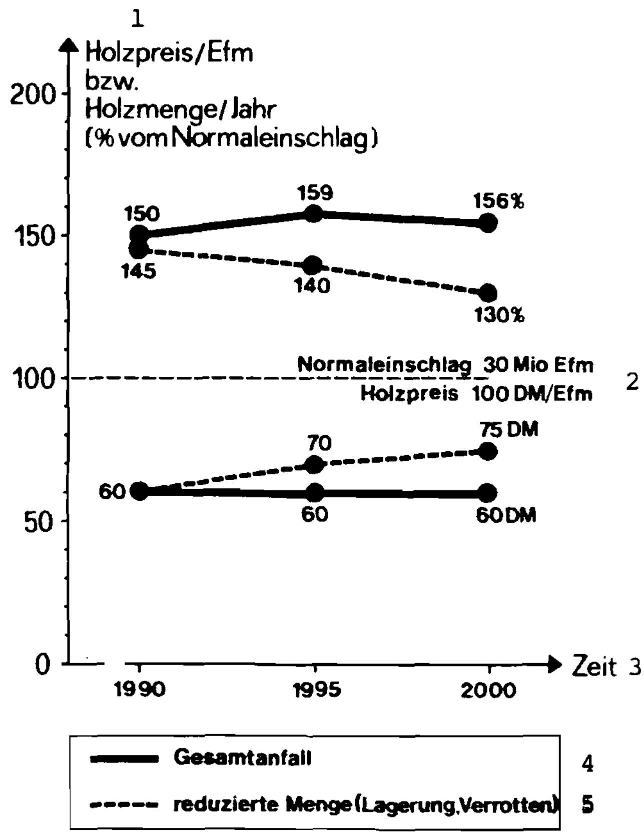
Figure 9. Annual sanitation felling in percentage of normal annual fellings (Source: Fähser, 1985.)



Notes for Figure 9.

1. **Sanitation fellings in % of the normal fellings**
2. **Disadvantageous**
3. **Middle**
4. **Usual fellings (30 million cubic meters inside bark)**
5. **Advantageous**
6. **Time**

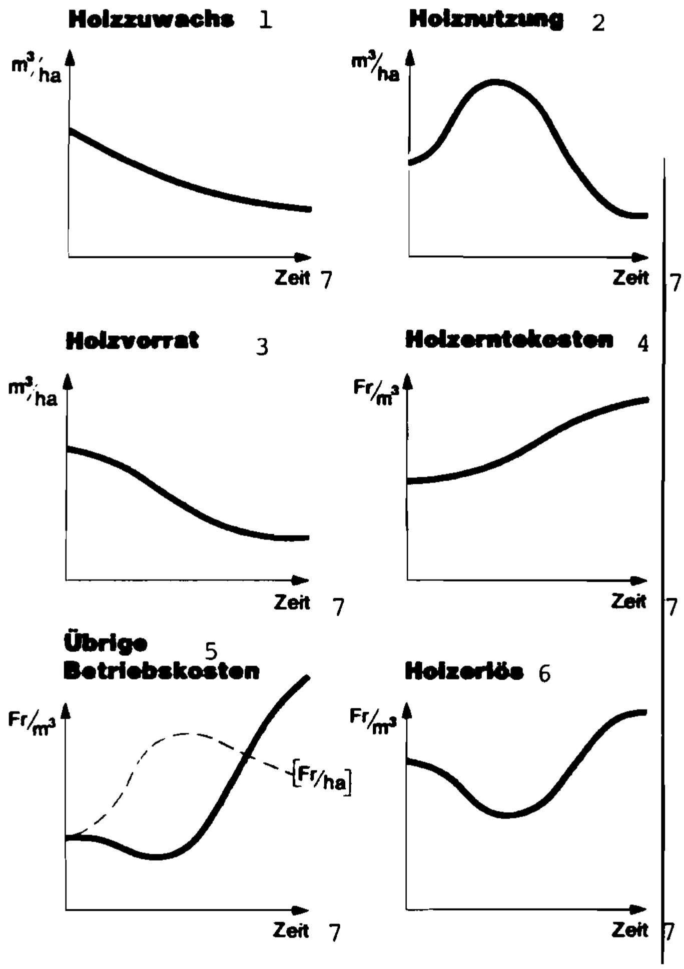
Figure 10. Timber production and the hypothetical timber price. (Source: Fähser, 1985.)



Notes for Figure 10.

1. Price of roundwood/cubic meter or wood supply/year (in % of usual fellings)
2. Above the line: usual fellings 30 million cubic meters, below the line: price of roundwood 100 DM/cubic meter
3. Time
4. ——— Total supply
5. ——— Reduced roundwood supply (storage, rotten wood)

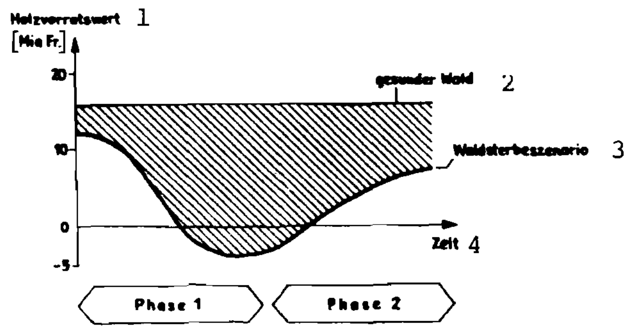
Figure 11. Principle graphics of the factors influencing operational results in forest damage scenarios in Switzerland. (Source: Basler *et al.*, 1986.)



Notes for Figure 11.

1. Increment m^3/ha
2. Fellings m^3/ha
3. Growing stock m^3/ha
4. Costs of harvests Sfr/m^3
5. Other management unit costs Sfr/m^3
6. Timber net proceeds Sfr/m^3
7. Time

Figure 12. Development of the growing stock due to forest damage in Switzerland. (Source: Basler *et al.*, 1986.)



Notes for Figure 12.

1. Value of the growing stock million Sfr
2. Undamaged forest
3. Forest decline scenario
4. Time