SUSTAINABLE AGRICULTURAL DEVELOPMENT: THE ROLE OF INTERNATIONAL COOPERATION

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Air Pollutants and Options for Their Control: Experiences from the European Scene

BACKGROUND

During the first half of the twentieth century, air pollution had a predominantly local character in Europe. But since the late 1960s, Europe has been aware of the threat to the environment from the effects of pollutants from large emission sources transported over long distances.

At the end of the 1970s, the air pollution problem (mainly acid rain) was recognized as one of the most severe threats to the environment in Europe. As an effect of the alarming reports on the acidification problem the Convention on Long-Range Transboundary Air Pollution was adopted in 1979 within the framework of the United Nations Economic Commission for Europe (ECE). A first result of the implementation of this convention was an improvement of the Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP). A second breakthrough for the implementation of the Convention was the *Protocol on the Reduction of Sulphur Emissions or Their Transboundary Fluxes* by at least 30 per cent adopted in Helsinki in July 1985. A third important step in implementing the convention was a protocol conceiving control of emissions of nitrogen oxides, which was signed in Sofia in November 1988. The protocol, signed by 25 countries in Europe and North America, calls for a stabilization of the emissions of nitrogen oxides. In Sofia, 12 countries signed a declaration on a 30 per cent reduction of nitrogen oxide emissions. Thus the abatement of air pollution effects has a high ranking on the political agenda in many European countries.

EUROPEAN EMISSIONS

The emissions of SO_2 are presented for sub-regions of Europe in Table 1. The individual countries are grouped according to the ECE classification:

Nordic: Finland, Norway, Sweden

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EEC-9:	Belgium, Denmark, France, former Federal Republic of Germany, Ireland, Italy, Luxembourg, Netherlands, United Kingdom
Central:	Austria, Switzerland
Southern:	Greece, Portugal, Spain, Turkey, Yugoslavia
Eastern:	Albania, Bulgaria, Czechoslovakia, former German Democratic Republic, Hungary, Poland, Romania
USSR	

TABLE 1 *European SO_2 emissions (in thousand tonnes SO_2)*

Region	(1) 1980	(2) 1989	(3) CRP 1995	(4) Unabated 2000	(5) Maximum feasible reductions
Nordic	1 200	554	475	1 048	211
EEC-9	17 264	9 414	9 064	13 297	1 564
Central	455	168	138	412	100
Southern	5 935	6 876	8 748	10 656	3 024
Eastern	16 381	15 870	13 726	15 690	2 714
USSR	12 800	9 300	8 820	11 960	1 370
Total Europe	54 035	42 182	40 971	53 063	8 983

Source: Amann and Sörensen (1991).

Columns 1 and 2 describe the emissions as computed by the RAINS-model (Alcamo *et al.*, 1990), column 3 illustrates emission levels as expected in the year 1995 after implementation of the current emission reductions agreement. Column 4 presents the estimated emissions with the projected fuel consumption without any emission control measures. Column 5 illustrates the emission levels by applying all currently available emission control technologies.

There has been a strong reduction in the SO_2 emissions between 1980 and 1989 for the whole of Europe. At a sub-regional level, this is not the case for the Eastern and Southern regions. Further reductions, according to current plans for 1995, will improve the conditions slightly. It is also questionable whether the Eastern, Southern and USSR regions will in reality achieve any improvements by the year 1995; from the last column in Table 1 it can be seen that there are big possibilities for reductions by implementing available emission control technologies.

The emissions of NO_x are presented in Table 2. In this case, total planned reduction by 1995 in comparison with the emissions in 1980 is only about 5 per cent. There are also uncertainties concerning NO_x emissions; it is far from clear that the Southern, Eastern and USSR regions will be able to achieve the reduction goals. As in the case of SO_2, there is potential for reductions of NO_x if available emission control technologies are implemented.

TABLE 2 *NO_x emissions (in thousand tonnes NO_2)*

Region	1980	CRP 1995	Maximum feasible reductions
Nordic	736	514	350
EEC-9	10 003	7 751	3 691
Central	425	297	164
Southern	2 088	3 254	1 456
Eastern	4 594	4 581	1 676
USSR	9 454	9 454	3 678
Total	27 317	25 854	11 027

Source: Amann (1989).

For ammonia emissions, no protocols on reduction have yet been signed. The development of emissions between 1980 and 1987 is presented in Table 3. About 95 per cent of the totals stem from the agricultural sector. During the period studied, there have been no reductions of total ammonia emissions in Europe.

In addition to the specific emissions mentioned above, it can be suggested that ozone concentrations are much above established critical limits in all of Europe. There are also emissions of various trace elements of at least 375 000 tons per year (Nilsson, 1991a).

TABLE 3 *Ammonia emissions (in thousand tonnes NH_3)*

Region	1980	1987
Nordic	169	166
EEC-9	2 769	2 034
Central	141	136
Southern	1 187	1 206
Eastern	1 635	1 661
USSR	1 146	1 255
Total	7 045	7 205

Source: Klaassen (1990a).

IMPACT OF AIR POLLUTANTS

The different air pollutants have harmful effects – individually or in combination – on several sectors of the European economy. Leipert and Simonis (1990) have identified the following problems or problem areas:

- health hazards,
- material damage,
- vegetation degradation,
- agriculture production,
- forest production,
- water pollution.

It is not possible to discuss all of the cases in the space available, hence the presentation will concentrate on the impacts of air pollutants on forestry as an example of an approach to analysis. This is based on more detailed work by IIASA (Nilsson *et al.*, 1991a).

Modelling forest decline attributed to air pollutants

The first step in quantifying the effects of air pollutants is to classify the distribution of the forests of each country into several sensitivity classes with respect to sulphur and nitrogen depositions. The sensitivity classes are based on capabilities of forest soils to act as buffers against acidification from deposition of sulphur and nitrogen compounds. Highly sensitive sites have low buffer capacity, the opposite applying to low-sensitivity sites.

Specific *critical loads* and *target levels* of sulphur and nitrogen deposition have been assigned to the individual sensitivity classes. Critical loads are quantitative estimates of an exposure to one or more pollutants, below which significant harmful effects to specific sensitive elements of the environment do not appear to occur. Target loads are less restrictive with respect to deposition loads, in that they incorporate consideration of other pollution-control factors, such as the economic.

Critical loads for sulphur and nitrogen have been defined by the United Nations Economic Commission for Europe (UN-ECE, 1988). Target loads for sulphur have been proposed at levels somewhat higher than the ECE critical loads by the Beijer Institute Centre for Resource Assessment and Management, University of York, U.K. (Chadwick and Kuylenstierna, 1988). The target loads used for nitrogen are the same as the critical loads set by UN-ECE (1988). The analyses carried out by IIASA are based on the target loads presented in Table 4.

By combining the IIASA Forest Study data base on forest resources in Europe (Nilsson *et al.*, 1991b) and the IIASA RAINS model (Alcamo *et al.*, 1990) it was possible to estimate the extent of forest area and standing volume, with depositions exceeding target loads today and in the future. The deposition estimates generated by the RAINS model for the year 2000 are used in the analyses. These are based on the current plans announced by

TABLE 4 *Target loads for sulphur and nitrogen deposition used in the forest-decline scenarios (grams of substance per m² per year)*

Substance Sensitivity	Conifers Low	Conifers Medium	Conifers High	Deciduous Low	Deciduous Medium	Deciduous High
Sulphur[a]	2.0	1.0	0.5	4.0	2.0	1.0
Nitrogen[b]	1.5	1.0	0.3	2.0	1.2	0.5

Notes: [a]Target loads set by the Beijer Institute (Chadwick and Kuylenstierna, 1988) based on critical loads set by ECE (UN–ECE, 1988).
[b]Target loads for nitrogen are the same as critical loads set by ECE (UN–ECE, 1988).

individual governments to reduce emissions of SO_2 and NO_x (see Tables 1 and 2). Basic calculations were carried out at the country level; the aggregated results are presented in Table 5.

Table 5 shows that planned pollution-abatement strategies will not be effective in reducing risk to forests from pollutants. In the year 2000, most of the

TABLE 5 *Exposure of European forests to significant amounts of air pollutants*

Pollutant Forest type/period	Region Nordic	EEC-9	Central	Southern	Eastern	European USSR
Sulphur						
Coniferous						
1985	59	88	98	62	98	27
2000	48	76	93	84	98	21
Deciduous						
1985	19	34	50	18	84	4
2000	7	24	46	40	76	3
Nitrogen						
Coniferous						
1985–2000	75	83	100	34	76	53
Deciduous						
1985–2000	52	55	86	21	47	36
Ozone						
1985–2000	1–2xCL	1.5–2.0xCL	2.0–2.5xCL	n.a.	1.5–2.5xCL	?

Notes: Data for sulphur and nitrogen are percentages of the total forest area where target loads for the pollutants are exceeded. Data for ozone are based on diurnal concentration distributions, April–September 1986.
n.a. = not available owing to insufficient data.
CL = critical load
For a quantification of the damage cycle and growth effects, see Nilsson *et al.* (1991b)

Source: Nilsson and Posch (1989); Nilsson (1991b).

European forests will still have depositions and concentrations exceeding the target loads for SO_2, NO_x, NH_3, and O_3.

Researchers in Berlin have developed an elaborate tool known as PEMU (Bellman *et al.*, 1991) for analysis of cause–effect relations between air pollution and forest conditions. Input data to the PEMU system are based on field observations made since the early 1960s at a set of test sites along deposition gradients. This analytical tool has been employed in estimating the decline effects on forests if depositions exceed target loads. Results from the PEMU system are expressed in terms of a damage cycle and growth losses. The international criterion for monitoring forest decline attributed to air pollutants is loss of foliage, different degrees of which define different decline classes. The damage cycle describes how many years a forest stand of a particular sensitivity class stays in different defoliation classes at a specific rate of pollutant deposition. Using the German system, it has been possible to generate quantitative estimates of the damage cycle showing that the decline process is more rapid for more sensitive sites and with increasing depositions. Growth effects are linked to the loss of foliage and have consequently also been estimated by the German system. From these results it can be suggested that:

- the nitrogen depositions compensate the individual decline effect of sulphur depositions up to the critical load limit for nitrogen (during the enrichment phase);
- during the disintegration phase (depositions above critical load limits) the combined effects of sulphur and nitrogen deposition lead to increased decline in comparison with individual effects of sulphur and nitrogen.

To mitigate the negative effects of the decline process in forests, some silvicultural measures can be taken. The objectives are to increase stand vitality, delay the decline process and save commercial wood. Examples of the measures used are intensified thinning, shortened rotation periods and changed species composition. The quantified mitigative measures are presented in Nilsson *et al.* (1991b).

THE TIMBER ASSESSMENT MODEL

A matrix-type simulation model has been built to generate scenarios of the development of forest resources. A detailed country-by-country data base for Europe has been assembled by the IIASA Forest Study to link with the simulation model. The model generates scenarios of growing stock and timber-harvest volumes over time by country (and sub-regions of a country) and by species group and age, making it possible to undertake a general timber supply assessment. Two major forest-model concepts were used within the matrix approach: (1) the unit area and its characteristics, and (2) the tree and its characteristics. The first concept is developed by Sallnäs (1990) and the second by Houllier (1989). The decline component described in the former section has been incorporated in these model concepts.

IMPACTS OF AIR POLLUTANTS ON FUTURE EUROPEAN WOOD SUPPLY

Work using the Timber Assessment Model has been carried out for two types of conditions relating to air pollution: the 'with' (decline) and 'without' (no decline) effects. Simulations cover a period of 100 years (1985–2085). The decline simulations are based on the effects of sulphur and nitrogen without consideration of the effects of other pollutants. The emissions are only quantified and taken into account up to the year 2000. The impact of the air pollutants on future wood supply is presented in Table 6.

Using the calculations, it can be seen that the loss of potential harvest in Europe caused by emissions of air pollutants according to current reduction plans is about 112 million m^3 per year over 100 years. However, it should be stressed that the results for European USSR are preliminary.

TABLE 6 *Aggregated results concerning potential harvests*

	Potential harvest in million m^3 o.b./year for all species and average for 100 years		
	Without air pollution effects	With air pollution effects	Removals in 1987
Nordic	155	144	121
EEC-9	150	126	109
Central	25	19	22
Southern	78	71	72
Eastern	126	92	100
European USSR	272	242	264
Total Europe	806	694	688

Source: Nilsson *et al.* (1991a) and Sallnäs and Hugosson (1991).

ECONOMIC IMPACT

It is hard to visualize a political debate concerning concrete air pollution abatement strategies being based only on the volume effects, as described above. To obtain a more complete picture there is a need to express the decline in monetary terms. However, the economic calculation should not be the only foundation for the formulation of required abatement strategies.

The emission of air pollutants today will cause harmful effects, not only for the existing European generation, but also for those of the future. The long-term effects will influence both welfare and well-being. These aspects lead us to conclude that economic valuations must be conducted in a long-term, political – economic perspective. Thus the evaluation should be centred at the level of the national (political) economy. The basic approach to show the aggregate impact of different policies and effects on the national economy is to study changes in the income accounts of the GNP (OECD, 1990). Therefore the simple concept of adjusting the national accounts for the losses caused by air pollution has been followed. The starting-point for the valuation has been based on multiple-use forestry and the primary forest products industry. Multiple-use forestry, as a concept, involves taking into account the social welfare aspects of forestry. The value-added component for industrial production only takes into account the incremental losses caused by air pollutants and their effects on primary industries. The economic impact, according to this calculation, is presented in Table 7.

The economic impacts deal only with forestry. As illustrated earlier, other sectors can also be influenced. Based on work by Leipert and Simonis (1990) a rough estimate can be made, distinguishing between economic impacts on forestry and those on other environmental sectors. According to this estimate, the forest decline is between 11 and 18 per cent of the total economic impact of air pollutants. By employing this estimate, the total costs of air pollutants in Europe can be calculated to be in the range of 160–260 billion dollars per year. Of course, there are large uncertainties in this calculation.

TABLE 7 *Economic impacts on multiple-use forestry/primary forest products caused by air pollutants*

Region	Billion dollars/year
Nordic	2.9
EEC-9	7.4
Central	1.6
Southern	1.8
Eastern	8.5
European USSR	6.6
Total Europe	28.8

Source: Nilsson (1991c).

CONTROL EXPENDITURES

Shaw and Nilsson (1991) have analyzed the control expenditures needed to place all European forest resources within the target loads (see Table 4). With existing control technologies they found that to be impossible. The best result (most of the forests within the target loads) was achieved by implementing the best available control technology, for which expenditures are presented in

Table 8. Implementation of best control technology means a reduction by 70–80 per cent of SO_2 emissions and by about 60 per cent of NO_x emissions.

The costs for ammonia reduction are not calculated on a European scale, though Klaassen (1990b) has presented some calculations for the Netherlands. A 70 per cent reduction (which is the plan for the country) would cost 1.4 bilion dollars per year and a 30 per cent reduction 78 million dollars per year. Thus, to save the European forests from negative impacts, control expenditures of at least 90 billion dollars per year are required. However, if this could be achieved, most harmful effects in the other environmental sectors would also disappear (total economic impact: 160–260 billion dollars per year).

TABLE 8 *Control expenditures in billion dollars/year*

	SO_2 emissions	NO_x emissions
Best available control technology	50.2	39.7
Current reduction costs (plan to1995)	8.0	~8.0

Source: Shaw and Nilsson (1991).

INTERNATIONAL IMPLICATIONS

The major policy-related international implications are the following:

(1) *Doing what is planned is not enough.* It can be concluded from the analysis that the current reduction plans will be insufficient to halt negative impacts of air pollutants. Alcamo *et al.* (1991) stress that the air pollution problem may first appear in sectors other than forestry after the year 2000. Therefore it is crucial to take long-term environmental consequences into account when assessing the effectiveness of emission reduction plans.

(2) *The best will be expensive.* As illustrated above, the control expenditures will be very high. Many countries cannot afford the required measures. Therefore strong international cooperation is required to generate the necessary funds. It is obvious that implementing the best available technology will be worthwhile and have a high rate of return for European society.

(3) *International cooperation will save money.* Alcamo *et al.* (1991) have shown that international cooperation in implementing the new technologies is required and will save money.

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DISCUSSION OPENING – LAURI KETTUNEN*

Air pollution is a very suitable topic for an international conference because no state can avoid its harmful effects. Pollutants spread with the wind far away from national boundaries, so both polluters and neighbouring states suffer the consequences. Most countries are polluters and, subsequently, must address the problems of harmful side-effects, both at the national and international level. Although this conference is not making decisions, it is distributing information which will affect decision makers all over the world.

Dr Nilsson's paper deals with three issues: (a) air pollutants in Europe; (b) their effect on the growth of forests; and (c) their estimated economic effects. It is rooted in the system analytical work conducted by IIASA, which is oriented towards the future. Analysis is based on well established knowledge, and there can be no doubt about the importance of his message. I confess that I found the material rather hard to understand and I would have welcomed the use of maps to help get to grips with the rather abstract material. Nevertheless, Dr Nilsson has provided a good overall view of the problem and of the importance of reducing it, which, as an agricultural economist, I welcome.

The analysis indicates that SO_2 pollutants have decreased considerably in Europe in 1980s. This is an indication that the protection of the environment has produced results. During the 1990s, the situation will continue to improve, although uncertainties in forecasting exist for some areas. The results of the IIASA study demonstrate that attaining pollution target levels is not enough. Looking towards the year 2000, air pollutants might slow forestry growth by up to 27 per cent, even if target levels are reached. This being the case, future growth of forests will correspond to present felling levels.

The report states that damage caused by air pollutants costs 160–260 billion dollars annually. It is unclear how this figure is estimated. Dr Nilsson points out that European states might avoid these expenses by utilizing modern technology. This approach would cost approximately 80 billion dollars a year. How well decision makers understand these figures, and to what extent they are willing to act on the recommendations, is difficult to determine. Investments are being made to improve the situation. Industry and heating and electricity plants are continuously improving their technology, so we can expect further improvements in reduction of pollutants. Whether these actions are sufficient is another issue. It is also worth noting that Dr Nilsson only provides the final results, and some explanation of the types of models behind his calculations would have been helpful. For example, what are the confidence limits of the forecasts? I believe they are quite sizable. Is there any sense then, in making 100-year forecasts?

As an example of some of the complexities involved in considering costs and benefits, as they occur over time, experiences from my home town in

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northern Finland, located close to the Soviet border, may be useful. My home town is situated in one of the poorest provinces, known as Hunger Land, where the unemployment rate is consistently the highest in Finland. Consequently, people have moved to southern Finland or abroad in search of better opportunities. In the 1970s, the construction of a large industrial complex, nearby in the Soviet Union, helped to improve the economic situation. The industrial complex planned to exploit large iron ore deposits in the region. Since this area in the Soviet Union was unpopulated, Finnish workers were recruited to build the whole processing plant and the housing complex. This provided employment opportunities for many men and women of my home town for over a decade, the quality of life improved, and the number leaving in search of other opportunities diminished. Today, however, the industrial complex is a big air polluter. The forests in my home town are suffering from the acid rain caused by this complex; even the trees in my small forest plot are suffering. For those people who originally built the factories, the blessing of the 1970s has become a burden in the 1990s. Finland has pushed the Soviet Union to clean up the whole industrial complex and other polluting industries located close to the Finnish border. We are providing economic assistance to help the Soviet Union in this task. Finland recognizes the sacredness of the environment and the consequences of industrial development, and more importantly, is willing to act.

Pollution can also have important effects on agriculture, both directly and indirectly. In Finland and neighbouring Scandinavian countries, forests play a significant role in the agricultural economy. In Finland, for example, forest income makes up about 11 per cent of farmers' total income, and any long-run decline in the growth of forests will have an indirect impact on agriculture. Furthermore, it is also important to consider the way in which air pollutants directly affect farming, and to note that the effects can be complex. Agriculture mainly suffers from the increase of ozone in the atmosphere. Some studies show that, of all air pollutants, ozone is the most harmful, causing about 80 per cent of the reduction in crop production. There are also problems with heavy metals and with polluted rain which increases the acidity of the land and requires more lime to be added to the soil. According to research done in Finland, the cost increase of the latter is small. It totals about 8 per cent of the annual liming costs, or about 0.6 per cent of fertilizer costs. The important point, however, is that the full balance sheet of effects is still imperfectly understood and requires more research. Part of the complication is that effects can be reciprocal. Agriculture can also pollute the environment. For example, ammonium deposits, produced only by agriculture, are harmful to forests. These pollutants account for about 20 per cent of the acid rain in Finland. The reduction in the number of dairy cows and of animals for fur raising has decreased the amounts of ammonium deposits. Further progress in reduction is possible through better feeding and housing of animals. Improved handling, storage and spreading of manure would also reduce pollution.