FUTURE ENVIRONMENTS FOR EUROPE: SOME IMPLICATIONS OF ALTERNATIVE DEVELOPMENT PATHS

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Foreword

With the completion of the Report of the World Commission on Environment and Development (popularly known also as the Brundtland Commission Report) in 1987, and the subsequent worldwide attention given to that study, the concept of *ecologically sustainable development* has gained broad recognition. It is now commonly acknowledged that economic development and ecological sustainability are not contradictory goals. To the contrary, they are interdependent – the economy of a country cannot grow over the long term, when its environment is being hopelessly degraded, and a country experiencing severe ecological degradation cannot restore its environment without developing economically. Most of the focus of ecologically sustainable development has been on the less developed countries in Latin America, Africa, and Asia. Because of the desperate straits of the populations in those areas, such focus is certainly merited.

Our IIASA study, focused on Europe, had at its inception in 1985 two goals. The first was methodological. We reasoned that if in fact it were possible to conduct a study of European environmental problems 40 years into the future, perhaps similar studies could be conducted for the less developed continents. We believe that this European "experiment" has been successful and we strongly support the undertaking of "future environments" studies elsewhere in the world.

The second goal was one of substance. What precisely could we learn about the major environmental problems that could confront future generations of Europeans, and how would we begin to solve those problems now, rather than bequeathing them, in their most severe manifestations, to our children and grandchildren? We also believe we have succeeded, at least in part, in realizing this goal.

I am pleased, therefore, to introduce this very important study for I believe it will be a major contribution to the ongoing effort to achieve an ecologically sustainable world.

I would also like to single out for special praise the study's two sponsors, the Ministry of Housing, Physical Planning, and the Environment, Leidschendam, The Netherlands, and the Ministry of the Environment, Prospective

Group, Paris, France, who had the wisdom and foresight in 1985 to understand the potential importance of this study, and without whose support and constant encouragement we would not have been able to complete it.

Ted Munn
Leader
Environment Program

Major Findings

This study analyzes eleven European environmental policy "dilemmas" for four alternative socioeconomic development pathways to the year 2030. The dilemmas include problems associated with: water management, soil acidification, forestry wood supply, marginalized land, sea level rise, coastal problems, chemical "time bombs", non-point source toxic materials, transport growth, urbanization, and summer oxidant episodes. On the basis of this analysis, the following conclusions were drawn:

- Because of the linkages between the European and global environments, sustaining the *European* environment in the 21st century cannot be fully achieved without sustaining the *global* environment.
- The continuation of present trends in economic development and environmental protection in Europe and elsewhere is not sufficient to prevent further deterioration of the European environment.
- High economic growth in Europe and elsewhere without adequate environmental protection accompanying such growth will lead to even more severe environmental problems.
- Environmentally friendly development in Europe offers the hope of mitigating local and regional-scale problems specific to Europe.
- But these actions, in and of themselves, cannot solve problems within Europe stemming from global scale changes. To accomplish the latter, the rest of the world must also follow environmentally friendly pathways.
- Thus, European nations should do all in their power to enact environmentally friendly development both in Europe and the rest of the world.

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Contents

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1. Introduction

1.1. The Global Problem

In spite of enormous advances in our ability to understand, interpret, and ultimately manage the natural world, we approach the 21st century in awesome ignorance of what is likely to unfold, in terms of both the human activities that affect the environment and the responses of the earth to those activities. One certain fact is that the planet will be subjected to pressures hitherto unprecedented in its evolutionary history. The world's population is likely to grow from 5 to 8.2 billion within 35 years. Over this same time period, energy consumption could easily double relative to 1980, food production must increase by 3% to 4% yearly, and general economic activities could grow up to fivefold [report of the World Commission on Environment and Development (WCED, 1987)].

Moreover, "tomorrow's world" will not simply be an inflated version of "today's world" with more people, more energy consumption, more industry, and so on. Rather, the world of the 21st century will be qualitatively different from today in at least three important respects. First, new technologies will transform the relationship of man to the natural world. In the positive sense, industry will pass from an emphasis on *products* to be manufactured to an emphasis on *functions* to be performed (Colombo, 1985). A prime example is the gradual transition from an agriculture heavily dependent on chemicals to one that is essentially biologically intensive through the application of biotechnologies. In the negative sense, the release of bioengineered organisms may pose new kinds of risks if the development and use of such organisms are not carefully controlled.

The second major change differentiating tomorrow's world from today's is climatic change. Owing to the accumulation of greenhouse gases in the atmosphere, average annual global temperatures are expected to increase to levels higher than at any time over the last 200,000 years. And yet even the most advanced climate models currently cannot predict how regional and continental climates will change.

Third, as noted by Clark (1987a), society has moved beyond the era of localized and relatively simple environmental problems. What were once local incidents of pollution shared throughout a common watershed or air basin now involve many nations. What were once acute, short-lived episodes of reversible damage now affect many generations. What were once straightforward questions of conservation versus development now reflect complex linkages. These problems will become more pronounced over the next century, as society enters an era of increasingly complex patterns of interdependence of the global economy and the world environment.

Relative to earlier generations of problems, these emerging patterns of interaction are characterized by profound scientific ignorance, enormous decision costs, and temporal and spatial scales transcending those of most contemporary political and regulatory institutions.

1.2. The European Problem

The European environment is tightly linked to the global environment by global systems such as climate and stratospheric ozone. Typically, such linkages are reciprocal in nature – European activities affect the global environment, and what happens outside of Europe affects the European environment. Moreover, European supply and demand for natural resources are linked to global supply and demand. Thus, for example, the use of European land for wood production will depend to a large degree on the availability (or lack thereof) of global forest supplies. Hence, the problem of managing the European environment must be viewed within the context of the global environment.

However, it is important to note that not all of Europe's problems are global ones; European societies can do much to put their house in order regardless of what is occurring on the global scale. Effects such as acid deposition and the build-up and release of toxic materials are essentially regional and continental-scale problems. Although even these are coupled to climate by complex feedbacks, their solutions depend explicitly on European actions to mitigate these effects.

1.3. The Goals of the Study

The purpose of this study is to provide new insights into the long-term management of the European environment during an era of fundamental transitions in technologies, climate, and scale of effects. The word *environment* is taken to include not only air, water, soil, forests, etc. but also the quality of life in a general sense. The area studied is Europe, stretching from the Atlantic Ocean to the Ural mountains, and the period of time studied extends from the present to the year 2030. The focus is on ecologically sustainable development, in terms of both the opportunities afforded to European societies in seeking to achieve it and the constraints imposed on development by the slow adaptive capacities of ecological systems.

As a fundamental premise, we assume that management of long-term environmental problems can be improved despite considerable uncertainties that will continue to thwart the formulation of detailed predictions of future environments (White, 1983). Hence, the study's focus is not on predicting the future, or even on predicting an array of futures. Instead we assume that the future is uncertain and we propose new methods of managing *the present* in such a way that future technological, socioeconomic and environmental developments will not produce major shocks on society, and in fact may be beneficial in some cases.

The specific objectives are as follows:

(1) To characterize the large-scale environmental transformations that could be associated with plausible scenarios of Europe's socioeconomic development over the next 40 years or so, with special attention being given to a few *not impossible* alternative scenarios or technological breakthroughs that might occur.
(2) To describe and assess the effectiveness of alternative technological and institutional steps to manage long-term, large-scale interactions of Europe's future development with its natural environment.
(3) To identify the research and monitoring priorities for improving the ability of scientists to provide *policy relevant* assessments of the environmental transformations described in (1).

2. Methods

2.1. The Construction of Plausible Scenarios

There is no doubt that the current state of the European environment is greatly affected by political and socioeconomic actions sometimes stretching back over many centuries. A study of future environments for Europe must therefore begin with an assessment of political and socioeconomic factors, and some working hypotheses (scenarios) for the future. These must then be coupled with scenarios of environmental trends. In both cases, the number of possible indicators is so large that it is necessary to limit the choice.

Our selection, shown in *Table 2.1*, was developed after a review of various studies [Brundtland Commission report (WCED, 1987), etc.] and after discussions with peers in the science and policy communities. Even this "wish list" is too large, and the working set of indicators will be rather smaller. The choice of sectors, components and indicators is of crucial importance.

We should mention here that the scenarios to be presented are assumed to be *plausible*, but not necessarily *probable*. Who could be so rash as to predict the environmental state of Europe in the year 2030? Our goal is to use the scenarios as "straw men" to illustrate some of the current dilemmas in Europe and to help in the development of robust policies for managing the present to cope with the very uncertain future.

Table 2.1. Selected socioeconomic sectors, environmental components and associated indicators.

Socioeconomic Sectors	*Associated Indicators*
Population	Annual change in numbers and ages
Energy	Energy production by fuel type, SO_2 and CO_2 emissions
Industry and transportation	Labour force, production capacity, pollution emissions
Agriculture	Yields, soil type
Forestry	Annual wood supply and wood use increments
Cross-sectoral	Water demand
Environmental components	
Climate	Temperature, precipitation and interannual variabilities
Hydrology	Sea level rise, water availability, soil moisture, lake and groundwater levels, river flows and interannual variabilities
Air quality	SO_2, O_3, NO_x and CO_2 concentrations; S deposition
Soil quality	Acidification, salinization, erosion, nutrient depletion/saturation, absorption capacity, toxification
Water quality	Acidification, eutrophication, toxification
Biota	Primary productivity, species diversity, endangered species
Land use	Percent of land used for forest, agriculture, built-up areas

Another point to be emphasized is that environmental impacts are frequently delayed for decades (environmental "time bombs") and displaced in space, sometimes through series of poorly understood intermediate interactions. Great uncertainties surround these long-term and large-scale issues, but there is nevertheless a very real need to formulate appropriate environmental policies. See Stigliani (1988), for an elaboration of the problem.

Finally it should be noted with regret that although the sectoral approach is used for convenience, compartmentalization by sectors and environmental components is one of the causes of poor environmental management. Such an approach masks the essential features of the global problematique, viz., the myriad of linkages and feedbacks. To compensate partially for this compartmentalization, the scenarios will be followed in Section 4.8 by a summary discussion of the internal consistency amongst scenarios.

2.2. The Selection of Not-Impossible Alternative Scenarios

The scenarios mentioned above evolve smoothly from present conditions. The possibility exists, however, that a scenario curve may change slope or even undergo a rather sharp discontinuity. Such low-probability but not-impossible happenings are called *turning points* in this report. These divergences from the most plausible scenarios are assumed to occur in the first 30 years of the 21st century but the indicated year in each of the figures (see, for example, *Figure 3.2*) should be taken only as a rough estimate.

2.3. Elaborating the Resulting Policy Dilemmas

Having created sets of scenarios and turning points (Sections 3 and 4), a series of policy dilemmas has been produced (Section 5). These dilemmas have been used to challenge very senior European scientists, environmental managers and policy analysts in carefully organized "Policy Exercises". Here it should be re-emphasized that a primary objective is to develop a new style of long-term environmental management. Another is to resolve specific issues, which in any event are evolving over time and require the use of adaptive management strategies. Thus the policy dilemmas are vehicles for reaching our goals.

3. Socioeconomic Futures for Europe*

3.1. General Socioeconomic Scenarios for Europe

Studies of European environmental futures must fail unless socioeconomic factors are taken into account. Four principles shaping human behaviour are 1) maintenance of some hierarchical structure (based upon birth, education and wealth, for example); 2) a desire to have knowledge prior to making decisions (including those about the environment); 3) the "business-as-usual" syndrome of the industrial and commercial sectors; and 4) growth (including overcoming scarcity and managing abundance). In this connection, the environment may be damaged by both high and low income groups in society (e.g., over-use of energy in industrialized countries and of fuel wood in developing countries). Historical experience suggests that although social change is usually very slow, the cumulative effects may be quite substantial.

In a general sense, some plausible socioeconomic hypotheses for Europe include:

- An increasing emphasis on the desirability of better environmental quality, leading for example to continuing progress in the internalization of the costs of environmental damages.

* Many of the ideas contained in this Section were developed at a Task Force Meeting held at IIASA 29 February – 1 March, 1988.

- An increase in cottage industries and other home activities.
- A net migration of industry out of Europe.
- An increase in unemployment. Full employment may be a paradigm for the 20th century but not the 21st. The work week will decrease and leisure time will increase correspondingly, with an associated increase in travel and leisure-related activities. These trends are shown in *Figure 3.1*.
- In Western Europe at least, a decline in the importance of national boundaries. Many retired people will spend their winters in Southern Europe. Similarly there will be increasing summer recreational pressure on the Alps.

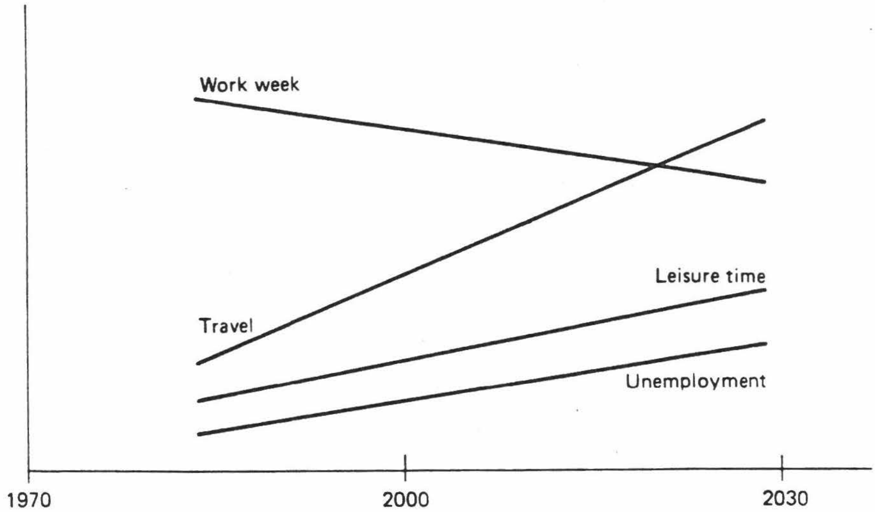

Figure 3.1. Some hypothesized social trends in Europe to the year 2030.

Some *not-impossible turning points* include the following:

- War.
- A sudden, severe economic depression.
- Migrations due to economic or environmental factors.
- Public pressure, whether right or wrong, that the quality of life as measured by, for example, the unemployment rate, has become intolerable, leading to major new actions by governments.

3.2. Population

Figure 3.2 gives a plausible scenario and some turning points for population changes in Europe up to year 2050 (Wolf *et al.*, 1988). The conventional-wisdom scenario (third curve from the bottom) is that of the United Nations, which is based on the assumption that fertility, which has been falling since 1960 will rise slowly, almost reaching the replacement level by the year 2020. Introducing a plausible increase in immigration of one million persons annually from 1995 to

2004 (third curve from the top) has little effect on total population. However, the following *turning points* are not impossible:

- A baby boom occurring in the period 1990–2015, of about the same size as that just after World War II (uppermost curve).
- A "magic drug" becoming available, decreasing mortality by 50% for people over 60 years of age (second curve from the top).
- A fertility decline to a level that is already reached in some Western European countries (second curve from the bottom).
- An AIDS-like epidemic, with 50% of 30–50 year old people dying after 2010, the rest of the population not being affected (lowermost curve).

The rationale for these curves is given in Wolf *et al.* (1988).

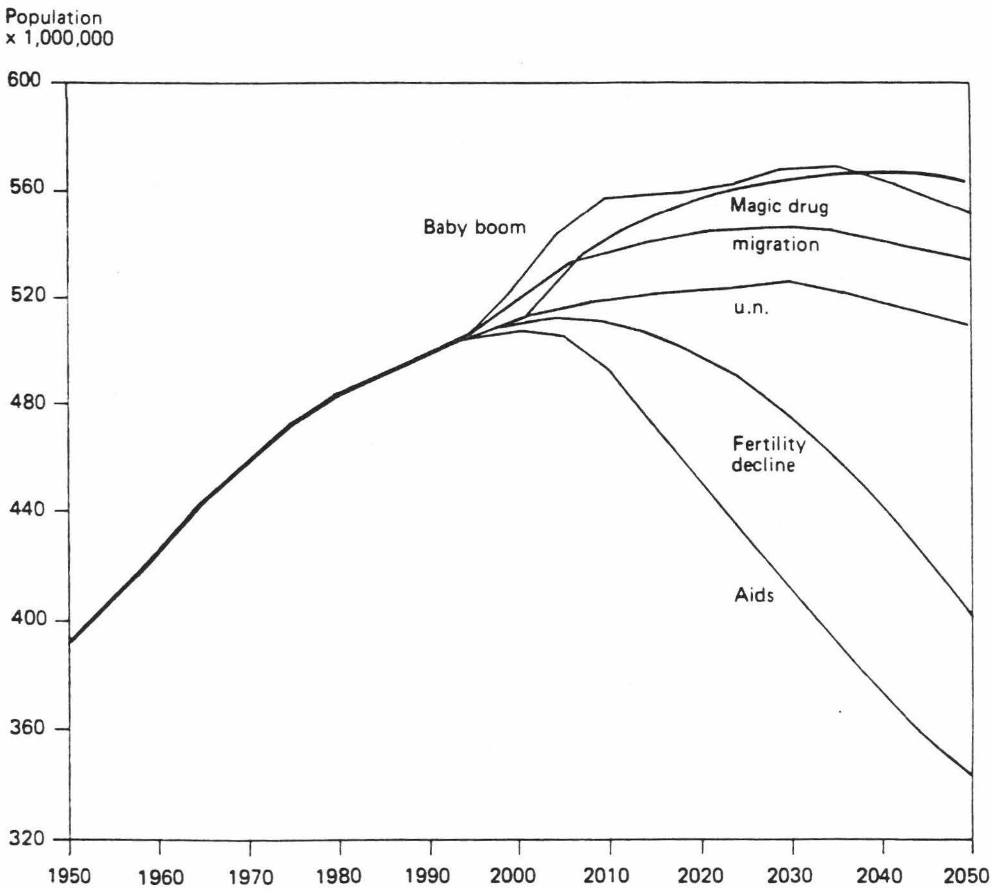

Figure 3.2. Scenarios for population size in Europe, not including the European part of the USSR (Wolf *et al.*, 1988).

3.3. Energy

The European energy scenarios for 1980 to 2000 are based on the official energy pathways reported by each of the European countries; the projections to the year 2030 are based on a conventional technology scenario described in Rogner (1986). The results are summarized in Tables *3.1* to *3.3*, successively for Europe, Eastern Europe and Western Europe.

Table 3.1. Energy consumption in Europe (in exajoule) (percentage distribution in brackets).

Year	*Coal*	*Oil*	*Gas*	*Nuclear*	*Hydropower*	*Other*	*Total*
1980	29 (29%)	44 (43%)	19 (19%)	3 (3%)	5 (5%)	2 (2%)	102
2000	37 (27%)	40 (30%)	32 (24%)	18 (13%)	7 (5%)	2 (1%)	136
2030	48 (28%)	32 (19%)	39 (23%)	34 (20%)	11 (6%)	5 (3%)	169

Table 3.2. Energy consumption in Eastern Europe (including the European part of the USSR) (in exajoule) (percentage distribution in brackets).

Year	*Coal*	*Oil*	*Gas*	*Nuclear*	*Hydropower*	*Other*	*Total*
1980	18 (36%)	17 (33%)	12 (24%)	1 (1%)	1 (3%)	2 (3%)	51
2030	27 (29%)	13 (14%)	25 (27%)	22 (24%)	5 (5%)	1 (1%)	93

Table 3.3. Energy consumption in Western Europe (in exajoule) (percentage distribution in brackets).

Year	*Coal*	*Oil*	*Gas*	*Nuclear*	*Hydropower*	*Other*	*Total*
1980	11 (22%)	27 (52%)	8 (15%)	2 (4%)	4 (7%)	1 (1%)	52
2030	21 (27%)	19 (25%)	14 (18%)	12 (16%)	6 (8%)	4 (6%)	76

The main features of the scenario for Europe as a whole (*Table 3.1*) are as follows:

- Increasing consumption of total energy.
- Decreasing importance of oil (both in absolute and relative terms).
- Increasing use of nuclear energy.
- A rather stable contribution of coal and gas to total energy consumption.

While coal and oil are the major fuel types in Eastern Europe during the 1980's, the scenario in *Table 3.2* shows coal remaining the major fuel type, with gas becoming as important as coal around the year 2030.

As seen in *Table 3.3*, oil is nowadays the major fuel type in Western Europe, contributing to over half of the total energy consumption. Its relative importance is expected to decrease significantly, such that coal and oil will become equally important before the middle of the next century, amounting to about half of the total energy consumption.

Not-impossible turning points are:

(a) Increased public resistance to nuclear power, including a moratorium on the development of nuclear power generation. There are two possible results. Messner and Strubegger (1986) conclude that the effect on Europe's energy systems would be manageable and that natural gas would replace nuclear energy. Alternatively, coal could be the replacement form of energy.

(b) Development of "safe-fail" reactors and better communication between the nuclear industry and the public, overcoming public resistance to nuclear power. It should be pointed out that fusion is not likely to be ready before the year 2050.

(c) Large supplies of natural gas (biogenic or non-biogenic) are discovered at deep levels in the earth.

(d) Development of hydrogen-based energy systems through the separation of carbon from natural gas, or through the electrolysis of sea water. Energy for carbon separation or electrolysis could come from nuclear or solar power.

(e) Development of technology for capturing CO_2 emissions from the burning of fossil fuels.

(f) Breakthroughs in the efficiency of energy transmission and use, which could greatly decrease energy demand in *Tables 3.1* through *3.3*, by as much as 20% in the year 2015 and 40% by the year 2030. For example, superconductivity at ambient temperatures could make feasible the generation of electricity without transmission losses.

(g) A shift towards the goal of achieving sustainable energy futures by the end of the 21st century. This would require fundamental structural and life-style changes. Nakicenovic and Messner (1982) postulate two scenarios: a) a "hard solar" scenario which relies upon sustainable use of biomass, hydropower and solar thermal potentials and b) a "soft solar" scenario which relies to the maximum possible extent on decentralized, local and on-site energy conversion.

3.4. Industry and Transportation

Some plausible scenarios include the following:

(a) Industry

One of the underlying hypotheses is that economies of scope or flexibility of production will be one of the driving forces of industrial development. This means that competitive advantages are sought by diversification and customizing of products and thus by focusing on special market niches. These developments are taking place especially in manufacturing industries, but also increasingly in the heavy process industries. There will also be an increased level of automation, more efficient use of materials and energy, recycling of water, and lower emissions of pollutants to air and water. Biotechnology will appear, leading eventually to lower emissions and less chance of dangerous chemical spills (Joly and Bandelier, 1988). Industry in Europe will continue to be located near the raw material sources (Nordic countries and Central Europe) and the markets.

(i) Steel and basic metals industries

- Declining markets in Europe, strong international competition, narrow markets of specialized steels and more diversification of products.
- A production capacity of about 70% of that of today in the year 2005; the decline in the labour force may be even greater.
- Increased consortia and collaboration.
- Increased automation, more efficient use of raw materials and products and recycling of old products.

(ii) Chemical industry

- Increasing diversification into many products such as fine chemicals.
- Severe international competition.
- Greater efficiency, more recycling and more automated control resulting in less use of energy and raw materials and less emissions to the environment.
- A declining labour force.

(iii) Manufacturing industries

- Growth and an increase in the associated labour force.
- Products becoming more complex, diversified and customized. European industry will move towards specialized and knowledge-based products.
- Technology-oriented services such as design, planning, engineering and project delivery continuing to play an important role in Europe.
- Increasing automation, laser tooling, and utilization of information technology.
- Subcontracting networks and collaboration growing in importance.
- Replacement of steel by alloys, ceramics and high-strength plastics. This will change the nature of pollutant emissions to the environment.

(b) Transportation

- Increasing number of kilometres per day per person despite the fact that electronic information transfer is also increasing rapidly. This is because personal mobility will increase with increasing income, a more spread-out living style and a decrease in the cost of travel relative to income. (The increased personal mobility will be accomplished for short distances by automobiles and for longer distances by air travel.)
- Declining slow-transportation freight modes (rail and ship), losing some of the market to shipment by truck and air.
- Increasing air shipment of high value goods such as electronic equipment, precision machinery and luxury automobiles because of the lower risk of damage and the shorter time during which inventory is tied up.
- A 4% increase per year in international freight transport in Europe.
- Insufficient petroleum to supply the transportation demand after the year 2030, and not enough natural gas after the year 2060. This means that hydrogen from, for example, hydrolysis of sea water may have to be used.

Some *not-impossible turning points* include the following:

(a) Industry

Pronounced deviations from the conventional scenarios could occur because of environmental breakpoints such as climatic change, or economic or political disasters such as depressions or wars. See also Section 3.1.

(b) Transportation

- An increase in the use of low quality gasoline (because of a shortage of higher quality hydrocarbons), resulting in an increase in emissions of air pollutants.
- A deliberate policy to reduce road usage and air transport because of the necessity to reduce pollution. This might be brought about by having heavy taxation on fuel, direct user restrictions or by a concerted rejuvenation of rail systems.
- A sudden interruption in the energy supply for transportation or a large reduction in international trade due to conflicts or protectionism, resulting in a large reduction in pollution emissions.

3.5. Agriculture

Arable land, used for growing annual or permanent crops, currently covers about a third of Europe. An annual increase in productivity of 1% is assumed for growing cereal crops until the year 2000 and 0.5% for the period 2000–2030, being an extrapolation of present trends (De Wit *et al.*, 1987; Wong, 1986). *Table 3.4* summarizes the resulting major trends for cereal crops.

Table 3.4. Plausible agricultural development of Europe for the period 1980–2030 in terms of the amount of land (in million ha), the total production (in million tonnes), as well as yield (in tonnes/ha).

	1980			*2000*			*2030*		
Region	*Land*	*Prod.*	*Yield*	*Land*	*Prod.*	*Yield*	*Land*	*Prod.*	*Yield*
Nordic[1]	3	10	3.3	2	9	4.5	2	10	5.0
EEC-9[2]	27	120	4.5	18	98	5.4	13	82	6.3
Central[3]	1	5	4.5	1	6	5.5	1	6	5.8
South[4]	15	42	2.8	14	46	3.3	11	44	4.0
Eastern[5]	84	189	2.3	68	200	3.0	60	216	3.6
Europe	130	366	2.8	103	359	3.5	87	378	4.2

[1] Finland, Norway, Sweden.
[2] Belgium, Luxembourg, Denmark, France, FRG, Ireland, Italy, The Netherlands, UK.
[3] Austria, Switzerland.
[4] Albania, Greece, Portugal, Spain, Yugoslavia.
[5] Bulgaria, Czechoslovakia, GDR, Hungary, Poland, Romania and the European part of the USSR.

In total some 40 million ha of agricultural land are expected to be taken out of production, corresponding to about 30% of the current land used for growing cereal crops. The largest decrease in land used for agriculture is in the EEC, where about half of the agricultural land might be set aside for non-agricultural purposes. The increases in productivity and in areas taken out of production will lead to a decrease in the size of the labour force. [In the Netherlands, the decrease is estimated to be about 2.5% in the next 20 years (Nijkamp and Soeteman, 1988).]

Rapid advances in new technologies, notably biotechnology and information technology, may lead to many unexpected transformations in European agriculture (Joly and Bandelier, 1988). The annual growth rate of agricultural production, now about 1%, might double as a result of new technologies. Biotechnology will lead to the emergence of new products (i) to control disease and to make crops resistant to pests and diseases, and (ii) to produce cultivars for harsh environments (e.g., salty soils and poor climatic conditions) (von Weizsäcker, 1986). The breeding of plants that are resistant to diseases or pests could result in a considerable reduction in the use of insecticides and pesticides. In addition, the improvements in biotechnology may result in growing crops that are able to fix nitrogen and therefore require less chemical fertilizers, which again provide opportunities to diminish nitrate pollution in water and air.

The role of biotechnology for growing biomass energy has been assessed by Lewis (1986). By the year 2000, about 2.5 exajoule net biomass energy may be produced in EEC-9 plus part of the Nordic countries and Southern Europe. This would require about 14 million ha of land previously used for agriculture or forests. A wide application of information technology at the farm level may improve the management of pests, as well as conserve energy, water and land.

The resulting *not-impossible turning points* for European agriculture are summarized in *Figures 3.3* and *3.4* (Brouwer and Chadwick, 1988) as follows:

- A further increase in productivity which could be as much as 2% per year (upper curve in *Figure 3.3*). Such an increase in productivity may result in a further reduction of agricultural land when compared to the conventional scenario (lower curve in *Figure 3.4*).
- Adaptation to poor local conditions such as soil, water or climate (upper curve in *Figure 3.4*). This could maintain the socioeconomic structure of rural areas, although it would further aggravate the current problems of agricultural surpluses.
- Improvement of the environment, through the application of, among other possibilities, nitrogen fixing crops, integrated pest management and recycling of agricultural waste. This approach can be promising in the highly productive agricultural lands of Europe.
- Increasing monoculture, through wide application of clones, reducing landscape diversity in rural areas.

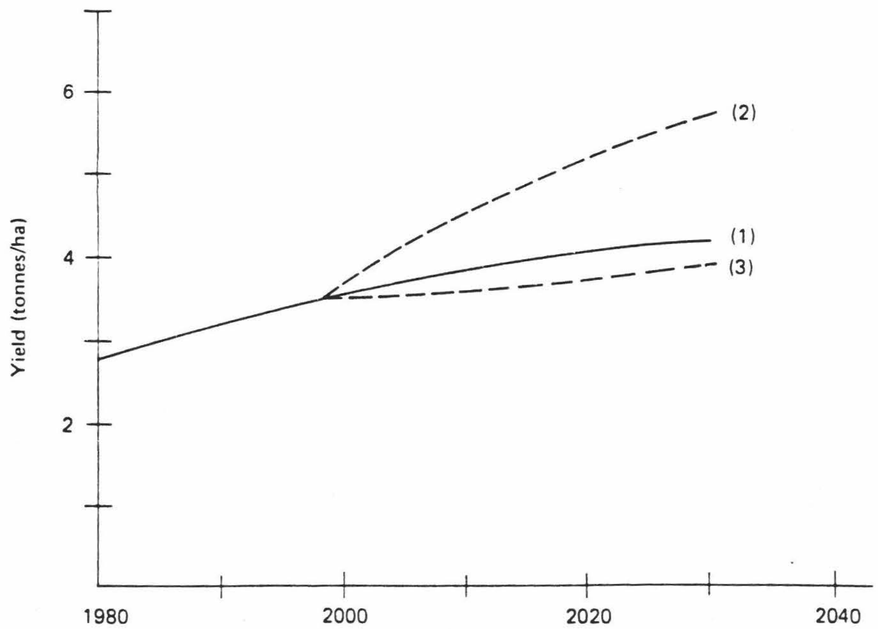

Figure 3.3. Agricultural scenarios for yields in Europe to the year 2030: yields (1 = conventional wisdom; 2 = increase in productivity; 3 = adaptation to poor local conditions).

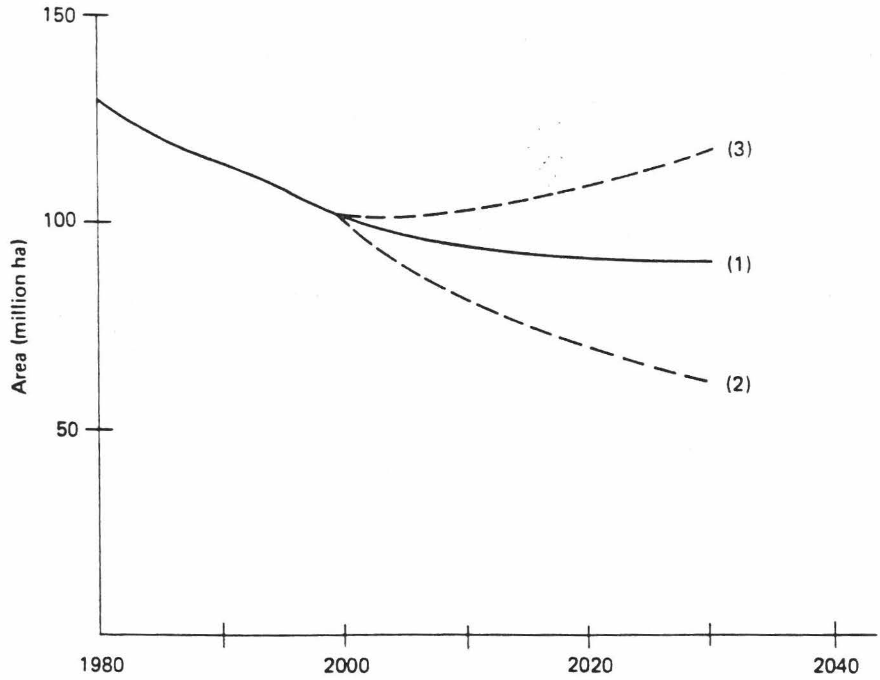

Figure 3.4. Agricultural scenarios for land use in Europe to the year 2030: land use (1 = conventional wisdom; 2 = increase in productivity; 3 = adaptation to poor local conditions).

3.6. Forestry*

Figure 3.5 shows scenarios for annual final consumption of forest products (expressed in round-wood equivalents), net annual increment (NAI) of the European forests and annual fellings for Europe (ECE-FAO, 1986). Both NAI and annual fellings are expected to increase steadily, with the the gap between increment and fellings continuing to be substantial. This means that Europe will continue to have a rather large untapped wood supply which could be a driving force for increased wood processing capacity. There will be a steady increase in total demand for forest products. The strongest increase will occur in paper and wood products, with a modest growth in the demand for pulp. The demand for sawnwood and panels will stagnate or increase slightly.

* This subsection was contributed by S. Nilsson, Environment Program, IIASA.

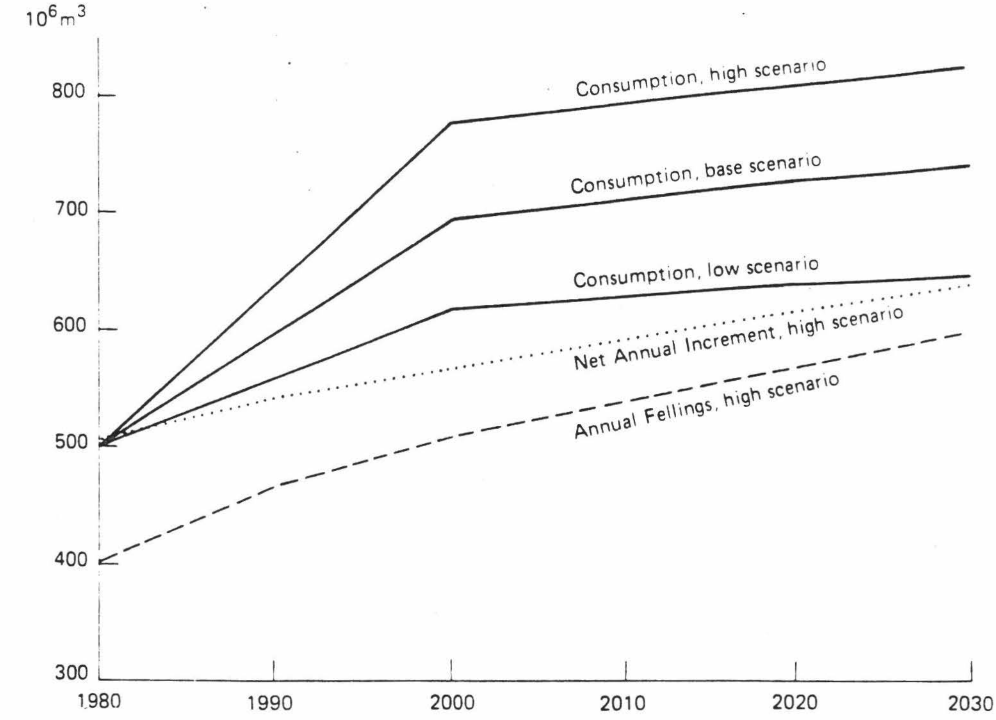

Figure 3.5. Scenarios for annual forest fellings, net annual increment of the forest, and annual final consumption of forest products in Europe (all in units of cubic metres per year). The low scenarios are based "on modest, but realistic assumptions" while the high scenarios are based "on most expansive (but still realistic assumptions)." (Source: ECE-FAO, 1986.)

If the fellings and wood processing capacities in Europe do not increase, Europe will have to import increasingly large quantities of forest products from other continents. The pattern of raw-material input to industry will change in the future. Wood will be substituted by wastepaper, residues, fillers, etc. This will influence the future structure of industry. Based on these conditions for the scenario presented in *Figure 3.5*, industrial investments are likely to be concentrated on improving the competitiveness of existing capacities for sawnwood, panels and pulp. A rather strong expansion in wood processing capacity is foreseen for paper and board products (see also Kreysa, 1987; and Nilsson, 1988).

The factors that could produce not-impossible turning points are mainly environmental rather than technological. They will be discussed in Section 4.6.1.

4. Environmental Futures for Europe

4.1. Climate

Climatic scenarios that might be expected in the year 2030 under *slight* climatic change are those of Lough *et al.* (1983), based on historical analogues*. The main features of the temperature scenarios shown in *Figure 4.1* are the slight to moderate warming in summer, but in winter slight cooling in most of Europe and slight warming in other parts. Spring and autumn patterns (not shown) are similar to those in summer.

An important related statistic is the interannual variability in temperature. For winter (*Figure 4.2*), the numerical value of this statistic increases except in Italy, Greece and the Balkans.

Scenarios for precipitation and interannual variability of precipitation are given in *Figures 4.3* and *4.4*. There is a general tendency for drier summers and wetter winters. The patterns of interannual variability are rather complex but in general there is more variability in spring and autumn, with less in summer and winter. See, for example, the summer values in *Figure 4.4*.

Comparable analogue scenarios for cloudiness indicate generally greater amounts of cloud by the year 2030 (Henderson-Sellers, 1986).

Climatic scenarios for *strong* climatic change in the year 2030 are based on simulations obtained from the general circulation model of the British Meteorological Office (Mitchell, 1983) assuming that the equivalent concentration of carbon dioxide were double that of today:

- Much higher temperatures, more than 4°C warmer in winter over Scandinavia and northern USSR (*Figure 4.5*).
- Increased precipitation over the northern half of Europe, and decrease over much of Southern Europe (*Figure 4.6*).

A *not-impossible turning point* is based on the speculation of Broecker (1987):

- Much colder temperatures due to the deflection of the Gulf Stream from Northern to Central Europe.

* Lough *et al.* (1983) compared the mean temperature and precipitation patterns for the years 1934–1953 with those for 1901–1920. Averaged over the Northern Hemisphere, these were the warmest and coolest 20-year periods since 1880.

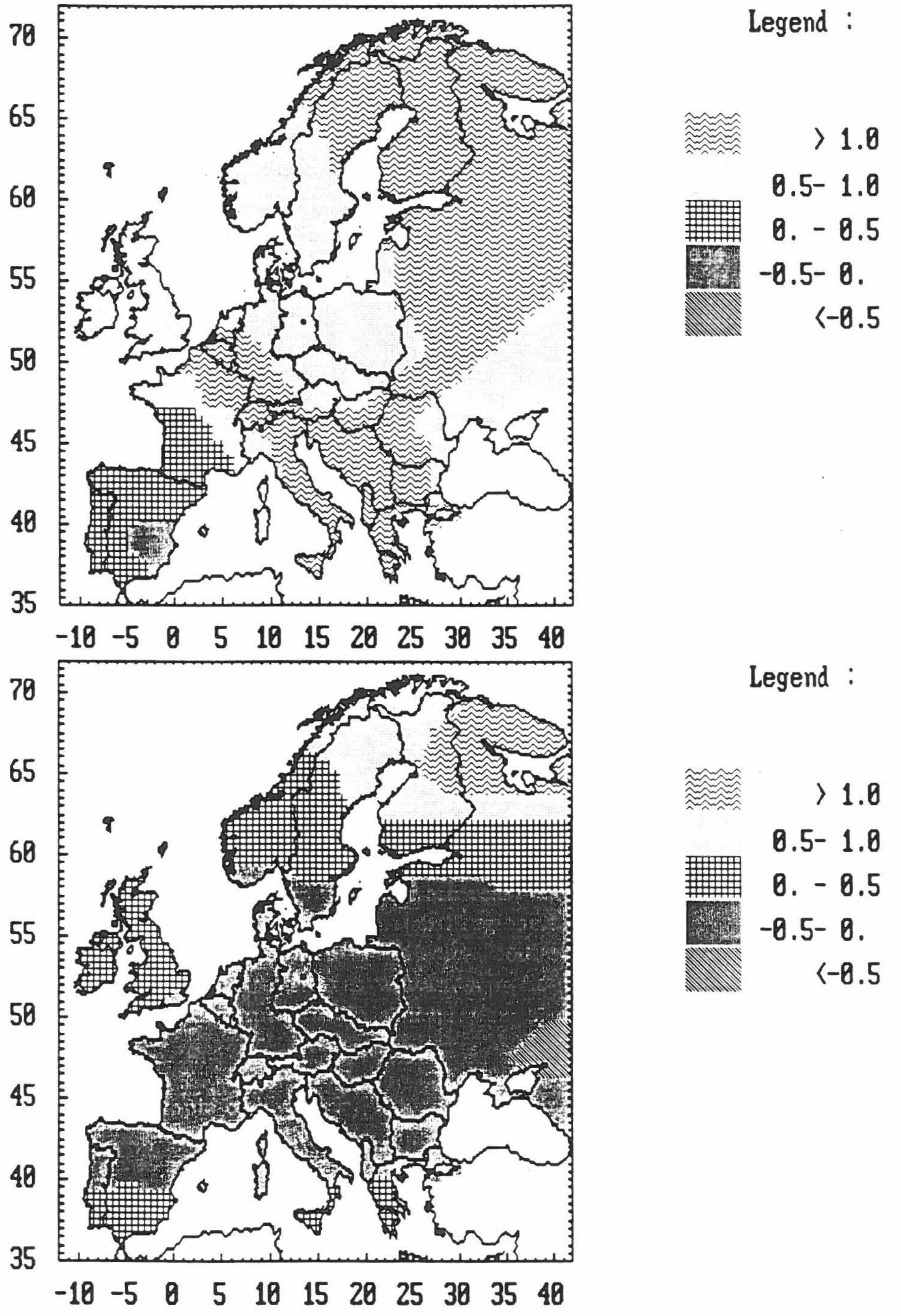

Figure 4.1. Expected changes of temperature in summer (upper) and winter (lower) (in °C) (Lough *et al.*, 1983). Note that summers are generally warmer. Winters are slightly cooler in most of Europe but slightly warmer in other parts.

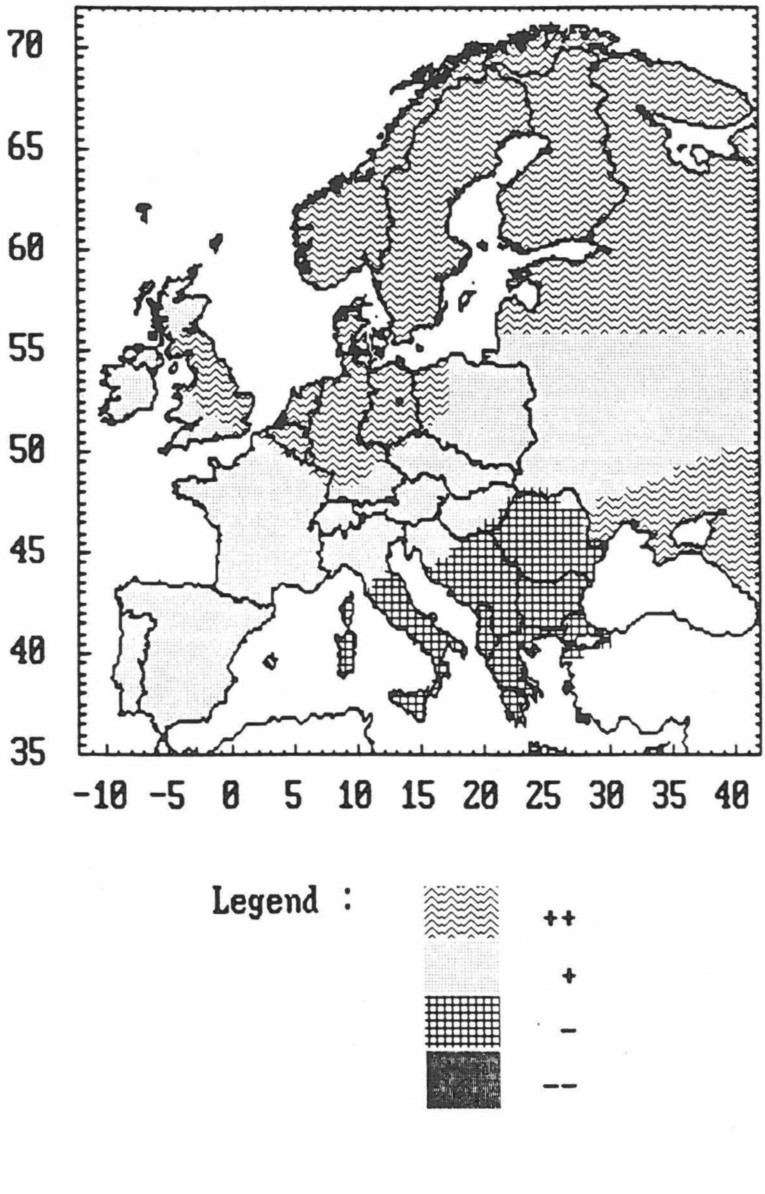

Figure 4.2. Expected changes in winter temperature variability (standard deviations) (Lough *et al.*, 1983). The changes are not very large.

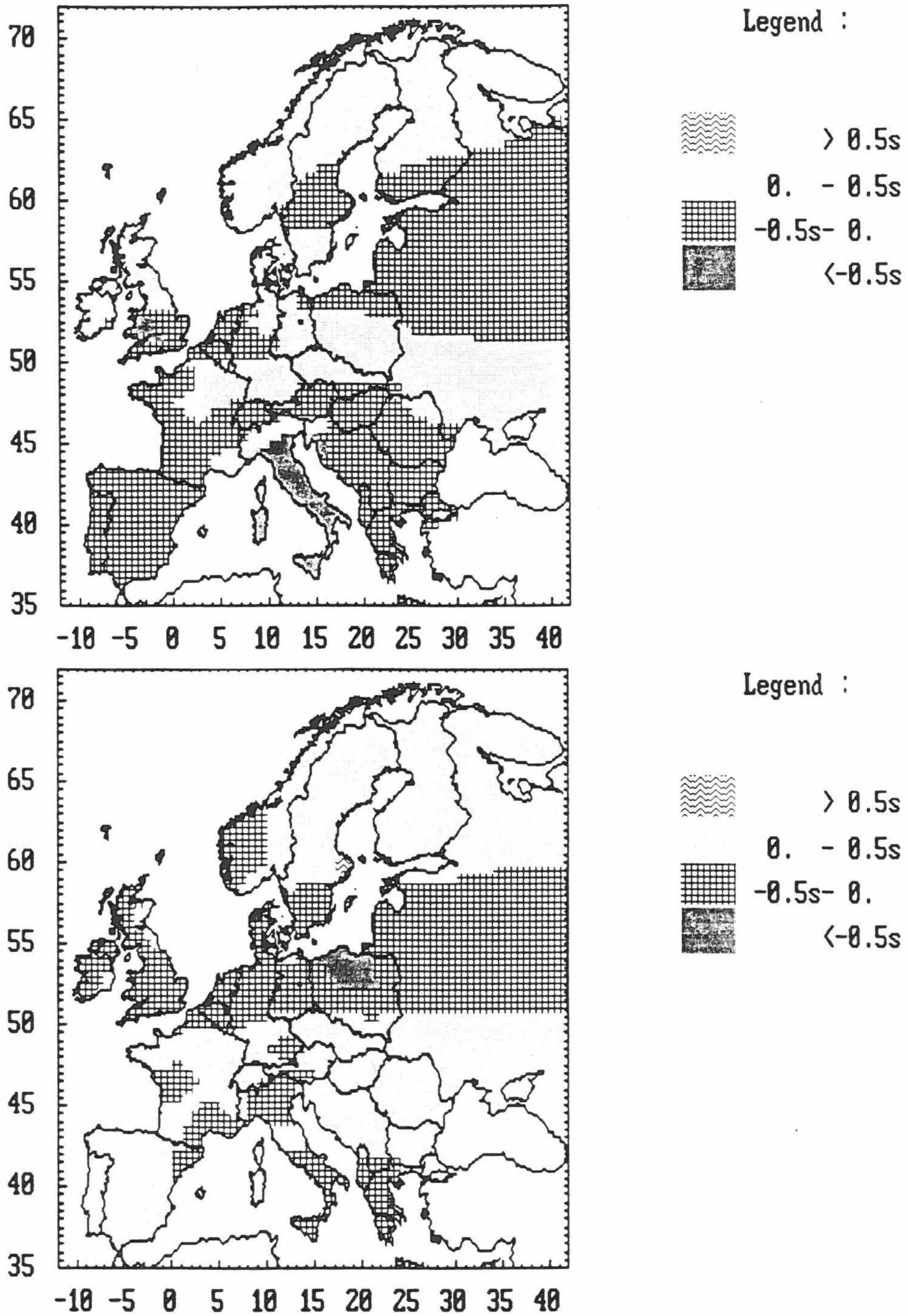

Figure 4.3. Expected changes in precipitation in summer (upper) and winter (lower) as multiples of the standard deviation (Lough *et al.*, 1983). Note the tendency for drier summers and wetter winters.

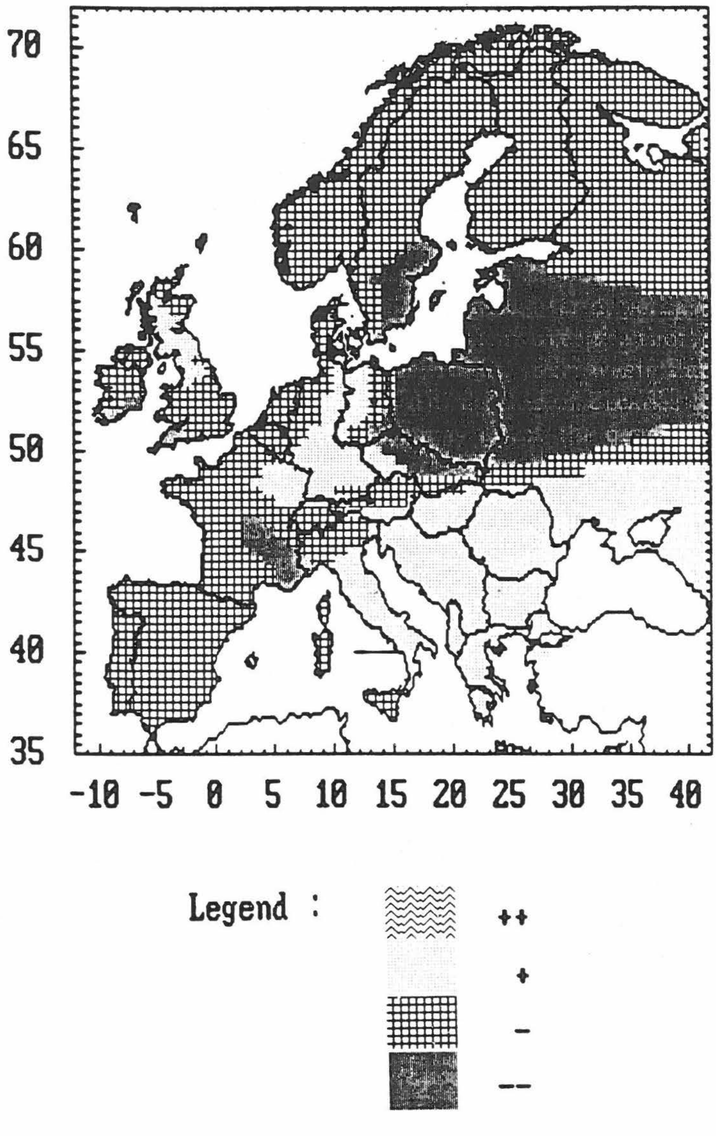

Figure 4.4. Expected changes in the interannual variability of summer precipitation, cold period to warm period (Lough *et al.*, 1983). The changes generally are not large.

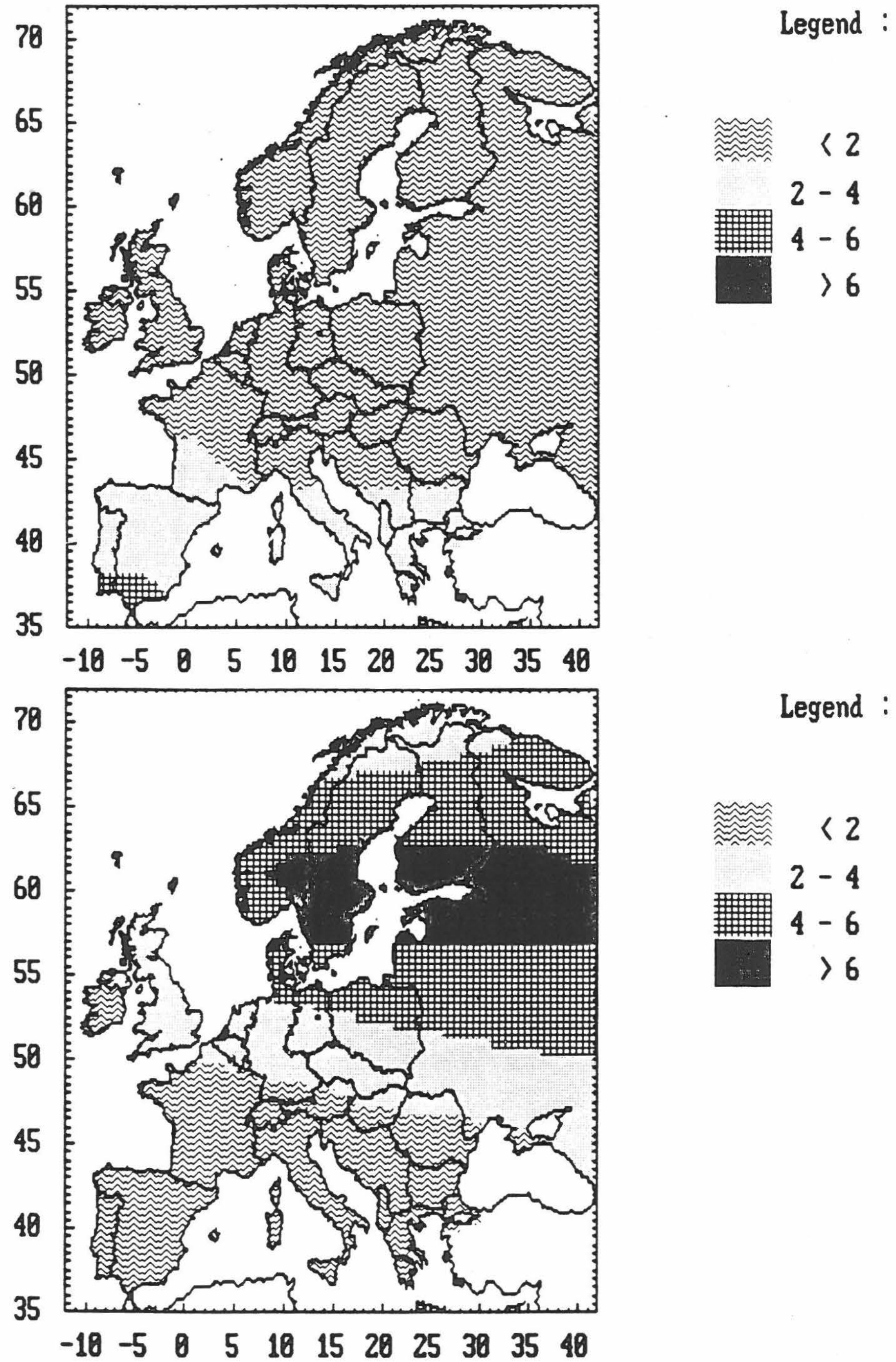

Figure 4.5. Temperature increases expected in summer (upper) and winter (lower) as a result of the equivalent doubling in concentration of CO_2 (in °C) (Mitchell, 1983). Note the considerable warming in all parts of Europe.

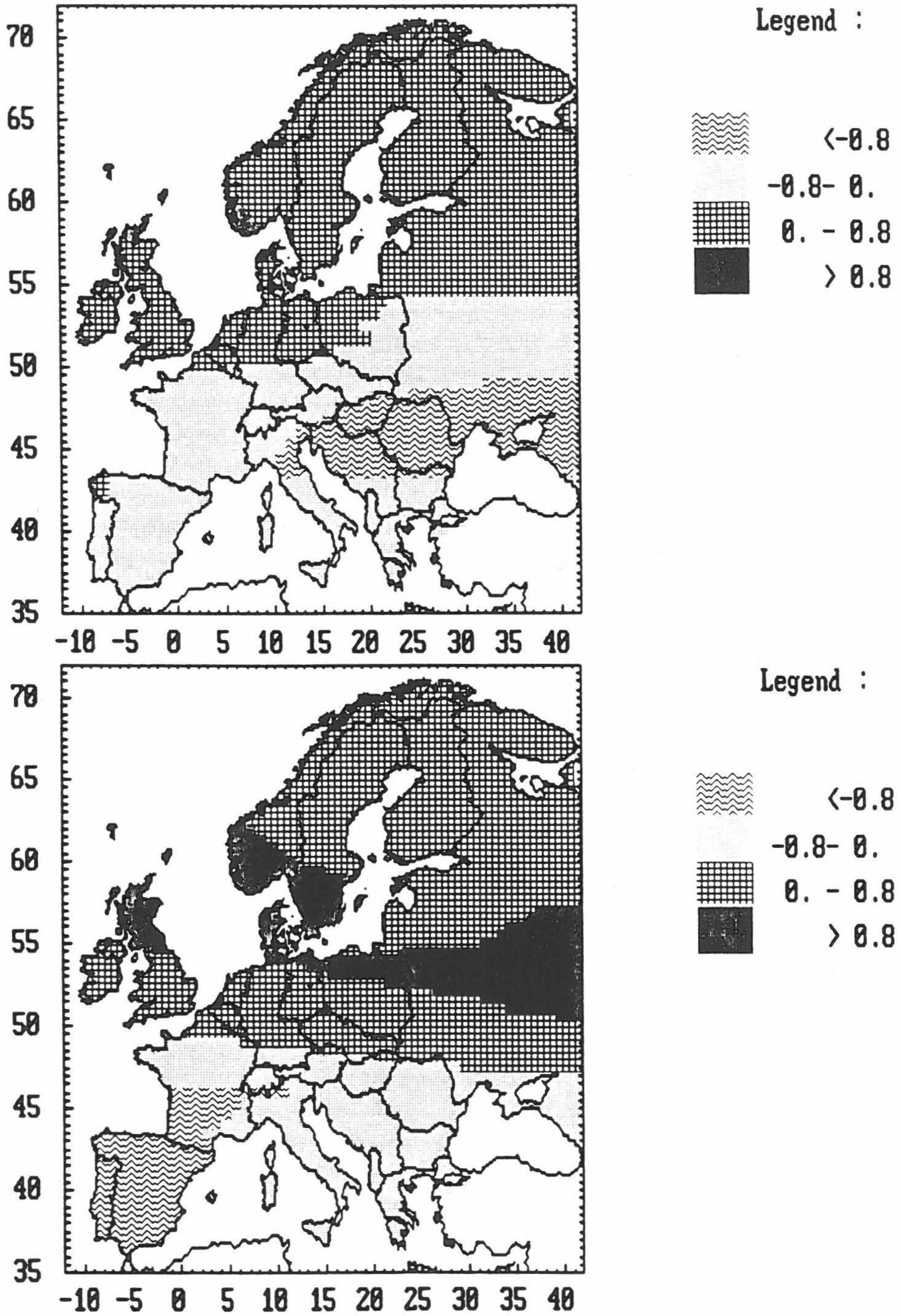

Figure 4.6. Precipitation changes expected in summer (upper) and winter (lower) as a result of the equivalent doubling in concentration of CO_2 (in mm/day) (Mitchell, 1983). Note the increased precipitation over Northern Europe and decrease over much of Southern Europe.

4.2. Hydrology

4.2.1. Scenarios for sea level rise

Climate warming will cause a global rise in sea level. The areas most at risk are estuaries with important industrial facilities and rich agricultural land (Hekstra, 1988). A widely accepted scenario for the extent of this rise is shown in *Figure 4.7*, the turning points being shown by the upper and the lower curves (Jäger, 1988).

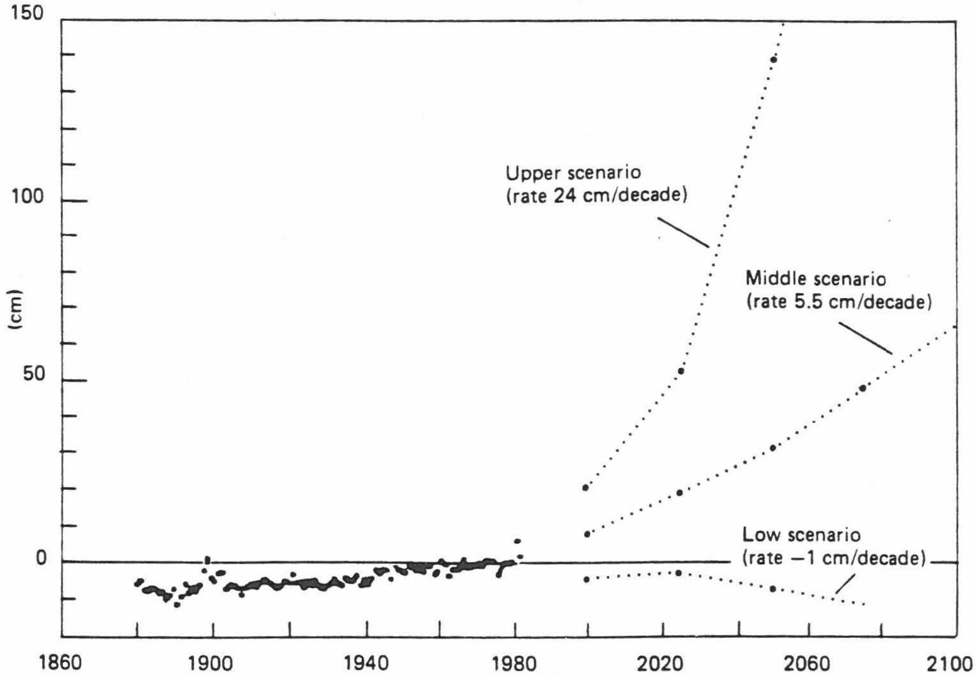

Figure 4.7. Scenarios for global sea level rise (Jäger, 1988). The chances that the actual sea level will fall below the upper, middle and lower scenarios are 90%, 50% and 10%, respectively. These are global values; local changes need to be evaluated individually.

The resulting impacts are as follows:

- Erosion of beaches and coastal margins.
- Decrease of usable land.
- Increase in frequency and severity of flooding of low-lying lands.
- Loss of dunes and coastal wetlands.
- Inland flood-plain penetration of saline waters, affecting agriculture and drinking water.
- Resuspension of toxic materials from estuarine sediments.
- Mobilization of toxic materials from waste dumps.

4.2.2. Plausible hydrological scenarios

Based on the temperature and precipitation scenarios of Lough *et al.* (1983), the hydrologic changes in Europe for the year 2030 are:

Spring:	More evapotranspiration; less precipitation; earlier spring snow-melt.
Summer:	Much more evapotranspiration; less precipitation.
Autumn:	More evapotranspiration; more precipitation.
Winter:	Less evapotranspiration over most of Europe, but more in the Mediterranean countries; more precipitation.

The net result would be a significant reduction in water availability in summer in soils, lakes and rivers, and a lesser reduction in spring. For autumn and winter, conditions would be rather similar to current ones.

Some *not-impossible hydrologic turning points* are as follows:

- A major increase in evapotranspiration during the summer half of the year (see, for example, Bultot *et al.*, 1988).
- A substantial decrease in soil moisture, particularly in the summer, in Central and Southern Europe (Manabe and Wetherald, 1987).
- A reduction in river flows, particularly in the summer, in Central and Southern Europe.
- Increased frequency of floods in Northern Europe (see for example, Olejnik, 1988).
- An increase in streamflow variability, particularly in Northern Europe. [An increase in variability is more serious than a decrease in mean flow (Kaczmarek and Kindler, 1988).]
- Earlier spring snow-melts in the Alps. [The summer snowline will rise about 180m/°C of warming (RIVM, 1988).]
- Glaciers and permafrost ultimately melting (RIVM, 1988).
- An increase in the length of the ice-free season in lakes and seas. [The length of the ice-covered period in Finnish lakes would decrease by 40 to 60 days (Kuusisto, 1988).]
- An increase in the length of the navigation season in the Arctic Ocean.
- Loss of the attractiveness of some of the favoured areas for winter sports.
- Changed water circulation patterns in the Mediterranean Sea due to the changed water temperatures and wind fields, causing depletion of oxygen and changes in biological productivity (Zavatarelli, 1988).

The hydrological scenarios and turning points given above suggest that water supplies could decrease over some areas of Europe during the next 30 to 50 years, particularly over the southern half of the continent. However, water consumption may not increase very much over this period if the price of water use increases. [Between 1970 and 1980, the price of water in the OECD countries increased by 100 to 200% (Theys, 1987).] Three countries (Belgium, Poland and GDR) are already facing water stress (with more than 500 people to be

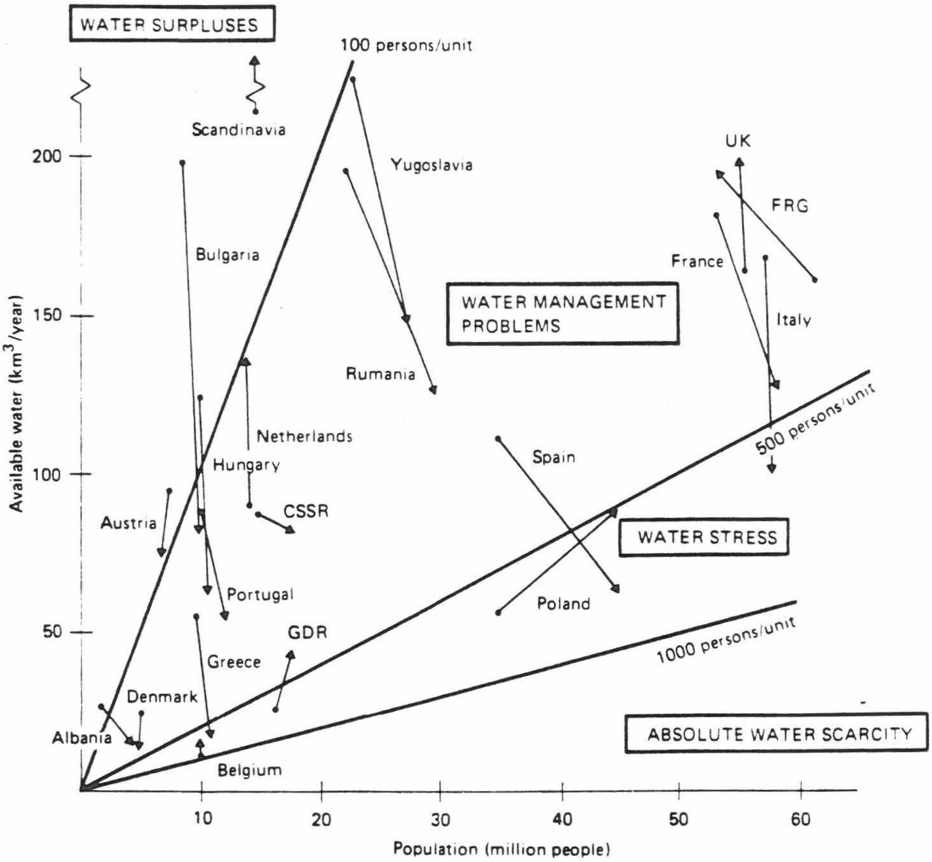

Figure 4.8. Hydrologic shifts for various countries based on the British Meteorological Office CO_2-doubled general circulation model and UN population projections for the year 2025 (United Nations, 1986). (Source: Brouwer and Falkenmark, 1988.)

supported on a flow of 1 million m^3 water per year). These countries have a per capita level of annually available water that is in the range between 1,200 and 1,600 m^3. This is the amount of water potentially available for domestic and a multitude of agricultural and industrial purposes. Within a country, of course, local availability depends on access to reservoirs for flood flow storage, well systems, etc. There are also shortages during the growing season in some Mediterranean countries.

*Figure 4.8** compares national changes in water availability and population for current levels and the year 2030, by which time strong climatic change is assumed to have occurred (see *Figures 4.5* and *4.6*).

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* It should be noted that this figure takes no account of water quality, which, if adversely affected, will be another limitation on water availability. For example, sea level rise (causing salt-water intrusion) could render much of the groundwater supplies in the coastal lowlands unsuitable for human consumption.

Under this scenario countries suffering water stress by the year 2030 may include not only Belgium and Poland, but also Greece, Spain and Italy. Many other countries will find it necessary to improve their water management programs. Only Austria and the Scandinavian countries are expected to have water surpluses.

4.3. Atmospheric Pollution and Regional Acidification

(a) Emissions

Scenarios for European emissions of sulphur oxides and, for comparison, carbon dioxide, are shown in ***Figures 4.9*** and ***4.10***. The conventional wisdom energy scenario is that described in Section 3.3. Note that, despite the expected increase in production of energy during the next 50 years, the emissions of SO_2 and CO_2 are not forecast to increase dramatically because of increased adoption of SO_2 emission control technologies and an increased use of natural gas.

The other curves in ***Figures 4.9*** and ***4.10*** represent emissions resulting from the ***not-impossible turning points*** described in Section 3.3.

- If nuclear power is replaced by coal, emissions of both SO_2 and CO_2 will increase [curves (a)].
- If after the year 2000, public resistance to nuclear power is overcome, the resulting increased use of nuclear power would result in greatly reduced emissions of SO_2 and CO_2 [curves (b)].
- Increased use of natural gas from deep levels in the earth could replace both nuclear power and coal and would result in very great decreases in emissions of SO_2. The fractional decreases in CO_2 emissions would be less than that for SO_2 because natural gas still contains some carbon [curves (c)].
- If the energy system becomes primarily hydrogen based, emissions of both SO_2 and CO_2 could greatly decrease [curves (d)], provided that fuels used for the production of hydrogen do not contain sulphur or carbon.
- Whatever the mix of fossil fuels, development of CO_2 capture technologies will reduce emissions of CO_2.
- Breakthroughs in the efficiency of energy transmission and use would decrease the emissions shown in ***Figures 4.9*** and ***4.10*** by as much as 20% in the year 2015 and by 40% in 2030.
- Attaining a sustainable energy supply in Europe by the "hard solar" scenario referred to in Section 3.3 could result by 2100 in a decrease of about 40% in CO_2 emissions relative to the 1975–1980 period. The "soft solar" scenario would result in a decrease of over 60% in CO_2 emissions. In both cases, SO_2 emissions would be virtually eliminated.

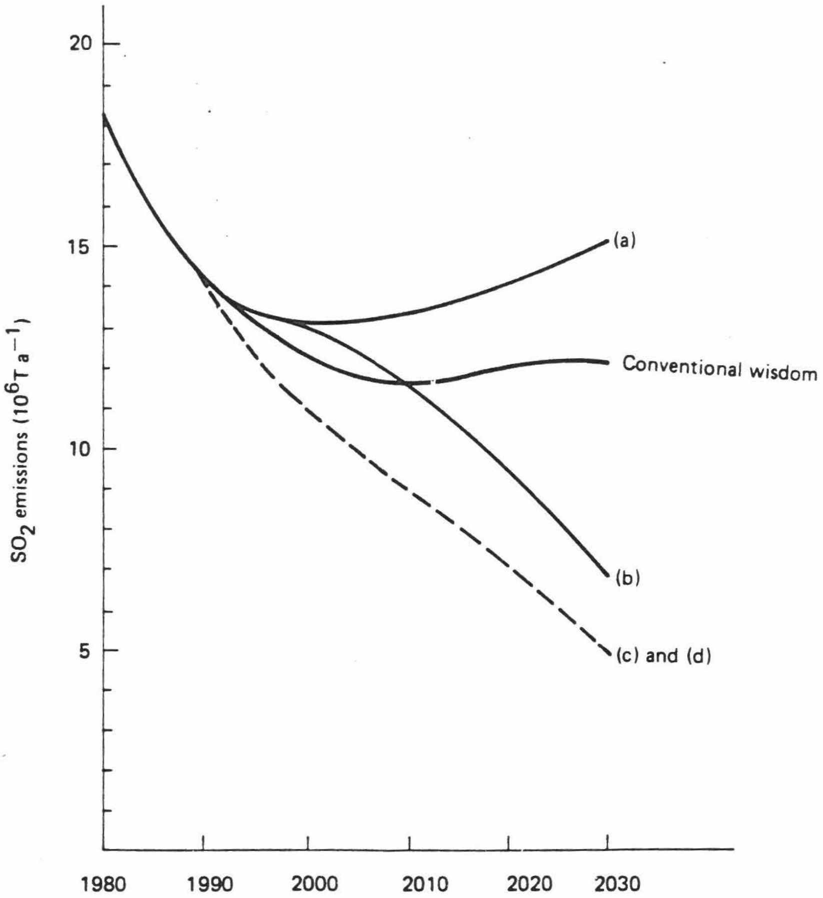

Figure 4.9. Scenarios of sulphur emissions (in 10^6 tons/year) for Europe to the year 2030. Conventional wisdom curve: based on scenario given in *Table 3.1*. Curve (a): nuclear power replaced by coal. Curve (b): increased use of nuclear power. Curve (c): increased use of natural gas from deep wells. Curve (d): hydrogen based energy system.

(b) Sulphur deposition

The IIASA RAINS model (Alcamo *et al.*, 1987) can be used to estimate sulphur deposition, given an emission field. Using this approach in the case of SO_2, *Figures 4.11* and *4.12* show patterns of sulphur deposition in the year 2030, based on the hypotheses contained in *Figure 4.9*, curves (a) and (c/d). In the case of a move away from nuclear power to coal, the sulphur deposition flux exceeds 10g S/m^2/year in Central Europe and 1g S/m^2/year over most of Europe. These values should be compared with the critical loads for sulphur for sensitive aquatic ecosystems and forest soils which are estimated to be as low as 0.3 to

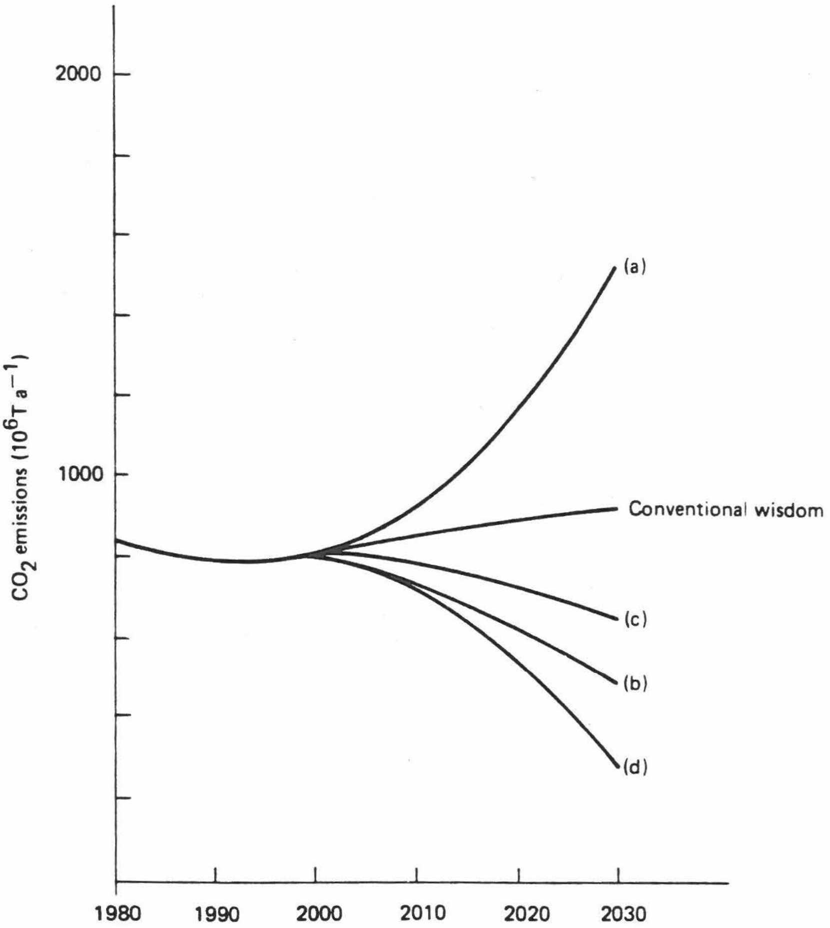

Figure 4.10. Scenarios of carbon dioxide emissions (in 10^6 tons/year) for Europe to the year 2030. Curve (a): nuclear power replaced by coal. Curve (b): increased use of nuclear power. Curve (c): increased use of natural gas from deep wells. Curve (d): hydrogen based energy system.

1.5g S/m^2/year. It would appear that the critical loads will be exceeded over a large part of Europe.

Figure 4.12 shows that if the energy system were based more upon natural gas or hydrogen (the latter produced without the combustion of sulphur-containing fuels), the maximum deposition flux would decrease to 3–4g S/m^2/year and the critical loads would be exceeded over a much smaller area than in (a) above.*

* These projections do not take into account the effects of nitrogen deposition, nor the fact that receptor sensitivities (and, therefore, the critical load) vary over Europe. Also, the wind and precipitation fields are assumed to be the same in year 2030 as in 1980.

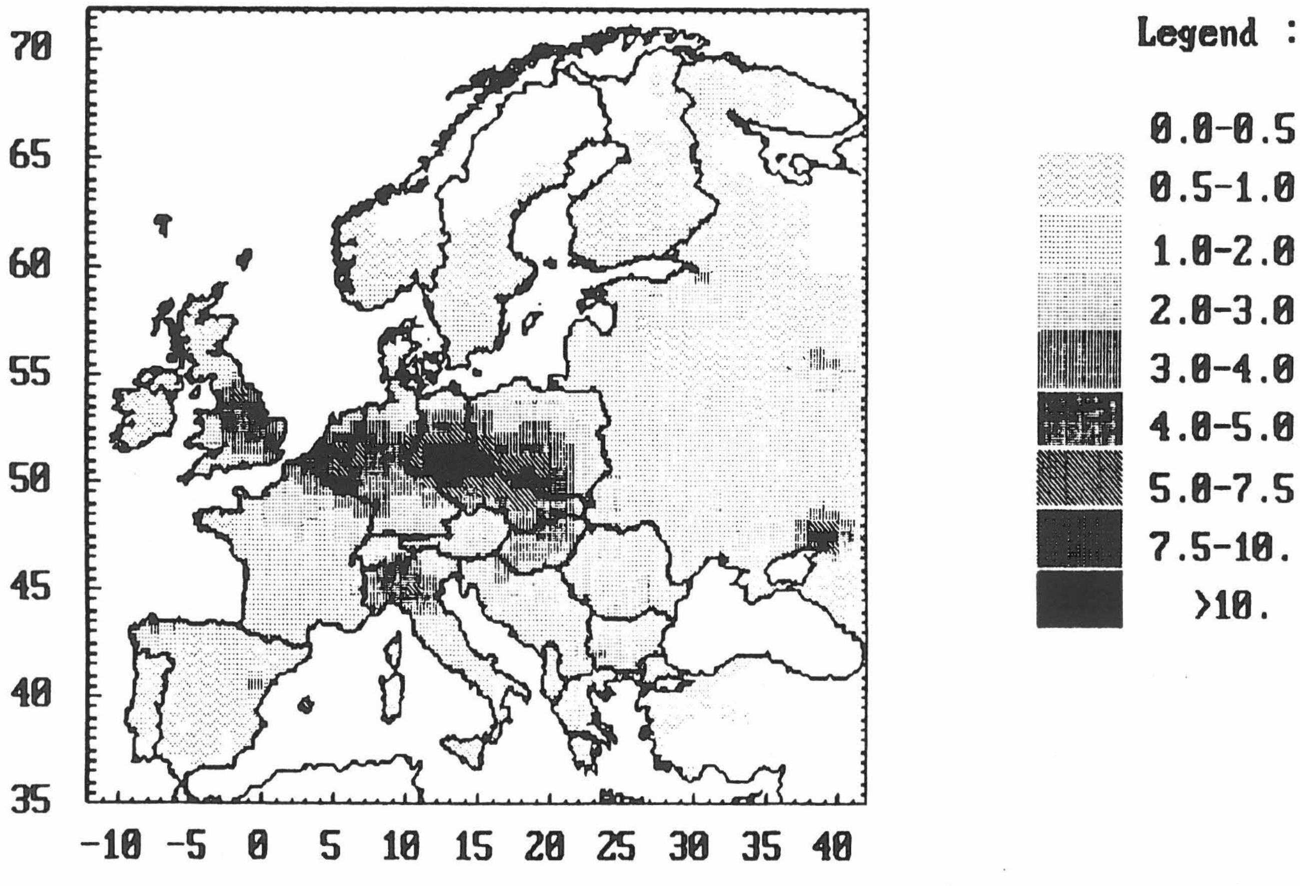

Figure 4.11. Total sulphur deposition (g/m^2/year) for year 2030 for SO_2 emissions assuming nuclear power is replaced by coal, curve (a) in *Figure 4.9*. Critical loads of sulphur deposition would be exceeded over much of Europe.

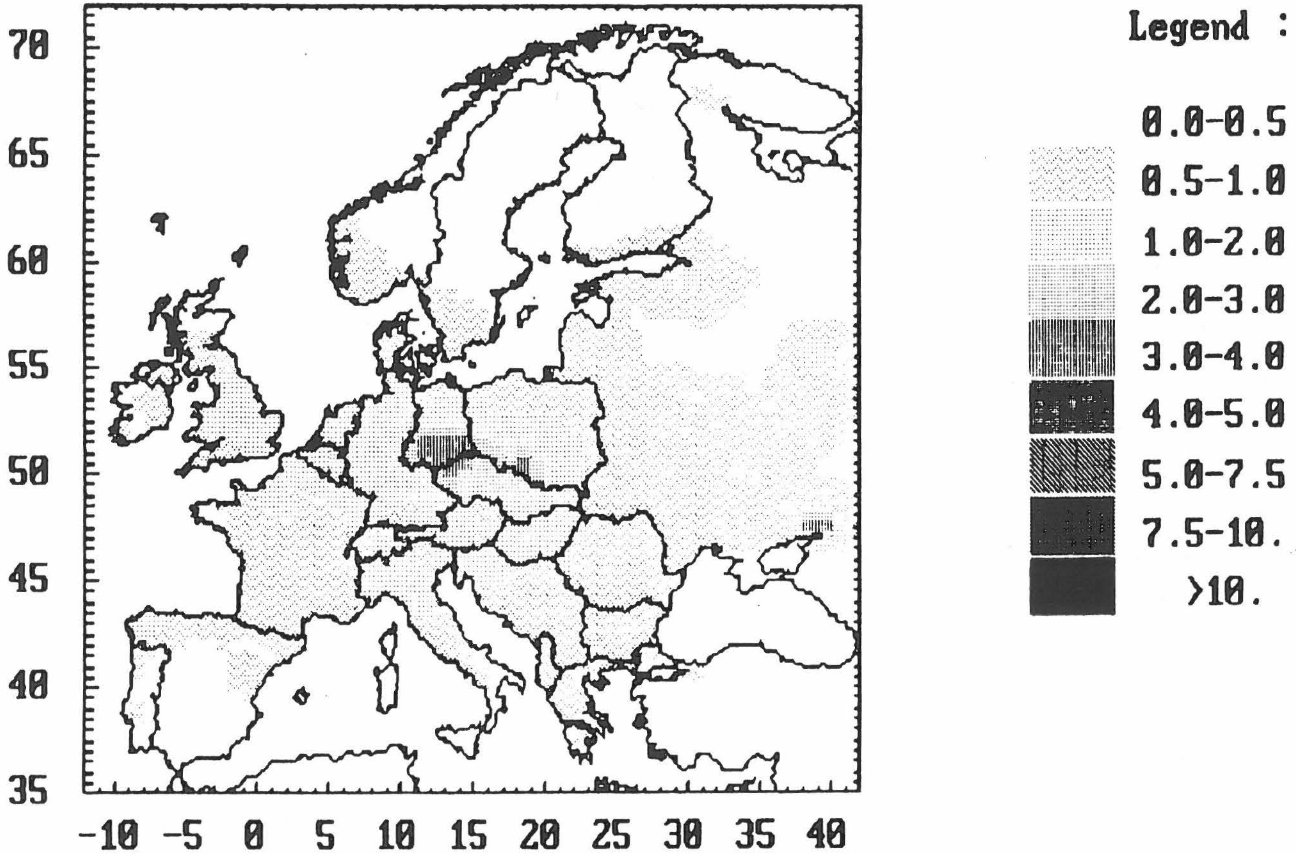

Figure 4.12. Total sulphur deposition (g/m^2/ year) for year 2030 for SO_2 emissions assuming increased use of natural gas from deep wells, or a hydrogen based energy system, curves (c/d) in *Figure 4.9.* Critical loads would be exceeded over a much smaller area than in *Figure 4.11.*

(c) Ozone

Surface ozone concentrations have been rising in Europe over the last two decades and will continue to increase (Feister and Warmbt, 1987; Darmstadter *et al.*, 1987). As summers become drier and warmer, the use of air conditioning equipment may increase, driving up the consumption of energy and the emission of oxides of nitrogen. Summertime episodes of high ozone concentrations will become more frequent and more intense (Darmstadter *et al.*, 1987). In fact, these not-impossible projections are as follows:

	Actual values				*Projections*	
Year	1890	1920	1950	1980	2030	2080
O_3, (ppb)	10	20	35	55	130–180	130

These projections are supported by some model simulations of Brühl and Crutzen (1988), who suggest that present average tropospheric ozone concentrations in the Northern Hemisphere could double by the middle of the 21st century.

4.4. Soil Quality

4.4.1. Acidification (depletion of soil buffering capacity)

The forest soil submodel of RAINS takes into account geographical variations in sensitivity to acidity. ***Figures 4.13*** and ***4.14*** show comparisons of forest soil acidity in 2030 in six countries of Central Europe for emission curves a and c/d of *Figure 4.9.* The figures are in the form of histograms of percentage area with pH within the specified ranges for each country and for the six countries combined (to the right of the map). The histograms are heavily shaded for the "conventional wisdom" scenario and more lightly shaded for the others.

By 2030, the "conventional wisdom" scenario will result in 35% of the forest soils in the six countries having a pH value of less than 4.0, 50% between 4.0 and 4.3 and 10% between 4.3 and 4.5. The greatest fraction of forest soils with pH less than 4.0 will be in the GDR (75%) followed by Poland, Czechoslovakia and Austria (45–50%).

Turning point scenario (a), in which nuclear power is phased out, will result in a slight increase in the area of forest soil with pH less than 4.0 (from 35% to 40% in the six countries), a corresponding decrease in the area with pH between 4.0 and 4.3 and little change in that with pH between 4.3 and 4.5 (*Figure 4.13*). Little change is expected in Austria and Czechoslovakia.

If the energy system were to be based upon natural gas or hydrogen (emission turning point scenarios (c) and (d)), the change would be more pronounced (***Figure 4.14***). Note that in ***Figure 4.14***, the ranges of pHs have been shifted upward from those in ***Figure 4.13*** to accommodate this improvement. In the six

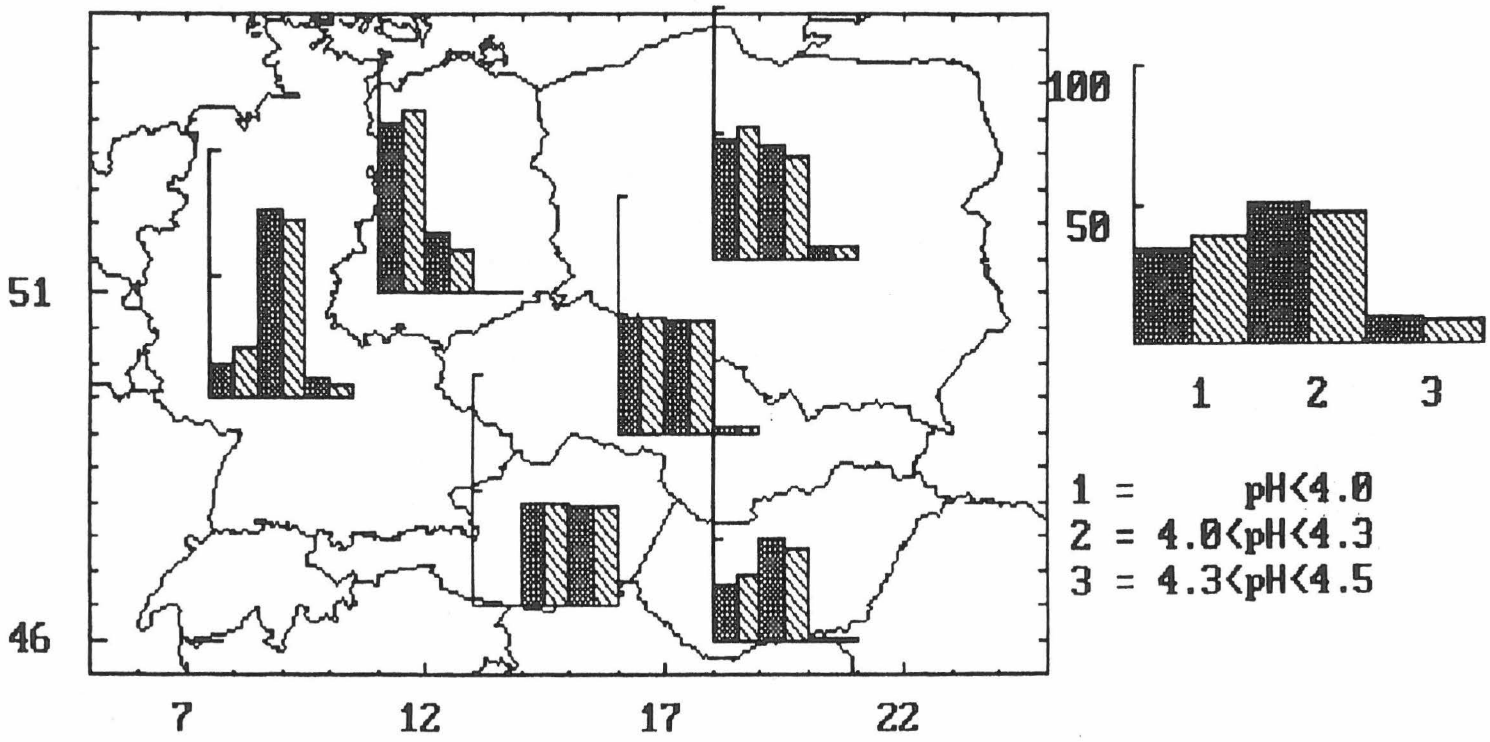

Figure 4.13. Percentage area of forest soils in Central Europe in the year 2030 within the specified pH ranges, as predicted by the IIASA RAINS model for two scenarios: The darker histograms show the distribution assuming the "conventional wisdom" scenario while the lighter histograms assume that nuclear energy will be replaced by coal. Histograms are shown for individual countries; the histogram to the right of the map is an aggregate for all countries.

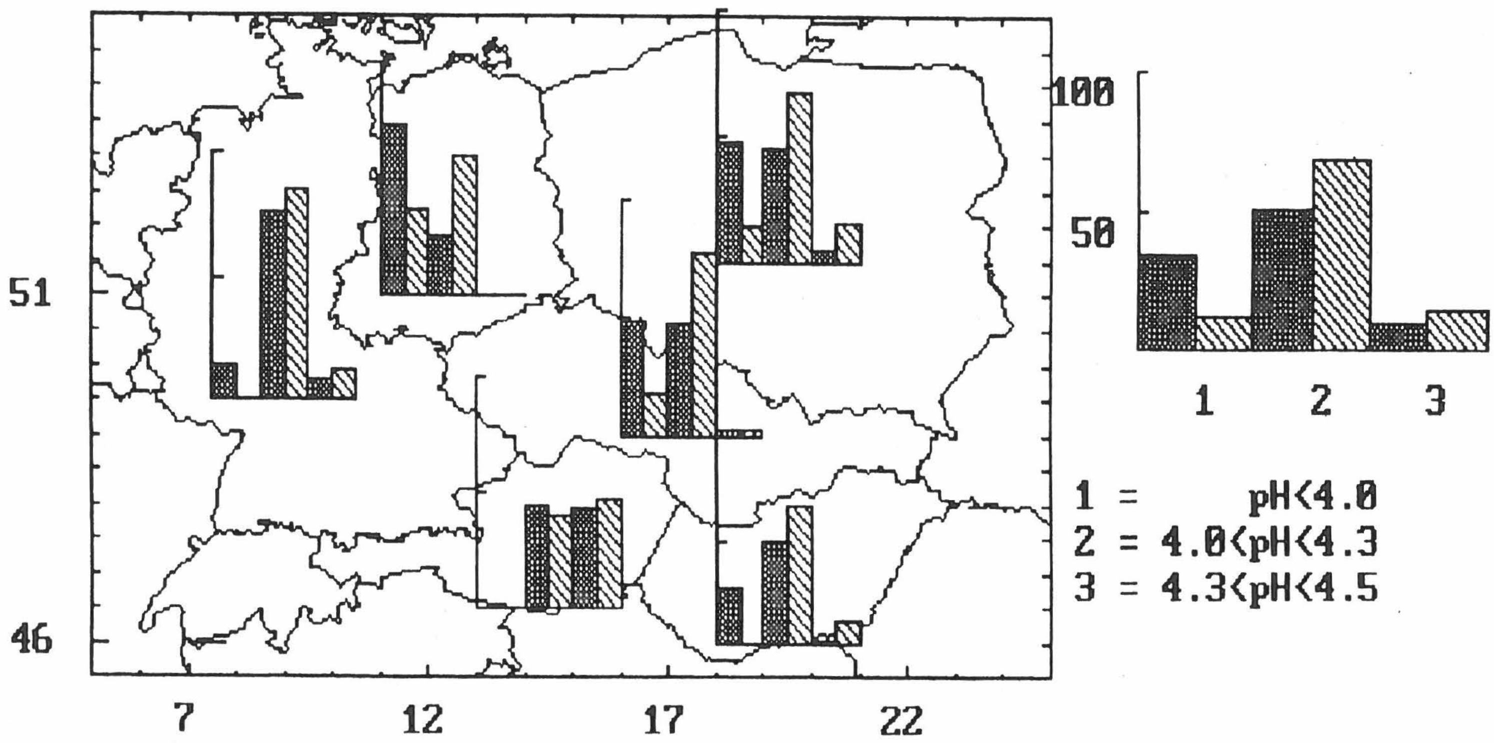

Figure 4.14. As in *Figure 4.13*, except that the lighter histograms represent the distributions assuming an increased use of natural gas or hydrogen for the production of energy. Note that because of the large improvement associated with this scenario, the histograms are shifted to higher ranges from those in *Figure 4.13*.

countries, the percentage area of forest soil with pH less than 4.0 would drop from 35 to 15% while the percentage area between pH 4.0 and 4.3 would increase from 50 to 70%. Large changes would occur in all countries but Austria.

4.4.2. The accumulation and future releases of toxic materials

Various toxic materials may accumulate in soils. Their sources are manifold, e.g., industrial emissions, combustion of fossil fuels, dissipative end uses of some consumer products (e.g., asbestos in insulation and automobile brakes, lead in gasoline), corrosion of urban structures, composting with contaminated sludge, leaching from garbage dumps, incineration of solid wastes containing these materials.

Accumulation in agricultural soils is of major concern because of the possibility of uptakes of these materials in crops. For example, cadmium inputs, in addition to the sources listed above, occur as a trace impurity during the application of phosphate fertilizers. Although current concentrations of cadmium in crops in Europe appear to be well below levels considered safe for human consumption (except for local hot spots) accumulations over future decades may raise concentrations above safe levels. Calculated projections of daily intakes of cadmium in the European Community over the next 100 years highlight the potential seriousness of the problem, *Table 4.1* (Hutton, 1982).

Table 4.1. Current and future dietary intakes (μg/day) in the UK and Denmark for two scenarios of plant cadmium concentrations.

Country	*1980*	*2080 (low)*	*2080 (high)*
UK	21	30	57
Denmark	30	42	79

These predicted intake levels are average values: accordingly, intake for some proportion of the population in the EC could exceed the tolerable intakes (57 to 71 μg/day) recommended by the WHO.

When heavy metals are present in a mobilizable form, their danger to the biosphere is magnified many times. One of the major factors affecting mobility is acidification. The concern is that as soils acidify, their capacity to absorb toxic heavy metals such as cadmium and mercury is greatly diminished, and the increased mobility of these metals leads to uptake by plants or leaching into local water courses. In addition to metals from anthropogenic sources, naturally occurring metals such as aluminum begin to leach from soils acidified to levels of 4.0 to 4.3.

In agricultural soils, a major cause of acidification is nitrogen fertilizer in the form of ammonium. The tendency for agricultural soils to acidify is controlled by the addition of lime, which keeps soil at around 6.0. A potential turning point is the abandonment of marginal farm land in the coming decades, which in Western Europe could amount to around 20% of the total of current agricultural lands. Upon the cessation of liming, these lands may acidify rapidly

(Stigliani, 1988). Since some of these areas have received high inputs of heavy metals, a drop in pH, to perhaps 5 for clay soils and 4 to 4.5 for sandy soils, may cause discharges of heavy metals, pesticides and other toxic materials into ground and surface waters.

4.4.3. Phosphorus saturation of farmlands

Unlike nitrogen fertilizer which is leached from soils relatively quickly, phosphorus is stored for a long time until saturation occurs. At that point, additional phosphorus inputs will result in its rapid leaching into ground and surface waters. There is therefore, a potentially serious turning point for parts of Europe if current phosphorus application rates continue.

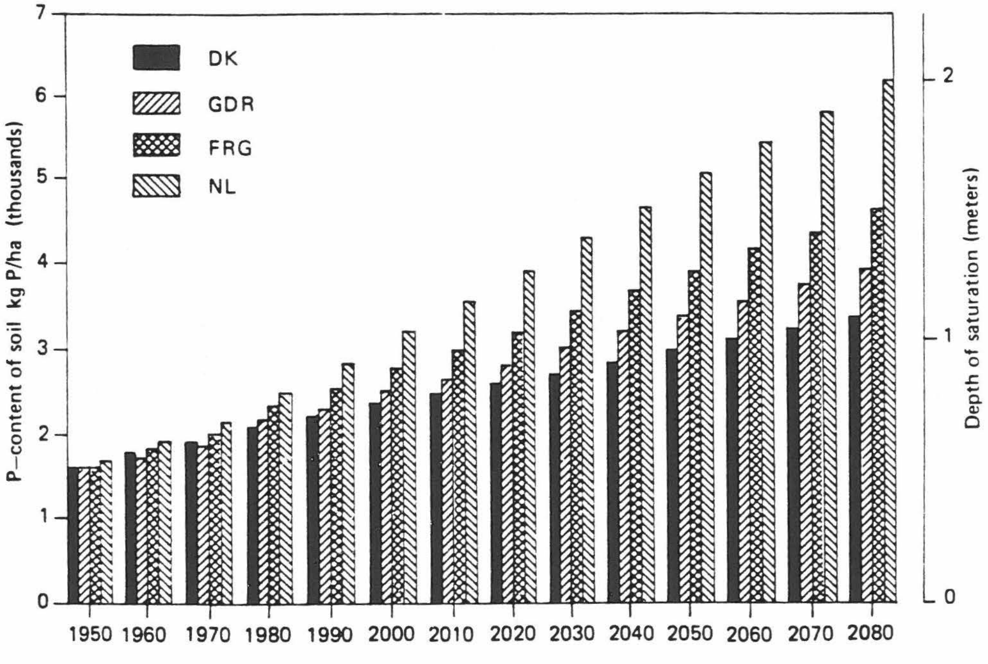

Figure 4.15. Projected changes of phosphorus content of soils from 1950 to 2080 in Denmark (DK), the German Democratic Republic (GDR), the Federal Republic of Germany (FRG), and the Netherlands (NL). The right-hand scale shows the depth of saturation assuming a phosphorus sorption capacity of 30 kg P/ha/cm. Estimates were based on the assumption that phosphorus application in future would be the same as for the period 1980 to 1985. (Source: Behrendt, 1988.)

Figure 4.15 shows historical trends and plausible scenarios for the phosphorus content of agricultural soils in four European countries; the 1980–1985

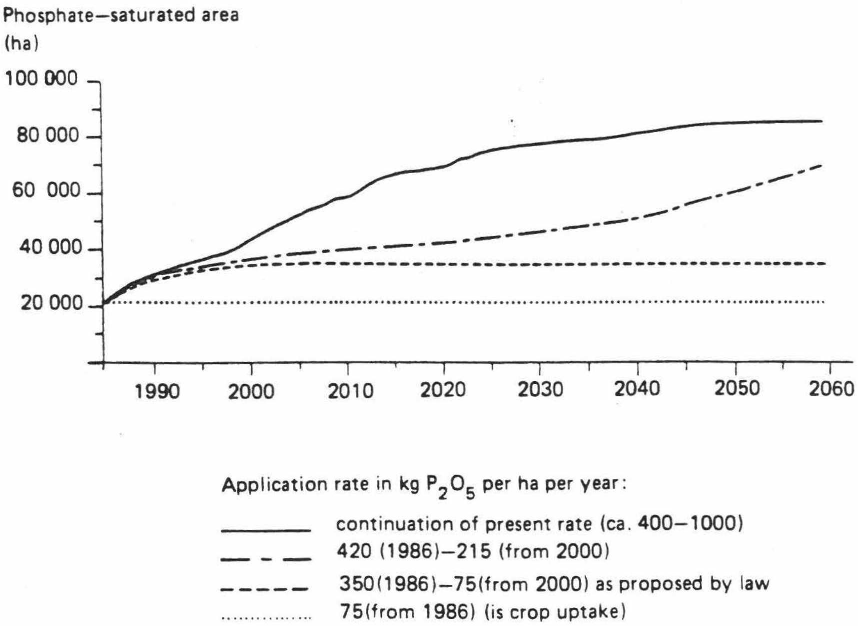

Figure 4.16. Long-term extension of the area of phosphate-saturated maize land in the Netherlands for four scenarios of phosphate application. (Source: Breeuwsma and Schoumans, 1987.)

phosphorus application rates are assumed to continue (Behrendt, 1988). Currently, most European soils are not phosphate-saturated, the main exception being some 20,000 ha of farmland in the Netherlands, where large quantities of manure are applied (see *Figure 4.16*). However, over a time scale of decades to a century, the top 1 to 2 metres of agricultural soils in these countries could become saturated.

Once phosphorus is released, eutrophication of streams and lakes becomes a real threat. (In 1984–1985, over 3.5 million tons of phosphorus were applied as fertilizers in Europe, as compared with 0.7 million tons as detergents.) The most vulnerable soils are those with low phosphorus adsorption capacities and high water tables.

The phosphorus cycle of forest ecosystems is currently well balanced, so a conversion of farm land to forest would be advantageous for soils vulnerable to phosphate leaching. However, if crop yields in the remaining farm land were to be increased to maintain overall agricultural productivity, increased inputs of phosphorus may result, leading to even more rapid saturation (Behrendt, 1988).

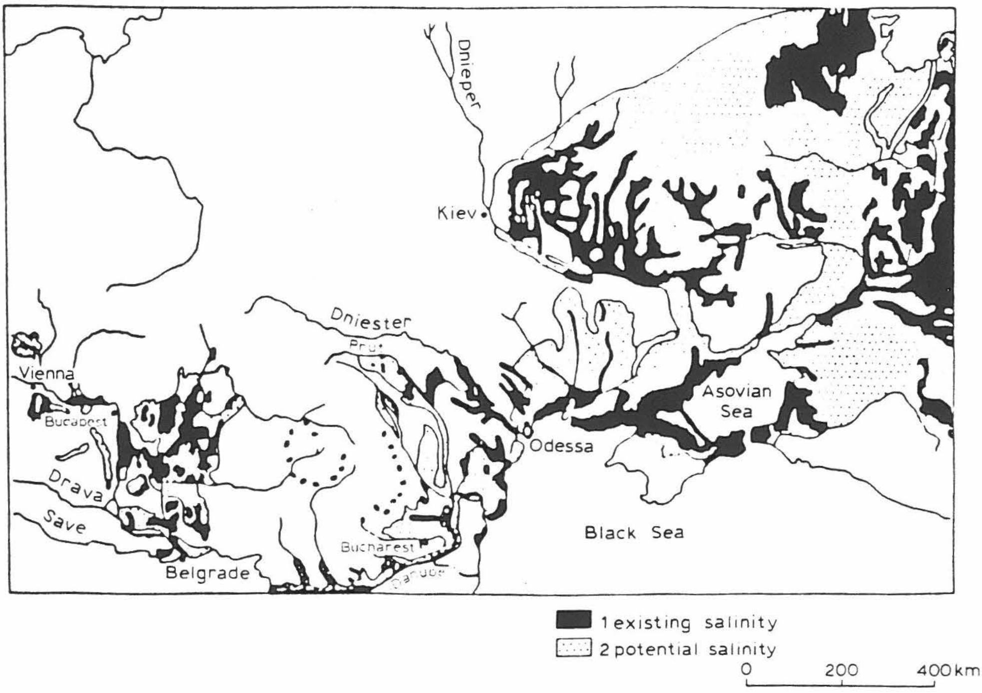

Figure 4.17. Salt-affected soils and potential soil salinity as consequence of extended irrigation (Szabolcs, 1988).

4.4.4. Soil salinization

Soil salinity results in a decrease in agricultural productivity. More than three quarters of the salt-affected soils in Europe occur in Hungary, Spain and the USSR, but parts of Austria, Bulgaria, Czechoslovakia, France, Greece, Romania and Yugoslavia are also affected. Soil salinity is closely related to the salinity of groundwater, thus causing a problem for irrigation and drinking water. In theory, soil salinization can be prevented through appropriate water management techniques. However, if such measures are not taken in Europe, some *not-impossible turning points* for salinization are:

(1) Soil salinization of some fertile agricultural areas around the river basins of the Danube, Brut, Dnieper, Don and Volga (*Figure 4.17*) if there is further extension of irrigation in these regions with semi-arid climatic conditions.
(2) An extension of soil salinity in the Mediterranean region into the river basins of the Tejo, Ebro, Po and Rhone (*Figure 4.18*) due to warmer and drier summers and increasing use of irrigation.
(3) Intrusion of salt water into groundwater in the coastal lowlands of Northwest Europe (*Figure 4.19*) due to a rise in sea level.

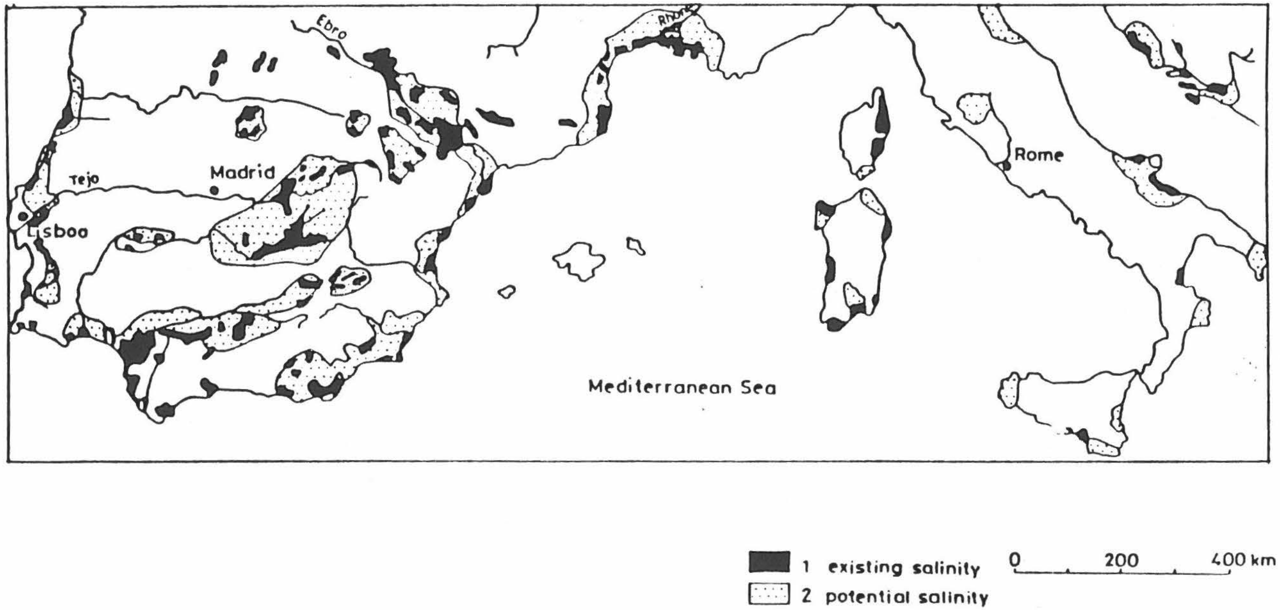

Figure 4.18. Salt-affected soils and potential salinity as consequence of climatic change (Szabolcs, 1988).

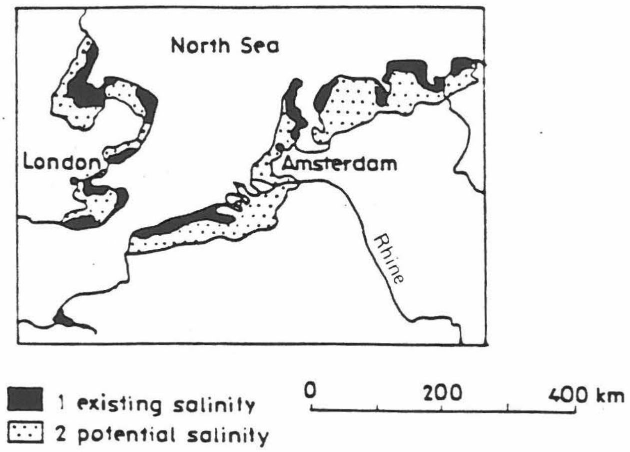

Figure 4.19. Salt-affected soils and potential salinity as consequence of sea level rise (Szabolcs, 1988).

4.4.5. Soil erosion

(a) Northwest Europe

The loess soils of cultivated land in Northwest Europe are highly vulnerable to erosion, the magnitude and frequency of rainfall events between April and August being critical. However, although climatic change may result in increased rainfall, as shown in ***Figure 4.6***, the tendency toward increased erosion may be offset by a longer period of protective vegetative cover (due to a longer growing season), and more active soil fauna which will help to maintain the integrity of the soils. Hence, the extent of soil erosion is not expected to increase significantly from climatic changes. Furthermore, soil erosion may be controlled by conservation and minimum tillage (De Ploey, 1988) as well as by crop rotation systems. Also new technologies are being developed to improve the physical properties of the soils by synthetic polymers (Imeson, 1988).

(b) The Mediterranean Region

In the countries bordering the Mediterranean Sea, there is potential for an increase in erosion due to climatic change, mainly because soil structure in this region is more easily destabilized than in Northwest Europe. The extent of soil erosion might increase here either directly by a decrease in organic matter levels or indirectly through changes in vegetation and land use (such as cultivation of land on slopes or after the occurrence of forest fires).

(c) The Alpine Region

Soil erosion occurs in Alpine regions, causing landslides and mudslides. With increased recreational use, and forest decline due to air pollution and climate warming, a plausible scenario is that soil erosion problems will intensify.

4.5. Water Quality

4.5.1. Acidification of lakes in Fennoscandia

Using the IIASA RAINS model for given sulphur emission scenarios, the percentage of lakes in each of several regions in Norway, Sweden and Finland, whose pH falls within specified ranges, can be estimated. The resulting distributions for turning point scenario (a) in *Figure 4.9*, in which nuclear power is phased out, are shown in *Figure 4.20*. As in *Figures 4.13* and *4.14*, the distributions are compared with those from the "conventional wisdom" scenario. It can be seen that the model predicts changes of only a few percent in the distributions resulting from the relatively large changes (positive and negative) in the turning point scenario.*

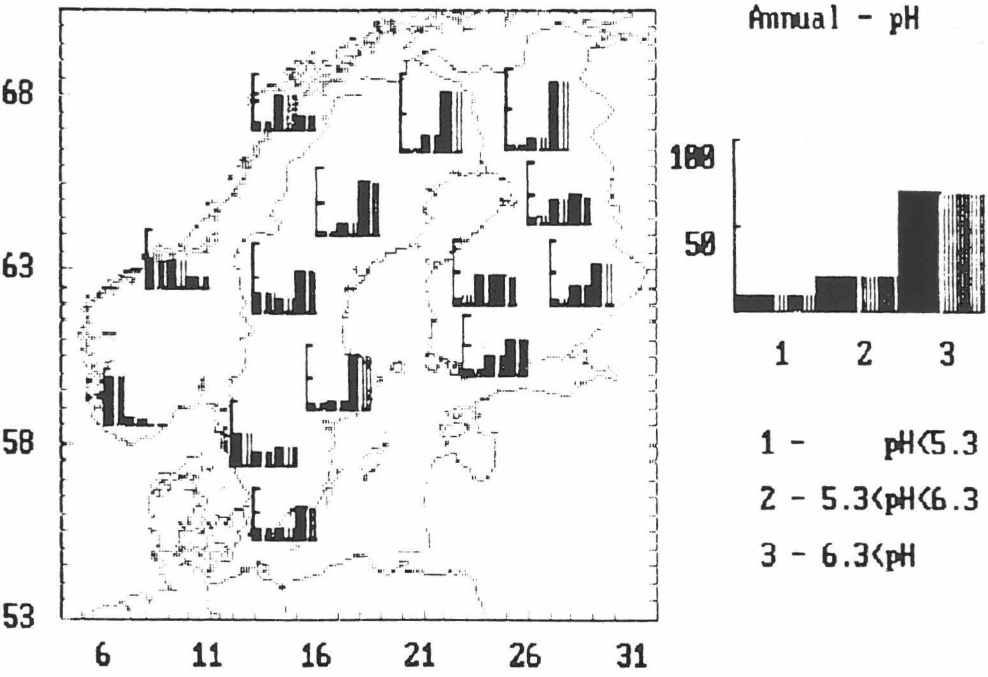

Figure 4.20. RAINS model prediction of the percentage of lakes within Fennoscandia in the year 2030 within the specified pH ranges for two scenarios: the "conventional wisdom" scenario (dark histogram) and the phaseout of nuclear power (striped histogram).

Similarly small changes were found in the case of turning point (c/d) in *Figure 4.9*, in which the energy system is based upon natural gas or hydrogen (results not displayed). Nevertheless, one may observe that about 10% of the

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* There are several possible reasons: (a) The buffering capacities of lake/watershed systems are already so low that future changes in deposition have little overall effect upon them. (b) The histograms emphasize the most sensitive lakes, i.e., those with pH values less than 5.3. It should also be noted that currently the RAINS model does not treat acidification resulting from nitrogen deposition.

lakes would have a pH < 5.3. At these pH values alkalinity is not available in the lake to neutralize acidifying deposition.

4.5.2. Eutrophication

As indicated in Section 4.4.3, the area of farmland saturated with phosphorus may increase, posing a future eutrophication threat for ground and surface waters.

Rates of eutrophication may increase with increasing temperatures (R. Wollast, Free University of Brussels, personal communication, 1986). The turning points for climate warming (see Sections 4.1 and 4.2) therefore imply that eutrophication rates may increase significantly.

4.5.3. Anoxia and the accumulation and release of toxic materials in estuaries and coastal areas

Overfertilization of coastal waters is already causing episodes of oxygen depletion, fish suffocation and H_2S generation; see, for example, Schroder (1985). Particularly in the Baltic and Adriatic Seas, these episodes are expected to become more frequent due to greater runoff of nutrients from increasing use of fertilizers, and in the Adriatic and Black Seas due to increasingly inadequate sewage systems as a result of the rising numbers of tourists in coastal resorts.

The sediments of many European rivers, estuaries and coastal waters are already contaminated with heavy metals and other toxic materials. A plausible scenario for the next 50 years is that toxic discharges into these water bodies will decline. Nevertheless, the sediments have the potential to release the toxic materials accumulated over past decades. Under conditions of anoxia, the mobilization of certain toxic materials is repressed: as the oxygen levels in the water increase, these materials may become more water-soluble (Stigliani, 1988). Thus, ironically, a reduction of runoff from nitrate fertilizers, and an improvement of sewage treatment (both of which tend to increase the oxygen supply of receiving waters), may trigger a release of these metals, causing a new wave of toxic effects. The effects may be amplified by sea level rise, if this phenomenon is accompanied by mechanical disturbance of the sediments.

4.5.4. Changes in wetlands

Freshwater wetlands serve an important role in the cycling of major chemical pollutants such as sulphate, nitrate, and toxic materials. Because they provide an anoxic medium, they may chemically transform chemicals that flow through them. Riparian wetlands serve to buffer adjacent rivers from nitrogen runoff from agricultural activities (Pinay and DeCamps, 1988). In areas of high atmospheric sulphur deposition, wetlands also store sulphur as insoluble sulphides.

Important turning points for wetlands are associated with climatic turning points, viz., an increase in temperature throughout Europe, an increase in precipitation in Northern Europe and a decrease in Southern Europe, and a rise in sea level. These changes would lead to:

- A drying out of freshwater wetlands in Southern Europe. Rivers previously protected by adjacent wetlands would experience a new wave of nitrate inputs; stored sulphur would also be released, causing new episodes of sulphuric acid leaching (Stigliani, 1988).
- Creation of brackish wetlands in coastal zones. These wetlands may, in fact, protect coastal marine environments somewhat by effectively storing heavy metals and other toxic materials as insoluble sulphide precipitates. However, if these areas are reclaimed through drainage works and the construction of dikes, there is likely to be a release of the stored materials as the lands become oxygenated.

4.6. Biota

4.6.1. Forests*

Plausible scenarios for net annual increment (NAI) and annual fellings for the forests of Europe were presented in *Figure 3.5.* Here we look at factors that could send these variables on quite different paths. These factors include:

(a) Forest dieback mainly due to air pollution (*Figure 4.21*). The annual decline in forest volume in many European countries may eventually exceed the annual fellings by 5 to 10 times (Nilsson and Duinker, 1987).
(b) Extinction of the boreal forest due to rapid climate warming (Jäger, 1988).
(c) Breakthroughs in genetics and tree breeding (*Figure 4.22*).
(d) Increased demand for recreation and protection forests (*Figure 4.23*).
(e) Large-scale conversion of agricultural land to forests (*Figure 4.24*).
(f) Significant increases in processing capacity in the pulp-and-paper industry (*Figure 4.25*).

The resulting *not-impossible turning points* shown in *Figures 4.21* to *4.25* are as follows:

- A European wood-supply shortage developing over the long term, as a result of forest decline and increased demand for non-wood forest uses (recreation and environmental protection).
- The wood-supply shortage being resolved or postponed by 20–50 years, due to large-scale conversion of agricultural land, genetic breakthroughs and/or substitution of non-wood materials.

* This subsection was contributed by P. Duinker, Environment Program, IIASA.

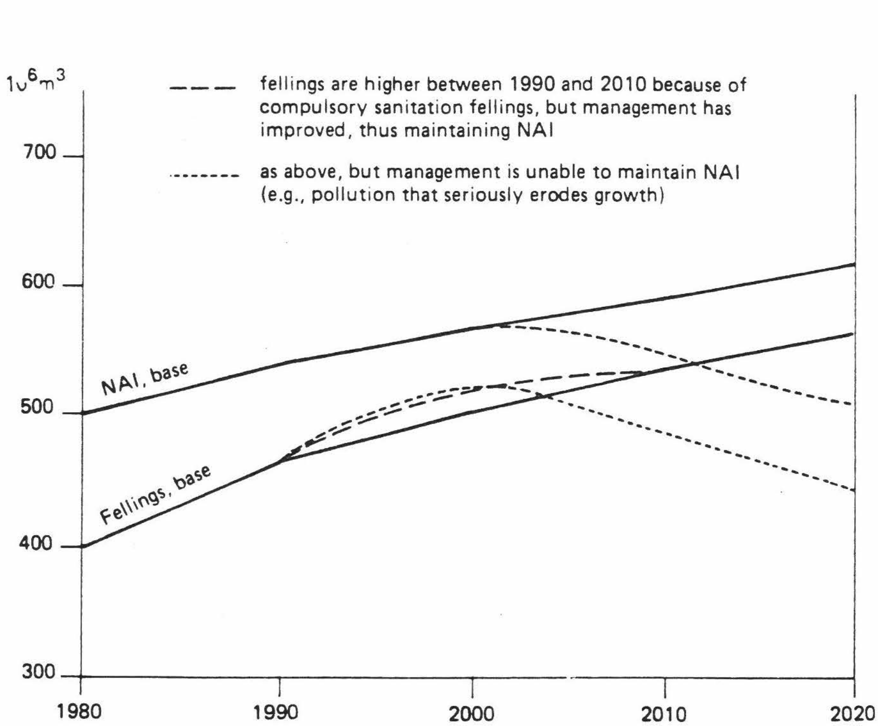

Figure 4.21. Turning points for annual forest fellings and net annual increments resulting from forest dieback.

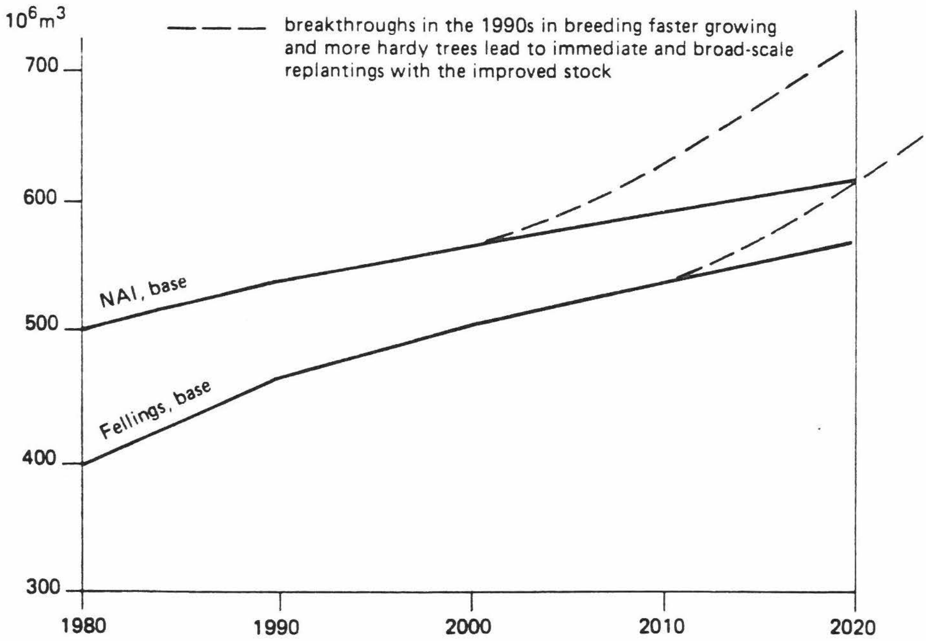

Figure 4.22. Turning points for annual forest fellings and net annual increments resulting from breakthroughs in genetics and tree breeding.

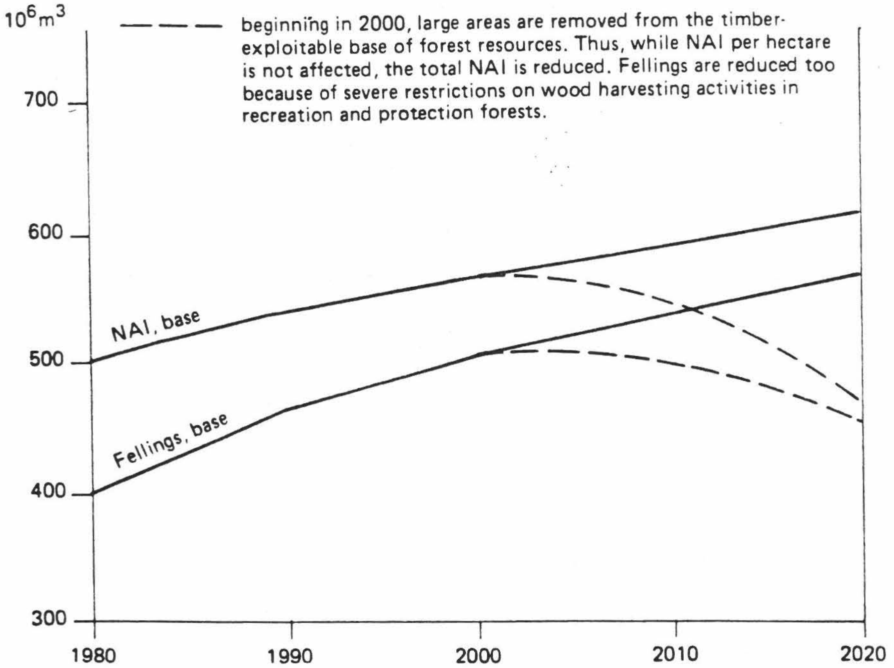

Figure 4.23. Turning points for annual forest fellings and net annual increments resulting from increased demand for recreational and protection forests.

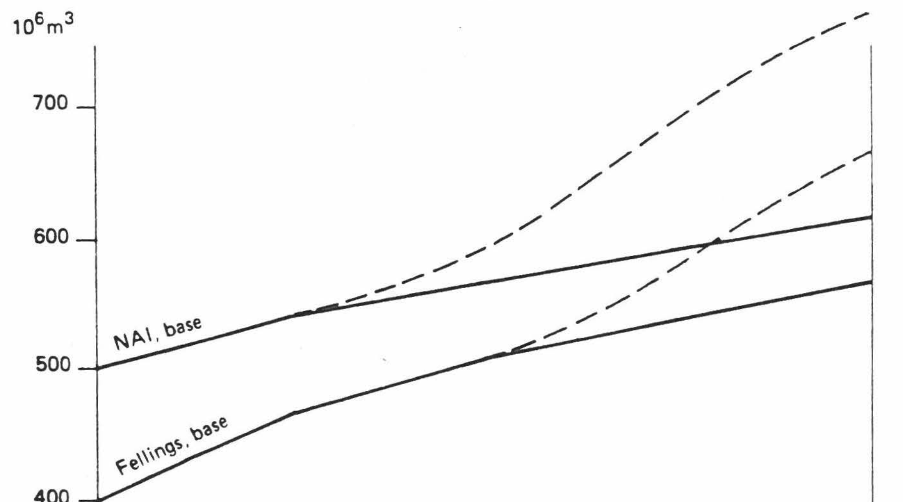

Figure 4.24. Turning points for annual forest fellings and net annual increments resulting from large-scale transformation of agricultural land to forest.

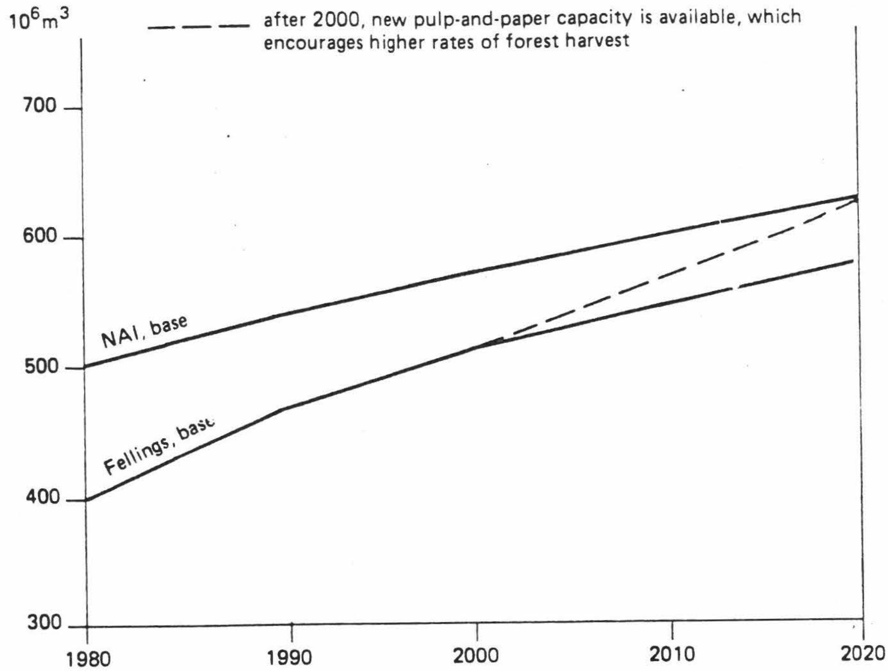

Figure 4.25. Turning point for annual forest fellings resulting from significant increases in processing capacity in the pulp-and-paper industry.

- A wood-supply shortage occurring as early as 2015, due to greatly increased demand for forest products and a collapse in overseas supplies of wood and wood products.

These turning points have economic consequences, which in turn affect the state of the European forests. See Kornai (1988) for a description of a simulation model that could be used to explore the various policy dilemmas resulting from these turning points.

4.6.2. Species diversity

Species diversity has decreased in Europe over the last 50 years, and many species of flora and fauna are on endangered lists. Of the approximately 11,000 vascular plant species in Europe, for example, 1400 were considered to be endangered in 1977, and 277 were believed to be especially vulnerable; by 1982, the number in the latter category had increased to 344 (ECE, 1988a).

There are several reasons for this situation:

- Loss and fragmentation of habitats.

- Environmental pollution, including acidic deposition and widespread use of pesticides and herbicides.
- Invasion of competing species and biological pests.

Climate change over the next 50 years will place additional stresses on biota. Some examples include (Anonymous, 1988; De Groot, 1988):

- Sea level rise will cause drowning of many coastal marshes.
- Shifting of natural vegetation zones, e.g., decline of the boreal forest, will lead to a loss of food and habitat for many species.
- Major warming in the Arctic and Subarctic will significantly affect the hatching patterns and food supplies of Arctic shore birds.
- Climate change will affect migration patterns and could favour biological invasions. (This might lead, for example, to increasing use of pesticides and herbicides.)
- Species confined to nature reserves are likely to be particularly vulnerable to climate change.

Scenarios and turning points for species diversity will not be given. This is because ecosystem models are not sufficiently advanced to provide simulations of changes in climate and other factors. Nevertheless, there is at least qualitative recognition that changes in species diversity will occur in the next 50 years, and that some of these changes might be profound and economically disruptive.

4.7. Land Use

Land use changes are caused by human activities, including socioeconomic and geopolitical development, and environmental factors. Environmental changes will have major implications for land use changes since they might set limits to resource use options or create new opportunities.

Urbanization/industrialization/transportation

No major changes are expected except in coastal lowlands of Europe which include great estuaries with important industrial harbours and rich agricultural land. These areas are at risk because of the projected sea level rise, which could lead to major restructuring of the urban fabric.

Recreation

Intensive year-round development of the coasts of the Mediterranean, as well as those of Portugal, the Bay of Biscay and the Black Sea are expected. Some further development of summer recreational facilities will occur in mountain areas.

Agriculture

(1) *Technological changes:* Technological advances, especially those associated with genetic engineering, are likely to result in the potential for large shifts in the critical limits for a whole range of crops currently used in European agriculture and horticulture, and to a lesser extent for forest crops as well, over the next decades.

(2) *Changes in policies:* The level of agricultural subsidies (including the growth of biomass) will determine future land use patterns to a large extent. For example, under present levels of subsidization, there might be by the year 2000 a need for an additional 6–23 million ha of land for the EEC-10; on the other hand if all subsidies were withdrawn, there would be a surplus of about 35 million ha (Lee, 1988).

(3) *Climate changes:* Land use boundaries are likely to shift in response to climatic change that imposes new geographical limits on plant growth, with a shift of 5–7° in a northerly direction. *Figure 4.26* gives some indication of this for selected crops (Brouwer and Chadwick, 1988). The potential northern shift of the boundary for sugar beet, winter wheat, spring barley and potatoes could mean that approximately 18–20 million ha of present-day forest land in Northern Europe (the northern boreal forest) could be cleared for the growth of some of these crops. In Southern Europe (Mediterranean area and bordering the Black Sea) it would most probably no longer be feasible to grow perennial tree crop products (citrus fruits and olives) successfully and a switch would take place to such crops as cotton (and possibly rice) under irrigation. This is due to a limitation on crop growth in parts of the Mediterranean with the southerly boundary shifting 3–5° N. Between these two extremes, significant shifts in cropping regimes would be possible. Also to be mentioned are the loss of rich agricultural land that would result from a rise in sea level, and a shift of alpine agriculture from pasture to the growth of crops such as vegetables, fruits, wine and tobacco (Hekstra, 1988).

(4) *Changes in farming practice:* In the future land use for agricultural purposes may be affected by more stringent regulations to reduce the leaching losses of nutrients and pesticides to ground and surface waters. In principle there are three options, i.e., (i) decrease the intensity of chemical inputs, (ii) change the use of land by different cropping systems such as a crop rotation with cereal growth, leaving ploughed land unsown, and (iii) establish special restrictions on using chemical fertilizers and pesticides by policy instruments (such as taxes). Brink (1988) has concluded that a decrease in the intensity of land use would be most favourable for reducing leaching.

(5) *Net changes:* As a *not-impossible turning point*, less intensive agricultural activities will result in reduced yields. In order to maintain overall production, more land would be needed to compensate for reduced yields per hectare. As another turning point, climate warming could lead to clearance of large tracts of land not currently devoted to agriculture, to enable new crop varieties to be exploited. More likely, however, net agricultural land use

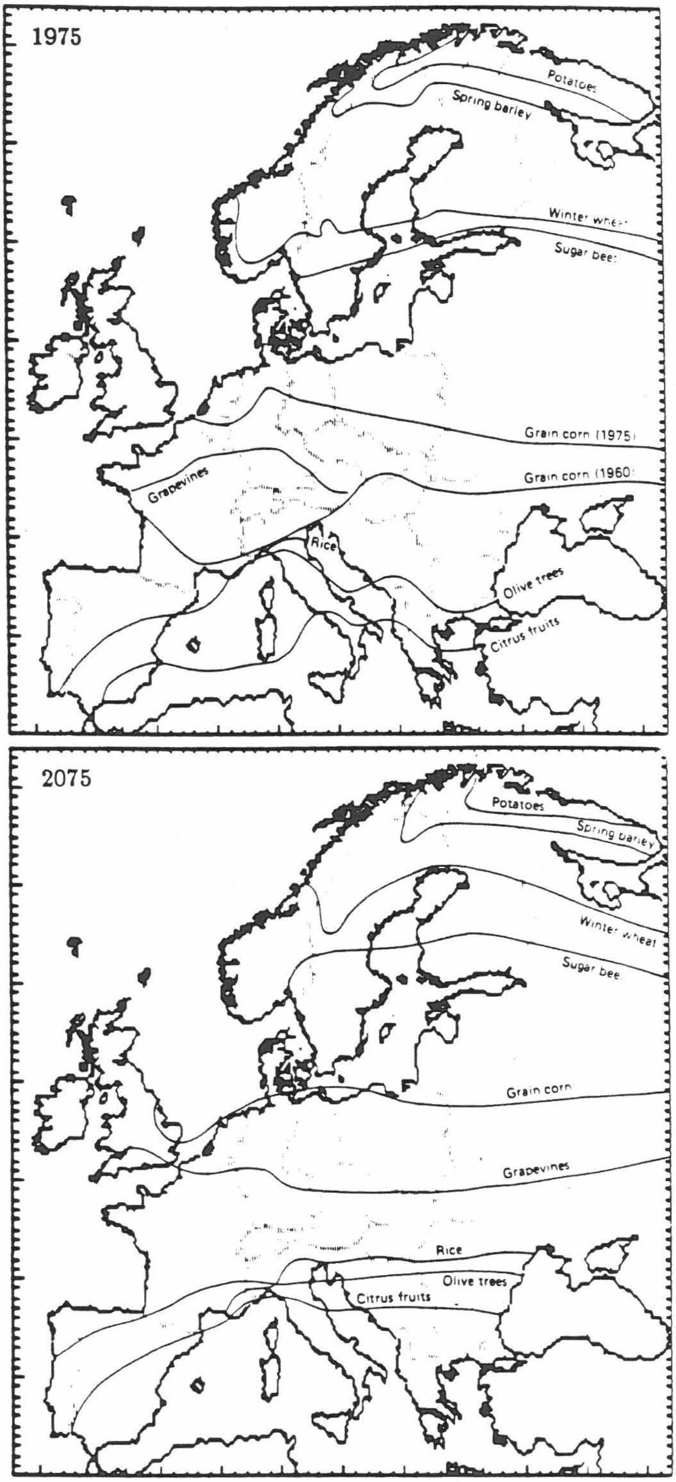

Figure 4.26. Northern cropping boundaries in Europe for 1975 (Andreae, 1981) and 2075. Note the northward shifts of these boundaries.

changes will be small due to over-production with respect to demand. Another factor working against an expansion of agricultural land will be the development of new crop varieties allowing yields per unit hectare to continue to increase.

4.8. Internal Consistency Amongst Scenarios

The scenarios and turning points described in Sections 3 and 4 are reasonably consistent with one another. Without attempting to demonstrate this in detail, it may nevertheless be useful to mention some of the most important interactions. These are of two types:

(a) Those resulting from changes initiated globally (e.g., increases in global CO_2 or methane emissions) leading to global environmental changes (e.g., in climate or sea level) causing European environmental, geopolitical and socioeconomic changes.
(b) Those initiated in Europe (e.g., changes in sulphur or NO_x emissions) leading to European environmental, geopolitical and socioeconomic changes.

As an example of Type (a), turning point scenarios for climate warming would lead to:

- A decrease in heating degree days and of winter energy consumption.
- An increase in summer air conditioning demands, and of summer energy consumption.
- An increase in summer evapotranspiration, reducing river flows and causing impacts on hydroelectric power production, inland navigation, water quality and industrial water supplies.
- Longer ice-free summers in northern seas, lakes and rivers.
- Longer growing seasons in northern regions.
- An increase in eutrophication of water bodies.
- A drying up of freshwater wetlands in Southern Europe, causing a new wave of nitrate inputs to adjacent rivers; also causing sulphuric acid leaching.

As an example of Type (b), the turning point scenarios for sulphur deposition in the case of a move away from nuclear power would lead to:

- An increase in the areal extent of regions where target loadings are exceeded.
- An increase in the areal extent of forest decline.
- An increase in the number of acidified lakes and rivers.
- Realization of the not-impossible turning points in *Figure 4.21* concerning net annual increment and annual fellings for the forests of Europe.
- A reduction in species diversity in currently forested areas in Europe and in acidified lakes.

5. Policy Dilemmas and Policy Exercises

5.1. Policy Dilemmas

Environmental problems are intimately linked to socioeconomic activities, and solutions involve complex trade-offs between economic, social, and scientific considerations. Often there are no easy solutions, and policy makers are confronted with the dilemma of choosing from a set of policy options, none of which is appealing for a number of reasons, e.g., high scientific uncertainty, high-stake economic and political risks, potential for social upheaval. Below are some dilemmas of importance in strategic planning for the long-term ecological and economic sustainability of Europe. They are based on discussions with senior European policy advisors and environmental scientists participating in our various workshops.

5.1.1. Managing water resources in an era of climatic change

Typically, water management policies consider foreseeable consumption changes but assume that the climate, although undergoing considerable year-to-year variation, will not change over the long term. In the construction of new reservoirs, for example, it is assumed that basin precipitation over the last 30 years is representative of future conditions. However, how would a significant change in water availability affect such policies? The question is problematic because scientists cannot estimate with any degree of precision, how global climatic change will affect water availability at the water basin scale. Yet reservoirs, dams, municipal water works and flood-control systems are built to last at least 50 years. In our scenarios, water shortfalls are hypothesized to develop in Central and Southern Europe, with water surpluses in Scandinavia; see Section 4.2.2.

The dilemma is therefore whether, and in what ways, to introduce long-term policies containing costly safety factors, given the uncertainties in current projections of water availability.

5.1.2. The acidification of soils and lakes in Europe

As discussed in Section 4.4.1, even considering the planned reductions in emissions of sulphur dioxide in Europe by 1993, Central Europe will still be threatened by widespread and continuing soil acidification. By 2030, about 40% of the forest soils in this region could have pH values less than 4 (Alcamo *et al.*, 1987). In such a scenario, these soils would no longer support productive forests and lakes.

The solution to this crisis is to reduce emissions even more than planned, and this would require intergovernmental action. But large emissions in some countries, primarily in Eastern Europe, cannot reasonably be expected to decrease substantially in the next 30 years unless there is a substantial transfer of funds from Western to Eastern Europe for this purpose, or if there is a change in the industrial structure of Eastern Europe. Another option is to increase energy efficiency dramatically, but efforts to implement this strategy in the past have largely failed. A final option would be to switch from fossil fuel to nuclear power. In a post-Chernobyl world, this option may no longer be viable. The dilemma then is to find a mix of acceptable options, given the technological, economic and political constraints involved.

5.1.3. Long-term forestry management and the possibility of a shortfall in the wood supply

There is currently an oversupply of harvestable wood in Europe. Even with this relative abundance, Europe imports 30% of its wood to fulfill demand. But some possible combination of factors may cause a severe wood shortage. The current over-supply is expected to peak around 2010. During the same period the European demand for paper pulp is expected to increase by 150%. In order to meet its demand, Europe may have to import even more wood than in previous decades. But working against this need could be a drastic reduction, on a global scale, of harvestable wood owing to an unprecedented trend in global deforestation, especially in the developing countries. This situation may lead to a critical global shortage by the year 2030. If Europe wishes to be self-sufficient by that time, a decision to plant new forests will have to be made in the next decade or so. Extra land may have to be set aside for forest plantations, and decisions will have to be made about which lands should be designated for this purpose. Moreover, future productivity of European forests is already quite uncertain, since (as discussed in Section 4.6.1) forest decline may continue.

The problem here is somewhat similar to that of water resources. It is difficult to mobilize the key institutional, private and public-sector actors required to implement a long-term forest resources policy at a time when there is no current crisis, and where there is uncertainty about future wood supplies.

5.1.4. Areas of Europe marginalized by mainstream economic and agricultural development

In general terms, changing patterns of economic development in Europe leave some areas economically deprived. Such a situation is currently occurring in two economic sectors – marginal agricultural areas and former centres of heavy industry. The emerging problem is that while productive areas provide a source of tax revenues, some of which may be used for the maintenance of the land, abandoned lands provide no such revenues, and outside sources of funding will have to be allocated to maintain them. A less expensive option is simply to neglect the lands. For the latter choice, however, potentially serious environmental problems may arise.

In the EC countries, there are current discussions for reducing farm lands by as much as 20%. However, the soils in these abandoned lands will experience large chemical changes, owing to the cessation of large man-made inputs of fertilizers, lime, and pesticides. This change could cause large perturbations in the environment including the leaching of toxic materials, and changes in the flow of nutrients to water bodies (Stigliani, 1988). Other problems could occur, including the disappearance of landscapes (important for the tourist industry), and increased risks of landslides, avalanches and floods.

Regarding the abandonment of heavy industry, as noted in a recent EC study (Haines and Joyce, 1987), future plant closures may constitute major sources of land contamination, as old plants with large stores of buried toxic materials are left unattended.

5.1.5. Coastal problems

An environmental change that may have a very great impact on European coastal areas is a significant sea level rise, say of approximately 0.5 to 1.0m. Although the time-horizon of sea level rise may be relatively long term, perhaps half a century or more, the dilemma to policy makers will occur over the short term. Most elements of urban systems – dikes, buildings, roads, toxic waste dumps, sewage systems, etc. – are renewed or replaced on a timescale of decades to a century. This means that current planning decisions may affect the development of coastal cities for decades into the future. The question is whether these decisions should take potential sea level rise into account?

This problem may be most severe along the Mediterranean coast, because of potentially large increases in population. Beginning in 1992 among the EC countries, national borders are expected to become more open and citizens may be allowed to resettle without restriction. Thus, for example, retired people from Northern Europe may move to the Mediterranean area. In addition, tourism may expand owing to large numbers of retirees, increased life expectancy, and more leisure time because of a shorter work week.

Whereas the problem of sea level rise is on the timescale of several decades or more, other kinds of environmental degradation may occur over the short term. The question is whether coastal areas have, or will have, adequate facilities to accommodate large increases in population? If not, there could be rapid environmental degradation. Already on the Adriatic coast and elsewhere in Southern Europe, untreated sewage discharged directly into the sea during the summer tourist season is one of the most serious local environmental problems. Towns with say 20,000 inhabitants in the winter, may have 50,000 inhabitants in the summer, and existing sewage treatment facilities are inadequate. Construction of sewage treatment plants is expensive, and many areas of the Mediterranean have lagged behind the rest of Europe in making the necessary investments. Other requirements for accommodating the increased populations such as roads, and adequate land-fill space for solid waste disposal may also be lacking.

Although large coastal cities may have a significant tax base and an in-place institutional apparatus for implementing protective measures, smaller towns with recently expanded populations may not have sufficient resources. Losses in property damage and costs of new or expanded pollution treatment facilities may devastate local economies.

Here again there is a problem of tradeoffs between very costly protective measures versus the even more costly impacts that might ensue, taking account of the uncertainty in future projections.

5.1.6. Toxic materials build-up: the potential for chemical time bombs

There are many possibilities in the environment for the accumulation and sudden release of harmful man-made chemicals. Moreover, such releases may come as surprises to the public and policy makers alike, and by the time that they are recognized, it may be too late to avoid much of the damage. Ideally, what is needed are long-term, broad-scale research, testing, and monitoring programs for identifying potentially harmful chemicals and anticipating their potential accumulations before they actually occur. Current strategies are usually inadequate since they are designed to examine and monitor chemicals whose sources are well known, e.g., nitrate, sulphate, etc. But there are chemicals present in the environment for which there is little available information on source strengths. Past experience has demonstrated that it has generally been very difficult to secure funding for long-term monitoring programs that focus on new chemical substances whose environmental pathways and toxicities are not well known. This dilemma is described in more detail in Section 5.3.

5.1.7. Non-point-source emissions of potentially toxic substances

Studies of pollution sources in the Hudson river basin in the USA show that in recent years, pollution from urban and agricultural runoff outweigh emissions from point sources such as industrial plants and sewage treatment facilities (Ayres and Rod, 1986; Rohmann and Lilienthal, 1987). In fact, for the eleven toxic materials studied, the emissions from non-point sources were several orders of magnitude higher than from point sources in most cases. This probably reflects the effectiveness of environmental regulations in controlling industrial and other fixed-point emissions.

If this trend is also emerging in Europe, an entire new strategy will need to be developed to cope with toxic materials. Many of the toxics are released during use or disposal by the consumer, individually in very small quantities, but the cumulative long-term build-up may be large. This applies to packaging materials, lubricants, solvents, flocculants, anti-freezes, detergents, soaps, bleaches and cleaning agents, dyes, paints and pigments, most paper, cosmetics, pharmaceuticals, fertilizers, pesticides, herbicides and germicides, and so on. Emissions of potentially toxic substances from such materials are extremely difficult to regulate. A major problem is that with a few notable exceptions, a detailed book keeping of the flow of hazardous chemicals through the industrial economy is not available, especially after the products leave the production phase and enter the commercial and consumer-use phase (Ayres *et al.*, 1989; Norberg-Bohm *et al.*, 1988). Another problem is to develop an effective strategy for reducing emissions. Two possible approaches are the promotion of alternative environmentally "friendly" products, and implementation of extensive recycling programs.

5.1.8. Controlling global emissions of CO_2

For global-scale issues, Europe is a comparatively small region. Can European societies adopt policies to influence global phenomena, or are they condemned to endure global change passively, only mitigating it when possible with adaptive policies? A global convention on greenhouse gases is one possibility. The history of conventions on acid rain and chlorofluorocarbon gases suggests that it takes about two decades to reach international consensus. Even if a convention to regulate CO_2 emissions were signed, say in the year 2010, it is not at all clear that the agreement would be effective for at least another 25-50 years, particularly in the Third World. One dilemma then is how to speed up the global response to this urgent issue. Another dilemma is how to cope with climate change brought about by large increases in fossil fuel consumption in other continents, even if Europe has managed to reduce its emissions of CO_2. (There are of course other global issues such as stratospheric ozone depletion, which should also be considered.)

5.1.9. Transportation needs versus air quality

A large increase in passenger and freight travel, particularly for cars, trucks, and airplanes is expected in the coming decades.* Since by that time, however, supplies of clean oils may be relatively scarce, clean liquid fuels for transportation may be prohibitively expensive, and choices may have to be made between environmental concerns and meeting the demands for transport. Thus, emissions from mobile sources may become the major source of air pollution, especially in the case of air travel, which may double in Europe within the next 30 years.

Even if abundant and relatively cheap liquid or gaseous fuels were to become available, the problem of NO_x emissions as a by-product of high temperature combustion may not be solved. Current models suggest that tropospheric ozone resulting from NO_x emissions by aircraft may increase considerably (Brühl and Crutzen, 1988).

Another option to alleviate the transportation problem is to use high speed hydrogen burning aircraft which fly in the stratosphere for intercontinental flights. However, a global fleet of such planes would emit large quantities of water vapor, the environmental effects of which are currently unknown.

* It has recently been estimated that there will be 36 million cars on British roads in the year 2020, compared with 21 million in 1988 (The Times, November 9, 1988).

5.1.10. Urban and suburban land development

In the future, the use of European land may become more socially, economically, and politically interdependent, resulting in more spatial and temporal integration than has occurred in the past. This trend may result in more broad-scale specification of land for certain uses. The problem is, however, that some land uses, which may be attractive from the standpoint of short-term economic gain, may be irreversible, at least on a time scale of three to four generations. Urbanization is one such use. Suburban sprawl has occurred in the vicinity of all major European cities, often destroying fertile farm land and nature reserves.

In contrast, some argue that in fairness to future generations, land use policies should foster the preservation of the environment, natural resources, and the multi-functionality of land. However desirable these goals might be, implementation of such a policy would require, in the next decades, a turning point in public support for the way societies use the land. Currently, there is probably not enough social acceptance for prohibiting lucrative land use activities that might impinge on the interests of future generations.

5.1.11. Increasing summer demand for electricity, and the impact on air quality

In North America as far north as New York State, energy consumption is greater in summer than in winter, because of the widespread use of air conditioners in offices, houses, automobiles, etc. This is not the case in Europe where peak energy loads occur in winter. However a not-impossible scenario is that:

- European life styles will change and air conditioning will become socially important.
- Demand for air conditioning will increase as climate warming causes an increase in the frequency and intensity of summer heat waves.
- In addition, many citizens of Northern Europe will retire in the Mediterranean area, where heat waves are more common than in their homelands.
- Summer energy loads will increase during these heat waves leading to peaks in NO_x emissions from power stations, and massive large-scale oxidant episodes, as well as an increase in the acidity of rain.

With respect to policy formulation, this potential crisis could be prevented if measures are introduced soon. These measures could include more stringent NO_x controls than currently envisaged on power stations, disincentives for buying air conditioners, and development for more energy efficient air conditioners. The dilemma is how to place this issue on the current environmental agenda for Europe.

5.2. Methods of Formulating Long-Term Environmental Policy

There is general agreement that standard means for factoring scientific information into long-term strategies for managing the environment are inadequate. One major problem with the policy dilemmas described above is the huge information gaps in scientific knowledge that currently preclude the development of rigorous, quantitative analyses for predicting environmental change. Moreover, for the information that is available, we do not yet know how to use it optimally in the formulation of prudent policies that both protect the environment and foster economic development. Another perhaps more fundamental problem is that currently, there is no established mechanism by which scientists and senior policy people can exchange ideas on the long-term management of the environment in a way that produces new, useful information. As a result, policy makers are often disappointed by the lack of "policy relevance" in much of the scientific research, and scientists are often discouraged because their research appears to have no impact on public policy.

As noted by Brewer (1986), the two common means of science/policy synthesis, "Blue Ribbon" panels and large-scale computer simulation models for environment-economic analysis, although quite useful in some contexts, are less so for analyzing long-term, broad-scale ecological changes. Blue Ribbon panels are particularly suited for reaching consensus on complex but well-bounded scientific questions. However, the policy aspects, if any, are often overlooked or treated naively.

Large-scale environment-economic models are hindered by the sheer complexity (and non-linearity) of real world phenomena. Wack (1985a,b) has noted that planning based on mathematical forecasts can be reasonably accurate during relatively stable time periods. But precisely for that reason, models fail when they are most needed: in anticipating fundamental changes that require a new way of thinking about and planning for the future. Another important point raised by Beck (1983) is that the need for personal judgement is not eliminated by models. Indeed, if models are used merely to provide "answers", then the decision maker has in effect abdicated much of his power to the model builders.

Both Wack and Beck have argued forcefully for a "scenario" approach to managing an uncertain future. They note that the role of scenarios is to enhance the decision makers' understanding of the future by providing perceptions of several possible future environments against which decisions can be tested. The goal is not to predict the future, but rather to manage the present, learning to live with uncertainty, to factor it into the decision process, and to build bridges between decision makers and scientists.

Advocating such an approach in no way reduces the value of modelling. On the contrary, the complexities of the real world are such that without some assistance in organizing this complexity, decision makers are increasingly helpless and forced to make decisions without any real idea of their consequences. The distinction, however, is that the models must be judged not against the criterion of how accurately they can reveal actual future trajectories, but on how useful they are in enhancing the knowledge and understanding of decision makers by exploring the dynamic consequences of some of the complex assumptions.

Scenarios and computer simulations are important building blocks in our approach to long-term policy formulation. But the central foundation is the so-called *policy-exercise*, whose methodological framework has been developed within IIASA's Environment Program over the last three years (Brewer, 1986; Toth, 1986, 1988). The method utilizes alternative scenarios of possible future European environments as the centre-piece for structuring appropriate policy responses. Senior environmental scientists and policy makers are confronted with scenarios dealing with a specific environmental problem posed as a "policy dilemma". The full time-span of the scenarios is not revealed initially. Rather, the scenario is presented in "time slices" (say 2005, 2015, 2025). At each time, the participants are asked to describe policies for appropriate management of the environment. The suitability of the policies are then tested as the future events in the scenario unfold. In fact, the future evolves partly in response to the succession of policy moves made by the participants. Moreover, the participants are invited not only to participate in the exercise, but also, if they wish, to challenge the validity of the scenario presented. However, the challenger must then defend his or her vision of the future. Such interplay is encouraged to ensure that the scenarios challenge the decision maker's preconceived ideas about what *will* happen, and accordingly may teach managers to think in terms of an *uncertain* future.

The objective of a policy exercise is not to develop a firm set of environmental policies for the next 50 years but:

(1) To sensitize policy makers to uncertainties due to natural and human factors and to alert them to the possibility that some of their current policies, even though well intended, may lead to disastrous consequences over the long term.
(2) To train policy people in how to use adaptive management strategies, which are continually updated as new information is received.
(3) To convince policy people of the need for regular "policy exercises" with scientists, as a preferred method of setting environmental agendas and priorities.

5.3. An Illustrative Example: Toxic Materials Build-Up – the Potential for Chemical Time Bombs

"Toxic Materials Build-Up – the Potential for Chemical Time Bombs" was one of the dilemmas investigated in IIASA's Policy Exercise Workshop, held on June 17–18, 1988 in Baden, Austria.* The brief description of this dilemma given in Section 5.1.6 will be elaborated here to illustrate the usefulness of the policy exercise approach.

* The authors are indebted to Prof. J.-P. Vanderborght, Free University of Brussels, for his assistance in preparing this simulation.

The goal of this particular exercise was to assess the effectiveness of current or new management strategies in protecting ecological systems from the build-up and surprising release of toxic materials. Methods were sought by which institutions, technologies, and research and monitoring efforts could play a significant role in anticipating potential problems before they actually occur.

The first part of the exercise was a simulation of the sudden releases of an unknown toxic chemical on three occasions, separated in time but linked by a common cause. Participants were asked to develop strategies for mitigating the effects of the chemical. The second part of the exercise was a critical evaluation of the strategies proposed during the simulation, and recommendation of other strategies that, in hindsight, may have been more effective.

Initially, the exercise focused on a small geographical area, namely a coastal region in the Po River basin, Italy. A specific setting was selected in order to provide realism and a tractable spatial scale. However, the conclusions drawn address the general question of chemical "time-bombs" and what to do about them.

A panel of four participants tried to mimic the responses of local health authorities to these events. To begin, the year was 2020, and the panel was confronted with a sudden and mysterious fish kill in a small estuarine tributary of the Po (designated hereafter as Event A). The Panel's first task was to develop an appropriate action plan. The effectiveness with which the proposed plan could provide early warning of further episodes was tested against a second episode, which occurred six years later and farther upstream (Event B). In similar fashion the effectiveness of the second action plan was tested against a third episode occurring even farther away, in a large area north of the Black Sea (Event C). The simulation ended at this point.

Table 5.1 provides relevant background information on the environmental conditions in the area prior to 2020. This information was provided to the Panel at the beginning of the exercise. *Table 5.2* discusses the three episodes of toxic poisoning in 2020, 2026, and 2030. This information was made available to the Panel in sequence, and only after they had responded to the preceding event. *Table 5.3* describes the causes of the three events. This information was not given to the Panel. *Table 5.4* presents a summary of the Panel's responses to the events as they unfolded.

As can be seen, the Panel's responses were not atypical and were not particularly effective. What actions should have been taken? This was the subject of lively discussion, which led to the following suggestions:

(1) Better early warning monitoring systems (see Section 6 below, in which some of the proposals have been incorporated).
(2) Historical reconstructions of episodes of chemical poisoning in other regions, including assessments of strategies that ought to have been adopted.
(3) Particularly in the case of episodes that have some curious or unexplained features, detailed biogeochemical assessments (the problem may seem to go away – but it may reappear somewhere else at some future time).

Table 5.1. Hypothesized environmental conditions in the tributary of the Po River before event A.

A major clean-up of the discharges to the tributary from point-source pollutants was accomplished by 2000, and no episodes of fish kills had been reported since then. Although continuous monitoring had not been conducted, water quality generally appeared to have been excellent. Farming, the principal use of land in the basin of the tributary, had remained at a constant level for decades, with no major changes in chemical inputs to the land.

Table 5.2. Scenarios.

Event A:	Fish kills reported in small tributary of the Po near the Adriatic coast in June 2020.
Event B:	A second episode of fish kills covering a more extended area upstream of the first event occurred in 2026.
Event C:	A third and more extensive episode of fish kills occurred in 2030 in an extensive agricultural region in the USSR north of the Black Sea.

Table 5.3. Causes of the events: a not-impossible scenario.

- A pesticide, XB-10, had been used for over two decades in all the affected regions. However, no environmental problems had occurred prior to 2020. The pesticide is highly toxic, but laboratory tests showed it to be immobilized in soils so that leaching to ground and surface waters did not occur. Its decomposition products are leached from soils, but these are not environmentally harmful. In 1995, XB-10 was approved as "environmentally safe" under the EC Directive requiring pre-market testing of new pesticides.
- Although immobilized in soils under normal conditions, XB-10 is leached rapidly from salinized soils. The salt ions compete with the pesticide for absorption sites on soil particles, resulting in the desorption of the pesticide molecules and their leaching to aquatic systems.
- Event A was caused by a series of severe coastal floods by which salt waters from the Adriatic Sea permeated into an agricultural area heavily contaminated by XB-10. The cause of the flooding was a slight rise in sea level in the Adriatic Sea.
- Event B was caused by more extensive sea level rise. Salinization was caused by direct flooding of the soils bordering the river and by salt water intrusion into groundwaters which were subsequently used for irrigation.
- Event C was caused not by sea level rise, but by a great increase in irrigation for intensive agricultural production (see *Figure 4.17*). The groundwaters in this region are quite salty, and soils under heavy irrigation were susceptible to salinization.

Table 5.4. Summary of panel's responses to events.

Event A:	*Response*: (1) River water, fish tissue and biological organisms analyzed. *Results*: (1) Unknown chemical agent found in fish tissue and plants. (2) Agent identified after six weeks as residue of XB-10. *Follow-up Actions*: (1) Fish tissue monitored and "bioprobe" experiments conducted. (2) Other health agencies in the area notified. (3) XB-10 not banned; there was insufficient evidence. The episode appeared to be an isolated event. *Key Factor not Addressed*: (1) No information on how the chemical suddenly appeared in fish after two decades of use.
Event B:	*Response*: (1) Call for a ban of XB-10. (2) Soil conditions investigated in affected areas. *Results*: (1) Connection made between sea level rise, salinization, and increased mobility of the pesticide. (2) XB-10 banned in EC. *Follow-Up Actions*: (1) Long-term monitoring program established in the river basin. (2) Warning issued to families not to drink from public water supplies until clearance given by health officials.
Event C:	*Response*: (1) Connection is made to irrigation as a cause of salinization and subsequent leaching of XB-10, but it is too late to mitigate most of the damages. End of simulation.

(4) Following from (3), an international "incidents registry" should be established, the goal being to foster close collaboration amongst environmental agencies across Europe, exchanging information routinely on the environmental release of toxic chemicals.

(5) More rigorous standards for premarket testing of potentially toxic substances such as the hypothetical XB-10, including assessment of mobility in changed physical and chemical environments.

(6) Establishment of source inventories and environmental pathways in Europe for each such substance.

(7) Creation of incentives for the development of new technologies, including bioengineering, for treating contaminated soils, and groundwater.

6. Early Warning Monitoring Systems*

6.1. Introduction

In order to respond appropriately to a wide array of policy dilemmas, two questions should be asked:

(1) Can warning of an undesirable environmental trend be obtained in sufficient time to affect policy decisions?
(2) Even if sufficient warning is obtainable, can a policy be formulated (and implemented) to reverse or slow down the trend, or to mitigate the impacts?

In this Section, we deal with the first question. In Section 7, we shall consider the array of policy dilemmas in terms of their "manageability", assuming that early warning is indeed available.

6.2. A Conceptual Framework

Many kinds of environmental monitoring systems are operating in Europe today: see Appendix C for a list of some of the principal ones. However, a major problem encountered when trying to detect change in geophysical or ecological time-series is the natural variability in the environment. By the time a trend has been identified and found to be statistically significant, it is often too late to affect policy decisions, except at extremely high costs to society.

Recognizing that environmental problems are generally caused by socioeconomic activities, a better approach is to seek to locate the earliest point in a cause-effect chain that can be used as an early warning indicator. For example, it is important to identify new technologies that will ultimately release significant amounts of a toxic substance into the environment, either as an industrial waste or subsequently through end-use disposal (e.g., chlorofluorocarbons in spray cans). It is often not possible to penetrate far enough back into the cause-effect chain to find an appropriate socioeconomic indicator (e.g., in the case of multiple causes, or cumulative small impacts which have already compromised the future to a certain extent).** However, there may be intermediate points in cause-effect chains where biogeophysical monitoring could provide at least a suggestion that change is imminent. For example, following Broecker's theory that climate warming would cause a southward deflection of the Gulf Stream, an early warning indicator is the salinity profile in the Atlantic Ocean south of Greenland (Broecker, 1987).

The implication of this line of reasoning is that there is a continuing need for: (1) models capturing the linkages between socioeconomic factors and environmental changes; and (2) assessments of the environmental impacts of new

* The basic framework for this Section was developed at a Think Tank held at IIASA August 4-5, 1988.

** But see Section 6.3.

technologies, regulations, policies, operational procedures and cultural shifts. *Figure 6.1* provides a conceptual framework for these ideas.

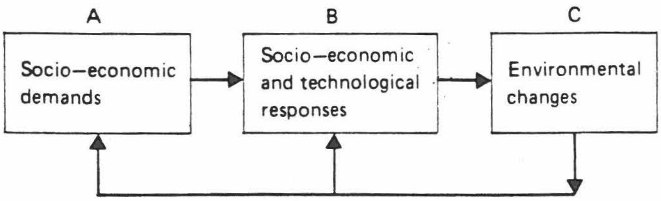

Figure 6.1. A conceptual framework for an early-warning monitoring system. The elements to be monitored should include not only environmental parameters but also selected indicators from Box B and if possible from Box A. In order for the system to be useful, the linkages between the boxes and the feedbacks should be captured in appropriate models.

6.3. Some General Principles

The design of an early warning monitoring system is problem-specific and also depends very much on the scenarios developed (including not-impossible futures). It is therefore difficult to provide more than some tentative suggestions on the nature of such a system. There are, however, some general principles that may be helpful:

(1) The probability of rapid changes in an environmental system increases with increasing rates of change in the socioeconomic driving variables and/or in the environmental components. The usual management practice of trying to maintain steady-state conditions in the face of external change leads to a reduction in resilience and imposes additional stress on the system.

(2) Most socioeconomic/environmental systems contain some variables that respond more quickly and/or to a greater degree than do others to external stress factors. But root-mean-square fluctuations about a trend-line may be much larger for some of these variables than for others. It is therefore important to estimate the stress-response characteristics and the statistical properties of the main variables of the system. Only then can the best early-warning indicators be selected. See, for example, Wigley and Jones (1981), where it is shown that climate warming is more likely to be revealed in middle latitudes in summer, even though the warming will be greatest at high latitudes in autumn and winter.

(3) Some socioeconomic changes cause greater environmental stresses than do others. One should therefore begin by trying to attempt to quantify the stress-response relations, selecting those that give the greatest impact per unit of change in the socioeconomic variables.

(4) An appropriate spatial scale to consider in an early warning system is that of a catchment area, which is easily disturbed by both natural and

anthropogenic processes but which is sufficiently large to remove some of the noise surrounding the signal. Of course, political and/or socioeconomic boundaries may not correspond to those of the catchment area, creating design problems for the monitoring systems. Of the various types of catchment areas available for study, large semi-closed ones will be particularly useful. The Caspian Sea is one example, where freshwater flow has been declining since the 1930s, partly due to the increasing use of irrigation. The Caspian Sea is in fact particularly suitable as an outdoor laboratory for joint monitoring of environmental and socioeconomic factors (Antonovsky *et al.*, 1988).

(5) Cumulative small disturbances operating over the last 50 years or so may already have compromised the future environment. The goal of an early warning system is then to provide an estimate of when the system might become economically non-profitable or might even collapse ecologically. As a first step towards constructing an early warning system for such applications, an inventory of relevant historical data should be prepared. This should be supplemented with indirect indicators of past conditions, e.g., pollution emission factors such as amounts of coal mined, lead smelted, etc. Here the ***materials-balance approach*** will be particularly useful. [See Ayres and Rod (1986) and this report, Section 9.1.2.]

6.4. Some Candidate Early Warning Indicators of Environmental Change

Some early warning indicators of environmental change in Europe are suggested below. In each case, the indicator will need to be elaborated, in collaboration with potential users of such information. Particular attention will have to be paid to temporal and spatial resolutions.

(1) *Energy*: consumption; efficiency; percentage use of each type of energy system; summer/winter ratios of consumption; emission inventories; development of new technologies for pollution emission controls.

(2) *Water quantity*: supply (separately for each major source type); consumption by main users; consumption per US$1000 of GNP.*

(3) *Natural renewable resources* (both terrestrial and aquatic): loss of habitats; competition for food or space; nutrient losses and gains; buffering capacities of soils and lakes; oxygen depletion in lakes and seas; lime applications to acidifying lakes, forests and agricultural land; accumulation of toxic substances; output of production per unit of resources (including energy) used (Tolba, 1986); imports and exports of natural resources and products.

(4) *Managed renewable resources*: harvests (quantity and types); nutrient losses; accumulation of toxic substances; fertilizer, pesticide and herbicide sales; imports and exports of primary and processed foods. See *Table 6.1*

* Current values are estimated to be 146, 75, 90 and 44 m^3 for Poland, Czechoslovakia, GDR and FRG, respectively, for example (Kindler, 1988).

(Huffman, 1987) for some early warning indicators of "trouble ahead" in the agricultural sector. In the four categories given in *Table 6.1*, system sustainability is probably most important, although most difficult to quantify.

(5) *Pollution control equipment*: fact sheets on technological developments and assessments of their potential; installation of air pollution control equipment and construction of sewage treatment plants; installation of recycling systems; fact sheets on community recycling programs; funds expended.

(6) *Land use*: changes in allocation amongst urban, industrial, agricultural, forest, recreation, transportation and special dedicated uses of land (e.g., military); rate of development of resort and retirement areas [see, for example, Manning (1988)].

Table 6.1. Indicators that could provide early warning of "trouble ahead" in the agricultural sector (Huffmann, 1987).

Physical Sustainability	Changes in topsoil depth, soil organic matter content, structure, texture, bulk density, compaction, buffering capacity, salt content, concentrations of toxic substances, slope steepness and length of slope, cropping practices and climate.
Economic Sustainability	Changes in farm incomes, debt/equity ratios, capital use efficiencies, employment rates.
Social Sustainability	Changes in self-satisfaction of farmers and farm workers, migration to cities.
System Sustainability	Changes in ability to withstand shocks such as droughts, floods, pest outbreaks, etc.

6.5. Some Examples

For some of the long-term environmental dilemmas discussed in Section 5, we can tentatively suggest some early warning monitoring strategies, ranking our ability to obtain such warnings for the array of dilemmas.

Example 1: Summer oxidant episodes (a simple case to analyze) (see Section 5.1.11)

Scenario: Increased severity and frequency of oxidant episodes in Southern and Central Europe due to increased use of air conditioning equipment, leading to increased energy consumption during summer heat waves and to increased emissions of NO_x from power stations. The problem could arise as a result of climate warming, changed life styles, or a combination of both.

Early warning indicators: Annual sales of air conditioners; summer energy consumption. (Note that data would be required for all of Central and Southern Europe.)

Example 2: Water shortages (see Section 5.1.1)

Scenario: Increased competition for water due to climate warming, with decreased rainfall in the southern half of Europe. There may be water "barriers" (Kindler, 1988) in some countries that will seriously hinder development.

Early warning indicators: Gross regional product (GRP) and water availability, together with a model relating the two. As an example, Jansson (1988) has described a study of water demand and supply on the island of Gotland (in the Baltic Sea), where regional economic development is subject to water constraints. There has been a decline in the reserves of fresh water since the middle of the last century, due to reduced groundwater recharge and increased surface runoff as a result of land drainage and reclamation. Using a rather detailed model, the relation shown in *Figure 6.2* was developed as a tool for policy analysis. At low levels of water availability, the food and cement industries, and the tourist sector on the island would be almost eliminated. So trends in GRP and water availability are appropriate early warning indicators of approaching water barriers. [Although water consumption is not expected to increase very much over Europe as a whole (see Section 4.2.2), there might be national exceptions, and this parameter should also be monitored.]

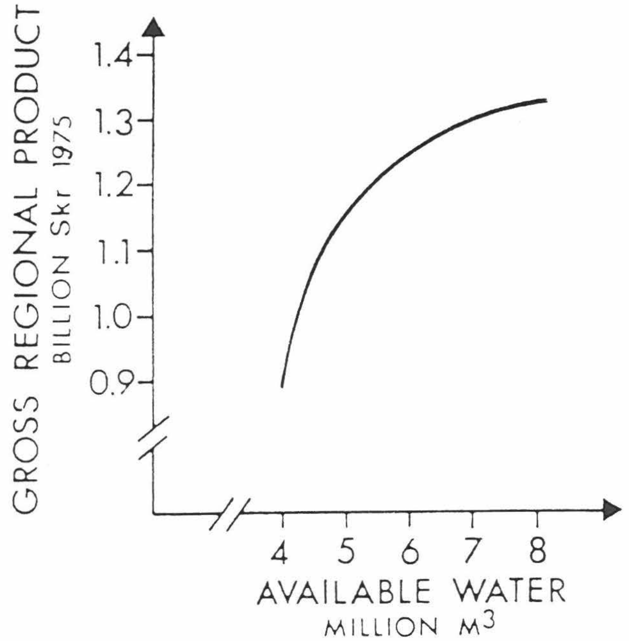

Figure 6.2. Gross regional product (GRP) versus available water for the island of Gotland in the Baltic, based on an ecological-economic model (Jansson, 1988).

Example 3: Soil acidification (see Section 5.1.2)

Scenario: Steady or even increasing emissions of SO_x and NO_x, causing increasing soil acidification.

Early warning indicators: First priority – annual emission inventories; regular monitoring of soil buffering capacity. (Note that pH is not a useful early warning indicator.)

Example 4: Wood supply shortfalls (see Section 5.1.3)

Scenario: Rapidly declining wood supply due to increased demand for wood, collapse in overseas supplies and decline of the European wood supply (due to tree age, air pollution and/or climate warming).

Early warning indicators: Imports and prices of wood and wood products from overseas; European wood demand; European wood supply (including tree ages, hectares of forest, net annual increment of standing stock). Note that declining imports, increasing wood demand, decreasing supply and declining recruitment of replacement trees would soon lead to a wood supply shortfall.

Example 5: Abandoned farm land (see Section 5.1.4)

Scenario: Farmland abandoned and neglected. Cessation of liming, leading to leaching of toxic substances and nutrients into water bodies. Wind erosion of soils in Southern Europe during dry spells. Increased risk of avalanches and mud slides in the case of abandoned alpine meadows.

Early warning indicators: Income per hectare of marginal farms; rate of abandonment of farm land; soil characteristics of such lands.

Example 6: Sea level rise (see Section 5.1.5)

Scenario: Sea level rise of 1 metre over a very few decades.

Early warning indicators: None available, although some intermediate warning would be given by local measurements of sea level and the salt content in groundwater, together with some general indicators of climate warming such as emissions of greenhouse gases and rises in the temperatures. Hydrographic models could be used to identify the coastal zones at greatest risk.

Example 7: Chemical time bombs (see Section 5.1.6)

Scenario: Changes in land use and climate, and slow continued accumulation of toxic materials in soils and sediments, despite decreasing emissions of these substances, increasing the potential for the release of chemical time bombs as described by Stigliani (1988).

Early warning indicators: An accurate, detailed accounting of the flows of hazardous chemicals through the industrial economy, based on the concept of Industrial Metabolism (see Ayres *et al.*, 1989). This entails a materials-balance approach which tracks pathways of chemicals from production and processing to end uses and disposal. Often, estimates of the accumulation of trace substances in the environment can be obtained more accurately by this method than by standard monitoring. In this connection, the direct emissions of potentially toxic substances from factories may not be so important in some cases as end-use disposals, e.g., lead batteries, CFCs in refrigerants.

It will also be of critical importance to monitor the chemical changes that regulate the main ecological storage capacities for toxics, e.g., buffering capacity, adsorption capacity, and redox potential (see Stigliani, 1988).

Example 8: The crisis in air traffic and the introduction of hydrogen-burning aircraft (see Section 5.1.9)

Scenario: A large increase in air travel, both inter-city within Europe and inter-continental, causing great stress on overloaded air-transport systems. A resulting increase in NO_x emissions and in tropospheric ozone (Brühl and Crutzen, 1988), exacerbating the summer oxidant episode issue discussed in Example 1. Also, development of a new technology for high-speed aircraft, flying in the stratosphere and burning hydrogen as fuel. But combustion of hydrogen, normally a clean technology in the troposphere, has unknown and possibly harmful consequences in the stratosphere.

Early warning indicators:

(a) For tropospheric ozone – aircraft traffic and NO_x emission data.
(b) For stratospheric effects – none available. Once research and development on hydrogen-burning aircraft is sufficiently far advanced, it will be difficult to prevent operational use. It is therefore important to maintain a close watch on engineering developments and to undertake concurrent assessments of the atmospheric impacts of such aircraft.

6.6. The Role of Models

A successful early warning monitoring system requires that the inter-relationships amongst socioeconomic and environmental processes be reasonably well understood. Sometimes the linkages between causes and effects are quite direct and the main question to be discussed is the speed with which the environment would respond to the postulated socioeconomic changes. The dilemma on summer oxidants is a good example.

Sometimes, however, the linkages between causes and effects are rather tenuous. For example, the scenarios shown in *Figure 4.7* reveal quite substantial differences in sea level rise for the 90, 50 and 10% probability cases. As pointed out by Jäger (1988), the uncertainties in these estimates are contributed about equally by uncertainties in future greenhouse-gas concentrations and in the resulting response of the climate system. In such cases, a monitoring system could not be designed that by itself would provide sufficient early warning to influence policy formulation. In such cases, model predictions themselves give the only early warning signals.

7. Some Plausible Environmental Consequences of Four Alternative Development Paths

7.1. Some Selected Development Paths

Reflecting on the information contained in the six previous sections, one could envisage a myriad of alternative development paths and environmental scenarios for Europe. Elaboration of these many pathways would not, however, be of any use to policy people, and a short list is essential. Future studies could explore other options of special interest to particular groups of people.

The development paths considered in this section are:

(1) *Present trends continuing in Europe and elsewhere*, i.e., slow economic growth and modest success in slowing down environmental change, implying moderate climatic warming by the year 2030 (i.e., greater than the changes given in *Figures 4.1* to *4.4*, but less than the changes shown in *Figures 4.5* and *4.6*, and a sea level rise of about 20 cm).

(2) *High-growth economy in Europe and elsewhere*, with continued economic expansion, and only lip-service being paid to the environment.* This development pathway implies strong climatic warming as shown in *Figures 4.5* and *4.6*, and a one-metre sea level rise by the year 2030.

(3) *An environmentally friendly economy in Europe and elsewhere.* There would be greater conservation and recycling of natural resources, energy efficiency, emission controls and similar environmentally friendly actions, as well as a significant reduction in emissions of greenhouse gases. This development pathway leads to only slight climatic warming by the year 2030, as shown in *Figures 4.1* to *4.4*, and minimal sea level rise.

(4) *An environmentally friendly economy in Europe but not elsewhere*, where there is high economic growth without adequate environmental protection, implying strong climate warming by 2030 as in pathway (2).

These four development pathways are sufficiently different (in terms of socioeconomic development trends) to provide useful comparisons of environmental consequences. Development pathway (4) raises the interesting question: "What if Europe becomes a good environmental housekeeper, but other parts of the world aim for high industrial growth without adequate environmental protection?" Also it should be emphasized that even in the case of the environmentally "best" development pathway (3), European sustainability over the long term is not necessarily guaranteed. This is a question that requires considerable additional research.

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* As noted in the Brundtland Commission Report (WCED, 1987), poverty is a major cause of environmental degradation, especially in the less developed countries. Hence, the assumption made here is that high economic growth and ecological sustainability are incompatible only when societies are not willing to enact the appropriate measures necessary for sustaining the environment.

The term *environmentally friendly* is not defined specifically. However, actions that would contribute to an environmentally friendly world are discussed in more detail in Section 8.2.

7.2. A Framework for Assessing the Seriousness of the Dilemmas

Even when the number of European development paths is limited to four, quite a few environmental components and indicators could be used in the assessment of each development option (see *Table 2.1*). Again a very short list is essential, particularly if development pathways are to be compared. In subsequent studies, the social consequences of various other combinations of the scenarios and turning points given in Section 4 could be usefully evaluated.

A good way to provide a focus for the assessment is to use the short list of dilemmas discussed in Section 5.* For each of these, the following characteristics of the hypothesized future conditions are important:

Factor	Explanatory remarks
(1) *Intensity*	Severity per unit area or unit population
(2) *Extent*	Spatial aspects
(3) *Preventability***	Is society willing and able to act soon enough to forestall or ameliorate the problem before it becomes serious?
• Early warning	Can the environmental problem be detected before the effects are manifested?
• Uncertainty	How certain are model predictions?
• Available technology	Are there technological means available to forestall or solve the problem?
• Cost	How expensive are the measures to counteract the problem?
• Social/political acceptability	Are there over-riding social or political barriers to overcome the problem?
(4) *Environmental Response Time*	Once society undertakes remedial measures, how long does it take the environment to recover (years, decades, centuries)?
(5) *Social Adaptability*	If the problem cannot be forestalled or solved, is society willing or able to adapt to the new conditions?

* The dilemma on controlling global emissions of CO_2 (Section 5.1.8) will be excluded because it is implicit in development pathways (2) and (4).

** A measure of the time scale required to mobilize societal responses to perceived environmental threats compared to the time period before the onset of the full manifestation of the effects.

Tables 7.1 to *7.4* show for each of the development paths an assessment of the seriousness of each characteristic with respect to each dilemma for the year 2030. In each cell of the tables, a number 1, 2, or 3 is assigned according to our assessment of seriousness; i.e.,

1: not serious
2: moderately serious
3: very serious.

A number for the factor ***Preventability*** is obtained as an arithmetic average of the five subfactors. The rationale is that all of these contribute to an overall assessment of whether or not society can or will react soon enough to forestall and/or ameliorate the problem. This is to be contrasted with the factor ***Environmental Response Time***, which is an indication of how soon the environment will react to measures once they have been undertaken. Obviously, an irreversible effect would have an infinite response time and would result in a seriousness value of 3.

It is important to note that the simplified scale of 1, 2, 3 was chosen because this assessment is of necessity qualitative in nature. A more finely-tuned scale, in our opinion, would have given a misleading impression of precision. Currently, no generally accepted quantitative methods exist for comparing the seriousness of widely different environmental problems. Thus, recent studies evaluating the relative seriousness of a range of environmental issues have employed a qualitative approach (Darmstadter *et al.*, 1987; EPA, 1987). As noted in the US EPA study (1987), the results of such qualitative analyses can be regarded as judgmentally correct and unlikely to be far wrong. That study further noted that for the purposes of priority setting, absolute precision is not mandatory. Rather, what is required is sufficient precision to allow comparative ranking. Such a qualitative approach is taken here, and we believe that the method is useful for the purpose of comparing the seriousness of the various dilemmas on a European-wide basis. For particular regions, concerns and priorities might be different, but our approach could easily be adapted to suit the needs of other assessments.

Tables 7.1 to *7.4* contain too much information to permit useful visual comparisons of the relative seriousness of various combinations of dilemmas and development pathways. However, they are included for reference, providing our best estimates of seriousness for each development path, dilemma and dilemma characteristic. In Section 7.3 the information is given in aggregated form.

Table 7.1. Development Pathway (1) for the year 2030: *Present Trends Continuing in Europe and Elsewhere.* The numbers 1, 2, 3 represent degree of seriousness from low to high, with respect to the impact characteristic being evaluated.

Dilemma	*Intensity*	*Extent*	*Preventability*						*Environmental response time*	*Adaptability of society*
			Early warning	*Uncertainty*	*Available technology*	*Costs*	*Social acceptability*	*Average value*		
Water management	2	2	(2)	(2)	(2)	(2)	(2)	2	2	2
Soil acidification	3	2	(3)	(1)	(1)	(3)	(2)	2	2	3
Forestry wood supply	2	1	(2)	(3)	(1)	(2)	(1)	2	2	2
Marginalized land	2	2	(2)	(1)	(1)	(2)	(2)	2	1	2
Coastal issues										
• Sea level	2	2	(2)	(3)	(2)	(2)	(2)	2	2	2
• Pollution	2	2	(2)	(1)	(2)	(2)	(2)	2	1	2
Chemical time bombs	2	1	(3)	(3)	(3)	(2)	(2)	3	3	2
Non-point toxics	2	1	(3)	(3)	(3)	(2)	(2)	3	3	2
Transport growth	3	3	(2)	(3)	(3)	(3)	(2)	3	3	3
Urbanization	1	1	(1)	(1)	(1)	(2)	(2)	1	1	1
Summer oxidant episodes	3	2	(1)	(2)	(2)	(2)	(2)	2	1	2

Table 7.2. Development Pathway (2) for the year 2030: *High-Growth Economy in Europe and Elsewhere* (with little concern for the environment). The numbers 1, 2, 3 represent degree of seriousness from low to high, with respect to the impact characteristic being evaluated.

			Preventability								
Dilemma	*Intensity*	*Extent*	*Early warning*	*Uncertainty*	*Available technology*	*Costs*	*Social acceptability*	*Average value*	*Environmental response time*	*Adaptability of society*
Water management	3	2	(2)	(3)	(2)	(3)	(2)	2	3	3
Soil acidification	3	3	(1)	(1)	(1)	(3)	(2)	2	3	3
Forestry wood supply	3	3	(2)	(3)	(3)	(3)	(3)	3	3	3
Marginalized land	2	3	(2)	(2)	(2)	(2)	(2)	2	2	2
Coastal issues										
• Sea level	3	2	(2)	(3)	(2)	(3)	(3)	3	3	3
• Pollution	3	2	(2)	(2)	(2)	(3)	(2)	2	2	2
Chemical time bombs	3	2	(3)	(3)	(3)	(3)	(3)	3	3	3
Non-point toxics	3	2	(3)	(3)	(3)	(3)	(3)	3	3	3
Transport growth	3	3	(3)	(3)	(3)	(3)	(3)	3	3	3
Urbanization	2	2	(1)	(2)	(2)	(2)	(3)	2	2	2
Summer oxidant episodes	3	3	(1)	(2)	(2)	(3)	(3)	2	2	3

Table 7.3. Development Pathway (3) for the year 2030: ***Environmentally Friendly Economy in Europe and Elsewhere.*** The numbers 1, 2, 3 represent degree of seriousness from low to high, with respect to the impact characteristic being evaluated.

Dilemma	*Intensity*	*Extent*	*Preventability*						*Environmental response time*	*Adaptability of society*
			Early warning	*Uncertainty*	*Available technology*	*Costs*	*Social acceptability*	*Average value*		
Water management	1	1	(1)	(2)	(1)	(1)	(1)	1	1	1
Soil acidification	1	1	(1)	(1)	(1)	(3)	(1)	1	1	1
Forestry wood supply	1	1	(1)	(2)	(1)	(2)	(1)	1	1	1
Marginalized land	1	1	(1)	(1)	(1)	(2)	(2)	1	1	2
Coastal issues										
• Sea level	1	1	(1)	(2)	(1)	(1)	(1)	1	1	1
• Pollution	1	1	(1)	(2)	(1)	(2)	(1)	1	1	1
Chemical time bombs	2	1	(2)	(2)	(1)	(3)	(1)	2	2	1
Non-point toxics	2	1	(2)	(2)	(1)	(2)	(1)	2	2	1
Transport growth	2	3	(1)	(2)	(2)	(3)	(1)	2	2	2
Urbanization	1	1	(1)	(1)	(1)	(2)	(2)	1	1	1
Summer oxidant episodes	1	1	(1)	(2)	(2)	(3)	(1)	2	1	1

Table 7.4. Development Pathway (4) for the year 2030: ***Environmentally Friendly Economy in Europe, but not Elsewhere.*** The numbers 1, 2, 3 represent degree of seriousness from low to high, with respect to the impact characteristic being evaluated.

Dilemma	*Intensity*	*Extent*	*Preventability*						*Environmental response time*	*Adaptability of society*
			Early warning	*Uncertainty*	*Available technology*	*Costs*	*Social acceptability*	*Average value*		
Water management	3	2	(2)	(3)	(2)	(3)	(2)	2	3	3
Soil acidification	1	1	(1)	(2)	(1)	(3)	(1)	2	1	1
Forestry wood supply	2	2	(2)	(3)	(2)	(3)	(2)	2	3	3
Marginalized land	2	3	(2)	(2)	(2)	(3)	(2)	2	2	2
Coastal issues										
• Sea level	3	2	(2)	(3)	(2)	(3)	(1)	2	3	3
• Pollution	1	1	(1)	(2)	(1)	(2)	(1)	1	2	2
Chemical time bombs	3	2	(3)	(3)	(2)	(3)	(1)	2	2	1
Non-point toxics	2	1	(2)	(2)	(1)	(2)	(1)	2	2	1
Transport growth	2	3	(2)	(2)	(2)	(3)	(1)	2	2	2
Urbanization	2	2	(1)	(2)	(1)	(3)	(2)	2	2	2
Summer oxidant episodes	2	2	(1)	(2)	(2)	(3)	(1)	2	1	2

7.3. Environmental Implications of Alternative Development Paths

7.3.1. Assessment of alternative pathways

Table 7.5 summarizes, for each combination of development pathway and dilemma given in *Tables 7.1* to *7.4*, our integrated assessment of seriousness for the year 2030. To obtain the numbers in *Table 7.5*, the numbers corresponding to the five factors in each row of each table were first summed. These summations resulted in "raw scores" with a possible range from 5 to 15. These were then converted to a scale of 1 to 3 as follows: 5-8 = 1; 9-11 = 2; 12-15 = 3. Both the "raw scores" and the smoothed values were used in the analyses in Section 7.3.2. Viewing *Table 7.5* across a row, one may observe how the ranking of a particular dilemma changes according to development path. Viewed vertically, one may observe the relative seriousness of each dilemma for a particular development pathway. Also listed are the relative rankings of the dilemmas in the 1980s. Each column is summed, providing an overall index of seriousness relative to the dilemmas for each development path. The minimum score, corresponding to the most favourable environment is 11. The maximum score, corresponding to the least favourable environment, is 33. The relatively low value (14) assigned to the 1980s' environment should not be interpreted as signifying that the current European environment is without major problems. Rather, it suggests that with respect to the dilemmas that we have chosen, the potential major consequences have yet to be experienced. In fact, the dilemmas were specifically chosen as problems for the future, rather than those that are currently fully manifested.

One may observe that relative to the 1980s, pathway (1) (*present trends continuing in Europe and elsewhere*) would lead to a somewhat more degraded environment in 2030, since all of the dilemmas except *urbanization* and *summer oxidant episodes* would become more serious. The dilemmas are somewhat tempered by only moderate European climate change.

Pathway (2) (*high-growth economy in Europe and elsewhere, but low environmental concern*) would lead to strong deterioration with respect to all dilemmas. Some of the degradation is related to specific European activities, which would cause increased consumption of natural resources, as well as increased chemical inputs to the environment. Broad-scale, strong climatic change creates problems related to *water management, sea level rise*, and *summer oxidant episodes*, and global deforestation affects *forestry wood supply*.

Pathway (3) (*environmentally friendly economy in Europe and elsewhere*) is the only one for which the dilemmas are largely solved, although the problem of *transport growth* would remain due to the rapid increase in demand in air travel.

Pathway (4) (*environmentally friendly economy in Europe, but not elsewhere*) is particularly interesting because it highlights the important question of the linkages of the European environment to the global environment. It thus represents the optimal degree to which Europe can protect its environment when high growth, non-sustainable development is occurring in the rest of the world.

Table 7.5. Ranking of dilemmas for the 1980s and according to development path for the year 2030. The numbers 1, 2, 3 represent degree of seriousness from low to high.

Dilemma	*1980s*	*Pathway (1) Present trends continuing (Europe and elsewhere)*	*Pathway (2) High-growth economy/low env. concern (Europe and elsewhere)*	*Pathway (3) Environmentally friendly economy (Europe and elsewhere)*	*Pathway (4) Environmentally friendly economy (Europe but not elsewhere)*
Water management	1	2	3	1	3
Soil acidification	2	3	3	1	1
Forestry wood supply	1	2	3	1	3
Marginalized land	1	2	2	1	2
Coastal issues • Sea level • Pollution	 1 1	 2 2	 3 2	 1 1	 3 1
Chemical time bombs	1	2	3	1	2
Non-point toxics	1	2	3	1	1
Transport growth	2	3	3	2	2
Urbanization	1	1	2	1	2
Summer oxidant episodes	2	2	3	1	2
Total	14	23	30	12	22

Compared to pathway (2), the worst-case scenario, one may observe that Europe definitely would benefit from an environmentally friendly pathway (seriousness score of 22 versus 30).

A final point that should be made with respect to *Table 7.5* concerns the near equivalence (23 versus 22) of the seriousness scores for pathways (1) and (4) (*present trends continuing in Europe and elsewhere* versus an *environmentally friendly economy in Europe but not elsewhere*). In both cases, serious problems arise by the year 2030 but they are different:

Pathway (1)
(moderate climate warming)

- *soil acidification*
- *transport growth*

Pathway (4)
(strong climate warming)

- *water management*
- *forestry wood supply*
- *sea level rise*

Hence it should not be construed from *Table 7.5* that pathways (1) and (4) are more or less equivalent with respect to overall environmental impact. In fact, if a fifth development path were envisaged (*present trends continuing in Europe, but with strong climate warming*), the number of "very serious" problems would be more than the three associated with pathway (4).

These findings strongly suggest that Europe should proceed quickly in implementing an environmentally friendly pathway of economic development. However, such a policy will not resolve many of the long-term environmental dilemmas facing Europe. As *Table 7.5* clearly shows, there is need to promote environmentally friendly strategies not only in Europe but also in the rest of the world. By way of example and through financial and technological incentives, Europe should assume a leadership role in this most important task.

7.3.2. Ordering the dilemmas

Two questions remain to be considered:

- Which dilemmas are most sensitive to the development pathway selected?
- Within each development path, which dilemmas are most serious?

Table 7.6 provides an answer to the first question.* As can be seen, *water management*, *soil acidification*, *forestry wood supply*, and *sea level rise* are most sensitive to the development path chosen. On the other hand, *transport growth* and *urbanization* are relatively insensitive to the development path selected.

* In the preparation of *Tables 7.6* and *7.7*, "raw scores" (ranging from 5 to 15) were used; see authors for details.

Table 7.6. Grouping of dilemmas with regard to their sensitivity to development path for the year 2030.

Relatively sensitive to development path
• Water management
• Soil acidification
• Forestry wood supply
• Sea level rise
Moderately sensitive to development path
• Marginalized land
• Coastal pollution
• Chemical time bombs
• Non-point toxics
• Summer oxidant episodes
Relatively insensitive to development path
• Transport growth
• Urbanization

Table 7.7 provides an answer to the second question, showing the dilemmas that ought to be of most concern for Europeans for each of the four development paths. The first remark to be made about this table is that the ordering of the dilemmas changes from one pathway to another, and this undoubtedly would cause problems in the formulation of policies expected to be robust over a range of development pathways. Secondly, the table reemphasizes a point made earlier, viz., that the seriousness of the environmental problems facing Europe in the year 2030 depends on two factors:

(1) Failure to take effective global actions to control greenhouse gases and deforestation [development paths (2), (4) and to some extent (1)], leading to serious European problems with respect to *water management, forestry wood supply* and *sea level rise.*
(2) Failure to take effective European actions to control local and regional environmental degradation [development paths (1) and (2)], leading to serious problems with respect to *soil acidification* and *transport growth.*

Pathway (2) is the worst, combining failures to take both global and European actions. This leads not only to the five problems listed above but also to three additional very serious ones: *chemical time bombs, non-point toxics* and *summer oxidant episodes.*

Finally, *Table 7.8* is included to emphasize the very important effects that strong climate warming would have on the European environment. Nearly all of the 11 dilemmas become more urgent to resolve with increasing probability of a major change in climate.

Table 7.7. Ranking of the dilemmas for the 1980s and for each development path for the year 2030.

Pathway	*Very serious*	*Moderately serious*	*Not serious*
1980s		Soil acidification Transport growth Summer oxidants	Water management Forestry wood supply Marginalized land Sea level Coastal pollution Chemical time bombs Non-point toxics Urbanization
Present trends continuing (Europe and elsewhere)	Soil acidification Transport growth	Water management Forestry wood supply Marginalized land Sea level Coastal pollution Chemical time bombs Non-point toxics Summer oxidants	Urbanization
High-growth economy/ low environ-mental concern (Europe and elsewhere)	Water management Soil acidification Forestry wood supply Sea level Chemical time bombs Non-point toxics Transport growth Summer oxidants	Marginalized land Coastal pollution Urbanization	
Environmentally friendly economy (Europe and elsewhere)		Transport growth	Water management Soil acidification Forestry wood supply Marginalized land Sea level Coastal pollution Chemical time bombs Non-point toxics Urbanization Summer oxidants
Environmentally friendly economy (Europe but not elsewhere)	Water management Forestry wood supply Sea level	Marginalized land Chemical time bombs Transport growth Urbanization Summer oxidants	Soil acidification Coastal pollution Non-point toxics

Table 7.8. Potential effects of a strong global climate warming on the European environment.

Dilemma	*Effect*
Water management	Large changes in water supply (both up and down)
Soil acidification	Changing weather patterns would change acid deposition patterns (worse conditions in some areas, better conditions in others)
Forestry wood supply	Increased temperatures, major changes in precipitation, seriously stressing boreal forests
Marginalized land	Some areas may become unsuitable for current uses, owing to salt water intrusions, latitudinal shifts in areas of optimal crop production, etc.
Coastal issues	Sea level rise causing soil and groundwater salinization; flooding of toxic waste dumps located near coasts
Chemical time bombs	Sea level rise mobilizing heavily polluted sediments with clean waters; drying of wetlands causes release of many toxic materials
Non-point toxics	Not greatly affected if recycling is effective
Transport growth	No specific direct effects
Urbanization	Current urban land use in coastal and alpine regions may not be suitable under changed climatic conditions
Summer oxidant episodes	Increases in NO_x owing to increased demand for electricity, especially in Southern Europe in summer for air-conditioning

8. Major Findings and General Recommendations on Policies Appropriate for Sustaining the European Environment

8.1. Major Findings

Based on the analyses presented in Section 7, the major findings of the study are:

Major Findings

- Because of the linkages between the European and global environments, sustaining the *European* environment in the 21st century cannot be fully achieved without sustaining the *global* environment.
- The continuation of present trends in economic development and environmental protection in Europe and elsewhere is not sufficient to prevent further deterioration of the European environment.
- High economic growth in Europe and elsewhere without adequate environmental protection accompanying such growth will lead to even more severe environmental problems.
- Environmentally friendly development in Europe offers the hope of mitigating local and regional-scale problems specific to Europe.
- But these actions, in and of themselves, cannot solve problems within Europe stemming from global scale changes. To accomplish the latter, the rest of the world must also follow environmentally friendly pathways.
- Thus, European nations should do all in their power to enact environmentally friendly development both in Europe and the rest of the world.

8.2. General Recommendations on Policies Appropriate for Sustaining the European Environment

8.2.1. Ecologically sustainable development as a conceptual framework for European environmental policy

Ecologically sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (WCED, 1987). This goal is one with which everyone can certainly agree. However, there is currently lack of clarity about how precisely to achieve it, although development pathway (3) in our analysis (*environmentally friendly economy in Europe and elsewhere*) appears to be approaching that goal. [See Turner (1988) and Munn (1988) for a more detailed discussion.]

The first pre-condition in the search for sustainable development is for European societies to recognize that many of the major environmental issues facing Europe are long-term (e.g., half a century), large-scale (continental to global), interconnected and, prone to surprises (chemical time bombs, for example).

The second pre-condition is that societies should develop a philosophy by which they are willing to sacrifice short-term gains (economic or otherwise) for the sake of long-term benefits to future generations. But this pre-condition can only be met if societies have sufficient information to recognize the need for sacrifice, and if governments provide institutional means (incentives, for example) to ensure that people feel that they are treated fairly. Within this framework, a number of general recommendations can be made.

8.2.2. Promotion of environmentally friendly development in Europe and the world

Europe. European societies must act to ensure that potential long-term, large-scale environmental problems are addressed today so that they will not worsen in the future. With respect to the dilemmas discussed in this study, *Table 8.1* lists examples of such actions.

The World. Within the various international forums available, European nations should use their influence to promote ecologically sustainable development in all parts of the world. This would include facilitation of the transfer of environmentally friendly technologies to the Third World and encouragement of actions such as those indicated in *Table 8.1.* Even as a matter of self-interest, Europe should set an example in the reduction of emissions of greenhouse gases and should encourage other regions to do likewise.

Table 8.1. Environmentally friendly mitigation actions.

Dilemma	*Action*
Water management	Public acceptance of water-conservation practices; development and implementation of water-saving technologies
Soil acidification	Large reductions in SO_x and NO_x emissions by implementation of cleaning technologies
Forestry wood supply	Reductions in ozone and acidity; long-term planning of timber harvest
Marginalized land	Program for soil protection and landscape preservation, reforestation, etc.
Coastal issues	Large reductions in runoff of N, P fertilizers; installation of sewage treatment plants
Chemical time bombs	Introduction of early-warning monitoring systems; research into factors causing sudden chemical releases; establishing an international "incidents registry"
Non-point toxics	Extensive recycling of commercial and domestic products; reduction of N, P fertilizer runoff; use of environmentally friendly products; integrated pest management in agriculture
Transport growth	Use of clean fuels and clean combustion technologies
Urbanization	Long-term land use planning with strong public support
Summer oxidant episodes	Large reductions in NO_x and hydrocarbon emissions; energy conservation

8.2.3. Recommendations to citizens

Above all, the public must become more environmentally conscious. Citizens must accept the stewardship of the environment as their personal responsibility. They must view ecological sustainability and its fulfillment as an obligation to future generations. Some of the not insignificant ways in which people can help include:

- Conservation of energy, water, and materials.
- Recycling of wastes.
- Selection of environmentally friendly products: those requiring minimum amounts of energy to produce and those whose end-uses or residues cause minimum environmental damage.
- Participation in consumer-related activities pertaining to environmental protection.

Before such a strong public commitment will occur, however, governments must strongly support environmental education programs that will sensitize the layman to the critical issues and motivate him to act. Another important governmental activity would be the provision of environmental information that permits citizens and the private sector to make environmentally sound decisions.

8.2.4. Recommendations to industry, agriculture, forestry and business

Industry, agriculture, forestry and business can contribute substantially to the promotion of sustainable development. That industry is aware of these opportunities is clear from recent publications such as WICEM (1984) and CONCAWE (1987). As noted by Yu. Izrael* (personal communication, 1988) the most cost-effective environmental management strategies for the long term are quite different than for the short term. Moreover, the selection of a single "best" strategy is made difficult owing to the many complex linkages amongst economic, technical and institutional factors. In some instances, e.g., declining industries, it may be wise to opt for short-term measures while for emerging industries, it may be crucial to implement long-term strategies, which may require incentives, economic or otherwise. In general terms, however, some of the ways that sustainable development can be promoted include:

- Conservation of energy, water and materials in industrial processing.
- Waste reduction, e.g., through recycling, and designing manufacturing processes that create less waste. [There is growing realization that the cost of handling wastes is becoming excessive so that waste reduction makes good sense economically (Hollod and McCartney, 1988).]

* Chairman of the USSR State Committee for Hydrometeorology.

- More efficient pollution control equipment in factories, power stations, automobiles, etc. In the European Community, the pollution control sector already generates more than 1% of Community Gross Regional Product (CONCAWE, 1987). A related statistic is that the money spent on pollution control in ECE countries is estimated to be less than the cost of pollution damage (ECE, 1987).*
- Promotion of environmental assessments of new technologies and products, and giving higher priority to those deemed to be more environmentally benign.
- Active promotion of environmentally friendly products and technologies.
- Reductions in agricultural pollution through implementing strategies for limiting, to a minimum, excess chemical fertilizers and pesticides. Such strategies include conservation practices, new, more efficient, less-polluting technologies, and the promotion of integrated pest management schemes, such as biological control (Bal and van Lenteren, 1987).

Finally as noted by A.S. Isaev** (personal communication, 1988), the forest industry has special responsibilities with respect to environmental management. Woodlands play a crucial role in stabilizing the natural environment. They greatly influence and regulate hydrologic cycles, and thus the flow of waters and local humidity conditions. They also filter air pollutants, thus protecting vulnerable soils and water bodies within forested watersheds. For example, the unique purity of the water in Lake Baikal is a result of the filtering effects of the surrounding forests.

Thus, forests should not be viewed as merely a "mine" for wood products and paper but should be managed to take advantage also of their positive influences on the environment. In the FRG, forests are to be planted for the dual roles of recreation and environmental preservation. Similar measures should be considered elsewhere. In the USSR, for example, forestation of new land created by the receding of the Aral Sea will be necessary for protecting soils against salinization caused by wind-blown salt deposition.

8.2.5. Recommendations to governments

Prohibition and regulation are only two of the instruments available to governments to improve the quality of the environment. Various tax incentives, pricing structures, effluent charges, international trade policies and other mechanisms are available, and may be more effective in many cases. Some examples are:

- Incentives for conserving energy and water, recycling of wastes, and reducing industrial wastes.

* The ECE Secretariat comments (ECE, 1987) that: "ECE member countries are continuing to use up their environmental assets, either because the assimilative capacity of the environment is exceeded or because ecologically unsustainable activities are engaged in."
** Chairman of the USSR State Committee for Forestry.

- Financial support for industrial research designed to improve energy efficiency, e.g., in houses, automobiles, electric appliances, etc.
- Incentives for preserving productive soil for agriculture (OECD, 1979). (Developers should be given incentives to locate settlements, industry and recreational facilities on poorer soils.)
- Support for environmental education programs that will sensitize the layman to critical environmental issues.
- Provision of environmental information that permits citizens, industry, agriculture and business to make environmentally-sound decisions.

  (a) Publication of natural resource inventories and related data banks.
  (b) Labeling of environmentally friendly consumer products.

8.2.6. Recommendations to international organizations

The dilemmas described in this report are generally large-scale, involving many European countries. Intergovernmental organizations such as ECE, EEC, CMEA, EFTA, OECD and WHO-Europe are therefore important players if the long-term environmental agenda for Europe is to be meaningful. At the present time these organizations have established Working Groups which provide valuable coordination and harmonization with respect to the European environment. See, for example, ECE (1986, 1987, 1988b). The approaches taken are very appropriate for resolving problems of the current and next decade (e.g., transportation of hazardous goods, pollution of rivers and inland seas). However, more emphasis could be placed on the integrative approach required to deal with the large-scale interactive changes expected in the next 50 years. Even the monitoring data required to evaluate the European environment in an integrated way are missing for the most part. This is not intended to be a criticism of intergovernmental organizations but rather a suggestion that they expand their outlook, as indeed is occurring in some cases and some countries. One tool that would help in setting long-term large-scale environmental agendas is the *policy exercise*. Adoption of this approach at the European level is a major recommendation of this Study.

International non-governmental organizations (e.g., IIASA, SCOPE, IUCN) and programs (e.g., ICSU Global Change) can also contribute importantly to the resolution of regional to global environmental issues, establishing better scientific bases for environmental policy formulation.

Finally, the United Nations and international financial institutions such as the World Bank and the International Monetary Fund can play a large and crucially important role in promoting environmentally friendly development in the Third World. Because the global economy is so closely linked to the global environment, every effort must be made to proceed with ecological sustainability in the context of the global perspective.

9. Recommendations for Further Research

The analysis presented in this report was built on three components: scenarios, assessments and policy responses. It was however only a first attempt at a topic deserving much greater in-depth analysis. Listed below are recommendations for further research that will assist in the overall development of these components in the European context.

9.1. Tasks Related to Scenario Building

9.1.1. Land use modelling: an assessment of changing land use patterns in response to human change

Human activities as reflected in socioeconomic and geopolitical developments are major determinants of land use. In addition, biophysical conditions have major implications for land use, since they set limits to resource use options or define opportunities for them. As has been pointed out in Section 4, land use in Europe is changing at an ever increasing rate, and this trend is expected to continue, particularly in the event of climate change.

The planning and management of land use for long-term development require knowledge of (Manning, 1988):

- The supply of land as a resource, defined in biophysical terms based on climatic and soil conditions.
- Future demands on the land resource for human activities, described in terms of socioeconomic and geopolitical conditions, and demographic trends.

The characterization of supply and demand components shows that land use is determined by interactions among economic development and environmental change. A view on long-term and broad-scale sustainable land use in Europe as a response to human change can be defined as "the best possible long-term product of the interaction of supply... and demand..." (Manning, 1988).

As pointed out at IIASA's Warsaw Workshop on Land Use Changes in Europe (September 1988), there is an urgent need for scenarios of European land use over the next decades in response to human changes and their implications for: (i) the allocation of land between the various sectors (agriculture, forests, urban), (ii) the management of land (such as deterioration effects of land use) and (iii) the problems of externalities. Such scenarios will require an understanding of human activities and socioeconomic development in relation to land use patterns. The work should include the following components:

(1) Preparation of land use scenarios for Europe as a response to human change. Some plausible changes in European land use patterns are:

(a) *Environmental changes* such as climate change, causing changes in land capability to produce food, fibre and timber. Land use patterns are also changing due to changing agricultural practices to prevent deterioration effects such as leaching of nutrients affecting soils and groundwater quality.

(b) *Geopolitical changes* such as the extent to which land use patterns in Europe might change due for example, to an increasing demand for agricultural products on other continents combined with a decline in their land potential.

(c) *Changes in technologies* which might reduce the requirements for land, water and energy.

(d) *Changes in policies* (both national and international) such as the level of support for agricultural products. The level of subsidies to agriculture will determine future land use patterns to a large extent.

(2) Assessment of implications of such changes for development at the regional level (in terms of allocation, management and externalities). A series of regional studies should be established to prepare such an assessment. A criterion for selecting such regions might be the different stages of socioeconomic development (such as Gross Domestic Product per unit area or per capita), demographic trends (in terms of distribution between rural and urban population), or environmental components (such as land or water availability per capita).

(3) The allocation and subsequent management of future land use patterns at the regional level in the presence of important externalities (environmental, economic and political). This will require the identification of viable strategies within the concept of ecological sustainability.

9.1.2. Industrial metabolism: river basin studies and forecasting materials use

The use of matter and energy in our economic system – that part of the sum total of human activities that is concerned with the production and consumption of material goods and services generated thereby – is, in some respects, similar to the use of matter and energy by biological organisms and ecosystems. The term "industrial metabolism", coined by Ayres (Ayres, 1978; Ayres and Kneese, 1989), invokes this analogy.

There have been numerous studies on the global cycling of environmentally-active materials and how these cycles are perturbed by human activities. However, these studies focus heavily on the environmental effects of such perturbations, but say very little about how such materials flow through the industrial economy and end up in the environment. They (and other currently available studies) therefore give no impression of the detailed sources of pollution, how these materials will be used in the future, or how their uses may change.

Whereas pollution from point sources such as industrial plants and electric power plants can be measured directly, it is almost impossible to make detailed measurements of pollution at the sources from commercial and consumer uses of products containing harmful chemicals. Detailed information on dissipative consumer end uses obtained from economic statistics is important because it may be the only method available for estimating pollution from the use of a vast array of products. Currently, the relative contribution of these non-point sources to the total pollution load is not well known. However, as industry becomes more regulated in Europe, non-point sources of pollution may make up an increasingly larger fraction of the ambient pollution load. If this is true, the implications for public policy are enormous. It would mean that monitoring and control of pollution must focus not only on emissions from point sources, but also on emissions emanating from consumer use. This is not altogether a new idea. Public pressures were probably largely responsible for reducing emissions of phosphate in phosphate-containing detergents, and the partial ban on the production of chlorofluorocarbons (CFCs). However, these represent only two cases. Effective control of other deleterious chemicals will require much more public awareness of pollution caused by the use of commercial and domestic goods and products. Such awareness might promote "environmentally friendly" alternatives to common chemical products found to be environmentally harmful.

In this connection, river basin studies can be extremely useful for studying the cumulative effect of end-use sources of pollutants over large areas. Pollutants, generated by activities within a basin, may enter the river either by direct discharge or by runoff from urban, agricultural, and rural areas. Thus in a sense, the quality of a river's water with respect to loadings of toxic materials is an indicator of the integral sum of all pollutants generated within the basin. If the activities causing the pollution can be identified, and the emissions quantified, it may be possible to draw conclusions about the relative source-strengths of the various activities. Several studies of the Hudson-Raritan river basin in the US provide perhaps the best available data, on an extended spatial and temporal scale, of the sources of pollution in the river waters. The area of study encompassed about 37,000 km^2. It is an important industrial and commercial area extending from New York harbour in a northward direction about 200 km. Ayres *et al.* (1985) studied the history of pollution in the area for eight heavy metals and several other pollutants for the period from 1880 to 1980. The results clearly showed an historical shift in the major loadings of the heavy metals. Whereas in earlier decades point sources, mostly from industrial production processes, were the major sources of pollution, by 1980 pollution from dissipative consumption and its transport via urban and agricultural runoff was the dominant source for most of the metals considered. In another study of the same basin (Rohmann and Lilienthal, 1987), a similar conclusion was reached. Runoff of major pollutants was in some cases several orders of magnitude greater than emissions directly from point sources. Interestingly, no pollutant sources from runoff are currently regulated by the US Environmental Protection Agency.

It is not clear whether the results of this single river basin are typical of the more general case either in North America or Europe, and similar studies should be undertaken in European river basins. Also required is a deeper understanding of the changing "metabolism" of industrial society. The central goal is to understand and document how processes of industrial production transform resource inputs into outputs that must be absorbed and processed in the environment. The specific categories of industrial activity to be considered would likely include processes related to the flows of heavy metals, and inorganic compounds such as bromine, chlorine, sulfur, nitrogen, and halocarbons. This work would build on existing research (Ayres *et al.*, 1989; Norberg-Bohm *et al.*, 1988; Ayres and Kneese, 1989).

Once a detailed book keeping of the sources and flows of selected toxic materials has been determined, the next step would be to construct models for generating a range of plausible scenarios for materials use (i.e., quantities, types of usage and products, geographical distribution, and how uses may change in the future). These scenarios (along with land use scenarios described in Section 9.1.1) would complement the numerous existing scenarios for population and energy use.

9.1.3. Elaboration of the environmental impacts of other socioeconomic development paths

For the sake of clarity, and in order to illustrate a method of ranking the severity of the impacts of various dilemmas, only four development paths were considered in Section 7. However, the methodology could be extended to examine the impacts of other socioeconomic development pathways.

9.2. Tasks Related to Environmental Assessments

9.2.1. Climate chemistry

Numerous studies have been undertaken on the causes and effects of climate change, as well as strategies for coping with the expected changes. However, there is one important aspect for which much more analysis is required. This is the effects of climate change on the flow of deleterious chemicals in the environment.

Work in this area could build on studies reported in Section 4 that focused on nonlinear and time-delayed environmental effects resulting from saturation or shrinking of capacities of soils and sediments for adsorbing toxic materials (Stigliani, 1988). If one assumes that the flow of chemicals through the environment is more or less in steady state with respect to the current climate, then how would those flows change under a different climatic regime? Higher temperatures could significantly speed up biological reactions. Increasing or decreasing water availability will cause changes in flow rates and sedimentation of harmful materials. It will change the depth of water tables with subsequent changes in groundwater quality. Rising sea levels will stir up coastal sediments currently loaded with toxic chemicals.

Some of the topics that ought to be considered include:

(1) *Acidic deposition*: How would current patterns of acid deposition change under new climatic conditions?
(2) *Agricultural soils*: Would soil salinization be enhanced by warmer and drier summers, and what would be the impact on the leaching of toxic materials?
(3) *Wetlands*: What would be the environmental impacts of the drying out of wetlands? And if new wetlands were formed due to rising sea level, what would be the environmental effects?
(4) *Eutrophication of freshwaters*: How would a warmer climate affect rates of eutrophication?
(5) *Polluted estuarine sediments*: Would the toxic materials in these sediments be mobilized as a result of a rise in sea level?

9.2.2. Environmental discontinuities (break-points)

Within the last 100 years or so, there have been several major environmental discontinuities in Europe. What were the circumstances surrounding these events? And what general lessons would help in the management of discontinuities that are bound to occur in the next 50 years?

Examples of these discontinuities include:

- The decrease in the pH of Swedish rivers in the 1950s, first publicized by Svante Odén in the early 1960s.
- European forest decline in the 1980s.
- The great London smog of 1952.

Associated with this is the question of *outer limits* or *stability limits* (Gorshkov, 1988) beyond which a system collapses. It may be too optimistic to expect to come to grips with the outer-limits problem, but it is worth a try. The essence of this study is therefore to prepare a comparative historical review of environmental discontinuities in Europe.

9.3. Tasks Related to Policy Responses

9.3.1. Resource accounting systems

Resource accounting (RA) is a term used to denote a data gathering and retrieval system for keeping track of stocks and flows of natural resources. There is a widespread view that current systems of national economic accounting are incomplete and should be broadened to include natural resources. For example, a country with a large export-import trade surplus may not be in a healthy position if the surplus is at the expense of some non-sustainable uses of its natural resources, e.g., mining of the forests.

It might appear to be easy to establish an RA system. However, there are a number of difficulties:

(1) Statistical data are collected by country, province, county or township, whose borders rarely correspond with those of ecological systems.
(2) In the estimation of *stocks*, accessibility is an important consideration. Europe imports wood, for example, partly because of the inaccessibility of many forest stands. The quality of stocks is also important although difficult to quantify in some cases.
(3) In order to be useful, an RA must be based on a conceptual model of the resource system. The present lack of an agreed upon framework has led to fragmentation, inconsistency and gaps in natural resource data bases (Friend, 1988). One model is that of *mass balance*, which permits data to be quantified in consistent physical units, permitting estimates to be made of material and energy flows and balances. This model is used in Norway (Lone, 1987), for example, but other possibilities include the stress-response framework developed in Canada (Statistics Canada, 1978) and that of *supply-demand.*
(4) During the process of converting a stock into a flow, not all of the material is useful; some of the residues may go back into the stock or may cause harm to the environment. How should these residues be enumerated?
(5) At what point in the collection and manufacturing chain should the resource accounting be done? Should we count trees, logs or boards?
(6) The design of an RA system depends on the use to which it will be put. In the case of water, for example, this depends on whether the water is used for drinking, recreation, fishing, industrial coolant, irrigation or hydroelectric power generation.

In principle, an RA system would have many practical policy applications (IES, 1983):

- To plan long-term utilization of resources, and the implied environmental protection and rehabilitation measures.
- To support the environmental impact assessment process with respect to energy, resource and other development projects.
- To establish and monitor environmentally motivated regulation of human activities.
- To monitor resource conservation performance.
- To aid in the preservation of living species and their habitats.
- To promote education and illuminate public debate.

In order to provide a rational basis for probing the large-scale policy dilemmas facing Europe, an RA system is urgently required. National systems exist already in several countries, while components of a European RA have been built at IIASA (e.g., a European-wide forest wood-supply data bank) and elsewhere.

The tasks to be undertaken are as follows:

(1) Preparation of a state-of-the-art review on the published literature on RA systems.

(2) Organization of a review Workshop and publication of the results.
(3) In the context of policy exercises, identification of the specific needs for RA systems.
(4) Development of a framework for an appropriate European-wide system.

9.3.2. Policy exercises

(a) Policy exercises should be undertaken at the national level, and also involving two or three countries that share a geographic feature, e.g., a river basin, the Alps, the Adriatic, the Baltic, etc.
(b) A policy exercise should be undertaken in Eastern Europe, organized along the lines described in Section 5, to test the ideas concerning ecological sustainability in an East European context.
(c) Ultimately, the most important application of policy exercises remains to be tested: namely, using them to establish long-term environmental agendas for Europe as a whole. Noting that optimal solutions for particular geographic areas, sectors or components may in some cases lead to non-sustainable pathways in other parts of the European "system", it is essential that policy exercises be used to examine the large-scale environment-development dilemmas facing Europe in an integrated fashion. *Table 7.5* could provide a framework for such a policy exercise.

9.3.3. Early warning monitoring systems

Many of the monitoring systems currently operating in Europe are inadequate as early warning indicators of environmental change, however satisfactory they may be for other purposes. It is therefore recommended that:

(1) Current monitoring systems should be expanded to include socioeconomic indicators.
(2) The selection of indicators should be based on some well-formulated models of the impacts of socioeconomic stresses on the environment, including its valued ecosystem components.
(3) The system should be harmonized across Europe, providing time and space resolutions that meet the needs of the models and of the users of these models.
(4) The data system should be readily accessible and inexpensive to use, although the various types of data need not be collected and quality-controlled by one organization.

The suggestions made in Section 6 on socioeconomic indicators of environmental change need to be elaborated and tested. At the same time, potential users of such indicators need to be consulted, particularly ECE, EEC, CMEA, OECD, WMO and UNEP.

9.3.4. Tools available to implement public policy

The objective of public policy is to change society's attitudes and actions, individually and collectively. Two of the traditional tools used in this field are *regulation* and *prohibition*. However, there are many other possibilities for affecting the ways that society thinks and acts over the long term, as pointed out in the environmental context by Regier and Grima (1984) and Clark (1987b). For example, the construction of a power station, motorway or railway will lead to long-term changes in areas influenced by these constructions. Potential changes in the environment should be assessed and factored into policy decisions concerning such projects. Two important related considerations are: (1) the lag time between adoption of a policy and the achievement of the desired result; and (2) the detectability of the change.

Clark (1987b) has categorized the approaches that could be taken in public policy formulation with respect to the availability and use of land and water as follows:

- Modifying the growth/decline and geographic distribution of human populations.
- Modifying the preferences and demands of society.
- Changing the mix of uses of natural resources.
- Interventions involving market and non-market institutions.
- Interventions involving international institutions.

These mechanisms have been used successfully to resolve short-term environmental issues. There is need, however, for an examination of their usefulness in the case of long-term large-scale problems that are shrouded in uncertainty. As a first step, some background papers on various aspects of this topic should be commissioned, followed by a review meeting. The outcome would be a series of recommendations, including a research agenda for future work.

9.3.5. Application to other parts of the world

The methods developed within the framework of the Study "Future Environments for Europe" should be applied in other parts of the world. In particular, studies should be conducted for less developed regions of Africa, Asia, and Latin America. In addition, a North American Study should be undertaken, perhaps sponsored by the IIASA National Members for the United States and Canada.

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Appendix A

List of Meetings Held in Support of Study

Scientific Committee Meetings:

June 5–6, 1986
September 8–9, 1986
December 2–3, 1986

Joint Meetings of the Scientific Committee and the Policy Committee to Conduct Policy Exercises:

November 24–25, 1987
June 17–18, 1988 (Baden, Austria)

Task Force Meeting on the Impact of New Technologies on the European Environment:

February 29 – March 1, 1988

"Think Tank" on Early Warning Indicators of Environmental Change:

August 4, 1988

Workshop on Land Use Changes in Europe: Processes of Change, Environmental Transformations, and Future Patterns:

September 5–9, 1988 (Warsaw, Poland)

Meetings of Management Board for the Study:

November 23, 1987
June 17, 1988 (Baden, Austria)

Presentation of Study Results to Four Committees of the Dutch Parliament, The Hague:

December 1, 1988

Appendix B

List of IIASA Working Papers and Related Publications within the Framework of the Study

IIASA Journal Publications, Books, and Working Papers:

Ayres, R.U., V. Norberg-Bohm, J. Prince, W.M. Stigliani, and J. Yanowitz (1989, in preparation) Industrial metabolism, the environment, and application of materials-balance principles for selected chemicals. Research Report, IIASA, Laxenburg, Austria.

Behrendt, H. (1988) Changes in nonpoint nutrient loading into European freshwaters: trends and consequences since 1950 and not-impossible changes until 2080, WP-88-26, IIASA, Laxenburg, Austria.

Breiling, M. (1989, in preparation) Socio-economic and environmental aspects of tourism in alpine areas of Austria. IIASA, Laxenburg, Austria.

Brouwer, F.M. (1988) Determination of broad-scale land use changes by climate and soils. *Journal of Environmental Management* (in press).

Brouwer, F.M. and M.J. Chadwick (1988) Future land use patterns in Europe, WP-88-40, IIASA, Laxenburg, Austria.

Brouwer, F.M. and M.J. Chadwick (eds.) (1989, in preparation) Land use changes in Europe: Processes of change, environmental transformations, and future patterns. Kluwer, Dordrecht, The Netherlands.

De Groot, R.S. (1988) Assessment of potential shifts in Europe's natural vegetation due to climatic change and some implications for nature conservation, WP-88-105, IIASA, Laxenburg, Austria.

Hunek, T. (1989) Socioeconomic and environmental factors for a sustainable development of agriculture: socioeconomic approach; Poland case study. Rural and Agricultural Development Institute, Polish Academy of Sciences, Warsaw (contracted IIASA study).

Joly, A. and M. Bandelier (1988) The impact of new technologies on the environment, WP-88-43, IIASA, Laxenburg, Austria.

Käärik, A.R. (1989, in preparation) Sustainable development and land use policies. IIASA, Laxenburg, Austria.

Manning, E.W. (1988) The analysis of land use determinants in support of sustainable development, CP-88-01, IIASA, Laxenburg, Austria.

Nijkamp, P. and F. Soeteman (1988) Dynamics in land use patterns: socioeconomic and environmental aspects of the second agricultural land use revolution, CP-88-02, IIASA, Laxenburg, Austria.

Norberg-Bohm, V., J. Yanowitz and J. Prince (1988) Materials balance for bromine, chlorine, sulphur, and nitrogen in Europe, WP-88-73, IIASA, Laxenburg, Austria.

Olejnik, J. (1988) Present and future estimates of evapotranspiration and runoff for Europe, WP-88-37, IIASA, Laxenburg, Austria.

Ryszkowski, L., A. Kedziora and J. Olejnik (1989) Critical ecological factors for a sustainable development of agriculture in Poland. Department of Agrobiology and Forestry, Polish Academy of Sciences, Poznan (contracted IIASA study).

Schaffer, J. (1989, in preparation) Land use conversions from agriculture to forestry. IIASA, Laxenburg, Austria.

Souchu, P. and D. Etchanchu (1989) The environmental effects on the intensive application of nitrogen fertilizers in Western Europe: Past problems and future prospects, WP-88-93, IIASA, Laxenburg, Austria.

Stigliani, W. (1988) Changes in valued "capacities" of soils and sediments as indicators of nonlinear and time-delayed environmental effects. *Journal of Environmental Monitoring and Assessment* 10:245-307.

Wolf, D., B. Wils, W. Lutz and S. Scherbov (1988) Population futures for Europe: An analysis of alternative scenarios, WP-88-46, IIASA, Laxenburg, Austria.

Zavatarelli, M. (1988) Potential impact of the greenhouse effect on the Mediterranean Sea: Overview, WP-88-76, IIASA, Laxenburg, Austria.

Related Publications:

Kornai, G. (1988) Future market consequences of forest decline in Europe. WP-88-41, IIASA, Laxenburg, Austria.

Mermet, L. (1987) Game analysis, WP-87-84, IIASA, Laxenburg, Austria.

Munn, R.E. (1988) Towards sustainable development: an environmental perspective, IIASA preprint for International Conference: *Environment and Development*, Milano, Italy, 24-26 March, 1988. (to be published)

Nilsson, S. (1988) Factors affecting future investments in pulp capacity. WP-88-75, IIASA, Laxenburg, Austria.

Toth, F.L. (1988) *Practicing the Future*. Part 2: Lessons from the First Experience with Policy Exercises, WP-88-12, IIASA, Laxenburg, Austria.

Szabolcs, I. (1988) Interim report to IIASA of the salinization potential of European soils.

Appendix C

Some of the Principal Monitoring Systems in Europe

Introduction

Many kinds of environmental monitoring systems are operating in Europe. The major objectives, the kind of environmental information collected and the achievements are summarized below for the following systems:

- The CORINE program of the EEC (a co-ordinated information system on the state of the environment and natural resources of the European Economic Community) which was initiated in 1985. The program includes the EEC-12, i.e., Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, and United Kingdom.
- The EMEP program (a co-operative program for monitoring and evaluation of long range transmission of air pollutants in Europe) of the ECE.

The CORINE program

This program was initiated in 1985 with the following objectives:

(1) To provide information on specific thematic topics (among others, biotopes, atmospheric emissions, land use, land quality, and water quality).
(2) To support the improvement in the organisation of data collected in the European Community, its member states or international organizations.

The CORINE information system has data on the following phenomena (either already available, or scheduled to be available by mid 1989):

(1) Topography (coastline, water pattern of lakes, canals and reservoirs).
(2) Political boundaries (national and regional).
(3) Climate (thirty-year monthly and annual averages for factors such as precipitation, temperature, frost, relative humidity, evapotranspiration, wind speed, cloudiness, solar radiation).
(4) Soils (the basic soil information originates from the 1:1 million Soils Map of the European Communities including soil type, texture.
(5) Soil erosion risks and important land resources (areas in the southern part of the European Community that are subject to high erosion risks under present land use conditions, and erosion hazards along the Community coastline).
(6) Biotopes (a registration of sites that are important for nature conservation, currently including about 5,000 sites with information on location, area, altitude, habitat cover, human activities and species).
(7) Water (supply from groundwater and surface water, consumption).
(8) Water quality (mean monthly stream discharge for the period 1970 to 1985 including factors such as temperature, pH, chlorides, nitrogen, ammonium, dissolved oxygen, phosphorus, cadmium, and mercury).
(9) Atmospheric emissions (sulphur dioxide, nitrogen oxides, volatile organic compounds).
(10) Air quality (sulphur dioxide, smoke/particulates).
(11) Less favoured agricultural areas (mountainous or other less favoured areas, which require financial and other support to maintain their agriculture).
(12) Designated areas (location, region, date of establishment, designation and ownership).

In addition to the environmental components included in the CORINE program, information is also collected on the following socio-economic and demographic factors:

(1) Population (total residents, settlements, and urban/rural distribution).
(2) Employment (agriculture, industry, service, manufacturing, transport and communication).
(3) Energy (production, consumption, capacity, mining and resources).

The EMEP Program

The objective of the co-operative program for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP) is to monitor air components which can be used for testing models of the long-range transport of air pollutants. The sites are located in areas where the influence of local source area is as small as possible, and where the measurements can be considered to represent the pollution of a region.

There are 82 monitoring stations in 23 countries, and most of them belong to national networks. The major stations began measurements in January 1978. Information is collected on the following components: gases, particles and precipitation:

Gases include: SO_2, NO_2, HNO_3, and NH_3.
Particles include: H^+, SO_4^{2-}, NO_3^- and NH_4^+.
Precipitation includes: SO_4^{2-}, NH_4^+, NO_3^-, pH/H^+, Mg^{2+}, Na^+, and Cl^-.

Since EMEP uses information from national networks, different analytical and chemical methods are in use for each component, which complicates comparability of the results.

Appendix D

Acronyms

CFC	Chlorofluorocarbon
CMEA	Council for Mutual Economic Assistance
CONCAWE	Oil Companies' European Organization for Environmental and Health Protection
EC	European Economic Community
ECE	United Nations Economic Commission for Europe
ECE-FAO	United Nations Economic Commission for Europe-United Nations Food and Agriculture Organization
EEC	European Economic Community
EFTA	European Free Trade Association
EPA	United States Environmental Protection Agency
GNP	Gross National Product
GRP	Gross Regional Product
ICSU	Internation Council of Scientific Unions
IES	Institute for Environmental Studies, University of Toronto, Canada
IIASA	International Institute for Applied Systems Analysis, Laxenburg, Austria
IUCN	International Union for the Conservation of Nature and Natural Resources
OECD	Organization for Economic Cooperation and Development
RAINS	Regional Acidification Information and Simulation (acid deposition model, IIASA)
RIVM	National Institute of Public Health and Environmental Protection
SCOPE	Scientific Committee on Problems of the Environment
UNEP	United Nations Environment Program
WCED	World Commission on Environment and Development
WHO	World Health Organization
WICEM	World Industry Conference on Environmental Management
WMO	World Meteorological Organization
YSSP	Young Scientists' Summer Program (IIASA)