Ecological Sustainability of Regional Development

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Editors:

L. KAIRIUKSTIS *
A. BURACAS **
A. STRASZAK ***

* Environment Program, IIASA
A-2361 Laxenburg, Austria

** Lithuanian Academy of Sciences
Vilnius, Lithuania, USSR

*** Systems Research Institute
Polish Academy of Sciences, Warsaw, Poland

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS

POLISH ACADEMY OF SCIENCES, SYSTEMS RESEARCH INSTITUTE

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FOREWORD

In June 1987, an important international Workshop was held in Vilnius, Lithuanian SSR on the topic, "Ecological Sustainability of Regional Development". The number of participants numbered 65, coming from nine countries.

Many of the papers dealt with ecological-economic assessment methods used in East European countries for regional development planning. Some of the ideas were quite new to environmental planners from western Europe, and are of great interest to them. This is one kind of service that IIASA provides very well – bringing people together and bridging language barriers in the East-West context.

IIASA is pleased to be associated with the 1987 Workshop and with these Proceedings.

R.E. Munn
Leader
Environment Program, IIASA

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PART I

INTRODUCTION

1.1 ECOLOGICAL SUSTAINABILITY OF REGIONAL DEVELOPMENT: BACKGROUND TO THE PROBLEM*

L. Kairiukstis
Deputy Leader, Environment Program
International Institute for Applied Systems Analysis
A-2361 Laxenburg, Austria

During the last decade, almost all regions of the world have been under the process of social, economic, demographic and environmental restructurization. This fact results from three processes having world-wide importance: globalization of economic processes, shifts in technology and changes in natural resources and biospheric conditions.

The globalization of the economy and new technologies create new issues and almost every region in every country starts to face new challenges, irrespective of the social or institutional mechanism of economic life. In an economic sense in the domain of regional development problems, priority is given to the question of *competitiveness* of a region as compared to other regions. In order to realize the potential of a region, or to achieve the competitiveness of any region, human activities have usually been directed toward economic development of computer-aided manufacturing and computer-aided design of regional development strategies. The resources and environment of the region have been considered only as constraints, *if at all*. But in fact, a region is a human activity system, producing economic, environmental, demographic, and other transformations that are perceived as relevant to the survival of a specific population. Therefore the sustainable survival of the *human micro-population or ethnic group* within each defined geographical space, within the region must be considered as the main goal of regional development.

Nevertheless, industrial, agricultural and social development usually leads to the depletion of natural resources and human environmental deterioration. Forest decline, land desertification, soil erosion, and lake acidification are all examples of this. In some regions, this process is rapidly approaching a dangerous level, not only for the regions in question, but also for the biosphere as a whole. Therefore, the second domain is *ecological sustainability* of regional systems which today appears to be more important than ever before and must be considered on the same level as competitiveness of regional systems as was previously considered in an economic sense. Only equality of both domains can ensure productive human activities in a given region for an indefinitely long time.

Environmental and socio-economic systems are closely interrelated at the local and regional levels. They are likely to be simultaneously sensitive both to global biospheric changes as well as to changes caused by resource depletion, atmospheric pollution and eco-climatic variations at the regional level. An integrated approach to the assessment of the impact of ecological changes is

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therefore crucial to the development of comprehensive management strategies, which include a significant restoration component and provide both competitiveness and ecological sustainability of regional systems.

The International Institute for Applied Systems Analysis (IIASA) has, since the early 1980s within its Environment Program, been engaged in studies on acid rain, biosphere, and forestry case studies, which have made unique contributions to a better understanding of regional systems and problems, and have also developed methods and tools for their analyses. The author has participated in this work, contributing specifically to studies of dendrochronology and its applications, and integrated economic and environmental regional issues.

Using a network of collaborative organizations established in Europe, Asia, and North America, IIASA has organized several international meetings on different aspects of ecological sustainability of regional development.

Among those meetings are: Workshop on "Regional Resource Management" held in Albena, Bulgaria in autumn 1985, where the principal approach to analyze ecological sustainability of regional systems has been established.[1]

Dimensions required in defining the boundaries of regional systems:

- basic regional ecosystem components;
- main economic sectors to be analyzed;
- main factors causing impacts or disturbance on ecological sustainability of regional systems (natural eco-climatic changes and environmental pollutants were selected).

Finally, a class of investigation was designed to: 1. report on the state-of-the-art in case study regions; 2. undertake ecological modeling; 3. undertake ecological-economic modeling; 4. seek interface with policy makers.

Following the matrix above, the forest was chosen among the basic ecosystem components for special studies. As a factor causing an impact on ecological sustainability of the regional system, chemical and physical environmental changes were investigated.

With regard to chemical environmental changes, acid rain has been considered. Within IIASA's Environment Program, the Acid Rain Project has carried out investigations on the long-term effects of acid deposition in Europe. A policy-oriented model has been developed for use by international and regional or national decision makers, seeking better strategies for emission reduction. Several international meetings on problems of acidification have been organized.

Special studies on the forest as the most important biospheric subsystem and on the forest sector as one of the components of regional economic environmental systems have been carried out within the Environment Program at IIASA. In the framework of these activities an International Workshop on "Forest Decline and Reproduction: Regional and Global Consequences" was convened with the objective of seeking a consensus about the status and knowledge of forest decline especially in Europe. The Workshop, held in Krakow, Poland in March of 1987 has been considered as a most successful international meeting. In addition to presentations of some 60 papers on forest decline,[2] a set of resolutions was

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[1] *Regional Resource Management.* Volumes I, II. L. Kairiukstis (Ed.), July 1986, CP-86-24, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria.

[2] *Forest Decline and Reproduction: Regional and Global Consequences.* Proceedings of a Workshop held in Krakow, Poland, 23-27 March 1987. L. Kairiukstis, S. Nilsson, and A. Straszak (Eds.), September 1987, WP-87-75, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria.

adopted. These call for reductions of air pollutant emissions, sounder regional policies, improved monitoring of the extent and growth rate of forest decline, more research in specific areas, and increased transregional and international cooperation.

As far as physical environmental changes are concerned, natural eco-climatic changes can be evaluated from dendrochronologies. A worldwide network on Dendrochronology has been established. Dendrochronological information about physical environmental changes has been collected and analyzed. An international Workshop was held in Krakow, Poland in June 1986 on "Methodology of Dendrochronology: East/West Approaches". Methods establishing modern regional and transregional dendrochronologies have been developed and calibrated. The application methods, particularly for early indications of forest decline based on physical and chemical atmospheric changes have been improved. Actual reconstructions of past climate on regional and transregional up to the hemispheric level have been created.[3] This may help in the evaluation of future ecological sustainability of such regional components as forest, agriculture, aquaculture, and other biospheric subsystems.

Some steps for ecosystem redevelopment are also underway in current activities of collaborators of IIASA's Environment Program. Following the idea of noosphere, formulated by Academician V. Vernadsky at the beginning of this century, a model of biosphere development is under construction in the Computing Center of the Academy of Sciences of the USSR (Academician N.N. Moiseev). Several models for analyzing and forecasting regional reproduction have been created in Lithuania (USSR), The Netherlands, Japan, Poland, etc. Also, a Workshop on "Ecosystem Redevelopment: Economic Ecological and Social Aspects" was held within the framework of IIASA's Biosphere Project in Budapest in spring 1987.

Nevertheless, the practical steps which must be taken in the future to meet the objective of increasing ecological sustainability of the biosphere must be met through regional systems. The regional system is still a manageable system; and if the processes of socio-economic and environmental development within the regional systems are clearly understood and properly managed, ecological sustainability of regional development as well as economic competitiveness and sustainable survival of the human micro-population will be achieved.

Taking all this into consideration, a Workshop on "Ecological Sustainability of Regional Development" was held in June 1987, organized by the Lithuanian Academy of Sciences and the Committee for Systems Analysis, Academy of Sciences of the USSR and co-sponsored by IIASA. The participants of the Workshop held productive discussions on the following topics:

1. *Perception of regional socio-economic and environmental systems* (dimensions, basic components, and management criteria).
2. *Interdependency of regional, transregional, and global systems* (global atmospheric changes, transregional atmospheric pollution, and eco-climatic changes).
3. *Management of regional resources* (sustainable/unsustainable utilization of natural resources, current and future strategies).

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[3]*Methods of Dendrochronology*. Volume I. Proceedings of the Task Force Meeting on Methodology of Dendrochronology: East/West Approaches, 2-6 June 1986, Krakow, Poland. L. Kairiukstis, Z. Bednarz, and E. Feliksik (Eds.), Warsaw, 1987.

4. *Economic and ecological modeling of regional systems* (approaches, methods, models, software and data base construction).
5. *Optimization of regional development/redevelopment strategies* (criteria of optimized regional ecological management, multiple land use, and regional (national) physical planning and environmental management).
6. *The environment of the future.*

The discussions at the Workshop achieved the following:

- Substantiation of conceptual approaches in ecologically balanced regional socio-economic and environmental systems.
- Glimpse at the current level of knowledge on mutual interdependency of regional, transregional, and global economic and environmental systems as evident from:
  - anthropogenic pollutants,
  - eco-climatic fluctuations, and
  - global biospheric change.
- Contribution to develop an approach to regional (national) resource management which is best for long-term socio-economic and environmental regional development and for sustainability of the biosphere.
- Examination of possibilities of generalizing existing economic and environmental models and facilitation of their adaptability for managerial use in East and West socio-economic systems.
- Attempt to consolidate diverse approaches on sustainable regional development.
- Determination of priorities in research aimed at improving regional socio-economic and environmental policies.
- The Workshop adopted a final statement.

Providing these Proceedings to the broad community of regional environmentalists, economists, ecologists, agricultural forest and dendrochronology specialists, as well as to international organizations and decision makers, I sincerely hope that consensus will be achieved on ecological sustainability of regional development and ways will be found to sustainable survival of the human population within each geographical region.

1.2 ECOLOGICAL PROBLEMS: THEIR STUDY AND SOLUTION IN THE USSR -- GLOBAL AND LOCAL ASPECTS*

Academician A.L. Yanshin
Vice President,
Academy of Sciences of the USSR
Moscow, U.S.S.R.

The term "ecology" was suggested one hundred years ago by the German Darwinist Ernst Haeckel to denote a science that includes studies of the relationships of plants and animals with certain physico-geographical conditions. Studies of these relationships were then being carried out but the relationships themselves were assumed to be unchangeable. In the XIXth century the problem of their changes, and of the evolution of ecological relationships, had not yet been formulated; even the problem of human ecology had not arisen. This probably resulted from old religious notions that human beings are above nature and human society develops according to its own laws independent of the laws of the development of nature. Only the most intelligent people at that time reflected on what we now call "human biosocial nature", believing that human society should develop according to the laws of nature and not contrary to them. That idea was expressed most clearly by Friedrich Engels, who was one of the greatest natural scientists.

The time foreseen by Engels has now come. The general laws of evolution that are common to both human society and living and non-living nature which surrounds us have been considered by our contemporaries—including the Soviet scientists V.G. Afanasyev, N.N. Moiseev, D.K. Belyaev, I.T. Frolov, S.P. Mikulinsky and others, by the scientists from the Club of Rome, and in the recently published book by Ervin Laszlo, *Evolution: The Recent Synthesis*. In these works an attempt has been made to consider the social evolution of human society as a historically inevitable natural process. Some personalities can slow down, or hinder that process, but they cannot stop it.

The first scientist who considered human society as part of the history of the biosphere of the Earth was Vladimir Vernadsky. The 125th anniversary of his birth will be celebrated in March 1988 in the Soviet Union and many other countries, e.g., Czechoslovakia, France, and the United States of America, although Vernadsky's work is not sufficiently known in western countries. In his early papers at the end of the XIXth century, V.I. Vernadsky pointed to the huge and rapidly growing scale of human activity, quite comparable with the most powerful geological and geochemical processes occurring in the upper shell of the Earth. In these papers Vernadsky warned that a dramatic growth of human activity would inevitably produce situations dangerous for mankind itself, if that activity did not proceed in accordance with natural processes, but conflicted with them, disrupting the natural course of events. He warned that ignorance of natural processes and of the ways of their development and neglect for these processes may result

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in conflicts between human society and nature.

In his later works at the turn of the century, Vernadsky focused on the problem of a new science--geochemistry, which was emerging at that time and of an old science--mineralogy, which he had considerably renewed by his genetic approach. In these works Vernadsky carefully studied the behavior of each element in the biosphere--the Earth's shell where living matter exists; he discovered the role of each chemical element in human activities. At that time some of the chemical elements of the Mendeleyev's periodic system were not known to be of practical value. Now, all of them are not only used, but also chemical compounds of these elements are created that do not occur in nature. For instance, such elements as gold and silver were never found in a natural state but only as compounds. Now, pure aluminum, iron and titanium are produced in vast quantities. People have obtained these absolutely new forms of chemical elements unknown in nature.

At the General Assembly of the Academy of Sciences in 1911, Vernadsky presented a very interesting report. He pointed out that in future, mankind will definitely learn how to use the energy of atomic fission and thus get a source of energy of such a power that was not known before. That is very significant since the report was made only about 10 years after Becquerel and Pierre and Marie Curie discovered radioactivity. In 1911 no scientist took this prediction seriously. In 1922, Vernadsky repeated that prediction and said that the time of mastering nuclear energy was at hand. For the first time he raised the question: will mankind use this tremendous source of energy for increasing its wealth or for self-destruction? A clear warning was issued by Vernadsky back in 1922! A little later, in 1923, Vernadsky left Russia for Prague and Paris where for two years he lectured in geochemistry. In his lectures he revealed the role of each chemical element in the processes in the biosphere including human activity; that activity was considered by Vernadsky to be a biospheric process.

As a result of his investigation, a new science appeared--bio-geochemistry, i.e., geochemistry associated with life, with the activity of living organisms and living matter of the biosphere.

During the following years Vernadsky paid a lot of attention to the investigations of all the parameters of the biosphere and not only to the chemical processes in it. The questions he studied included: how much solar energy is consumed by green plants; what is the mechanism of the formation of elementary organic substances by plants powered by solar energy; and, what is the mass of living matter in the present biosphere. At the same time the first step had been taken in investigations of the evolution of the biosphere as part of the history of the Earth.

In 1926, Vernadsky's fundamental work *The Biosphere* was published. I regret very much that this work has not yet been published in English. We will do it in the nearest future. The lectures Vernadsky held at the Sorbonne were published in Russian and French in his book *Essays on Geochemistry*. Having generalized in these works his early studies of the biosphere, Vernadsky continued to study these problems until his death in 1945.

In 1940, another large and very important paper was published in Russia entitled *On the Autotrophy of Mankind* (this was published in French in 1925). The term "autotrophic" was introduced by the German physiologist W. Pfeffer to denote green plants, because only these plants consume solar energy by chlorophyll grains. Then these plants produce elementary organic substances, mostly carbohydrates, and in minor quantities, proteins and various fats using carbon dioxide, water and mineral substances that are extracted together with water by the roots of the plants. All animals are heterotrophic; they cannot produce organic substances out of inorganic ones, they either feed on plants or prey on each other. Human beings are also heterotrophic, as were the primitive people of the Stone Age. They were entirely dependent on the natural environment, dressed in animal skins, living in huts of stakes covered by animal skins, and fed on plants and animal meat. Vernadsky pointed out that in the process of the development of civilization people gradually acquired some autotrophic features. They learned to build their houses of bricks and concrete. Modern people are increasingly using synthetic fabrics for their clothes and even produce synthetic furs out of natural gas and other inorganic substancesecall meeting with our late President, Alexander Nesmeyanov, to discuss the organization of new reserves for preserving fur-bearing animals. He asked us, *why do we need fur-bearing animals when chemistry is now able to produce fur*?

V.I. Vernadsky followed very closely the early attempts to create synthetic food. We now know that microbiological processes permit production of proteins out of gas, and leaven out of timber wastes. Vernadsky believed that the creation of synthetic food will be a big step toward the autotrophy of mankind and its independence from the environment. Following his idea we can formulate a problem of synthesizing green chlorophyll plastids by which green plants consume solar energy. When people learn how to make synthetic chlorophyll, they will be able to produce unlimited amounts of food and fodder. This problem has not yet been properly formulated by scientists; however, it will undoubtedly happen in the next 100 years.

In the middle of the 1930s, during the last decade of his life, Vernadsky paid special attention to problems of the evolution of the biosphere, its qualitative changes beginning from the Earth's early days when only microbes inhabited the seas and oceans and the land was devoid of life and until the latest stage in the development of the biosphere when human beings appeared to change the biosphere. Returning to his earlier works Vernadsky studied the scales of human activity in more detail than before. He believed that collective human intellect will transform the spontaneously organized biosphere into a rationally controlled *noosphere* (noos is "intellect" in Greek). The noosphere is that stage of biosphere development where a collective human intellect has transformed it to meet the material, spiritual and esthetic demands of mankind.

In 1977, long after the death of V.I. Vernadsky, his paper *Scientific thought as a planetary phenomenon* was published. There he formulated 12 conditions essential to the transformation of the biosphere into the noosphere. I will not discuss all 12 conditions, and merely say that according to Vernadsky the main condition for the formation of the noosphere is removal of the threat of wars. As long as the possibility of wars exists, the biosphere cannot be transformed into the noosphere. Only the abolition of wars, only a friendly and peaceful life of all the people of our planet can ensure the right conditions for a noosphere.

Vernadsky died on January 5, 1945. A few months later nuclear bombs exploded over Nagasaki and Hiroshima. Vernadsky's prediction had come true: the energy of nuclear fission had been mastered. Unfortunately up to now a considerable part of the efforts of mankind has been spent on stockpiling nuclear weapons. Yet we trust that an agreement will be reached on uses of nuclear energy for peaceful purposes. At the same time, during the 42 postwar years, peaceful uses of nuclear energy have been increasing. In earlier times fearless explorers reached the North Pole. Nowadays ice-breaker ships with powerful nuclear engines easily pass through ice hummocks and polar ice on their way to the North Pole. By means of these ice-breakers a free passage is opened through the ice of the Arctic Oceans—from Europe to the shores of the Far East. Nuclear water distillers are working in deserts, on the coast of seas and salt lakes. They provide water for drinking and for technical purposes and generate considerable amounts of water for irrigation and planting of gardens and vineyards in deserts. A considerable amount of electric energy is now produced by nuclear power plants (50% in France and 17% in the Soviet Union). The Chernobyl tragedy warns all people of the Earth that they should deal with nuclear energy extremely carefully. We cannot, however, stop developing new sources of energy. Scientists in many countries are working hard on controlled nuclear fusion. We will probably be able to use the energy of nuclear fusion in the foreseeable future. The power of mankind will increase tremendously if we agree to use this energy only for peaceful purposes.

The past 30 years can be rightfully called "the Age of the Scientific and Technological Revolution". This is due not only to the tapping of nuclear energy. People have gone into outer space and hundreds of satellites are now orbiting the Earth, studying both space and the Earth's surface. An entirely new science has appeared—studies of the Earth by space methods to monitor the condition of forests, correct topographic maps, forecast snow melt and river floods, and assess crops. Earth studies by space methods are useful in many ways.

The dream of Jules Verne has come true: people have walked on the Moon. Space instruments acquire data about all planets of the solar system and comets that stray into it. We now have an idea about the physical conditions and the surface relief of Venus, Mars, Jupiter's satellites and the structure of Saturn's rings. At the same time, during these 30 years, detailed studies of the microcosm, of the elementary particles have been conducted. New branches of industry have appeared as electronics and microbiology have continued to advance. The molecular mechanism of the transfer of hereditary features has been discovered. On that basis a completely new science has emerged, i.e., genetic engineering, that has already brought important practical results. During this 30-year period powerful computers have been built; no research center can now work without them.

The changes that have occurred during the past 3 decades are tremendous. They benefit mankind. Great advances have been made combating infectious diseases. In the XIXth century, smallpox wiped out the whole population of many islands in the Pacific. Twelve years ago, the World Health Organization in Geneva announced a reward of $6,000 for the doctor who would report one case of smallpox. The reward has not been claimed. Smallpox has been eliminated from our planet. Strides have been made in combating other infectious diseases.

Mankind's impact on nature has at the same time resulted in those conflict situations that V.I. Vernadsky warned against at the end of the last century. The sheer scale of cultural activity resulted in the pollution of the atmosphere, the hydrosphere (including the ocean) and the upper crust.

At the same time a rapid growth of the population began, leading to serious ecological problems. In my youth nobody thought or wrote about these problems, except V.I. Vernadsky, a scientist of true distinction.

A number of new global ecological problems have appeared. I will only mention some of them. It has now been accepted by all the climatologists of the world that the increase of carbon dioxide concentrations in the atmosphere is due to the burning of vast quantities of fuel in internal combustion engines of vehicles, coal-fired power stations, etc. We know that the carbon dioxide concentrations have not been constant throughout the history of the Earth. I recently had great pleasure in presenting to the IIASA library the book *The History of the Atmosphere* that I wrote in collaboration with Corresponding Members of the Academy of Sciences of the USSR, M.I. Budyko and A.B. Ronov. We followed changes in the concentrations of various gases in the atmosphere during the past 500 million years since skeletal life forms appeared on Earth. But, let us not go so far back. Let us dwell on what has happened during the past 50 million years. From the geological point of view that is a very short period. Recent carbon dioxide concentrations are within 0.03%; 50 million years ago it was 0.4%, i.e., greater by one order of magnitude. We know definitely that at that time even the Antarctic had no ice cover and that it was inhabited by animals whose skeletons have been found. There were no drifting ice-floes in the Arctic Ocean. High forests were growing on Spitsbergen; this is borne out by coal deposits in Barentsburg. At that time, at 0.4% of carbon dioxide, the greenhouse effect was so intense that the climate of the Earth was everywhere warm, mild and there were no ice caps near the poles. We are of course very far from these conditions now. The concentration of carbon dioxide is increasing, however. And it is increasing not only in the urban areas but near the South Pole (according to the measurements of the Amundsen-Scott station) and on small coral islands in the Pacific, as well. These measurements show that in some cases the concentration of carbon dioxide is 0.045, i.e., it has increased by 50% in comparison with what it was in the first half of the century. Climatologists have revealed an increase in the average temperature of the lower atmosphere. It is still not large, only one or two tenths of a degree, but the temperature is increasing. Nobody doubts it and climatologists are now studying how this warming will influence the distribution of precipitation. Certain theories seem to be developing in this connection. They need of course checking.

In the Soviet Union three Institutes work in this field: the Central Hydrographic Institute of the State Committee for Hydrometeorology in Leningrad, the Institute of Geography, and the Institute of Physics of the Atmosphere of the Academy of Sciences of the USSR in Moscow. The latter has a big laboratory on the theory of the climate. The three Institutes have reported interesting data; the signs are that by the year 2000 a strip of climate more arid than at present will form in the south of Europe, to cover Spain, Italy, the northern Balkans, and the Ukraine in the Soviet Union. It will not stretch further to the east, however. North of this area and, what is very important to us, south of it, i.e., in Central Asia the amount of precipitation should considerably increase. We now observe that the snow cover near Moscow reaches 80-90 cm. The run-off of the Volga has considerably increased: it was especially large in the first half of 1986, when the level of the Caspian Sea rose by 8 cm. That amount of water was provided mostly by the Volga and to a lesser extent by the Ural River. Not everything is clear, however; absorption of carbon dioxide by the World Ocean has not been determined accurately enough, various scenarios are still being developed, but the general trend of the climatic processes has already been revealed. One of the most important problems of our times therefore is to work out a scenario of future climatic changes not only for one country or a comparatively small continent such as Europe, but for the whole world.

Let us consider some other global problems that have appeared recently. I have already said that large-scale air pollution is one of the main negative factors that have emerged during the past 30 years. The International Institute for Applied Systems Analysis is studying the important problem of acid rain. Smoke laden with sulphuric, nitric, and sometimes, hydrofluoric acids is carried by the winds over great distances. As a result, acid rain occurs in all the industrialized countries. When studying this problem, it is very important not only to determine the harmful effect of air pollution on the surrounding landscape but to involve economists in this work to show that control technologies can bring profit. This can be the case when the concentration of the vapor of sulphuric or hydrofluoric acids is sufficiently high. At low concentrations it will be unprofitable. I would like to give you the following example: in the Orenburg region in the Southern

Urals large copper deposits were discovered in the 1930s. In these deposits copper is combined with sulphur in the form of chalcosine, chalcopyrite and bornite. A plant and the city of Mednogorsk were built in the Urals, 120 km east of Orenburg. The plant produced high-quality copper; sulphur gases of high concentration were discharged into the air, which resulted in the following consequences: at first, tree tops withered and then forests underwent a complete degradation over a considerable territory. Our technologists and economists calculated, however, that it would be very profitable for the plant to retain this sulphurous gas and produce pure sulphur rather than sulphuric acid. The plant now produces copper and about 7,000 tons of pure sulphur per year. As a result the plant is more profitable. The Ministry of Non-Ferrous Metallurgy did not accept the project for a long time because sulphur is produced in the USSR by another ministry, the Ministry of Chemical Industry. Sulphur emissions can no doubt be reduced at a profit for those factories and companies that are melting sulphide ores.

Rivers and lakes have been polluted during the recent decades. I will later speak about what has been done to deal with this problem in the USSR. It is especially disturbing that the World Ocean has also been polluted. This is to a great extent due to the increasing offshore extraction of oil and gas from the shelf. The entire North Sea in Europe, the Persian Gulf, the Gulf of Mexico, the South China Sea—all these shallow-water seas are covered by a thick net of oil- and gas-extracting platforms. Such platforms are hugging the northern and southern shores of Alaska, the shores of California, Ecuador, Peru, and Northern Chile, the western shores of Australia, and the shores of India near Bombay. They are located in the Bass Strait between Australia and Tasmania, in the Bay of Siam and in the Gulf of Guinea in Africa.

In 1985, 680 million tons of oil were extracted off shore. More was extracted in 1986. I do not know the exact figure but it should be over 700 million tons. Moreover, many countries that have no deposits on land extract hundreds of thousand tons from hydrocarbon deposits under the sea floor. These are, e.g., Nigeria, Norway, Denmark, and the Netherlands. These oil fields are in fact the main polluters of the World Ocean, since a certain amount of oil is lost due to drill failures, and in the process of pumping oil into tankers. Of course shipping has increased and this also pollutes the ocean. Here is an example. In 1947, Thor Heyerthal sailed on the "Kon-Tiki" from Peru's shores to a small island in the Paumotu Archipelago. On his way he saw clean water, plenty of fish and other animals. Twenty-three years later in 1970, he made a trip on the sailing boat "Rha" from Morocco to the shores of Venezuela. All the way across the Atlantic Ocean he saw no flying fish, but observed oil slicks and encountered drifting plastic bottles and wastes.

The upper crust of the Earth and underground water are also being polluted. In many cases, under the influence of human activity, karst processes develop. This has occurred even in Moscow as a result of water leakage out of sewage and water-supply systems.

A mass movement for environmental protection began in the 1960s, about 25 years ago. In 1972, a special session of the United Nations focused on this problem. It was decided to form an international body on environmental programs—UNEP—that now has its headquarters in Nairobi. UNESCO also adopted a number of international environmental projects while the Soviet Union began to introduce environmental protection measures at about the same time. A society for nature conservation was organized in the Soviet Union back in 1923, but it was a nongovernmental organization. In the 1960s and 1970s the USSR Supreme Soviet adopted a number of laws on soil protection, water protection, air-space protection and also resolutions on the protection of the Black and Baltic Seas. The Council of Ministers established a commission on environmental protection to enforce the laws. This commission does no research but it ensures that ministries and factory managers abide by the adopted laws. Moreover, the commission can impose large fines and dismiss offenders from their posts. The head of the commission is one of the first Deputy Chairmen of the Council of Ministers of the USSR, presently V.S. Murakhovsky.

An interdepartmental committee for environmental protection was established at the State Committee for Science and Technology at the same time. In 1972, the Scientific Council on the problems of biosphere was organized at the Academy of Sciences of the USSR. Academician A.P. Vinogradov, its first chairman, was a well-known geochemist. After Academician Vinogradov's death in 1976, Academician A.V. Sidorenko was appointed to the post, and now I am in charge of the Council. I shall describe some aspects of its work.

We organize fact-finding conferences in various regions of the Soviet Union where abnormal ecological situations arise. I have participated in a number of such conferences: in Yakutsk on protecting the tundra and defining conditions for mining minerals in the tundra; in Kishinev, Moldavia, and in Yalta on improving the health resort zone in Kislovodsk and on the northern coast of the Black Sea. In 1984 I organized a visiting session in Yerevan. As a result, a governmental noosphere studies center was organized in Armenia. During the last two and a half years, this center has accomplished much: the proposed site for construction of a nuclear power plant has been changed, and it will be built in a remote and uninhabited valley in the mountains; the amount of Sevan water used by a chain of small hydro-power stations has been reduced; factories that polluted the air in the Ararat valley have been closed down. The last meeting of that kind was organized in 1986 in Ashkhabad, capital of Turkmenia. It was devoted to human ecology and natural conditions in the arid zone of Central Asia and Azerbaijan. The meeting considered what should be done to improve the environment in this arid region, where many oil and gas fields have been discovered. The meeting also examined health resorts in piedmontane and mountain regions of Central Asia, the stabilization of moving sands, control of desertification, and the rational use of the limited water in this desert.

In addition to these visiting sessions during the past two years, our Scientific Council on problems of the biosphere prepared the scientific basis for a number of governmental resolutions. We began with a study of a project to transfer waters of the rivers of Northern Europe and Siberia to the South of the country. We have comprehensively studied this question from the ecological and economic points of view, and have managed to prove that the transfer of the waters of the northern rivers (the Northern Dvina and Onega) into the Volga basin is of practically no use due to climatic changes that have begun. Over the past eight years the average Volga run-off has been 26 km^3 larger than that over the preceding one hundred years and is increasing. Building new reservoirs on the Upper Sukhona and Onega on fertile soils wastes money for only 6 km^3 of additional water is transferred into the Caspian Sea. But the Caspian Sea does not need water. Its level has begun to increase.. One should start thinking of how to decrease this level, e.g., by transferring large amounts of water to the Carabogaz Bay that earlier evaporated about 6 km^3 of water.

As for the Siberian rivers, the problem has not been removed from the agenda. The population of Central Asia is rapidly growing due to a high birthrate and the migration of Soviets from Siberia and the Far East to a region with better climatic conditions. Central Asia will need water. The resources of the Amu-Darya are practically exhausted. The completely exhausted Syr-Darya does not reach the Aral Sea. But the project on which work began is not satisfactory. It would give Central Asia only 8 or 10 km^3 of water. This is too little because due to faulty irrigation, Central Asia now loses about 26 km^3 of water. Measures on water economy should be taken there before water transfer from Siberia begins. It is probable that in the XXIst century we shall reconsider this project. In any case, we reported our calculations and presented them to the government and on August 14, 1986 it was announced that the transfer to the South of part of the run-off of the northern and Siberian rivers had been cancelled.

The second problem being studied under the supervision of our Scientific Council is that of Baikal, the wonderful lake, about 2 km (1741 m) deep, in eastern Siberia with amazingly clear water. Baikal waters are clean due to the resident fauna: a tiny swimming crayfish "epischura baikalensis" inhabits the upper layer of the water. It filters water through its body leaving the suspended particles in its tiny shell. Six generations of crayfish live and die during the summer period, and six times these epischura shells with their loads of suspended particles drop to the bottom. This explains the amazing purity of the Baikal waters. In 1955 it was decided to build a pulp-and-paper mill on Baikal. It was supposed to produce cellulose cord for the aviation industry. However, the industry stopped using cellulose cord and began to use a metallic one. The factory began to produce ordinary paper. And though there were water-treatment facilities, the factory polluted Baikal. We suggested moving the production of cellulose down the Angara river to the North where conditions are right for the production of cellulose. In April–May, 1987, our governmental bodies announced their decision to purify not only Baikal itself but all the rivers flowing into it, to enhance the sewage systems of the cities on these rivers, to stop the production of cellulose on Baikal and to move the factory to the new city of Ust-Ilim, being built on the Angara.

A third problem that our Scientific Council has considered is how to keep Lake Ladoga clean. This is the source of the Neva River, which provides Leningrad with water. This problem was mostly considered by our colleagues from Leningrad, but we discussed their proposals at meetings of our Council and then presented them to the government. A governmental resolution on the protection of Lake Ladoga has recently been published. This means that another of our regional ecological projects has been successful.

We are now examining the project to build another water reservoir on the Upper Volga near Rzhev to provide Moscow with water. According to this project, 60 km^2 are to be flooded but we are against building reservoirs in plains (they can be built in montain clefts). Fertile lands are too valuable to be lost to water reservoirs. We have succeeded in demonstrating that underground sources around Moscow can provide more water than could be obtained from this new reservoir. The latter was supposed to give 23 m^3 per second. We have shown that the underground sources around Moscow can give 35 m^3/sec. That was the main argument against building a new water reservoir. The Council of Ministers of the Russian Federation has already considered our proposals and agreed with them. The resolution is under consideration by the Council of Ministers of the USSR and will probably be adopted.

I have used these examples to show how environmental protection is developing in the USSR. Of course, our Scientific Council is not the only body working in this field. We have a powerful Soviet Committee for the International Program "Man and the Biosphere", headed by Academician V.E. Sokolov. This committee has been very successful in establishing nature reserves and saving many endangered animals. During the war, the European buffalo was practically exterminated in the Soviet Union. Now buffalo live in Belovezhskaya Pushcha on the border with Poland, a reserve on the left bank of the Oka River near Moscow, and the Northern Caucasus; a herd of buffalo has appeared in Lithuania. An attempt was also made to introduce buffalo to Central Asia but the buffalo ate the young trees and had to be removed.

The saigak is our steppe antilope. At one time the saigak population fell to 12 thousand but now in Kalmykia and Kazakhstan, it is at 600,000. The population has been completely restored!

Reserves helped greatly in protecting fur animals and the sable, particularly in the Kondo-Sosvinsky reserve on the eastern slope of the Urals and in the Barguzinsky reserve on Baikal. At first, the sables were bred within the reserve but later the animals were allowed to migrate into the forests of adjacent territories where sable hunting has now resumed.

There has been some progress in nature conservation and environmental protection in the Soviet Union, just as in many other countries as well. I am aware of the allocations of the government of the Federal Republic of Germany to clean the Rhine, and I know how many billions of dollars the United States of America has spent to clean the Great Lakes. Efforts in this direction will no doubt continue and should increase, due to the growing population of the Earth.

I have not mentioned soma other important ecological problems, such as desertification in tropical countries. A great deal has been done toward solving that problem. I would like to dwell now on the science of human ecology which gradually evolved as the above ecological problems were been studied. In the XIXth century, ecology included plants and animals but not human beings. Today human ecology or the study of human adaptation mechanisms to new, unusual and/or extreme situations assumes great significance. People survive in outer space and at sea depths of up to 200 m. In older times, in the regions of the alpine meadows in high mountains, only shepherds could live for half a year. Nowadays we build permanent settlements and mines for extracting minerals at an altitude of 4,000 m. Living conditions at such altitudes should be studied. A special institute of human physiology and pathology at high elevations has been organized at the Academy of Sciences of the Kirghiz SSR in Frunze. An institute of the same kind in Ashkhabad (Turkmenia) studies human ecology in dry hot desert climates. There are permanent settlements in the Antarctic where living conditions (half a year without sun and with a temperature of minus 60-70° Celsius) also must be studied.

And finally I should mention the problem of large cities. I think that the ecological situation here is no less extreme than in deserts or high mountains. The stress of living in large cities, exposure to X-rays instruments, noise, etc. is definitely extreme. It is not by chance that we have overcome infectious diseases while the deterioration of the human organism's functions intimately associated with city life is growing dramatically. The number of deaths from cancer in a city is proportional to its population. At the same time, in regions where there are no large cities, as in Yemen, our doctors could not find a single case of cancer in five years. Not only cancer, but chronic lung diseases, upper respiratory tract ailments, bronchitis, allergic diseases, malfunctions of the cardio-vascular system are typical diseases of large cities, let alone mental disorders. That is why the study of human ecology under extreme conditions, including those of large cities, are also likely to be given high priority.

I would like to say a few words about the near future. In the Soviet Union we are preparing to merge the many organizations for nature conservation and to establish a State Committee for nature conservation to be headed by one of the Deputy Chairmen of the Council of Ministers of the USSR. This is necessary to ensure that the resolutions of this Committee are obligatory for all firms and all ministries. This year a large program on biospheric and ecological investigations has begun to be drawn up at the Academy of Sciences of the USSR. Mindful of the great importance of biospheric and ecological investigations for the future of the whole mankind, the President of the Academy of Sciences of the USSR, Academician G.I. Marchuk, has agreed to head this program. The program will include the following sections (they have not yet been finalized): a section on the biological aspects of the program, headed by Academician V.E. Sokolov; a section on the geophysical aspects (mostly concerning the expected global changes of the atmosphere and measures to keep its purity), headed by Yu.A. Israel, Chairman of the State Committee for Hydrometeorology; a section on the ecology of industrial factories, led by Academician B.N. Laskorin, who was instrumental in designing a closed water supply for industrial factories in the USSR; a section on ecology of agriculture, headed by Academician Kashtanov, a Vice-President of the Academy of Agricultural Sciences; a section on conservation and recovery of soil fertility, headed by V.A. Kovda, Corresponding Member of the Academy of Sciences of the USSR; a section on conservation and recovery of forests, not only as a source of timber but as a necessary element of nature as well, headed by Academician A.S. Issayev, from Krasnoyarsk; a section on human ecology, to be headed by myself and some of my assistants; a section on regional ecological problems of Lake Baikal, to be headed by a Corresponding Member of the Academy of Sciences of the USSR, V.M. Kotlyakov, who is director of the Institute of Geography of the Academy of Sciences of the USSR. Finally there is the section on energy and mass exchange in the biosphere, headed by Academician K.Ya. Kondratyev.

I would like to add that the International Council of Scientific Unions (ICSU) has decided that beginning in the next decade, IGBP (the International Geosphere-Biosphere Program) will be a main subject of investigation. This program may cover a period of 500 million years, but attention will likely be paid to the changes that have occurred during the last 2 Ma, i.e., covering periods when glaciers repeatedly advanced and retreated in and out of northern Europe. Sometimes Europe resembled Antarctica and Greenland today but at other times walnut forests were growing in Yakutsk in the north of Siberia (their fruit was found and described by Academician V.N. Sukachev in the sediments of the last interglaciation near Yakutsk). Although the main elements of IGBP are still being considered by the Special Committee appointed by ICSU, it is likely that changes in the Earth's geography, in its climate, and in sea level over the past 2 Ma will be one of the main parts of the program. I think that IIASA, where interesting and important investigations of the biosphere are carried out, should become involved into this international program, it should widen its investigations of the biospheric problems. For example, it might be desirable to expand the IIASA European Case Study, in which environmental changes in Europe are being pieced together for the past 300 years, to include the whole globe and to extend the time scale from 300 years to 300,000 years.

I believe that this is a very important task. That is why I will contribute my own efforts to promote it, but the leading role must be played by the research scholars of IIASA. You can accomplish much and I wish you every success. Resolution of these crucial problems is of vital importance for the future of mankind.

PART II

PERCEPTION OF REGIONAL SOCIO-ECONOMIC AND ENVIRONMENTAL SYSTEMS

2.1 THE CHALLENGE OF SUSTAINABILITY – THE SEARCH FOR A DYNAMICAL RELATIONSHIP BETWEEN ECOSYSTEMIC, SOCIAL AND ECONOMIC FACTORS

Uno Svedin
Swedish Council for Planning and Coordination of Research
Box 6710, S-113 85 Stockholm, Sweden

1. The Concept of Sustainability

The concept of sustainability has emerged as a key one in the environmental field during the last few years. For example the World Commission on Environment and Development headed by the Norwegian Prime Minister Brundtland has used it as a key concept. But what is involved and what are the problems? Let us start with the implicit connotations. 1)

- The need for a sustainable development has as a starting point the observation that the present development is not sustainable. And something has to be done about it.
- The need for a new perspective changes the former approach to protect nature as such into an issue of a reoriented goal structure and agenda of socio-economic development. The merge of the "nature protection" agenda with the much broader issue of a fundamental change of the priority setting within the socio-economic goal structure is new.
- The escalation of the complexity of the issue is based on the idea that the protection of nature cannot be seen in isolation from a long-term survival of man-kind. The shift of focus is thus from an important but still *partial* objective to a more *general* objective. This wider connotation has several dimensions. It addresses the longer-term perspective of transgenerational issues. And it recognizes that we do not only deal with *universally* recognizable situations and themes (as the destruction of agricultural potential) but global issues as well. The micro phenomena and actions are reflected on to the macro plane. One example of this is how personal micro decisions by consumers on technical solutions link with the emergence of the ozone layer problem. At the same time global phenomena, like the CO_2 induced greenhouse effect, will give local impact, e.g., in terms of climatic changes.
  The generality of the issue thus also binds the activities performed in various parts of the world together.
- The call for sustainability not only puts a focus on to the design of the societal development philosophy itself but also points at the interlinkages between the natural world and the socio-economical and cultural aspects. This demands a deeper insight into the generating mechanisms of various

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buracas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

kinds of modern environmental problems. What happens to nature cannot be treated alone in terms of conventional "environmental management techniques" addressing themselves more to the effects than to the ultimate causes of what happens. On the institutional side this calls for much stronger forms of trans-sectoral approaches than has hitherto been the norm of government. Indeed also limited tasks like the restoration of lakes have called for a very high level of institutional and political ingenuity. What would then be the case for a proper design of a long-term management, e.g., of the Baltic surrounded by many countries, all with different ways of handling things and with different traditions as well.

With the increased generality of the approach and the hereby increased complexity of the topic several problems have to be highlighted. 2)

- The call for sustainability implicitly asks for something to be conserved. But what is it? In the forestry case is it:
  - a specific type of forest?
  - a capacity to grow trees?
  - a capacity to grow trees as well as other things in addition (thus transferring the issue from sustainability of forestry to sustainability of biomass production)?
- At which spatial size is the sustainability to be maintained? The term cannot indicate an overall freeze at all levels of a specific spatial pattern of biomass generation at a certain time. The idea of sustainability must rather in some way relate to a specific systems level. The outcome of the norm of sustainability is very different if it relates to the food-production capacity at the global level or if it relates to the country surroundings of Vilnius. The choice of the proper perspective involves thoughts about social control, societal risk management, distribution of income issues, etc. This clearly indicates that we need to integrate the more biologically-inclined issues of carrying capacity with those of societal goal setting and development of technological repertoires. Sustainability is not a fixed concept only related to biological and geo-chemical-physical environments. It is as much influenced by societal systemic considerations. This puts the problem of societal value into focus.
- "Sustainability" also opens the issue of the relationship between those features which have to be sustained and those which do not need to be sustained. Not everything is necessary to conserve. But what rules should we adopt for our choices? This question opens the entire issue of dynamics involved in "sustainability". Or to rephrase the issue: What is the dynamic relation between the "entity" to be sustained and the continuously changing surrounding context? We could even talk about this problem in a framework similar to that of evolutionary theory in biology: What is sustained – and *should* be sustained for us – in the flux of evolutionary change? Under which conditions is our "sustained performance" thought to hold? Constant surroundings yes – but what about changing settings? We could address this issue within the thought framework of dissipative structures: What type of setting in the term of energy flow are we supposed to consider in order to keep a dynamic stability of something?
- The issue of sustainability also directly introduces the problem of reversibility and irreversibility of phenomena. In certain instances we may allow a deliberate change, e.g. permitting agricultural field to be used for 100 years for coniferous forest plantation, knowing that the process in principle

is reversible. But what about genuine irreversible behaviours in our systems? Or even risks of irreversibilities?

2. Views of Sustainability by the World Commission on Environment and Development

In the Brundtland Commission Report "Our common future" the theme of "sustainable development" is introduced already in the first chapter and then runs as the key topic through the book. What are the main points? (They are given here in a somewhat compact form.)

- Humanity *has* the possibility to make development sustainable. The needs of the present are possible to meet without compromising the ability of future generations to meet their own needs.
- There are limits – but they are not absolute in character as they are set by the present state of technology, the social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities.
- Both technology and social organization can be improved.
- Sustainable development requires meeting the basic needs of all. A world, in which poverty is endemic, will always be prone to ecological and other catastrophes. This calls for an equity-oriented policy.
- The capacity to promote sustainability varies depending on the design of the political system. Sustainability is promoted by an effective participation by the citizens in decision making.
- There is need for greater democracy in international decision making.
- Rapidly growing populations can increase the pressure on resources and allow any rise of living standards. Thus sustainable development can only be pursued if size and growth of the population are in harmony with the changing productive potential of the ecosystem.
- Sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitations of resources, the direction of investments, the orientation of technological development and institutional change are made consistent with future as well as with present needs.

In the following sections we will further elaborate on these themes.

3. A Few Threat Test Cases of "Non-Sustainability" Performances

In order to further elaborate on our own perception of what a sustainable development could mean let us confront ourselves with a few test cases out of the repertoire of the most well-known environmental problems, which potentially could indicate a lack of sustainability.

Before we start let us only make the remark that already the word "threat" indicates a threat for *someone* and in relation to *some specific value*. But we will come back to that.

Case 1: ***Nitrogen leaching from agricultural practices***

In Sweden as in many temperate industrialized countries the leaching of nutrients from agricultural activities into streams and lakes have caused severe problems. In Sweden the lake Ringsjön in the south of the country has e.g. been exposed to such problems.

However, when we talk about the issue of sustainability would we then include this problem? Would it be included in our perspective of non-sustainability that the eutrophication of lakes is a sufficiently large problem at the level of survival of mankind? Or is it unfair to have the criteria of severeness so high in order to incorporate a problem on the sustainability agenda?

Or is it rather the (in many cases unnecessary) loss of important nutrients that is at the heart of the issue of sustainability? The loss of phosphorus (whenever that is the case) could be regarded as such a threat to mankind as phosphorous deposits seem limited on a world basis in the long run.

In Sweden agricultural activity in the south of the county Halland has created large problems in the close-by bay of Laholm, where all excess nutrients finally enter. The government program to revert the trend has only just begun. The authorities have to work a decade long to mend the harm done e.g., to fishing.

But solutions are not very easy to find as they have to involve agricultural technology and economic regional aspects as well as complicated issues in the field of legal regulation of rights and administrative procedures. Is this environmental threat a case for our non-sustainability topic and, if so, on which grounds? Obviously an entire region is affected. The problems span over a considerable time. Nobody knows if we really can reverse the trends. The costs for redevelopment activities are considerable to the national and regional levels. Changes in practices and individual rights involved will take many years.

Still another and connected theme: In large parts of agricultural Europe the groundwater has now been so penetrated by a high nitrogen component that it is unfeasible for immediate drinking. The detrimental effects do not now only go down in the soil layers to a few meters but are in many cases counted down to 50-100 meters, which means that effects given during a rather short time of maybe twenty years have now created in a practical sense an irreducible condition in which future society will have to pay the bill (e.g., through the cost of cleaning its drinking water). Are we here on the level of harm to sustainability and, if so, in what sense?

Case 2: ***Acidification of European forests and soil***

Without going into the details of the important and in some respects complicated pattern of causes and effects with regard to forest die-off we can only note a dramatic effect of long-term duration and wide supra-regional distribution in Europe. The problem obviously is not easily solved as potential causes involve both the structure of energy production in several countries as well as the exhausts from a car-based transport system. Thus the relationship between the problematique in the natural domain – the forest – and the causes on the societal level has the character of a deep inbalance and with possible causes to be changed only through considerable economic and societal reorientation. Is this an example of lack of sustainability? Could we contemplate vast regions in our industrialized countries without forests? And what will happen with other ecological facets if that comes true?

Case 3: *Destruction of agricultural potential due to chemical toxicants and erosion*

In many areas the contents of toxicants in the soil are increasing in Europe. This is partly due to fall-out from the air and partly due to water-solved toxicants from dumps and incomplete systems of waste management. Is this a sufficient threat to sustainability of e.g., Europe? Let us extrapolate the trend and contemplate a future for Europe in which its land has turned into a "chemical desert" in earlier useful areas for food production. If the activity of these areas now turn to production of "industrial crops" instead, and food is imported from less contaminated areas in other parts of the world, would that be seen as a new form of global division of labour or an unacceptable lack of regional sustainability?

In the same way vast agricultural areas are degraded through soil erosion as a recent report from the Science Council of Canada indicates: "A growing concern – soil degradation in Canada" (1986). Or to quote from that report: 3)

> "In the mind of the general public soils degradation is most often associated with drifting soils on the Praries during the "dirty thirties". However, soil degradation poses a much greater threat to Canadian agriculture today than it ever has in the past. Headlines publicize only the sensational events or disclosure what capture the media's imagination. They leave the impression that the problem is episodic. In fact, soil degradation is an ongoing, insidious problem that occurs in all parts of the country at a cost of over 3 million pounds per day or \$20-\$25 per hectare of agricultural land in Canada, or 38 per cent of net farm income. For many farmers, the cost of soil degradation represents the difference between profit and loss.
>
> The economic viability of agriculture in all regions of the country depends upon the productivity of the top 10 centimetres of topsoil. While topsoil is constantly being formed, it is also constantly being depleted. Under present farming practices this depletion can far outstrip the rate of formation.
>
> The contamination of topsoils with salt, or salinization, is another form of degradation. In Alberta it has been estimated that crop land affected by salinity loses from 50-100 per cent of its normal productive potential and costs farmers \$80 million per year in lost yields. As already noted, the total cost of soil degradation across Canada, not including off-farm costs, is \$1.3 billion annually. If these losses are allowed to continue, the cumulative cost of soil degradation to the Canadian economy could be enormous by the turn of the century."

Should this be regarded as a severe threat to sustainability or not? And why?

Case 4: *The erosion of biological diversity*

For many years now the problem of erosion of biological diversity has been pointed at as a most threatening issue. In a recent report by Edward C. Wolf ("On the brink of extinction: Conserving the diversity of life", World Watch Paper 78, 1987) an example of extinction rates for plant extinction in Latin American rain forests is given. The worst case scenario for the end of this century – assuming only the intact stands of forests in established parks and protected areas remain – indicates an eventual loss of 66 per cent of the plant species in the Latin American tropics. 4)

Projected Plant Extinctions in Latin American Rain Forests

	Estimate of Forest Area	Equilibrium Number of Species	Share of Species Lost
	(million hectares		(percent)
Original Forest Area	693.0	92,128	-
End of Century	366.0	78,534	15
Worst Case*	9.7	31,662	66

* Assuming only areas currently designated as parks and reserves remain intact.

Source: Adapted from Daniel Simberloff, "Are We on the Verge of a Mass Extinction in Tropical Rain Forests?" in David K. Elliot, ed., *Dynamics of Extinction* (New York: John Wiley & Sons, 1986).

Is this sufficiently threatening to be on the list of non-sustainable practices. And if so, why?

Case 5: *Climatic change due to the role of carbon dioxide and of other green-house gases*

At the Villach Conference in October 1985 the scientists from twenty-nine countries assessed the role of the increased carbon dioxide contents in the atmosphere (as well as other "green-house gases" and aerosoles) on the climate changes and associated impacts.

The Conference reached the following conclusions and recommendations.

1. Many important economic and social decisions are being made today on long-term projects – major activities of water resource management such as irrigation and hydro-power, drought relief, agricultural land use, structural design and coastal engineering projects, and energy planning – all based on the assumption that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption since the increasing concentrations of green-house gases are expected to cause a significant warming of the global climate in the next century. It is a matter of urgency to refine estimates of future climate conditions to improve these decision.
2. Climate change and sea-level rises due to greenhouse gases are closely linked with other major environmental issues, such as acid deposition and threats to the earth's ozone shield, mostly due to changes in the composition of the atmosphere by man's activities. Reduction of coal and oil use and energy conservation undertaken to reduce acid deposition will also reduce emissions of green-house gases; a reduction in the release of chloroflurocarbons (CFCs) will help to protect the ozone layer and will also slow the rate of climate change.
3. While some warming of climate now appears inevitable due to past actions, the rate and degree of future warming will be profoundly affected by governmental policies on energy conservations, use of fossil fuels, and the mission of some greenhouse gases.

Thus the uncertainty in some of the basic parameters was stressed at the same time as the urgency of the issue and the scale of its impact was agreed upon. Is this a sufficient threat to sustainability and, if so why?

Discussion of the Cases

How should we then relate to these cases with the criteria of sustainability in mind?

1. First of all there is some sort of *level* of the problem to be approached. It might concern the seriousness of the threat, its geographical coverage or its time depth impact. This is not to say that smaller problems should be ignored. It only states that issues tending to ruin the sustainability on nation or multi-nation levels have a certain dimension of seriousness related to the potential consequences.
2. The character of threat could be *universal* as well as *global* and still threaten sustainability.
3. The aspect of time span or the level of financing to revert the problems could have a character as to make the problems *irreversible*.
4. The timing as well as triggering situations might make the situation most unstable and worrying.

With this in mind several of our cases have such character as to provide unacceptable unsustainable performances at one level or another.

We need also in our analyses to make distinctions between the various types of threats. The problems might in a bipolar framework either be local or global. (So for the moment we disregard the interesting intermediary "regional level"). This gives rise to a 2 x 3 matrix.

		Solutions	
		Local	Global
Problems	Local	Nitrogen leaching	
	Global	Biolo- diver-	gical sity

Sets of problem solutions in different parts of the matrix have different characters.

Two extreme examples are drawn in the matrix to exemplify the point: on the one hand the very local-local character of nitrogen leaching (solid line) and on the other the much broader sphere of the "biological diversity" issue (dotted line).

4. The Role of Values

We have now dealt with the anatomy of non-sustainable development. Before entering the issue of action and problems related to policy let us as a bridge say something about values. This includes culturally-supported choices of options.

It is important to notice that such difference in values exist before entering a discussion on optimality of resource use or the future goals concerning the environment. Already at the level of what is considered a positive development, with regard to a specific environment, wide differences exist. This has relevance to the discussion on sustainability, as it points towards a key question: Sustainability for what? – And for whom? An example from the historical development of the Danish Juthland might make the issue clear. The Danish geographer Kenneth Olwig has used this case in order to illuminate this point. 5)

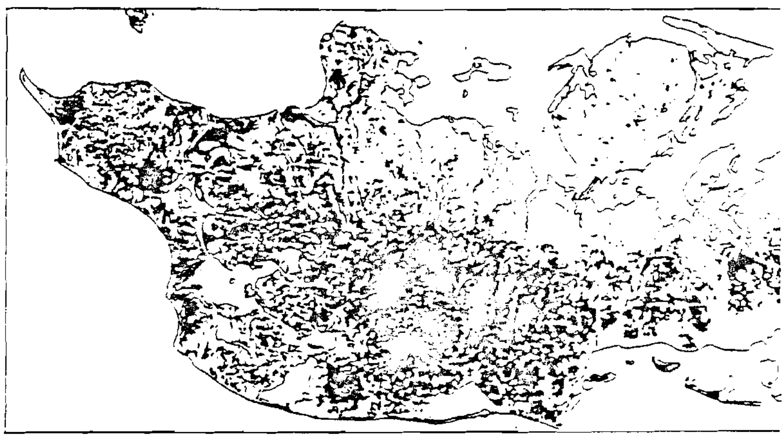
The heathland of Danish Juthland is used by Olwig to exemplify the relationship between our concept of nature and our use of nature. This relationship is by no means static over time. The Juthland heaths are noteworthy for the intensity of the development which they have experienced and the relationship between the development and the national ideology.

Webster's Dictionary defines a heath as:

> "A tract of wasteland ... an extensive area of rather level-open uncultivated land usually with poor coarse soil, inferior drainage, and a surface rich in peaty humus."

From mid 19th century land demand in Denmark rose, especially after the loss of north Schleswig to Germany in 1864. Bravely and industriously – to use the word of Olwig – "the local population waged war on the heather, encouraged not the least after 1866 by the then formed Danish Heath Society (Det danske hedeselskab). The success of this endeavour is mirrored by the following quotation from a geographical text. "After a century, over four-fifths of the heathland have been converted to agriculture and forestry ... Only a few patches of heath remain as scar-like reminders of the former waste, but in several places small areas of heath have been carefully preserved lest future generations forget the labours of the past."
Is this a story of a mighty success of a century-long economic development scheme that we are witnessing? Maybe, maybe not. The judgement of the answer depends on values. This is exactly the point. In fact the Danish relation to the heath expresses a battle lasting more than a century. Through his novels from the mid 19th century the Danish author C.C. Blicher created a national interest in the Juthland heaths. Others followed with publications on social and agronomic conditions. Among these was Frederik Carl Carsens who lamented the destruction of the forests he believed had once covered Juthland. He describes the heath as "dressed in dark, quite as if it were mourning our forefathers deeds, when they so willingly helped to steal the beauty it had inherited for eons." He believed that local landscape taste had to be changed if the local population was to reclaim the heathlands for cultivation. In the interest of agricultural improvement he promoted the beauty of a landscape of the type which supposingly had characterized the golden age prior to deforestation.

The activities of the Heath Society after a few decades became a successful national institution. As such – as Olwig states it – cultivation likewise became institutionalized. It was at this time a movement to preserve the remaining heaths developed, a movement that questioned the social, esthetic and ecological basis for continued heath cultivation.



From Olwig, K., Natures ideological landscape. The London Research series in Geography 5, Allen and Unwin, 1984.

Today considerable efforts are being made according to Olwig to find ways to restore the heaths to their former state. Experiments include grazing, burning and the physical removal of unwanted vegetation.

A very similar example from Sweden related to reforestation practices over two centuries shows the same type of features. The values change over time regarding to which type of landscape that has been seen as "interesting".

5. A Few Important Mismatches

We have so far seen examples of non-sustainability. And we have also discussed the plurality of values, not all of which support long-term sustainability of the biosphere. In fact most practices and policies of today on the societal level would, if continued for a long time, give non-sustainability effects with regard to the environment.

The reason, at least in parts, for this situation is the type of "patchyness" we have to live with due to historical circumstances with regard to ways of life, social norms, already developed technologies, societal institutions, administrative practices and inherited environmental conditions. Such a "patchyness" provides wide inconsistencies at various levels. This could be interpreted as a set of characteristic "mismatches" between what the real situation calls for and what is provided at the level of social norms, of technology etc. In the following we shall have a look at a few of these "mismatches".

5.1 The values mismatch

In all societies the value situation varies from social group to social group, from region to region, from profession to profession. The way in which limited pieces of values are made to relate to each other in hierarchical structures varies especially. The goal of sustainability of the biosphere is not immediately at the top of such a hierarchy in all quarters. It is rather so that long-term strategic goals, as long-term survival, seldom are given supreme consideration. This is the point where the Brundtland Commission has argued for a poverty relead strategy in order to pave the way for those individuals involved to be *able* to choose a long-term sustainability option (e.g., by not cutting down all trees in order to get the needed firewood for today's consumption).

5.2 The concepts mismatch

Closely related to the first category of mismatch is the "concepts" type. This relates to the mental analytical framework in which all decision, at micro as well as macro level, are made. Here we find ideas about types of logic in which to discuss matters. We also have to make a distinction between problems of optimization related to some sort of goal (which might be given in one or several dimensions) and problems originating more due to conflicts of interest.

To this class of conceptual problems we also find varying ideas over time on the relationship between preventive actions and curative ones. Ideas about evolutionary change and its root causes belong to this category. Are we e.g., expecting a balanced final steady state system or are we to address issues within a perspective of fundamental change in which drastic and surprising events occur in parallel to the emergence of entirely new possibilities.

In which way are we dealing with discontinuities and quantim jumps in our perspectives of the future, and what are our ideas about underlying causalities, if ever traceable? What is our view of social dynamics and the possibilities deliberately to change societal action into ways of doing things which are ruled by normally chosen paths?

In all these cases we deal with a plurality of though modes, all of which at the same time cannot be conducive to a "sustainable" use of the biosphere. But which thought modes are more conducive and which are less?

5.3 Analytical tools mismatch

Depending on which type of problem formulation we have adopted we design various tools for the treatment of the problems. The differences between economic theory and ecological theory is not only a very interesting test case of how to make different systems size and contents definitions. It also exemplifies varying focal points with regard to time, space and causality structure These problems are at the heart of many design problems in general relating to conflicts of perspective and interests.

5.4 Knowledge availability mismatch

In the case of the carbon dioxide problem with regard to climatic change the Villach declaration brought forward very clearly that there are identifiable gaps in knowledge of crucial importance for an understanding in detail of what will happen.

Not always is the situation so clear of what types of unknowing there is and where there is a need to fill the gaps. In many cases the not knowing of the problem at all is more the situation. The case of the ozone-depleted patches in the Antarctic atmosphere brings the point forth as did mercury poisoning in many ecosystems during the late sixties.

5.5 Knowledge-action mismatch

The case of CO_2 can be further elaborated. The lack of knowledge cannot be taken as an excuse for doing nothing on the policy arena. Often there is a need of quick responses despite the lack of perfect detailed understanding. (This is not to say that immediate action should be taken just in the case of CO_2).

5.6 Micro-macro levels mismatch

If individual actions give cumulative macro level ("global") problems there is a mismatch between the plane of problem origin and the plane of effects and even response. Typical is the case of the "tragedy of the commons".

5.7 Institutional responsibility mismatch

If ownership or other social responsibility structures do not match the created problems we lack the design for a sustainable future. This mismatch could have both spatial as well as temporal facets. There is a need for a cause and effect relationship in terms of responsibility, i.e., costs and benefits domains must overlap.

5.8 Policy patchyness mismatch

If the overall policy is built on a number of (semi-) independent policy areas there are frequent risks of unintended spill over effects from one area to another. In this case, e.g., overall taxing policies, regional redistribution policies, national security policies, industrial development policies or energy policies might easily spill over into the environmental area up to the level of being main determinants of effects in the biosphere.

5.9 Contextual changes mismatch

We have so far dealt mainly with threats to the sustainability of the biosphere which we can clearly identify to today. However, the patterns of threat (and possibility) are dependent upon their embedding in a wider socio-economic-cultural framework and in some situations also upon a naturally changed ecosystem (due to e.g., vulcanoe dust in the atmosphere etc.) There might emerge a mismatch between today's policies and future needs, when isolated policies aiming at problems perceived in one specific setting in time totally need to be changed when the entire context shifts.

		THE CONTEXT OF THE THREATS	
		Known today	Known only tomorrow
THREATS	Known today	Framework Toxicants in agricultural products Threat Cancer	Framework Flip-flop point in green-house causality Threat Changed speed of climate change
	Known only tomorrow	Framework Biotechnological development Threat Active, harmful organisms let free	Framework Development of technology with strong gravitational fields Threat Reduced human fertility

The table above provides a tentative agenda.

5.10 Public awareness mismatch

To be able to act, even on very good grounds, in favour of a policy of sustainability, there is a need of public support. Without the public awareness and participation such a support is uncertain, especially if the policy puts great demand on the public in terms of accepting costs for long term gains.

6. The Need for a Systemic View on a Sustainability Policy

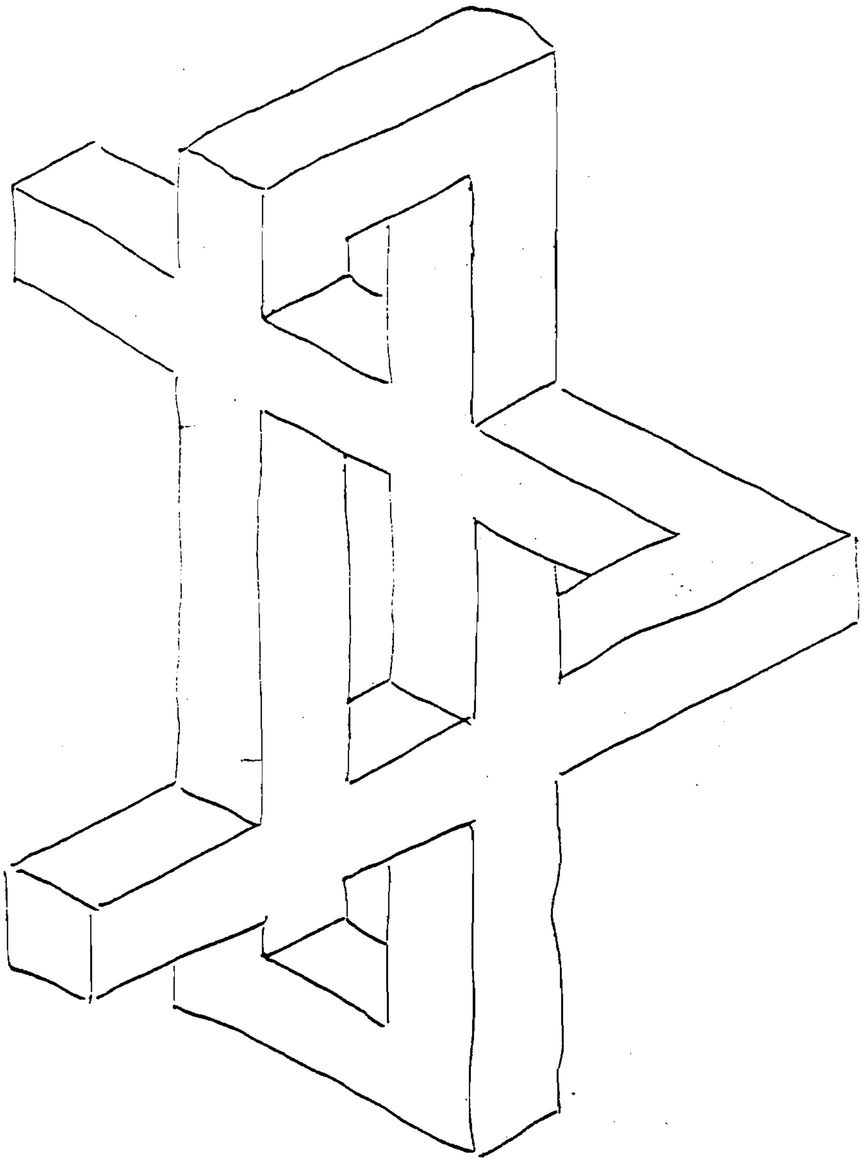
Many elements contribute to the build-up of a sustainable future. In a paradoxical sense many of them are internally inconsistent. An image that could be useful to consider is given by the Swedish artist Oscar Reutersvärd whose "impossible figures" have drawn considerable international interests during the last few years. (A series of Swedish stamps have e.g. helped to provide a wide reknown of these figures.) What do they tell us? (See "Perspective japonaise no 264".) There are two lessons. First of all a design of policy, e.g. concerning global environmental sustainability, is composed of so many conflicting parts that they become some sort of "impossible figure" when the elements of the policy have to be joined together. The impossible figure thus both exists and does not exist. What is the key reason for this paradoxical behaviour? The basic reason is that *local* incremental reasonableness is not sufficient to ensure *global* reasonableness. All the joints in the future are perfectly done – as viewed locally. And the design has a character of continuous acceptability. But the overall figure is still "impossible". We thus have to transcend our approach in building a long-term sustainability policy by adding "local" reasonable design units. A set of extra "global" criteria has to be added. 6)

But is it at all possible to find "possible (policy-) figures" that ensure sustainability on a global biosphere level? Or to rephrase the issue: Can we beside the vast class of impossible policy designs (including both obvious failures already at "local level" as well as the more intriguing border-line cases of "impossible figures") find at least one or few which are "really sustainable"?

It might not happen that we are able to find a total "ecosystem sustainable policy" design which is valid for every place and at all times, i.e. which thus is truly global. We may be faced with the situation where sustainability seems to be assured, *but only in a well-defined setting* (e.g., for a certain time cut and in a specific socio-economic and natural environment).

If we are aiming at a deeper and more genuine type of sustainability and if we disregard an illusion of a once for all fixed world, the solution must be dynamically changing sustainability. In order to promote an understanding of what this means we have to develop a set of key indicators which could provide a checklist on proper sustainability directions at a given moment and situation.

The aspiration would then rather be to develop policy indicators which jointly tell us if we are outside of a long-term sustainability realm or not, rather than trying to find *the* optimal sustainable design (if ever such a design is possible to envisage)> We are then back to a perspective in which we are searching for an understanding of serious irreversible phenomena, which either continuously and slowly (but forcefully) pave the way for our future *or* sudden arising fluctuations shocking the system beyond the limits acceptable to man.



After "Perspective japonaise no 264" Design by Oscar Reutersvärd

7. The Regional Level

To conclude, what has all this to do with the regional level? We can be fairly short in our response having made the remarks on the mismatches. The regional level is (irrespectively of the more detailed way it is defined) the intermediate level between the micro and the macro levels. Many things which are not possible to deal with forcefully on the micro level are possible to handle on regional level. Many phenomena which have global character and thus should have a global treatment are not possible to treat at that level due to lack of sufficient cultural, social or institutional homogeneity.

The regional level is a most interesting offer. But is has to be developed. And its specificity with regard to sustainability has be further scrutinized.

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2.2 SOCIAL CRITERIA AND PREFERENCES WITHIN ECOLOGICALLY SUSTAINABLE REGIONAL DEVELOPMENT*

Antanas Buracas
Lithuanian Academy of Sciences
Pozelos 52-315, 232600 Vilnius, USSR

1. Introduction

In this paper, an analysis will be made of factors impacting on regional biota and natural resources management and methodological approaches to regional sustainability of rational anthropogenic activity within biospheric systems. The social criteria of modeling systems integrating regional, economic and ecological productivity processes under technological dynamics will be conceptualized and some methodological aspects of their practical application for numerical alternative forecasts evaluated.

Regional management strategies include an evaluation of the utilization and regeneration of renewable natural resources and adequate regulation of anthropogenic activity, its growth and both structural, transregional, and interbranch changes aimed at sustainable ecological equilibrium and neutralization of negative influences. The managerial decisions are complicated as the result of multiple use of natural resources for different purposes by various social groups with multiple and often even conflicting or competitive objectives under their partial dynamic interdependence. The long-run programming of technological and socioeconomic activities with environmental constraints limiting the spatial and temporal use of ecological resources presupposes a longer time horizon of integrated socioeconomic and ecological forecasting as well as adequate future modifications in their institutional and organizational infrastructures. The purposes determining rational hierarchies of preferences and principles of their restructuring within ecologically sustainable regional development are also discussed.

2. Background and Criteria

Ecological *sustainability* of regional development under a socioeconomic conceptualization may be interpreted as a dynamic territorial structuring of anthropogenic activity which would: (a) ensure life support and well-being compatible with environmental protection, (b) neutralize unwanted pollution and/or negative influences resulting from uncontrolled global climatic changes and noospheric disturbances, and (c) stabilize conditions for biota spatial self-induced rational productivity.

Management which is oriented to socioeconomic criteria of ecological sustainability supposes that biological and climatic criteria, or parameters of sustainability must be used as restrictions, or as conditions limiting the sphere of

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buracas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

rational decisions for socioeconomic and sociogenetic activity. On the other hand, decisive biological criteria of sustainability within this conceptual approach cannot be integrated into management systems without their socioeconomic evaluation, i.e., the degree in which we may take into account some negative ecological disturbances and changes depends on the disposable material and financial sources and even on the possibility of using professional experts and special teams as necessary. As a result, the orientation of ecological sustainability is closely interconnected with real managerial limitations which must necessarily be taken into consideration when constructing multicriteria hierarchies for multisectoral simulation and forecasting of integrated socioeconomic and ecological productivity.

Firstly, the following important socioeconomic criteria of ecological sustainability may be marked and singled out for programmed management decisions:

- nonharmful sustainable environmental conditions for human life determined both by natural processes and anthropogenic activity (avoidance of uncontrolled genetic mutations, etc.);
- resilience of basic biota structu,-es to unexpected perturbations and sustainability of balanced rational interrelations between existing species taking into account their natural regeneration such as noospheric conditions;
- effective utilization of sustainable biota productivity (commensurate expenses and results in productive living resources, and interfering with criteria mentioned above); and
- combination of natural and anthropogenically regulated dynamic stability taking account of its internal and external parameters and factors, etc.

This *criteria set* is a means to conceptualize social *preference* hierarchies in forecasting and management practice, determination of intensity of resource utilization and territorial allocation, calculation of ecological productivity costs (including stimulation of natural restoration and neutralization of losses resulting from nonproductive usage of natural resources). The ecological sustainability criterion also supposes the determination of its *global, regional* and *sectoral* (by branches, activities, technological processes) *significance*. Beside, all ecological objectives of sustainable activity have to be oriented in order to maintain the biological potential in accordance with changing *needs and goals*, not only those present, but also for *future generations*.

The directions and parameters of sustainable anthropogenic activity depend, as is well known, on ecological disturbances resulting from both previous human activity as well as expected climatic and biospheric instability (soil and water contamination, atmospheric radioactivity, photo and nonphoto-oxidizers, the greenhouse effect and depletion of the protective stratospheric ozone layer, and so on). The regionalization of sustainability parameters and criteria of preferences within an integrated system of socioeconomic and ecological productivity is likely to be sensitive also to principles of commensurability of developing socioeconomic priorities.

3. Programmed Regionalization of Ecological Management

The Baltic republics are possibly leaders in the Soviet Union in programmed socioeconomic management of some processes of ecological productivity and rationalization of natural resources utilization. This has revealed the necessarily close *interconnections* between multi-aspect research on sustainability and *modeling* systems, on the one hand, and real state-managed regulation of anthropogenic activity on all territorial administration levels, on the other.

The multisectoral nonlinear system of regional productivity forecasting including ecological sustainability was constructed in the Institute of Economics, Lithuanian Academy of Sciences in 1980–1987. A schematic of integrated regional simulation of sustainable ecological development using this system is presented in Figure 1.

During 1983–1985, Lithuanian scientists, architects and representatives of various organizations interested in nature protection also elaborated a long-term regional scheme for multistage ecological sustainable management for the period 1986–2000. It revealed the *most problematic ecological areas* requiring particular sets of means to stabilize deteriorating situations by restricting some kinds of polluting anthropogenic activity and significantly stimulating the natural restoration of ecological resources. The modeling system supposes that possibilities exist of alternative interactive solutions.

The *institutional* structuring of ecologically sustainable programming supposes that normative decisions concerning alternative scenarios of regional development have to be taken on various levels of agro-industrial complexes, urban agglomerations, and other official social institutions and organizations.

The elaboration of programmed regional management scenarios (balanced or optimized) should be based on the evaluation of the following elements:

- levels of economic utilization of nonproductive resources (including possible destruction of certain species) in the process of intensification of the productive activity;
- improvement of the background cleanliness of the environment to predesignated levels;
- realization of possible mechanisms of productivity of the biological species under consideration and other natural resources; and
- preservation of recreational zones and natural reserves, and so on.

Simultaneously, it is necessary to elaborate an adequate legal system of corresponding administrative institutional control and adequate criteria for a complex economic evaluation of social utilization of ecological resources (recreation, etc.) and their technological and economic commensurability with the cost of restoration of damaged renewable resources.

Interactive computerized dialogues *amongst planners* using a multisectoral regional *simulating system for resource-by-resource* and *industry-by-industry evaluations* of integrated productivity processes will help to select the strategies of ecologically sustainable programmed development over the middle and long range.

The following sequence may be given in the elaboration of basic alternative scenarios.

First Stage. Perfection of the regional scheme of production development and distribution taking into account the possibilities of rationalization of anthropogenic exploitation of natural resources:

a) determination of structure and aggregated parameter levels of resource demands;

b) determination of capital investments necessary for enlargement and improvement of productivity structure of natural resources in the regional territory (taking account of other limitations);

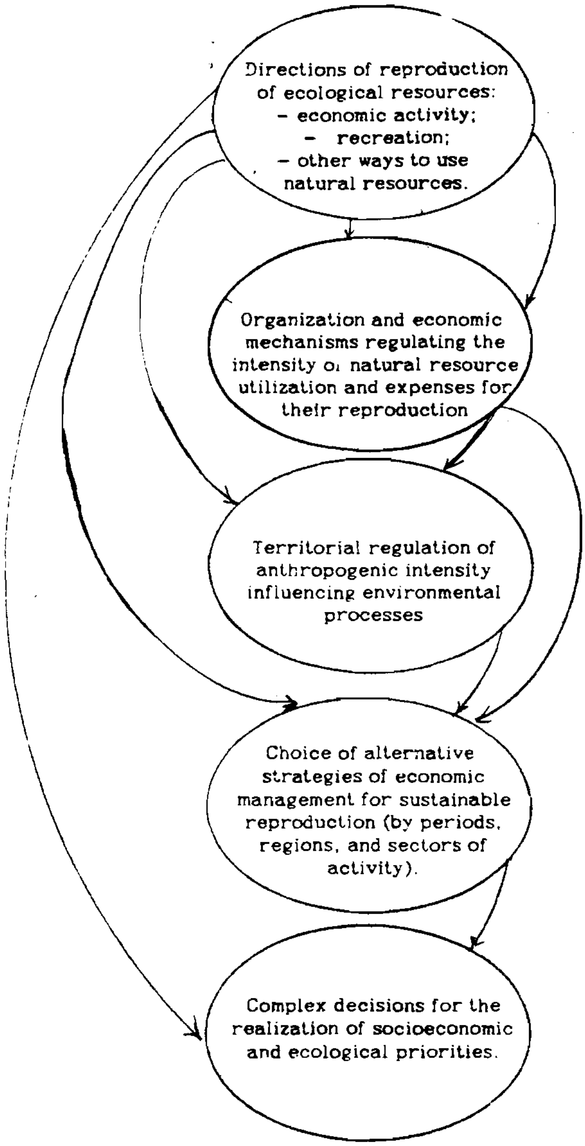

Figure 1. Management of sustainable ecological development influenced by anthropogenic activity.

c) determination of the volume of capital investments necessary for creation of the basic funds needed in the extraction industries, processing materials and establishment of their rational structure;

d) specification of volume and structure of import of resources and export of processed production envisaged for the perspective period;

e) evaluation of the influence of various variants of anthropogenic exploitation of regional resources in conformity with the general rate of economic growth (i.e., some neutralization of the impact of pollutants from other regions and control of territorial polluters of other regions.

Second Stage. Regional simulation of development of the industrial branch aimed at improving the ecological resource balance and environmental preservation for the perspective period:

a) determination of integrated systems of regional resources evaluation within the system of factors forming the regional environment;

b) sophisticated estimation of the cost of reducing background contamination to a normative level;

c) recommendations concerning the needed structural change of anthropogenic (industrial as well as agricultural) productive activity aimed at stabilization of the ecological situation within problem areas; and

d) evaluation of costs of rational reorganization of the regional industrial complex and other anthropogenic activities taking account of costs (including creation and maintenance of national parks and reserves; waterside preservation plantations along a sea-coast; acclimatization of valuable biological species; creation of agro-protective forests such as in windy and desert areas, etc.). The interaction parameters between components of socioeconomic and ecological productivity on the level of submodels (blocks) of the integrated system are modified after some cycles of iterative calculations and in accordance with regularities of multisectoral simulations set up in the structure on the macrolevel.

The *modeling system* considers the demand for ecological resources in accordance with the intensity of separate types, both anthropogenically regulated and semi-regulated, by the economic sectors and activities within the region. Constructive principles to compare environmental impact assessments and ecological costs by activity types are put forward using input-output matrix modifications. The practically used concept of regionally internalized ecological sustainability for long-range (20 years) socioeconomic forecasting based on developed systems of regional ecological monitoring has been realized as multisectoral interactive simulation with about 20,000 restrictions (without territorial division criteria) including:

[1]

a) integrated balancing block (1040 equations),

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[1]Alternative limitations and goal functions are not taken into account. The multifactoral simulative analysis is based on 1965–1986 annual data and integrates 26 industries, 12 income groups most homogeneous by life-style, and 32 products of final consumption.

b) ecological block (3744 equations),

c) financial block (8736 equations), including income (4,992) and consumption activity block (3072 expenditure equations),

d) demographic block (~ 800 equations); and

e) block of productive activity (~ 1000–1800 equations).

Ecologically sustainable development is basically simulated as the regional productivity of main natural resources (water, soil, atmospheric, biological and zoological resources, e.g., taking account of their functional and modality state: clean, thermal, acoustical, and chemical pollution, partly or thoroughly cleansed, polluted, neutralized, and so on), economic formation of capacities for neutralization, cleaning and sustaining natural recreation of biospheric resources (from financial investments), functions for exploitation costs, partial and complete loss functions. The interrelations between different regions and territorial transports of disturbances and pollution are initiated as external input-output (or export and import) balances by components, sectors or resources.

One of the most important problems at the level of regional ecological sustainability initiation was the differentiation of the most characteristic dependencies and indexes and the estimation of their integrating mechanisms in the most compact way – on the basis of dynamically-balanced regional productivity of the gross national product (GNP) and its natural components (prefabricated and natural material resources, demographic resources and productive capacities, and so on).

The next step in the realization of alternative goals of ecologically sustainable development simulation would be to work out the integration of multisectoral socioeconomic productivity models, on the one hand, and dynamically interconnected multispecies ecosystems, climatic or biophysical parameters, on the other (such as the CREAMS, POLLAPSE); constructive research was conducted at the Lithuanian Academy of Sciences from 1984–1985 and possibly at IIASA and other places.

4. Structuring the Basic Models of Integrated Regional Productivity Management

4.1 The achievement of alternative goals in regional development on the basis of integrated economic and ecological productivity assumes the determination of:

- full substitution, regional and branch displacements in funds and capacities, migration of labor resources,
- interchange and substitution of industrial technological means,
- replacement of hierarchies of goals with regard to the interconnection and complementary of (public) needs and values as a means for their satisfaction (extension of recreational services and leisure facilities network)

The alternative ways of development should be estimated by the measurement of costs (for technological organization, production of substitutes) and results (utility with regard to final consumption) taking into account the value of usable natural resources and neutralization of the industrial contamination of environment.

An alternative evaluation of resource limitations in terms of technological innovations is appropriate, both branch and interbranch technological determinations of production targets. Depending on the approval by state and other official managing institutions of preferable local variants of interbranch coordination within the defined territorial scheme, the following distribution of national economic complexes is expedient:

- productive capital investment industries,
- territorial complex of energy and fuel,
- complex of industrial infrastructure, etc.

The near-term integrated development of the regional systems of the Baltic socialist countries has already put on the agenda the formation and extension of the following interbranch complexes (taking into account the factors of ecological sustainability)

- trade-industrial complex,
- complex of social infrastructure,
- complex of ecological regulation and rational preservation of a favorable natural environment.

The modeled structure of the complicated interrelated branch and interbranch systems of interacting national economic complexes provides for specific ways of simulating connections between these structural regional distribution models, on the one hand, and general national economic and ecological and interregional systems of universal models, on the other. The character of simulating constructions and interrelations of different levels of simulation should be determined with regard to the hierarchy of institutional infrastructures and interactional peculiarities of departmental regional and central bodies of government and other managerial levels.

The typology (including the software) is conducive to elimination of inappropriate data as well as to perfection of the integrating process of *normative* forecasting of social, economic, and ecological productivity.

4.2 The software programming of integrated socioeconomic and ecological systems of multisectoral regional productivity is to be focused on a multivariant structural analysis of tasks in long-term planning and forecasting with a view to assessing the influence of socioeconomic processes on the growth rate and proportionality in meeting the system-forming needs of the region. Moreover, account is taken of the fact that functional needs are more constant in character than object-oriented wants (i.e., needs for particular material goods and services which follow changes in tastes and supply). Identical subordination is observed in functional and object targets manifested in the fluctuating intensity of developing demands as well as in the indices of supply and consumption of particular goods and services.

A matrix model, whose columns indicate the singled-out target components of the republic's perspective economic development and the lines show their programmed realization stage-by-stage in conformity with resources and other restrictions, may be utilized as a means to correlate the complex of both ecological and socioeconomic targets in the branch and territorial development of the republic within the period of perspective.

Application of the multisectoral economic and ecological system of productivity models provides for its variant solutions taking account of such externally-formulated criteria as increase in public welfare and intensity of social productivity, optimization of proportions of material production branches and branches of social infrastructure. It also permits limitation of the interrelated totality of social and economic indices represented by internal variables of the simulative system. Such a regime of functioning of the forecasting system ensures the realization of the basic methodological principle thus safeguarding the trustworthiness of prognoses made by socioeconomic systems which are characterized by a great number of interrelated parameters and verifying the conformity of prognostic calculations with different aspects of sustainable social and ecological development.

The functional correlations between particular economic alternatives such as the dependence of the volume of product capital investments on the volume of gross output by the branches, between the volume and structure of individual consumption, the indices of demographic structure and productive activity of the population manifest themselves in complex analytical forms. Hence, practical realization of the system of model analysis and the forecasting of GNP productivity may encounter computing difficulties in the software programming. With the increase in the number of earmarked industrial branches and the development of descriptive methods of economic activity, including the consumption habits of the population, and the assumption that all or the majority of the earmarked items represent internal variable systems, the number of restrictions concerning problems occurring in scrutiny of concrete scenarios considerably increases and amounts to several tens of thousands. This sometimes calls for artificial linearization of the formal description of actual dependencies and for the application of correspondingly simplified methods of mathematical solution.

4.3 Technological amelioration of alternative scenarios for integrated economic and ecological productivity processes based on a developed system of regional prognostic models should take into consideration the following aspects:

a) intersection of different social priority systems (including interdependent systems);
b) multi-extremality of social criteria of stochastically-interpreted social processes (especially those including obscure preferences difficult to formalize adequately);
c) inadequacy of benefit (utility) criteria with regard to different social groups in the stage of formation of aggregated target functions;
d) changes in the interrelation between typology (established stereotypes) and normality in the priority social, economic, and ecological systems for different time periods, territorial units, and the like.

Perspective scenarios in the field of social productivity with due regard for the interaction between regional development and the ecological environment should, in particular, allow for the following circumstances:

- coordination between branch and large-scale regional management decisions aiming at ecological preservation with regard to tasks of socioeconomic development;
- branch-by-branch achievement of land, water, and air purification from technological pollution in conformity with available and required resources;
- substantiation of expert and programmed targets in the field of development and distribution of individual branches (industries) in compliance with total and direct damage by pollution and expenditure for

refinement;

.substantiation of trends in the amelioration of industrial structure, domestic and social infrastructure, with due regard to the effect of industrial development on ecology as well as with a view to improving the comfortability and recreational facilities of the environment (conditions of work, rest and everyday necessities) for the micropopulation of any particular region.

Expenses for ecological resonrce productivity are fixed in accounts by branches and, hence, may be compared with the social and economic effect of ecological preservation. A definite regional unit is characterized by characteristic features in its common exploitation of natural resources and renewal. A considerable part of the information needed to evaluate the effect and expenses for resource productivity is reflected only in departmental or sectoral accounts and cannot be found on the level of centralized macroeconomic evaluations. This causes serious difficulty in reliably determining qualitative relationships between effects and costs in ecological resource productivity.

The volume of capital investment for basic environmental protection is determined by a function of fund productivity:

$$I^{c}_{tij} = \sum_{s=0}^{k} U_{t+sij} \frac{1}{B_{t+sij}} [S_{t+sij} P^{-b}_{t+sij} + (1 + B_{t+sij}) \times$$

$$\times \sum_{p=1}^{t+s-1} (-1)^{p} S_{t+s-pij} P^{-b}_{t+s-pij} + (-1)^{t+s} (1+B_{t+sij}) F^{0}_{ij}] \ ,$$

$$(t = 1,\bar{T} \ ; \ i = 1,\bar{n} \ ; \ j = 1,\bar{n}) ;$$

where: F^{0}_{ij} – basic funds of i branch for j resource productivity at the end of the base year; U_{tpj} – indices characterizing the lag in capital investment (U_{tp} – the part of funds introduced in the year which is formed from investments in t – p year), t_{ij} – coefficient of funds amortization, B – the function characterizing evenness of fund formation, P^{-b}_{tij} – the amount of funds necessary for the productivity of j resource. The volume of operating expenses for maintenance of funds for environment protection (E^{e}_{tij}) is determined by the amount of these funds. [2]

The total expenses for environmental protection of the productivity of resource j would be determined by structural matrix calculations of environmental protection expenses. Evaluations of renewable resources and the costs for their sustainability enable the identification of the dependence of expenses on the volume of resources restored. By extrapolating the indices of productive resources and necessary expenses, we should analyze the case resembling that of complete productivity of the usable resources. For example, the estimate of losses resulting from water contamination refers to the calculations of water volume indispensable to dilute the pollutant to the desirable level per unit cost of the natural resource. In practice, however, the institutions determining environmental protection do not restore to the necessary level the state of natural

[2]Principles of applied regional simulation of ecological productivity (i.e., pollution, purification, funds depletion and natural resource renewal) were practically realized in a multisectoral modeling system by V. Rutkauskas.

resources within the time period under review.

The functional evaluations of the damages incurred by nonrestorable use of resources are reflected by the damage function which is determined through observational data resulting, for instance, from atmospheric or water contamination. Thus, the total volume of losses resulting from nonrenewable use of resource j in branch i is determined in an analogous way as the function of the nonrestorable part of these resources and the volume of funds indispensable for their regeneration.

5. Generating a Priority System for Long-Term Assessment of Ecologically Sustainable Development

The question arises, to what degree and with what structural characteristics can current priorities be rationally applied until the end of the XXIst century and the following years. With changing criteria of rational assimilation of new and used natural resources and territories with new technologies (sea mining, coastal underwater plantations, etc.) the general interpretation of ecological sustainability is also significantly modified. New social and technological possibilities and approaches also require a reevaluation of traditional activity priorities as well as socioeconomic productive natural resources. New classical theory does not seem able to internally integrate the biophysical parameters and anthropo-technogenic influences into economic productivity modeling. A more complex understanding of noospheric management as a background for ecologically sustainable anthropogenic activity requires a change in assessment criteria for species interrelations, their well-being, cost discount and utilization of rare nonproductive natural resources. Even for the next decade (1990–2000), ecological admissibility becomes the most important social and economical criterion for many, especially biologically protected or overcrowded territories when programming the future displacement of productive capacities or determining acceptable amounts of outputs from traditional activities. The noospheric macro-zoning under this generalized approach to ecologically sustainable development would be more closely interconnected with an analysis of priorities for restructuring problem areas and evaluations of conflicting situations (high costs of pollution neutralization or remote displacement of highly dangerous technologies).

Under these conditions, the alternative scenarios of integrated socioeconomic and ecological productivity management attempt to take into consideration its stochastically changing determinants of sustainability solutions under subordinated multiple criteria systems. As a matter of fact, new methodological approaches, for example, in the theory of stability of dynamic systems, image recognition and other widely different fields also help to interpret in more depth the directions of generating future priorities within ecological sustainability of social development. The transient nature of preferences and perspective modifications of priority hierarchies depends significantly both on taxonomical criteria and managament methods of ranking.

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2.3 ECONOMIC CRITERIA AND TOOLS IN REGIONAL ENVIRONMENTAL MANAGEMENT*

K. Gofman and L. Kretchetov
Central Economic-Mathematical Institute
Krasikova 32, 117418 Moscow, USSR

In pollution source-receptor relations, the requirements of the latter are expressed via environmental quality standards. The achievement of the standards can be viewed as a main task of regional environmental management. A range of various legal, management and economical tools is involved in the solution of this problem. The role of each of them evidently depends on the specific regional conditions. However, the fact is that all these methods can play complementary roles in the solution of one and the same problem under the same conditions. The more stringent means could be assumed to be more adequate for environmentally critical situations while less rigorous controls can be effective in an ecologically milder condition. It is important to stress here that the most decisive requirements may turn out to be unattainable (which is often the case) or too costly if conditions are not created to meet them. So, the stringent requirements are to be accompanied by a flexible implementation system encouraging local initiative. Such a system would be highly effective especially when it broadly takes into account the polluters' inherent interests and stimulates their environmental protection activity. Such considerations strongly suggest that this kind of a system should be based on economical principles of management which could make environmental efforts profitable for pollution emitters. Within such a system the economical tools would not be taken then as mere control devices. Their role is much broader, i.e., formation of the infrastructure providing viability and effectiveness for the whole controlling mechanism of regional environmental protection activities.

The role of actually applied economical methods is quite considerable at present. Among them are charges, various systems of payment for usage of natural resources and for pollution of the environment, systems allowing bargains between two sources with the aim of lowering the burden of ecological loading from pollution sources. There are some other economical devices of both punishing offenders and stimulating nature. All of the economical tools are stimulating in a broad sense because each is directed at meeting the ecological constraints. Nevertheless, their nature of motivation can be different. It is clear that the means of enforcement and punishment can be effective to the extent that meeting the environmental requirements is a way of avoiding severe impacts. In this case the relations between the board supervising the observance of environmental requirements and a polluter are interactive. The necessity of using such means is obvious. Nevertheless, in many cases they have not shown their effectiveness or reliability primarily because of institutional barriers. That is the reason for the present search for other methods of economical regulation of a regional environmental protection activity. The system put forward by American economists for

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air pollution control and adopted by the Environmental Protection Agency in the USA should be considered rather promising. Underlying the system is the so-called bubble principle which highly raises a polluter's mobility in achieving ecological standards. As publications show, this principle allows creating the viable market system of "tradable discharge permits". Very numerous and diverse versions of such a system have been developed in the USA. The concept of a "bank" for emission permits has also been proposed. A polluter can notify the "bank" of his intention to reduce emission and get a certificate for a future possible increase of emissions. Other forms of banking have also been developed. The advantage of this approach is that it has a distinct orientation to lessen the ecological burden for regional enterprises. The motto of this approach is: "Engaging in environmental protection activities is profitable!" Similar systems have been adopted in principle in several states and some elements of them have been implemented. But the time does not seem to have come yet for drawing conclusions on their effectiveness. The above approach is not perfect. Its most vulnerable point is considered to be the lack of safeguards for keeping strictly to ambient standards. This is the cost to be paid for the extension of self-dependency of enterprises. The implementation of the bubble principle in particular requires strong safeguard measures. An objection can be found both in East and West publications against the system of tradable discharge permits which essentially comes to inadmissibility of making a profit from the environment. Indeed, such a threat really exists. To our knowledge, those who develop systems of tradable discharge permits are quite conscious of that threat and due measures are provided to control not only environmental quality but also the bargains themselves. In particular, so-called "offset ratios" are introduced allowing only bargains that improve environmental quality by a given proportion. On the other hand, too severe control can result in inadmissibly high transaction costs and make the market mechanism ineffective. The search for an optimal version is one of the problems of market regulation. The system of tradable discharge permits can be applied both in relatively unpolluted ecological situations and under critical circumstances requiring more stringent control measures. Advantages of the system are convincing enough to pursue further development in theory and practice. A proper modification of such a system is believed to be applicable in planned economy countries as well.

Centralized planning is the most important feature of environmental protection regulation in the USSR. For the purposes of regional management of environmental protection activities, a special board should be established, Ecological Regional Service (ERS), that would represent regional ecological interests by monitoring and coordinating studies on the impact of pollution sources on the regional environment. ERS should act to guarantee the observance of environmental quality standards. We believe that a leading role in the solution of this problem should be played by economical control methods. In principle, under centralized planning all of the above-mentioned forms of economical regulation can be considered applicable, among them systems of marketable discharge permits.

Regional environmental quality management would be much easier if branch enterprises present in the region could have their own Branch Ecological Service (BES). Among the functions of BES could be an on-line variation of production loading distribution for the branch enterprises. It could initiate a branch mutual assistance bank allowing an enterprise a reduction of production activity to offset increases in production activity in other enterprises. Information exchange and coordination of ERS and BES activities would be beneficial for both.

It would be expedient to divide the branch and regional environmental management into two stages:

I. advanced production and ecological planning, and

II. current regional management of enterprises' environmental protection activities.

Stage I includes coordinated determination of the level of branch production, on the one hand, and environmental quality standards together with discharge limits, on the other. Moreover, the branch planning system should take into account, alongside with other resource limits, the "ecological resource" limits presented as discharge limits and environmental quality standards. Figure I gives a rough flow chart of a three-step production and ecological planning algorithm.

Underlying ERS activity should be the notion of regional damage including ecological, social and economical damage. Damage is not necessarily expressed in terms of money only but in terms of various indexes. Environmental protection measures or transactions between regional agents can be considered allowable if, among other limitations, the damage avoided exceeds (with some coefficient) the damage done. It should be noted that this principle leads to prevent possible abuse of discharge permits trading. Furthermore, the principle allows measures and transactions in non-compatible units within current systems where bargains are allowed only between the pollution sources that influence the same receptors. The transfer of a pollution source beyond the limits of a zone of elevated pollution can serve as an example of an arrangement allowing assessment on the basis of regional damage, but not on the basis of impact coefficients. The assessment of measures and transactions on the basis of regional damage requires much information support and methods of damage calculation, so, at least initially, it would be more reasonable to use simplified and approximate methods. These can be based on an idea of identifying some sources (analog to bubble principle) or some recipients (bubble principle for recipients).

The more efficient the enterprises and the more possibilities they have for environmental protection, the more stringent are the requirements of the control system that should guarantee that there will be no decline of environmental quality. The reliability of such a system would be particularly great if it were oriented as a preventive system implementing measures capable of relaxing the emerging ecological tension. Among those are such measures as the development and implementation of special policies with respect to sources whose effect on ecological behavior are unpredictable or risky, the development and active implementation of methods of forecasting regional ecological episodes, keeping up the relations between ERS and BES for taking into account and coordinating presumed changes in the regimes of regional enterprises, which could highly raise the reliability of environmental forecasts. Among preventive means are the use of safety factors in areas with ecological situations rapidly changing for the worse (e.g., in swiftly developing industrial regions), since the time for ERS to react to changes would be reduced, increasing environmental risk.

How can it be guaranteed that ERS endowed with its broad rights would pursue policies defending regional interests and, at the same time, not abusing its power over polluters? What can be ERS's proper interests? They can reflect regional interests, but environmental interests can play only a minor role. It can happen that observance of environmental standards would stand in the way of making progress toward ERS's goals when it intends to further the development of regional industry. To circumvent this, polluter charges cannot be used to fund ERS, i.e., ERS should be financially independent from those being controlled.

A FLOW CHART OF PRODUCTION AND ECOLOGICAL PLANNING ALGORITHM

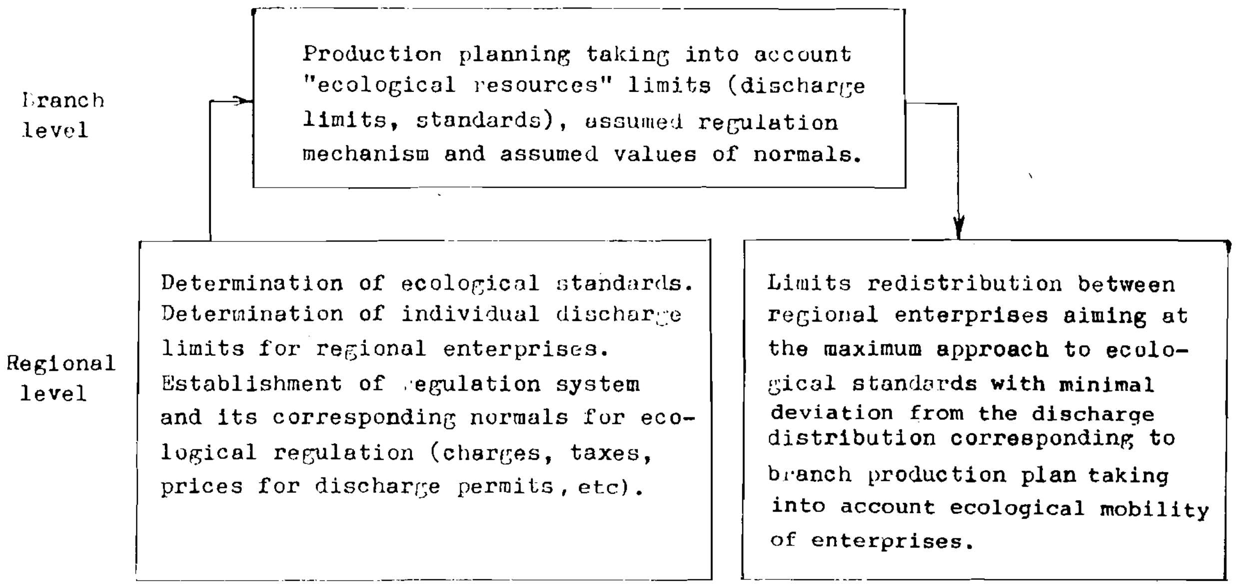

Fig. 1

What are the criteria for ERS's activity assessment? Criteria such as amelioration of regional environment with respect to the existing pollution level per ruble of costs of environmental protecting measures would not be useful, as would also be the case if the rate of decrease of pollution were related to the rate of polluters' production growth, etc. Criteria of that kind can hardly be effective because ERS would be able to make a better show at the cost of pursuing severe ecological policies with respect to regional polluters. The right general criterion should be formulated as relative (with respect to the planned environmental quality level) environmental quality increment achieved as a result of arrangements and transactions profitable for regional polluters with absolute observance of environmental quality standards. With this criterion the environmental protecting ambitions of ERS would not be an unjustified burden to polluters. On the other hand, ERS would have an economical incentive to better assist polluters in revealing and implementing their environmental protection reserves. Under such a criterion ERS and polluters would cooperate toward regional environmental amelioration.

Undoubtedly, this criterion has some drawbacks. For example, both ERS and polluters would be concerned with adopting an understated environmental quality standard during the planning stage. So, uninterested central and regional boards should fix quality standards. ERS becomes active during the implementation stage when all standards and planned limits are already fixed.

The above criterion for ERS's activity assessment involves the notion of arrangement or transaction "profitability" for emissions. This concept is objective to a degree. ERS and the polluter itself could differently assess profitability of a given measure for the source. In the spirit of the "profitability" requirement, the source's assessment should be adopted. This point of view would better respond to creating conditions and stimulating the polluters' self-sufficiency for achieving less costly standards.

The implementation of a regional environmental protection system seems to be reasonable to pursue in the following succession:

1. The establishment of ERS with proper legal and centralized financial support. The establishment of BES with due rights and branch financial support Coordination of ERS and BES activities.
2. Environmental quality monitoring. The development and implementation of an environmental quality forecast system.
3. Fixing the environmental quality standards and individual discharge limits
4. Implementing emission fees. Implementing charges for the use of natural resources.
5. Implementing emission and pollution charges and taxes.
6. Establishment of an Emission Bank.
7. Limited implementation of a tradable discharge permits system.

Methods that prove effective or promising under specific regional conditions should be further improved and broadly applied. The other versions of the environmental protection system development are possible depending on the particular regional environment.

Orientation toward regional needs is viewed as a main advantage of the proposed regional environmental protection system. At the same time, economic management tools underlying the system offer more possibilities for the best realization of the cumulative environmental protection potential of regional polluters. A branch and regional planning system allows one to take into account, to a considerable extent, the regional requirements already at the preliminary stage of planning, which makes the ERS's task of actual regulation of the polluters' activity much easier.

The main conclusions suggested by the above considerations are as follows:

1. The branch and regional principle should underlie the structure of a regional environmental protection system.

2. The activity of the regional environmental protection system falls into two stages:

- long-term planning, and
- current regulation of the actual ecological activity of regional polluters.

Competent central, branch and regional boards would establish environmental quality standards during the planning stage. Then actual regional regulation is implemented by ERS in cooperation with BES.

3. The regional environmental protection system should be based on legal, administrative and economical methods harmoniously interacting with each other. Diverse economic methods are bound to play a key role in assuring efficiency of the system, first of all by allowing full possible realization of the polluters' environmental protection potential, among them the Emission Bank and discharge permits trading both directly between sources and via ERS should be considered rather promising.

4. The assessment of regional environmental protection measures should be based on the notion of regional damage in terms of money or some relative indexes.

5. ERS should act mostly as a preventive board provided with a good forecast and control system.

PART III

INTERDISCIPLINARY OF REGIONAL, TRANSREGIONAL AND GLOBAL SYSTEMS

3.1 THE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAM (IGBP): THE ROLE OF OBSERVATIONS FROM SPACE*

K.Ya. Kondratyev
Academy of Sciences of the USSR
Sevastjarova 9, 196199 Leningrad, U.S.S.R.

1. Introduction

The scientific-technical revolution has created a global-scale interrelated set of problems: (i) the development of an ability to undertake mutually guaranteed annihilation; (ii) creation of massive debt in the developing countries and the necessity for a new economic order – a result of the exploitation of natural resources of the developing countries aimed, primarily, at fueling the arm's race; (iii) the occurrence of critical environmental impacts, manifested, in particular, by the barbaric exploitation of natural resources (for instance, tropical deforestation which has heavily changed the global carbon cycle, which can seriously affect the climate) and through uncontrolled pollution (e.g., transboundary atmospheric transport of pollutants affects many countries).

The interdisciplinary character of environmental problems needs closer cooperation of experts in the field of natural sciences as well as social sciences. In this connection, there is an urgent need for analysis (from the viewpoint of modern science) of the concept of the noosphere put forward by the outstanding Soviet scientist V.I. Vernadsky [27] and of the ideas of the interdependence of humanity and the biosphere. Experience of the recent past shows that none of the large-scale problems of natural science can be solved in isolation from an interdisciplinary system approach. Otherwise, only speculative approaches fraught with disinformation are available. For instance, apocalyptic forecasts of climate changes by the middle of the next century are not justified scientifically (see [17]); serious blunders in a number of important ecological forecasts (for instance, the Caspian Sea level, the decision to dam the Gulf of Karabogazgol, assessments of the consequences of diverting some rivers, etc). This suggests, in particular, an urgent need for serious discussion and concrete definition of the concepts of the environmental quality.

Complicated problems of the environment can be solved only by joint international efforts. One of the most forward-looking examples of cooperation is the IGBP, approved by the 21st General ICSU Assembly in September 1986. A major objective of this program is "to describe and to understand the interacting physical, chemical and biological processes which regulate the whole terrestrial system and a unique environment whose viability is maintained by this system; variations taking place in this system, and specific human impacts on these variations" [18, 25].

Studies are planned in five major directions [6, 25]: (i) retrievals of information on changes in the past from various paleoindicators; (ii) studies of the various processes taking place now in the environment; (iii) an analysis of

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global-scale changes in the biosphere; (iv) studies of the biogeochemical cycles; (v) studies of the global water cycle.

2. A Brief Description of the IGBP

The evolution of geosphere and biosphere is characterized by an intensifying interaction of their components which is, first of all, determined by increasing anthropogenic impact on the environment. This impact is manifested mainly through the transformation of nature by man and the growing anthropogenic environmental loadings which affect practically all components of the geosphere and biosphere (in some cases on the global scale) and require a systematic approach to studies of the coupled processes taking place in the geosphere and biosphere. Uncovering the laws of geosphere-biosphere interactions requires interdisciplinary studies of unprecedented complexity, pushing the respective problems to the front line of the current natural sciences.

Complex studies of the geosphere and biosphere have long since been needed, which in recent decades has been revealed in the establishment of numerous large-scale programs: the International Geophysical Year (IGY), the subsequent International Quiet Sun Year (IQSY), the World Weather Watch (WWW), and the Global Atmospheric Research Program (GARP). Other recent activities include the large-scale Middle Atmosphere Program (MAP), International Lithosphere Program, World Climate Program (with the World Climate Research Program as a component), a specialized International Satellite Cloud Climatology Project (ISCCP), as well as a large-scale Soviet program "Sections" aimed at studies of the role of oceans in short-term climate changes. There are two new international programs with the same objective: World Ocean Circulation Experiment (WOCE) and Tropical Ocean and Global Atmosphere (TOGA) program.

The following international projects on studies of biogeochemical cycles of various components are being accomplished under the aegis of SCOPE and UNEP: the IUGG/IAMAP Program of Global Tropospheric Chemistry, the International Hydrobiological Program, and the Man and Biosphere Program (within the framework of UNESCO).

Each of the enumerated (and some other) programs is characterized by a complex approach to solving particular problems. An analysis of the global ecological problem, on the whole, shows, however, an urgent need for coordinated efforts to achieve the goals of various programs and substantiating a *super-program* covering the key aspects of all geosphere-biosphere studies.

These circumstances have stimulated the development of the long-term International Geosphere-Biosphere Program (IGBP) – full launching of the observation system is planned for the 1990s – aimed at studies of global changes, especially with a view to the anthropogenic impact on the biogeochemical cycles of carbon, nitrogen, sulphur, phosphorus, water, and the dynamics of such factors of life support as solar radiation, the quality of air and natural waters, soil fertility, as well as interrelationships between biospheric and geospheric events [26].

First, on time scales of decades and longer, it is most clearly seen that the geospheric components constitute a coupled system, the interaction of individual components being characterized by synergistic manifestations (by the feedbacks that sometimes lead to a mutual intensification of various processes). This circumstance is of exceptional importance in a system approach, as well as interdisciplinary studies of physical, chemical and biological processes based on the implementation of a joint program.

Second, increasing anthropogenic impact on the geosphere-biosphere necessitates studies of the global-scale processes and changes. From the viewpoint of planning an observation system, this testifies to an important role of observations from space to support important conventional observation systems both now and in the future [1, 11]. For these problems, on the whole, paleo and comparative planetary analogies become particularly urgent [13, 17]. The latter means that geospheric studies must be closely connected with investigations of the origin and evolution of the solar system. This conclusion is important because the geosphere-biosphere system is not closed; rather, it is affected by various extraterrestrial factors (solar activity, galactic cosmic rays, etc.). Thus, there is no doubt that atmosphere, ocean, cryosphere, lithosphere, and extraterrestrial factors are key objects in studies of the geosphere and biosphere.

What worries us now is that some anthropogenic impacts on the global geosphere have already become noticeable (for instance, through increased concentrations of CO_2 and nitrogen oxides, which affect the global cycles of carbon and nitrogen) and can grow during a period of several decades, whereas our ability for countermeasures has the same (or even longer) characteristic time scale, which demonstrates the urgency of the problems.

The third circumstance of extreme importance is connected with the highly closed global cycles of substances. It was shown with the carbon cycle as an example [7–9] that undisturbed cycles are closed to an accuracy of 0.01%. Such an exact balance reflects an urgent problem of anthropogenic impacts on the geosphere and biosphere in such conditions, for instance, when more than 10% of the land is cultivated, and more than 30% is used both in agriculture and for other purposes [6]. Both the atmosphere and the water basins receive (in increasing amounts) substances having no analogs in nature. There are no reliable ideas, so far, about the long-term effects of these inputs. Estimates by Gorshkov [8, 9] show that the global carbon cycle is now open to about 10%.

Naturally, in studying an exceptionally complicated interdisciplinary problem, it is of primary importance to determine its key aspects, among them the problem of climate and its changes. The climate is a result of interactions between the components of the climate system (atmosphere-hydrosphere-lithosphere-cryosphere-biosphere) with numerous feedbacks.

At present, there is no problem in natural sciences of greater global-scale complexity.

In connection with the climate problem, the role of geosphere-biosphere interactions requires serious attention. This role is clearly seen, in particular, when the climatic effect of anthropogenic CO_2 concentration increase is considered. During recent years this problem has brought forth controversial conclusions about possible climate changes [14, 16, 17]. This has been caused by two circumstances: (i) the lack of sufficiently reliable models of the global carbon cycle (so far, the contribution by marine and continental biota is not clear); (ii) an inadequacy of climate theory from the viewpoint of interactive accounts of processes in the geosphere and biosphere. Though the climate theory can serve as an illustration of the importance of considering the effect of extraterrestrial factors, the physical mechanisms determining this effect are still unknown.

The climate problem is also very important from the practical point of view. It is well known that man's activities depend (sometimes critically) on climatic conditions (particularly concerning agriculture). Recently a new aspect of the problem has been outlined, i.e., a possible impact of a nuclear war on the climate and biosphere [6, 15, 17]. The respective estimates show an unavoidable global ecological catastrophe due to a strong climate cooling (*nuclear winter*), which must result from decreased solar radiation at the Earth's surface because of strong attenuation by urban and forest post-nuclear fires. Of still more importance is a climatic instability under conditions of such strong disturbances of the climatic system [17].

Bearing in mind the importance of the climatic problem, a respective interdisciplinary part within the IGBP must be formulated, taking into account the WCRP and other programs (WOCE, TOGA, ISCCP, etc.) which are now being undertaken. Considering specific features of such programs, it is clear that studies of interrelated problems of the physics and chemistry of the atmosphere, as well as biogeophysical cycles of such components as carbon, nitrogen, phosphorus, sulphur, and solar-atmospheric interrelationships within the IGBP, claim most serious attention since they are not properly foreseen in the ongoing programs.

The problems of atmospheric physics and chemistry are very important from the point of view of assessing the prospects for the evolution of the biosphere (its productivity) in conditions of growing anthropogenic impacts [16]. Among other problems, emphasis must be placed on the problem of disrupting the stratospheric ozone layer which protects the biosphere from harmful effects of UV solar radiation.

Though the conclusions about anthropogenic effects on ozone have been repeatedly changed [5], no doubt, there is great concern for the effect on the total ozone content and the vertical profile of the ozone concentration of ejected chlorofluorocarbons (CFC), carbon dioxide, nitrogen oxides, methane, and other gases. It is now clear that the effects of these components are closely interrelated, and therefore estimates of individual (isolated) components cannot be considered correct.

There is evidence (from observational data) of increased concentrations of CFC, methylchloroform, carbon dioxide, nitrogen monoxide, and methane. However, the lack of reliable data on the sources and sinks of the enumerated gases prevents realistic forecasts of their future trends (it is particularly true for methane) to be obtained [2].

The solution of the ozone problem, which is an important component of MAP, requires the implementation of an extensive program of laboratory, field and theoretical studies of interacting physical, chemical and photochemical processes in the troposphere and stratosphere, as well as large-scale monitoring of changes in the chemical composition of the atmosphere (for a large number of components).

As for the chemistry of the troposphere [4, 21], most urgent are studies of (i) water cycles; (ii) processes determining the dynamics of oxidants, especially O_3, SO_2 and NO_2; (iii) mechanisms of dry and wet deposition of pollutants on the surface of land and water; (iv) processes determining the content in the lower atmosphere of aerosol and such gases as CO_2, N_2O, CH_4, NH_3, and H_2O; (v) the effect of optically active atmospheric components on the radiative regime and climate. As in all other cases, the interaction between chemical processes in the troposphere and stratosphere are of principal importance.

To understand the biogeochemical cycles, it is necessary to study such controlling factors as (i) natural and anthropogenic inputs of minor components to the troposphere; (ii) their further transport; (iii) chemical transformations (including gas-to-particle conversions); (iv) scavenging from the stratosphere of minor gaseous and aerosol components (here the role of the cloud cover is significant). Of primary importance are studies of such biospheric components as forests in the tropics and midlatitudes, steppes and savannah, tundra, agricultural areas, upwellings, and open ocean. The following are of first priority [18]: (i) studies of the world ocean's euphotic zone; (ii) studies of the processes of atmosphere-biota interactions in various ecosystems existing on the Earth; (iii) analysis of processes in the biologically productive soil layer and its interaction with the atmosphere; (iv) long-term monitoring of the total and spectral solar radiation.

Climatic changes are determined by the important role of minor optically active atmospheric components (including ozone) in the development of the atmospheric greenhouse effect whose variations are an energy source of anthropogenic impacts on the climate. The increased ozone content in the troposphere observed during recent years illustrates this fact. Estimates show that the contribution of this increase to an intensification of the greenhouse effect is equivalent to the effect of an increased CO_2 concentration.

In the field of numerical modeling, the problem of development of interactive models which include dynamical and photochemical processes is most urgent to produce global budgets of O_3, CO and other critically important components. As before, approximate 1-D and 2-D models must play an important role in a study of regional transport, geochemical balances and the search for new important chemical reactions. Long-term objectives must foresee studies of the role of complex heterogeneous processes in the formation of global cycles of various components, with the emphasis on poorly studied processes in remote (background) regions of the globe.

In many respects, the chemical composition of the atmosphere has been formed and is being changed as a result of interactions with biosphere. The biosphere is a major source of various organic compounds and of such volatile halocarbons as methylchloroform. Correlations between respective processes are not always direct and unequivocal. For instance, chemical reactions with participation of nitrogen oxides in the troposphere can lead to both an increase and a decrease of the ozone content, which, in its turn, affects the vegetation cover. Variations in concentrations of N_2O, CH_3Cl and CH_4 in the troposphere affect the ozone content in the stratosphere, and this affects the biosphere, too.

A most important problem is the study of physical, chemical and biological processes responsible for the release and assimilation of various components by the biosphere (within different ecosystems). A second problem concerns the reaction of the biosphere to variability of physical characteristics and chemical composition of the atmosphere. Of first priority are gases whose content is being changed due to man's activity: CO_2, CH_4, N_2O, NO_2, and SO_2, as well as CO, which plays a substantial role in the chemistry of tropospheric hydroxyl.

There are grounds to believe that chemical and photochemical processes in the stratosphere and mesosphere, varying under the influence of extraterrestrial factors (solar protons events, galactic cosmic rays), are responsible for the mechanisms determining the effect of extraterrestrial factors on the climate.

A key factor of the formation of the chemical composition of the atmosphere is its interaction with the ocean, which is a sink for CO_2 and nitrogen oxides, but a source (in the regions of coastal lowlands and productive zones) of CH_4, H_2S and $(CH_3)_2S$, as well as a source of halogens, nitrogen oxide and water vapor for the atmosphere. An urgent problem is the study of ocean-atmosphere gas exchange as a result of corresponding chemical, physical and biological processes. The cardinal role of the ocean in the formation of the sulphur cycle should be given special attention. Here estimates are needed of the input to the ocean of fresh water, carbon, phosphorus, and suspended matter.

Atmospheric aerosol plays an important role as an optically active atmospheric component affecting the formation of climate [12, 14]. Volcanic stratospheric aerosol that causes strong and prolonged disturbances in the radiative regime and respective climate changes, is a most substantial manifestation of the effect of natural aerosols on radiation and global climate (dust storms are an important regional factor). The presence of anthropogenic aerosol in the troposphere is demonstrated as an upward trend in atmospheric turbidity and through the formation of atmospheric haze in high latitudes of the northern hemisphere. In any case, the mechanism of gas-to-particle conversion is of great importance (in the case of volcanic stratospheric aerosol this mechanism prevails), which determines the interrelationship between biogeochemical cycles of sulphur and nitrogen and the processes of atmospheric aerosol formation. Of great concern is an almost unknown effect of aerosol on the processes of the formation and dissipation of cloud cover. As has been mentioned above, the smoke aerosol resulting from post-nuclear fires is critically important.

One more first-priority component of the IGBP is the problem of biological productivity on land and in the ocean. Conditions for biological productivity on land are determined by resources of water, biogenic components and light; for the ocean, only the latter two factors are important. It follows that to assess conditions on land, it is important to obtain information about the global spatial and temporal distribution and rainfall intensity. Fluxes of biogenic components driven by rivers to coastal zones of the ocean and, due to mixing arriving eventually at deep layers of the ocean, as well as the transport of matter from land to ocean through the atmosphere, play a decisive role as factors of oceanic bioproductivity.

The assessment of the role of the latter factor is hindered by the unreliability of present climate models from the viewpoint of simulating the global distribution of precipitation and a need for taking into account increasing anthropogenic input of optically active minor gaseous components. This leads to a change of the temperature regime, affects the water cycle, causes acid rain and changes the concentration of toxic gases, soil fertility, and the content of nutrients in rivers and shelf zones. The variation in intensity of the UV solar radiation reaching the surface caused by atmospheric pollution can play a substantial role in affecting bioproductivity. Having determined the natural variability of bioproductivity, one faces an important problem of analyzing the anthropogenic effect. The solution of this problem will require investigations in various directions.

One of them is the global moisture cycle, whose formation is determined by an interaction of the thermal regime and atmospheric circulation, the processes of evaporation (including evapotranspiration), transfer and phase transformation of water in the atmosphere, the atmospheric circulation being coupled with the radiative regime affected by the anthropogenic variation in the atmospheric composition (including chemically and biologically active components). Major difficulties in solving the problem of the water cycle are as follows: insufficient reliability of the estimates of evapotranspiration on land, evaporation and precipitation on the oceans, inadequate parameterization of the processes of cloud formation and rainout. The role of the vegetation cover in the transport of water from soil to the atmosphere must be further studied. Data on global cloud cover climatology, distribution of precipitation over the oceans, and evaporation from the ocean surface are still fragmentary.

The leading role of the ocean in the formation of the global water cycle and the climate determines the key importance of the problem of atmosphere-ocean interactions and, in this connection, the program "Sections" has begun [see 19]. An interaction between the atmosphere and land surface has been studied rather poorly (this has resulted in the 1982 International Conference on Parameterization of Land Surface Processes and the recent International Satellite Land Surface Climatology Project – ISLSCP).

Snow and ice cover and its variability are fundamental climate-forming factors. A high albedo of snow and ice determines a strong (and interactive) dependence of climate on variations in the extent and properties of the snow and ice cover. Sea ice plays an important role as an insulating layer (it makes a large contribution by heat exchange through polynyas and open leads in high latitudes) and as an inertial component that transforms the annual course of temperature by shifting extrema due to latent-heat release during freezing in autumn and heat expenditure on melting in spring. Being a sensitive component of the climate system, ice cover is a useful indicator of climate changes.

Of principal importance is the fact that the continental biomass has been estimated to an accuracy of a factor 2 and changes in the time scale of decades are even less well known. Such a situation has been hindered by a large-scale effect of man's activity on natural ecosystems during the last 100 years (deforestation, wide use of monocultures in agriculture, etc.). Much more accurate estimates are needed of the total biomass for individual ecosystems and for land surface, on the whole, which will permit a more reliable analysis of the effect of variations in land use, climate, and an input of nutrients to global primary bioproductivity. The following studies are of first priority: (i) the effect on the input of biogenic components (nitrogen, phosphorus, and sulphur, in particular); variations in the concentration of oxidants; acid rain and heavy metal deposition on the carbon reservoirs; (ii) reaction of biota to environmental changes; (iii) factors that regulate the carbon ratio between living and dead components of ecosystems, and their dependence on anthropogenic impacts.

3. The Use of Space-Based Observation Techniques

Solution of the above problems requires the development of a global observational system using both conventional and space-based observation techniques, with undoubted priority being given to the latter. One must, first of all, analyze the adequacy of available observation means from the viewpoint of the IGBP problems, since it is clear that some of the present information needs on geosphere-biosphere can already be satisfied (either completely or partially) by the use of meteorological and Earth's resources satellites, as well as manned orbital stations. Also, it is clear that all the requirements for observational data can only be met by improving, expanding, and supplementing the available observation techniques. First of all, it is necessary to plan an adequate and optimal global system of observations [1, 11, 22].

3.1 Optimal planning of observational programs

The importance of the problem of optimal planning of a system of remote sensing from outer space is determined by a number of circumstances, including the high cost of the experiments, limitation by the weight of instruments, power supply and the volume of the on-board stored information. Besides, a number of scientific aspects of the problem must be borne in mind. The satellite-derived data interpretation is connected with the solution of mathematically incorrect inverse problems: using the characteristics of either reflected or absorbed radiation, one must retrieve the parameters that characterize the state of the environment. An incorrect nature of most of the inverse problems of remote sensing determines the critical importance of the choice of measurement conditions for the accuracy of the results [11, 22]. Therefore, a nonadequate choice of spectral channels or geometry of observations can considerably depreciate the observational results. On the other hand, a neglect of the information content of remote-sensing data can result in redundant information.

A similarity of requirements for systems of remote sensing, interesting for various branches of application, has brought forth the problem of planning multipurpose systems of remote sensing from space. Below we discuss two major strategies for optimal planning of such systems [22].

The economic strategy for optimal planning of the systems is based on maximization of the integral economic efficiency factor for a multipurpose observation system V under condition that the efficiences for individual problems v_i ($i = 1,\ldots,N$) are regulated by special limitations of the type of inequalities from above and from below [22]. One of the most efficient numerical algorithms for the solution of this problem is Balash's method used in calculations for planning the multipurpose systems of remote sensing of the environmental objects from space. All the problems are divided into four large groups: oceanology, hydrology, geology, forestry and agriculture. Each of these groups is subdivided. The number of partial problems in each of the basic groups varies from 9 to 14 [11]. As an illustration, we shall consider the results of the choice of an optimal set of spectral channels for a multipurpose survey in the interests of oceanology (Table 1).

Table 1. Specific problems within the group "oceanology".

Number	Problem
1	Sea surface state
2	Water turbidity
3	Sea ice
4	General near-shore marine survey
5	Mapping the coastal currents and tides
6	Global-scale mapping of currents, sea surface survey
7	Mapping the coastline and shallow waters
8	Bathymetry and topography of ice
9	Distribution and migration of aquatic organisms
10	Contamination of coastal waters
11	Impact of contamination on marine medium
12	Studies of bars, reefs, etc.

The number of spectral intervals (channels) required for the solution of 12 problems ($N = 12$) in the group "oceanology" (Table 1) totals 37 ($M = 37$), the number of particular channels m_i for the i-th specific problem ranging between 18 and 33 ($18 \le m_i \le 33$). This means that the volume of information for each specific problem is sufficiently large. It constitutes not less than half the whole volume of information for the entire group of problems "oceanology".

Calculations of the economic efficiency factors of the measurement channels K_j ($j = 1,\ldots,N$) have shown that some channels are potentially unprofitable (negative values of K_j) from the viewpoint of multipurpose application of the observational system. These are channels 0.40–0.45 μm and 0.69–0.73 μm. Measurements in the following spectral channels are economically best justified: 0.53–0.55; 0.59–0.61; 0.61–0.64; 0.55–0.57 μm. Here maximum values of $\{K_j\}$ are reached. Thus, even simple calculations make it possible to select from a large initial list of spectral channels those most substantial from the viewpoint of economic criteria. Similarly, one can consider other groups of problems and characteristics of the observation system (spatial and temporal resolution, periodicity, geometry, etc.).

The strategy of multipurpose planning of the space-borne remote-sensing system is based on the use of statistical techniques for processing the observational data [22]. Mathematical formalization of requirements can easily be made in this case [11]. As an example, we shall consider the problem of the choice of spectral intervals.

Combinations of the channels recommended for solution of specific problems form a multitude on the spectral axis. Having enumerated all the channels, we obtain a totality of elementary channels forming the basis for choosing any interval from the initial totality. We form a vector with the number of components n equal to that of the elementary channels. Let the indication vector x^j, the i-th component of which is either zero or unity (depending on whether the i-th elementary interval meets the requirements of the j-th specific problem or not), correspond to the j-th specific problem. With a set of requirement vectors $X = \{x^j\}$, the problem can be formulated of finding the vector x^* minimizing (maximizing) some purpose functional V determined by a set X. Further, the problem can be solved in two ways.

With the totality of vectors $X = \{x^j\}$ considered a statistical sample, the problem of multipurpose planning can be formulated as a problem of stochastic optimization, and to solve it, the techniques of principal components and factor analysis can be applied [22].

The choice of spectral intervals. Using the described procedure, one can choose single-bounded spectral regions for a multipurpose survey carried out in the interests of the following four groups of problems: I – oceanology; II – hydrology; III – geology; IV – forestry and agriculture. The number of specific requirements in the groups totaled: I – 102; II – 33; III – 36; IV – 32. In the numerical solution, one succeeds in selecting 7–9 factors for each of the groups of problems. The first four channels provide a 70% coverage of the mean square deviation in the space of requirements. In all cases, two IR channels are chosen: 0.73–0.8 and 0.9–1.1 μm and two intervals in the visible: 0.55–0.58 and 0.66–0.69 μm. The remaining channels vary depending on the group of problems. The next step is combining the enumerated groups of problems into complexes. With the exclusion of the O_2, H_2O, O_3, and NO_2 absorption bands, Table 2 gives the limits of optimal spectral intervals for the "oceanology" problems as well as the complexes of "land" problems and a combination of all the four groups. To achieve the 70% coverage of the initial MSD in the space of requirements, five channels are necessary (three in the visible, two in the near IR).

Table 2. The optimal choice of spectral channels for remote sensing.

Group of problems	Spectral intervals, μm				
	1	2	3	4	5
I	0.83–0.87	0.94–1.10	0.76–0.78	0.66–0.69	0.54–0.57
II–IV	0.94–1.10	1.20–1.25	0.51–0.57	0.66–0.69	0.40–0.49
I–IV	0.83–0.87	0.84–1.10	1.20–1.25	0.52–0.57	0.66–0.69

Optimal conditions for the survey from space. Let us discuss the choice of parameters of the survey that characterize the geometry of observations as well as the spatial and temporal resolution of the information obtained. We shall consider the following parameters: sun elevation, nadir angle of viewing, spatial resolution, coverage of the survey, and maximum periodicity. The requirements produced by specific problems with respect to these parameters totaled 73 [11].

For each of the five parameters, three types of requirements were chosen: high, moderate and low, which has markedly simplified the interpretation of the results of application of the factor analysis algorithm (Table 3).

Table 3. The optimization of conditions for the survey from space.

Parameters of the measuring system	Group of problems			
	I	II	III	IV
Sun elevation, deg.	15–30	15–30	15–30	15–60
Nadir angle of viewing, deg.	30	30	30	30
Spatial resolution, m	50–300	5–10	10–30	10–30
Coverage, km	400–1000	200–400	400–1000	50–200
Maximum periodicity, days	1	1	3–20	2–20

The obtained planning recommendations have also three grades for the survey parameters. Some similarity of requirements to the survey parameters is observed in oceanology and hydrology. High spatial resolution is required in hydrology. Similar requirements are found in geology, forestry and agriculture, with differences only in survey coverage.

A comparison of the results on the problem of optimization of the system of the spectral channels for remote sensing shows a certain consistency. The channels 0.53–0.57, 0.66, and 0.68 μm are most efficient for oceanology from the viewpoint of both strategies. Other channels located in the near IR (0.83–0.87, 0.94–1.1 μm) are only important from the viewpoint of multipurpose application of the obtained information. Their economic efficiency is twice as low as compared to the channels of the optical range.

These results show that the developed techniques make it possible, on a strict mathematical basis, to substantiate the optimal composition of the observation system and conditions for observations. The multipurpose applicability of the observation systems ensures the widest use of the obtained results. The proposed techniques for planning an observation system provide a certain economic effect of the space-borne remote-sensing systems both for economy as a whole and for its certain branches.

3.2 Some future means of observations

The global-scale nature of processes in the atmosphere, the ocean and on land necessitates a consideration of the Earth as a single interactive system in order to understand and forecast the state of this system. On the other hand, the complexity of the internal processes taking place in each of the system's components explains the necessity of their separate studies. An observation system must be a fast-operating system giving information about the planet as a whole and about its components, using for this purpose both conventional and satellite observation means.

The application of various techniques based on the use of data for various spectral regions and a combined processing of the conventional and satellite information (a 4-D assimilation) play an important role in the case of space-based remote-sensing techniques: only such an approach guarantees sufficiently high accuracy of the retrieved parameters [3, 4, 23, 24]. The calibration techniques ensuring long-term stability of the observational data and of the retrieved geophysical quantities are critically important. It particularly concerns the *solar* channels of the versatile space-borne instruments. An accomplishment of complex programs of subsatellite control and verification observations remains urgent. In this connection, realization in the future of a program like FGGY is highly recommended.

Theoretical studies to get a deeper insight into the interactive processes within the global numerical models as well as experiments on sensitivity, needed for the objective planning of the observation systems, are an exceptionally important component of the program on the whole. Further development of retrieval algorithms is important, too. From the viewpoint of developing the instruments and the retrieval techniques, increasing the reliability of the retrieved parameters such as soil moisture, rate of rainfall, the temperature and emissivity of land surfaces, wind vector is of special concern.

A considerable increase of the accuracy of the retrieved surface temperature and a resolution of 1 km are guaranteed by the MODIS instruments [4] having the following channels (the width of channels in nm is given in parentheses): 3.750 (90); 3.989 (50); 4.05 (50); 8.55 (500); 10.45 (500), 11.03 (500), and 12.02 (500), with the combined use of the MODIS data and remote sounding data.

Retrieving the phytomass, its global mapping, and a search for ways of retrieving the components of the surface energy balance are important problems. Lidars and 6-channel radars operating in the centimeter wavelength region are being developed to retrieve atmospheric sea surface pressure with an accuracy of about 1–2 mbar.

A complex of the on-board instruments for two polar-orbiting satellites (a sun-synchronous orbit 850 km high with crossings at 09:00 and 13:00 local time) and a manned orbital station (this complex consisting largely of tested instrumentation) includes [4]: a monitor for in-situ measurements of the cosmic environment; the ERB measuring instruments; a mid-resolution radiometer; a moderate-resolution spectrometer to obtain calibrated multispectral images; improved instrumentation for the operational sounding of the atmosphere; an IR high-resolution sounder; a microwave remote-sensing complex; a radiometer for global ozone monitoring; a monitor of the physical and chemical parameters of the atmosphere; a lidar and altimeter; the Doppler lidar wind sensor; a synthetic-aperture radar; a scatterometer; an advanced high-resolution multichannel microwave radiometer; instrumentation to obtain radiothermal images; radiometer scanning along the satellite's orbit; instruments giving multispectral imagery to obtain data about the color of the ocean; instruments for coordinate referencing, reading and transmission of information from ground-based and sea-based automatic platforms.

NASA (USA) prepares a permanent manned orbital station (MOS) which, presumably, will consist of three components [26]: (i) the MOS itself put into low orbit with an inclination of 28.5°; (ii) a module near the MOS on the same orbit to accomplish experiments on data processing and for other operations; (iii) a Polar Platform (PP) maintained by astronauts and put into a very high quasi-polar sun-synchronous orbit. The authors of [20] substantiate the necessity to use the PP for an operational solution of numerous problems connected with studies of the environment and natural resources, with the simultaneous utilization of the instruments of meteorological, oceanographic and Earth's resources satellites, both available and under development, aimed at realization of the PP project in the early 1990s. The scientific PP program can be divided into three stages (these stages are largely overlapping).

The atmosphere and the meteorological parameters. In this case the instruments for advanced satellites of the TIROS-N type (ATN) are the basis for the instrumental complex. This complex includes scanning multichannel radiometers (SMR) to obtain data on the brightness fields at different wavelengths and multispectral images (at a resolution of about 0.5 km), which enables one to solve the following problems: weather forecasts, assessing the precipitation; the ERB studies; mapping the global distributions of snow and ice cover and sea surface temperature (SST), of ocean currents and total ozone; monitoring hydrological phenomena; assessing the state of vegetation cover. Major requirements to the SMR consist of provision for precise radiometric calibration and a daily global data base. A separate complex consists of instruments for remote sounding of the atmosphere (an operational vertical sounder of the ATN satellites can serve as the prototype), which must twice a day give the needed information for the numerical weather forecasts on a grid with a step from 10–50 km to 250 km.

Ocean and ice. Here major problems are connected with increasing reliability and providing for synoptic global scale of the following information: SST and water mass characteristics (including the chlorophyll content); sea state, currents and gyres; concentration and properties of ice cover; wind speed, wind shear and SST. The following types of SMR are being developed: (i) advanced 7-channel (4.3; 5.1; 6.6; 10.65; 18.7; 21.9; 36.5 GHz) microwave radiometer with orthogonal polarizations (AMR) with an antenna 4 m in diameter, rotating at a speed of 60 rotations per minute. This device will enable one to retrieve: SST at a resolution of 25 km and accuracy 1.5K over a scanning band 1350 km wide; wind speed (0–50 m/s) with an error of 2 m/s (or 10%) at a resolution of 17 km; ice cover concentration with a 15% uncertainty, 9 km resolution and simultaneous classification into one-year and multi-year ice; total water content in the atmosphere with a 0.2 g/cm^2 uncertainty, 9 km resolution; (ii) IR radiometer scanning along the subsatellite trajectory – ATSR (SST retrievals with a 0.3K accuracy); (iii) a specialized 4-channel (19.3–85.5 GHz) scanning microwave radiometer SSM/I to equip the U.S. Defense meteorological satellites and the U.S. Navy oceanographic satellites N-ROSS; (iv) a 9-channel scanning complex to determine the color of the ocean (OCI) like the OZCS on Nimbus-7 (retrieving the chlorophyll content between 0.05 and 100 mg/m^3 to an accuracy of a factor of 2, at a spatial resolution of 500–800 m, as well as the suspended matter content to the same accuracy). A very important component must be the following active-sounding means: (i) radio-altimeter at 13.5 GHz, similar to that developed within the program N-ROSS (the error in estimating the height of satellite 8 cm; wave height 0.5 m; wind speed 2 m/s); (ii) a 6-beam 13.5 GHz scatterometer of the same origin; (iii) a synthetic-aperture radar (SEASAR) with horizontal polarization in the L-band.

Land. The Earth's resources complex consists of advanced high-resolution scanners used on Landsat. A multichannel scanner MLA is now being developed with varied (using the on-board processor) number of channels (8 to 32) in the wavelength interval 0.45–12.5 μm at a spectral (spatial) resolution 20 nm (10m). Scanning can be made in both the orbital plane (to obtain stereoscopic images) and perpendicular plane, with a scanning band 185 cm wide.

The GEOSAR complex, similar to SEASAR, is characterized by a specific set of frequencies, polarization and viewing geometry, which provides the remote sensing of land (cartography, geology, hydrology, glaciology, agriculture and forestry, as well as other fields of data interpretation). Apparently, a system of two PPs on the morning and afternoon orbits 900–1000 km high, visited by cosmonauts (to examine and repair the instruments, if necessary), is optimal.

The authors of [4] emphasize the exceptional importance of a powerful ground-based data-processing center for collective use. The instruments are developed by joint efforts of the USA, west-European countries, and Canada. So, for instance, Great Britain developed an instrument unit to sound the stratosphere and takes part in the development of a microwave complex. French specialists developed a system ARGOS to collect and transmit information from ground-based platforms. Canada has an interest in developing instruments for global monitoring of atmospheric ozone. Following an agreement between Great Britain, Italy, Canada, USA, France, FRG, Japan, and the European Economic Community, an International Committee on Earth Resource Satellites (IEOSC), responsible for coordination of the development of satellites to study the environment and natural resources, and an International Working Group on Polar-Orbiting Meteorological Satellites (IPOMS) were organized.

J. McElroy and S. Schneider [21] discuss the role of the Polar Platform within the NOAA's permanent space station program for operational observations of the Earth. The Polar Platform is an Earth's Resources Satellite put into the sun-synchronous nearly polar orbit. Since even the operational satellite-derived information (the PP data) must be used together with results of scientific research on improving instruments and techniques for data interpretation, prospects have been considered for joint application of the PP operational instrumentation and experimental equipment for the program "Earth's Observational System" connected with the International Geosphere-Biosphere Program.

A complex to study the solar-terrestrial relationships will include the devices used on the NOAA meteorological satellites (a sensor of total energy in the range 0.3–20 KeV released upon the precipitation of magnetospheric electrons and protons; a sensor of electrons and protons of moderate energy, from 30 to more than 60 KeV, and Block 5D-A spectrometer SS3/4 to measure a cumulative dose of the precipitated electrons in the range 2–10 MeV, as well as protons with energy more than 20 MeV; a monitor of the upper ionosphere plasma SSIE measuring the electron concentration, temperature and the electrostatic potential of the satellite; a scanning sensor of gamma- and X-ray emission SSB/A for the energy range 2–100 KeV; a sensor of the X-ray emission intensity SSB/S for energy levels 25, 45, 75, and 115 KeV, as well as a high-frequency receiver to monitor conditions for radio-wave propagation in the ionosphere SSIP).

The observations of the Earth's radiation budget components will be continued to obtain data on the spatial and temporal ERB variability on regional, zonal and global scales.

Information on the composition and the structural parameters of the atmosphere will be obtained by monitoring the physical and chemical characteristics of the atmosphere. The monitoring complex APACM consists of: (i) the Fabry-Perrot interferometer to retrieve the wind vector in the upper atmosphere (from the tropopause to the stratopause) using data on the Doppler shift of the absorption and emission lines; (ii) the monitor of the tropospheric composition (Fourier-spectrometer and conventional spectrometers tuned to the wavelengths corresponding to various components); (iii) the monitor of the upper atmosphere composition (a complex of spectrometers and radiometers for the UV, visible and submillimeter spectral regions, as well as the limb microwave sounder).

Meteorological observations will be made by the mid-resolution 6- or 10-channel image radiometer (MRIR) operating in the regime of time share. It is an improved version of the NOAA 4-channel AVHRR. A moderate-resolution image spectrometer (MODIS) is also being developed. It functions as an ocean color scanner. This instrumentation will make it possible to obtain images for 100 channels at resolutions 1 km (land) and 4 km (ocean). The IR and microwave scanning multichannel radiometers will serve as the basis for remote sensing of the atmospheric temperature and humidity. The instruments for the lidar wind sounding of the troposphere are being developed.

The complex for ocean monitoring is based on the following advanced instruments: the synthetic-aperture radar (SAR), radio-altimeter (RA), scatterometer (SC), microwave radiometer, the ocean color scanner (OCS). These instruments were used on Seasat and Nimbus-7 satellites. The SAR is of first priority. The SC must ensure the wind shear retrievals err not more than 1.3 m/s and 16°. The accuracy of the RA observations must reach 8 cm. It is assumed that the use of the data of the IR radiometer scanning along the subsatellite trajectory will allow one to retrieve the SST with an accuracy of 0.5K. Both the low-frequency and multi-frequency microwave radiometers will also serve this purpose. The data of the scanning multichannel radiometer SSS(I) will be very important.

Before an operational application of MODIS, the PP instrument complex will include the OCS. In the interests of the Earth's resources studies, a high-resolution image spectrometer (HIRIS) whose prototype is the SISEX spectrometer (128 channels, 0.4–2.5 μm range, 10–20 km resolution), tested on the Space Shuttle, as well as a specialized SAR (GEOSAR) may be developed. No doubt, the handling of this very complicated instrumentation by cosmonauts will ensure its efficiency and prolong its operation.

Summing up, we note that, with due regard to the efforts undertaken with a number of special programs, a major objective of the IGBP must consist in studying the interaction among the geosphere-biosphere components, with emphasis on the physical, chemical and biological processes on the land and in the ocean.

Since the key aspect of the IGBP are the biogeochemical cycles and their changes due to anthropogenic impacts, man should be considered here not only as a cause of the geosphere-biosphere transformations but also as an important object for study (from the viewpoint of changing conditions in the geosphere and biosphere affecting him). In this case, a major goal of the IGBP is an analysis of the present state of man-environment interactions and prognostic estimates.

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3.2 U.S. AND INTERNATIONAL PLANNING FOR THE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME

John A. Eddy
Office for Interdisciplinary Earth Studies
University Corporation for Atmospheric Research
Box 3000, Boulder, Colorado 80307, USA

1. Introduction

The International Geosphere-Biosphere Programme is a collaborative effort on the part of many nations to study the Earth and life upon it as an interconnected system. It aims are to monitor the global environmental changes that are now occurring, both naturally and due to the impacts of man, and to improve our ability to predict the 100-year future of the planet.

As such, it has much to do with this workshop in Vilnius, for its subject is the global environment and its underlying concern is the future sustainability and habitability of the planet. I think it true that the IGBP will provide the background information with which ecologists and social scientists will work in the decades ahead. I think it also true that without something like the IGBP, it would be almost impossible to make reliable predictions and responsible decisions concerning the future of the Earth's environment.

The IGBP was launched in September of last year at the 21st General Assembly of the International Council of Scientific Unions (ICSU) in Berne. The programme was approved unanimously by the scientific academies of the 71 member nations of ICSU – including all of the nations that are represented here in Vilnius. Although ICSU is a non-governmental, scientific body, we can be sure that the programme that it has launched will be backed by governments as well, through national, contributing programs, through bilateral and multinational programs, and through even broader, international projects.

Three features of the programme make it the largest and most ambitious ever undertaken in science. The first, just noted, is the fact that it is international, involving all the major nations of the world.

The second important feature is the interdisciplinary nature of the programme: the unanimous endorsement at Berne in September was made not only by national academies, but also by the 17 member unions of ICSU, representing the international unions of all the major branches of physical, chemical, and biological sciences, and many of the social sciences. What is more important, the program that was endorsed is designed to be interdisciplinary, and to involve all the major disciplines in the earth and biological sciences. The IGBP will combine efforts in oceanography, atmospheric science, geology and geophysics, hydrology, glaciology, soils science, terrestrial and marine ecology, and solar-

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buracas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

ICSU
International Council of Scientific Unions

International Scientific Unions

IAU	Astronomy	IMU	Mathematics
IUB	Biochemistry	IUTAM	Mechanics
IUBS	Biological Sciences	IUMS	Microbiological Societies
IUPAB	Biophysics	IUNS	Nutritional Sciences
IUPAC	Chemistry	IPHAR	Pharmacology
IUCr	Crystallography	IUPsyS	Psychological Sciences
IUGG	Geodesy and Geophysics	IUPS	Physiological Sciences
IGU	Geography	IUPAP	Physics
IUGS	Geological Sciences	URSI	Radio Sciences
IUIS	Immunological Societies	IUHPS	History and Phil.of Science

National Members

Argentina	German D.R.	Lebanon	South Africa
Australia	Germany, F.R.	Madagascar	Spain
Austria	Ghana	Malaysia	Sri Lanka
Belgium	Greece	Mexico	Sudan
Bolivia	Hungary	Monaco	Sweden
Burkina Faso	India	Mongolia	Switzerland
Brazil	Indonesia	Morocco	Thailand
Bulgaria	Iran	Nepal	Tunisia
Canada	Iraq	Netherlands	Turkey
Chile	Ireland	New Zealand	U.S.S.R.
China: Beijing	Israel	Nigeria	U.K.
China: Taipei	Italy	Norway	U.S.A.
Cuba	Jamaica	Pakistan	Uruguay
Czechoslovakia	Japan	Philippines	Vatican
Denmark	Jordan	Poland	Venezuela
Egypt	Kenya	Portugal	Vietnam SR
Finland	Korea, DPR	Roumania	Yugoslavia
France	Korea, PR	Seychilles	

Scientific Associates

include
International Society of Soil Science (ISSS)
International Union for Quaternary Research (INQUA)
Third World Academy of Sciences
Pacific Science Association

terrestrial physics.

The third important feature is the scope and duration of the program. The IGBP will involve programs of observations and process studies, modelling and interpretation. The observations will be made from space, from the surface of the Earth, and from the oceans. The program will begin in earnest in 1992 and last at least 10 years, and more likely 20 years. This amount of time is needed to build the base of data that is needed to detect significant global change, to assemble the world-wide scientific information system that will make access to this data available to everyone, to conduct needed process studies, and to develop the global environmental models that are the ultimate aim of the IGBP. That much time is also needed to plan and build the spaceborne instruments on which much of the IGBP will depend, to set up and operate a system of *biosphere observatories* on the ground and on the oceans, and to train scientists to work on interdisciplinary problems.

2. Rationale for the IGBP

What is behind the strong support for this program? I think it is three forces, that through coincidence have emerged at the same time and act in the same direction. One of these stems from the recent progress of science, another from technology, and the third from practical need.

A. Scientific Advances

Areas of study that examine the Earth and life upon it include oceanography, atmospheric science, geology and geophysics, hydrology, glaciology, soils science, terrestrial and marine ecology, and solar-terrestrial physics. As scientific disciplines they have operated for the most part as independent entities.

Recent progress in each of these fields now blurs the boundaries that previously separated them: advances in one field drive it inexorably into the domain of others, demanding an exchange of knowledge, of language, and of technique. Models of ocean circulation demand a knowledge of the dynamics of the atmosphere; models of global climate require biological inputs. The connections are probably best seen in biogeochemistry: the cycling of carbon, nitrogen, phosphorus and sulfur that connect the biosphere with the hydrosphere, the atmosphere and the land. The result is a modern merging of scientific disciplines, and the creation of a new science of the Earth as a whole of earth *system* sciences.

The IGBP promises to synthesize critical efforts in the earth and biological sciences at a time that is propitious: when pieces of the planetary puzzle now seem to be coming together.

B. Advances in Technology

A second, driving force is the availability of new technology that allows, for the first time, a global perspective of the Earth and the capacity to process and disseminate the stores of data that are needed to describe it.

Remote sensing of the Earth from space has come of age in the last few years, mostly visibly in advances in ocean sensing and in techniques that allow regional and global maps of biological productivity. Spaceborne sensing of the atmosphere and of the solid earth provide insights that were impossible to infer from transects or *in situ* measurements. These techniques allow one to sense global changes of key parameters in real-time, by comparing calibrated sequences of the same parameter. They are equally powerful in allowing global comparisons of two- and three-dimensional data fields of different parameters - for example, maps of sea-surface temperature with conincident maps of sea-surface productivity - to demonstrate connections that might otherwise go unseen.

Of equal importance are techniques of data handling, data display, data dissemination and of analytical modelling of multi-dimensional problems, made possible by new generations of modern computers and communication equipment.

Part of the success of the International Geophysical Year of 1957-1959 was the establishment of a world-wide network of data centers, based on airmail and on radio communications. The IGBP will be built on a computer-based data system that should allow immediate access and dissemination around the world. The same technology will allow one to portray data in new and powerful ways, and to synthesize and model on a global scale.

C. Practical Need

A third force behind the IGBP is the practical need to come to grips with an array of environmental problems that are the result of the ever-increasing use of the natural resources of the Earth: the problems of global habitability and environmental sustainability. About 10% of the land area of the planet is now under cultivation, and more than 30% is now under active management for the purposes of mankind. Chemical compounds for which there are no natural analogues are today released into the air and water in ever growing proportions. The consequences of these induced, global changes are difficult, if not impossible to foretell, based on our limited understanding of the system. An example is the "greenhouse" effect of increasing atmospheric carbon dioxide and other trace gases. Interaction and feedback between the atmosphere, oceans, land and biota cloud the prediction of the global, environmental changes that are certain to ensue. Other examples are the effects of acid rain, tropical deforestation, desertification, and the global changes in soils and groundwater that have followed from intensive agriculture and industry. In each case the critical processes that are involved transcend the bounds of single, scientific disciplines; in each case the causes and effects are international in scope, requiring international cooperation for their solution.

3. Scientific Objectives

The objective of the IGBP, agreed upon in Berne, is

> "To describe and understand the interactive physical, chemical, and biological processes that regulate the total earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are affected by human actions".

The emphasis on *interactive* processes directs the main thrust of the program at the parts of the total earth system that are now least understood: the interfaces between the biosphere, the atmosphere, the oceans, the solid earth, and solar-terrestrial space. The emphasis on the environment for *life* adds another element of focus: on those processes that most affect the biosphere. The emphasis on *global change* directs efforts at monitoring the fundamental parameters of the planet, to enable the program to detect global change in climate, atmospheric and ocean chemistry, soils, and biological species. Of especial interest are global changes that occur on time scales that are most significant for predicting the 100-year future of the planet. Emphasis on *human activities* recognizes that man today has become the principal perturber of the Earth's environment: the IGBP will attempt to further our understanding of the natural processes that regulate life on the planet, in order to be able to detect the man-made changes that are occurring.

Thus, while the IGBP will involve research in many fields, its principal emphasis will be directed at

> "those areas of each of the fields involved that deal with key interactions and significant change on time scales of *decades to centuries*, that most affect the *biosphere*, that are most susceptible to *human perturbation*, and that will likely lead to practical, *predictive* capability."

The IGBP will be designed around an integrated program of *process studies*, *observations*, and *modeling*. An important aspect will be the organization of worldwide programs of observations of key parameters of the earth system, to produce the data what will enable present and future generations of scientists to detect significant global change. These will demand sustained, long-term measurements of those variables that are required for analyses of physical, chemical and biological processes and for eventual use in global environmental models. Data needed from long-term monitoring includes: solar irradiance, volcanic emissions, concentrations of radiatively- and chemically-active gases, meteorological variables, land surface properties, ocean variables, land surface data, and information on paleoclimates derived from tree-rings, ice-cores, lake and ocean sediments, and geological deposits.

4. International Organization of the IGBP

The IGBP will be guided by a multidisciplinary committee of scientists who are themselves active in research in the biological and earth sciences, selected, in addition, to give broad international representations. That committee will first meet in July of this year to improve the initial definition of the program and to begin early planning.

5. Planning for the IGBP in the U.S.

The IGBP will be made up, by necessity, of national efforts that are coordinated internationally. In the U.S. these will be guided by the National Research Council through a new multidisciplinary Committee on Global Change that is under the cognizance of three commissions of the National Academy of Sciences: the Commission on Life Sciences; the Commission on Physical Sciences, Mathematics, and Resources, and the Office of International Affairs.

Funds for the U.S. Program will come from a variety of agencies, including the National Science Foundation, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the Department of Energy, the Environmental Protection Agency, the Department of Agriculture, and the Department of the Interior. NSF and NASA have developed their own, contributing programs, to be known as Global Geosciences and Earth System Science. In April of this year the President's science advisor, Dr. William Graham, appointed a new interagency committee to coordinate the activities of these and other agencies in studies of the Earth as a global system.

There is strong support for the program in the U.S. Congress, based n the fact that the IGBP, if successfully carried out, will provide practical information for policy decision involving the Earth's environment.

ICSU
International Council of Scientific Unions

SCGB
Special Committee for the Geosphere-Biosphere Programme

J. J. McCARTHY (Convenor)	U.S.	OCEANOGRAPHY
B. BOLIN	Sweden	ATMOS. SCIENCE
M.-L. CHANIN	France	AERONOMY
P. CRUTZEN	F.R.Germany	ATMOS. CHEMISTRY
E. S. DIOP	Senegal	GEOGRAPHY
S. DYCK	German D.R.	HYDROLOGY
J. A. EDDY	U.S.	SOLAR-TERRESTRIAL
W. S. FYFE	Canada	GEOLOGY
R. HERRERA	Venezuela	ECOLOGY
V. M. KOTYLAKOV	U.S.S.R.	GEOGRAPHY
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B. H. WALKER	Australia	ECOLOGY
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Executive Director
(Secretariat)

Thomas ROSSWALL Sweden

3.3 ACID RAIN IN EUROPE: MODELLING REGIONAL AND NATIONAL IMPLICATIONS

Jean-Paul Hettelingh and Leen Hordijk
IIASA, A-2361,
Laxenburg, Austria

1. Introduction

Acid rain leads to environmental effects and policy consequences that cannot be handled within a unique frame of reference, which allows for solutions that can be reached easily. The environmental effects result from emissions within and outside a particular country and they depend strongly on geological, geophysical and atmospheric circumstances. Mitigation of the acidification problem is different for every nation and is interrelated with economic and energy policies. Successful control strategies for transboundary pollution depend strongly on multilateral negotiations.

However, in order to tackle the acid rain problem in a multilateral context it is necessary that regional and national implications of solutions are shown in a way which allows for international comparability.

In this paper the Regional Acidification, Information and Simulation model (RAINS) (Alcamo et al. 1987) will be shown as an instrument that makes the acid rain problem more transparent in the sense that the problem is disaggregated into linked sub problems relating to energy, emission, abatement costs, deposition, soil acidity, lake acidity, direct forest impact and groundwater acidity aspects. Brought together in one model, RAINS provides a policymaker with results which are interregionally and internationally comparable.

In section 2, RAINS is briefly described. Section 3 concentrates on the national- and regional implications of the acid rain problem and the way in which RAINS offers a multilateral frame of reference that enables international comparison of all aspects of acid rain. The last section contains some conclusions.

2. The Rains Model

Detailed descriptions of the RAINS modules and their linkages are provided elsewhere (Alcamo et al. 1987, Hordijk 1987, Hettelingh and Hordijk 1987). A scheme of the linkages is provided in Figure 1.

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buracas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

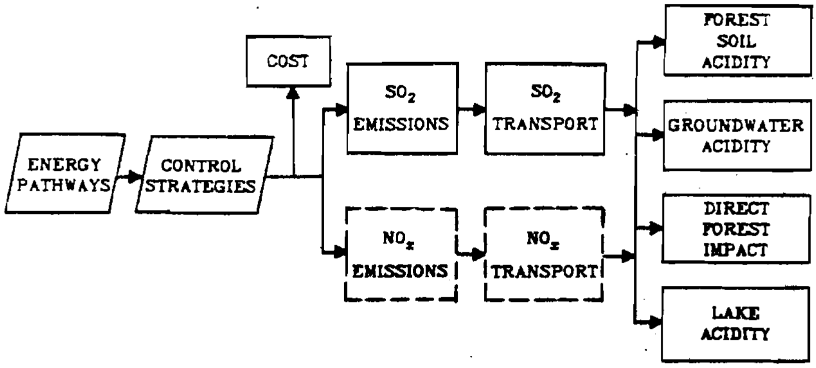

Figure 1. **Scheme of the linkages between the RAINS modules.**

The first module of the RAINS model,[1] the energy-emission module, has two main functions. The first is the display of the energy use of the European countries based on official governmental energy projections until 2000 as has been collected by the International Energy Agency (IEA, 1986). The RAINS model is referring to these figures as the Official Energy Pathway. Based on this scenario two other base scenarios are available in RAINS, i.e. a natural gas scenario and a nuclear phase-out scenario. The assumptions behind these scenarios are respectively related to a large scale application of natural gas and to the steady decline of the importance of nuclear energy to 2000. In Figure 2 the cumulative energy use of all European countries per energy sector is shown.

Next to the display of energy use per pathway, resulting sulfur and nitrogen emission can be displayed. The RAINS emission calculation for the years 1960 to 2000 are calibrated to the emission and energy use data available for 1980. Table 1 shows the emission data for 1980 implemented in RAINS.

The Energy-Emissions module also allows the use of RAINS to define the abatement of emissions by means of a control strategy to be applied on the sulfur dioxide exhaust resulting from one of the three energy pathways. The abatement options available to the user are: (1) the substitution of high sulfur fuels with fuels containing less sulfur (fuel switching), (2) the application of a combination of abatement techniques, i.e. Flue Gas Desulfurization (FGD), combustion modification and regenerative processes, (3) the straightforward definition of sulfur emission totals for chosen European countries until 2040. In the case of (1) and (2), the emissions for the reference years beyond 2000 are set to the level of 2000.

The Cost module provides the user with an estimation of the costs per country needed to implement a certain abatement strategy (Amann and Kornai 1987). Table 2 presents the combustion sectors distinguished in RAINS and the

[1]The RAINS computer model is running on an IBM-PC and compatibles, and contains all modules except groundwater acidification and direct forest impacts.

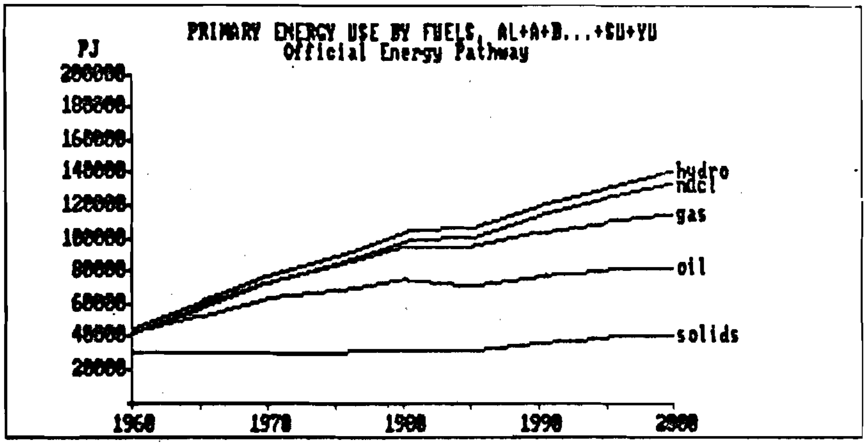

Figure 2. Official Energy Pathway; energy use of Europe subdivided in Hydropower, Nuclear, Gas, Oil and Solid Fuels.

Table 1. Emission of SO_2 in 1980 (Kilotonnes)

Albania	112	GDR	4607	Portugal	297
Austria	353	Greece	695	Romania	1482
Belgium	857	Hungary	1602	Spain	3258
Bulgaria	1026	Ireland	214	Sweden	484
CSSR	3140	Italy	3610	Switzerland	128
Denmark	453	Luxembourg	37	Turkey	960
Finland	584	Netherlands	450	UK	4678
France	3551	Norway	138	USSR	17617
FRG	3201	Poland	4027	Yugoslavia	1478
		EUROPE TOTAL: 59036			

applicable combinations of abatement technologies.

Depending on these technologies, investment costs, fixed- and variable operating costs are used to obtain country specific unit costs of abatement per ton of removed SO_2. Table 3 shows the parameters needed for the cost computation that are grouped in two categories: country specific and technology specific data.

Furthermore, an assumption is needed about the potential for old and new power plants in order to estimate abatement costs, which are much higher when abatement techniques are retrofitted to old power plants. It is assumed that power plants are phased out linearly within a lifetime of 30 years, and replaced by new installations. Finally the RAINS cost module derives for every country a national cost curve based on the least cost combination for each emission reduction level ranging from zero up to the technical feasible limit. In Figure 3 the cost

Table 2. Pollution control options (excluding fuel switching).

	Basic Control Options			
RAINS-Sector / **Fuel type**	**Low S fuel**	**Combustion modification**	**FGD**	**High eff. FGD**
Conversion				
Coal	x		x	
Oil	x		x	x
Power Plants				
Hard Coal	x	x	x	
Brown Coal		x	x	
Oil	x		x	
Industry				
Hard Coal	x	x	x	x
Brown Coal		x	x	x
Derived Coal	x	x	x	x
Oil	x		x	x
Domestic				
Hard Coal	x			
Derived Coal	x			
Oil	x			
Transportation				
Oil	x			

Source: Amann and Kornai 1987, p. 12.

Table 3. Input parameters to the cost module

Country Specific Data	Technology Specific Data
Sulfur content	Relative flue gas volume
Heat value	Lifetime of plant
Sulfur retained in ash	Sulfur removal efficiency
Average boiler size	Sulfur/sorbents ratio
Real interest rate	Maintenance costs
Electricity-, labour-, sorbents- and waste disposal-prices	Additional, in-plant, energy demand

curves for the Federal Republic of Germany are shown.

As can be concluded from Figure 3 the application of sulfur abatement techniques at the technically feasible limit leads to an emission of about 400 kt SO_2 for the Federal Republic of Germany in 2000. Similar graphs are available for all European countries.

The RAINS Sulfur Transport model is the next important module of the model. It computes the deposition of sulfur in all grids of Europe[2] as a result of national

[2]The grid size is 1 degree longitude by 0.5 degree latitude. The regional scale of RAINS is maximally the area between -12° longitude, 35° latitude and 42° longitude and 74° latitude.

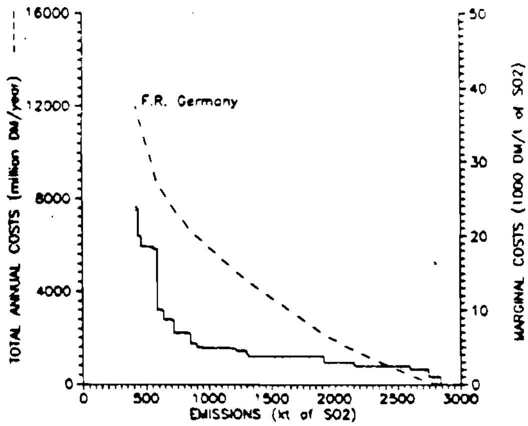

Figure 3. Marginal and total annual costs of SO_2 abatement in the Federal Republic of Germany, due to Official Energy Pathways in 2000.

SO_2 emissions. This computation makes use of a source-receptor relationship based on a model (Eliassen and Saltbones 1983) for long range transport of air pollutants in Europe developed under the Organisation of Economic Co-operation and Development (OECD) and the Cooperative Program for the Monitoring and Evaluation of Long Range Transmission of Air Pollutants in Europe (EMEP). In Figure 4 the deposition of sulfur is displayed in Europe in 2000 due to the European SO_2 emissions connected with the Official Energy Pathway.

The computation of the deposition can basically be considered as the RAINS model interface between the Energy-Emissions module on the one hand (supply of sulfur) and the impact modules on the other hand (sulfur buffering).

The RAINS Forest Soil Acidification module computes the decrease of the acid neutralizing capacity of soils. The module takes 88 soil types[3] into account. It is assumed that forests are allocated on soils with relatively low weathering rates (Kauppi et al. 1985). The user of RAINS may examine the effects of sulfur deposition in terms of the percentage of a chosen area that has an acidity (pH) that is different from a user specified threshold. Figure 5 is an example of the output that is provided to the user of this impact module, who wants to compare the effects of a 30% emission reduction strategy (1980 emission levels) between 2000 and 2040 on Central Europe.

According to the legend about 70% of the total displayed European region will have a pH level lower than 4 in 2040 compared to about 40% in 2000. In the German Democratic Republic for example the percentages are about 92% and 57% respectively.

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[3]The RAINS soil type data base has been digitized from the FAO UNESCO Soil Map of the World, Vol. 1, FAO-UNESCO, Paris, 1974.

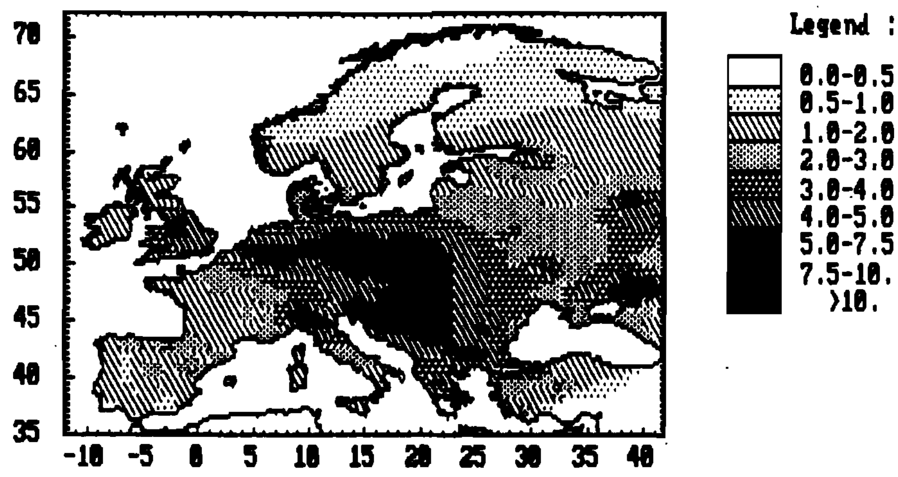

Figure 4. Total Sulfur Deposition ($g/m^2/yr$) in 2000, due to the Official Energy Pathways.

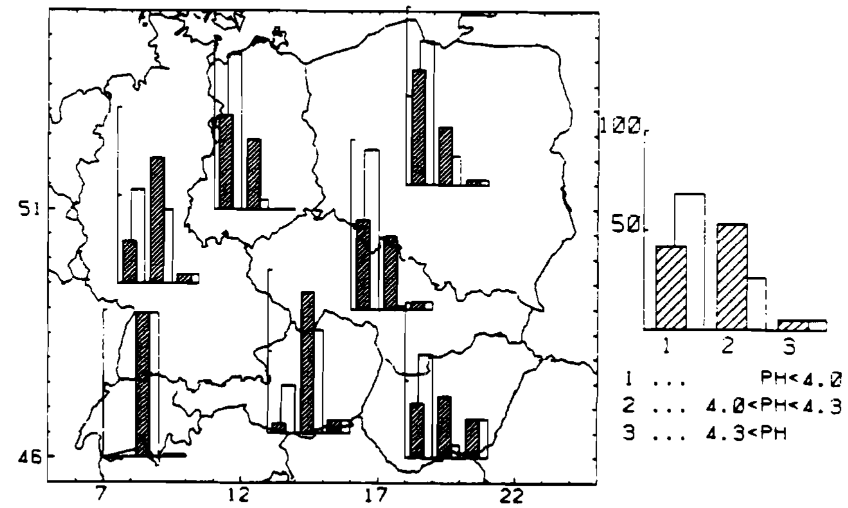

Figure 5. State of Soil Acidification in 2000 (hatched bars) and 2040 (bars) resulting from a 30% emission reduction.

The RAINS Lake Acidification module computes the acidification and alkalinity for lakes in Norway, Sweden and Finland. Contrary to the other RAINS impact models, the acidification of lakes is not dealt with on a grid bases. Instead, within these three countries, regions are distinguished within which the deposition gradient is assumed to be constant. The module is very detailed and takes into account meteorological, hydrological, soil chemistry and lake chemistry processes, which interact in order to simulate the acidification of a lake. By means of a Monte Carlo technique the module is given a stochastic character that enables the computation of the acidification of a typical lake that is assumed to represent the state of acidification of the majority of lakes in the region. In fact, statistical analysis (Kämäri et al. 1986; Gardner et al. 1987) has not shown all the parameters used in the model to be equally important in describing the acidification of the typical lake. Figure 6 is a display of the lake impact module.

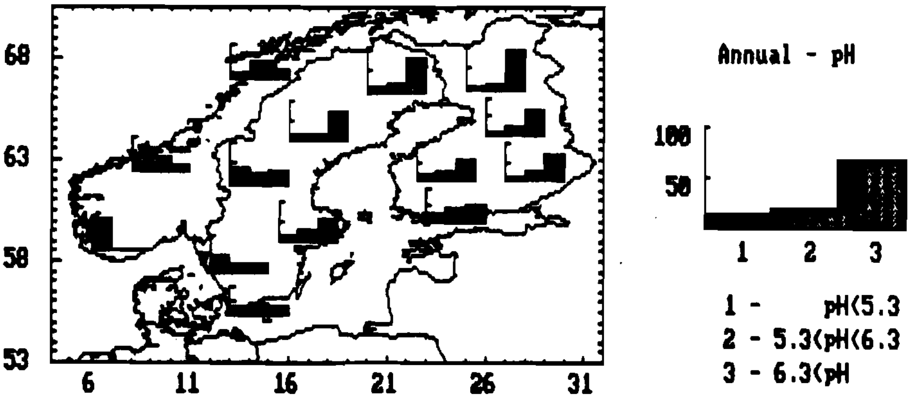

Figure 6. State of lake acidification in 2000 as a result of the deposition caused by the emissions of the Official Energy Pathway.

The legend in Figure 6 (outmost right) displays the percentage of lakes of the total area displayed of which the pH is smaller than 5.3 (class 1) between 5.3 and 6.3 (class 2) and bigger than 6.3 (class 3). The thresholds can be chosen interactively. The exact figures are displayed in Table 4.

Table 4. Percentage of lakes in Fennoscandia in specified pH ranges in 2000 due to the emissions of the Official Energy Pathway.

Region[a]	pH			<=			5.3		
	SF	N	S	SF	N	S	SF	N	S
1	18.0	94.0	28.0	34.0	5.0	43.0	48.0	1.0	29.0
2	15.0	45.5	49.0	28.0	38.4	29.0	57.0	16.2	22.0
3	7.0	15.0	17.0	27.0	56.0	28.0	66.0	29.0	55.0
4	7.0	-	40.0	21.0	-	28.0	72.0	-	32.0
5	3.0	-	14.0	11.0	-	17.0	86.0	-	69.0
6	-	-	11.0	-	-	16.0	-	-	73.0
All regions	5.4	51.5	19.7	15.7	33.1	20.5	78.9	15.4	59.8

[a] The number of lake regions distinguished in Finland (SF), Norway (N) and Sweden (S) is 5, 3 and 6 respectively.

The decrease of the buffering capacity of the soil leads to an increased risk for groundwaters in regions with thin soils and low weathering rates to become acidified. The RAINS Groundwater Acidity module (Holmberg et al. 1987) provides the user with an overview of sensitive areas in Europe ranging from least sensitive to most sensitive.

Contrary to other RAINS modules, the groundwater situation cannot yet be projected to future years. The module provides a static description which may be used as a qualitative addition to quantitative information about deposition or soil acidity in future years. It is a first step in the direction of extending RAINS with softer information to be stored in a Geographical Information System (GIS).

The RAINS Direct Forest Impact module (Mäkelä at al. 1987) translates annual average SO_2 concentrations computed in the Transport Module, into an accumulated dose of SO_2 to trees as a function of their exposure time. Depending on the annual measure of the length and warmth of a growth season[4] and the altitude classes (incrementing by 300 meters) within each European grid,[5] the stressed forest area per altitude class is computed.

The output of the RAINS Groundwater Acidity and Direct Forest Impact module have a graphical design similar to Figure 4. Examples can be found in Holmberg et al. (1987) and Mäkelä et al. (1987).

Each of the modules described above are thoroughly reviewed by means of open literature publications and review meetings (Hordijk, 1987). In addition to the scientific credibility another basic philosophy of RAINS is to use as much as possible data on which consensus has been reached on a European scale. An example is the use of the sulfur source receptor matrix (EMEP) in the Transport Module.

In the next section the national and regional implications of the Acid Rain problem are treated showing that the RAINS modular approach aside from the scientific credibility also leads to usefulness in an international multilateral context.

3. Regional and National Implications of Acid Rain: Rains as Measurement Standard

In order to develop a policy to revert a transboundary problem like acid rain basically two prerequisites are indispensable: (1) transparency of the problem and (2) a coherent national and international policy.

3.1 Transparency

Acid rain leads to stress which accumulates over time, on regionally dispersed environmental systems. The region may be bigger than Europe or smaller than a monument of which the material is damaged by acid rain and other pollutants (Feenstra 1984). The time horizon of the problem may be unimaginably far away. Apart from the spatial and temporal scale of the problem its measurable effects, i.e. tree dieback, may be a symptom of many interlinked processes. The conclusion is that a simultaneous treatment of all the aspects of the acid rain

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[4]The average temperature data of 1086 weather stations have been digitized.

[5]The data base has been created by M. Yamada, IIASA, 1987.

problem is difficult and disaggregation is needed. The goal of the disaggregation cannot be to choose the 'right' spatial and temporal scale and to distinguish between all the processes involved. Rather it is aimed to obtain parts that are manageable and relevant keeping in mind that a further disaggregation, to be represented in a policy, should lead to further tuning of policy ingredients and not to a reversal of policy directions. In terms of the acid rain problem a policy developed to start with the abatement of NO_x and SO_x may be further developed to finally result in the additional abatement of hydrocarbons, heavy metals, radiation and other hazardous waste. In other words the initial policy developed toward the international abatement of SO_2 (OECD, 1979) is correct in taking the state of scientific knowledge about air pollutant effects into account. In addition, it might be followed by an international policy to abate other pollutants, but it is unlikely that these additonal measures will contradict or reverse the findings about the effect of sulfur as part of the acid rain problem. A similar philosophy can be used when disaggregating the spatial and temporal scale of the problem.

As far as the spatial scale is concerned a distinction is needed between nations and regions. Since measures to abate pollution are taken on a national level and since national representatives are involved in multilateral negotiations the use of national statistics of emission to estimate pollution, pollution abatement and related costs seems a logical thing to do. On the receptor side it is less straightforward to define the proper scale. The more environmental systems a region contains, the less accurate an estimation of pollution impacts become. In the policy practice the measures taken until now (30% sulfur emission reduction of the 1980 level before 1993) are aimed at reducing effects that are clearly measurable, i.e. leading to a decreased forest die-back and lake acidification.

As before, it can be stated that a disaggregation of emissions into smaller (gridded) areas or a disaggregation of effect areas into ecosytems may lead to a more detailed targetted pollution control policy, but it is unlikely that such a policy will contradict current policies.

Regarding the temporal scale it is likely that current policy planning is a compromise between reverting environmental effects as soon as possible, important internal policy cycles (like elections), and financial resources. The result is a medium term (10-15 yr) planning of pollution abatement strategies. In terms of environmental effects, policy results may be difficult to measure taking into account the world's history with respect to the development of climatic- and ecosystems (Clark 1985).

3.2 RAINS a tool to increase transparency

The point made in Section 3.1 is that the 'ideal' disaggregation of a problem like acid rain is difficult to define. The aim should be a steady disaggregation of the problem into parts that can be recognized by policymakers so as to develop a stepwise policy of which the aggregate result remains coherent, targetted and scientifically sound.

RAINS is a model that aims at incorporating each and all of these prerequisites. The spatial scale is national on the emission side whereas the smallest scale on the receptor side is defined by soil types bearing forests. The entire model aims at treating the acid rain problem in steps reflected by the modular structure of RAINS. It only treats SO_2 but is now being extended with NO_x and NH_3. The inclusion of NO_x and NH_3 will provide a more detailed model output and perhaps a better understanding of the environmental impacts that have now only been attributed to sulfur.

RAINS provides results about national emissions, deposition, emission abatement, pollution abatement costs and environmental impacts that are comparable between nations, between regions and between reference years. The time horizon is about five times longer until 2000 than the time period involved in the current policy planning.

All these aspects of RAINS make it a credible tool to simulate policy measures and to evaluate these measures in an international context.

3.3 Coherent national and international policy

The evaluation of environmental impacts and its causes not only depends on factors mentioned in the previous section, but also on the international political context of the problem. The acidification of Scandinavian lakes has to a large extent been attributed to the emissions of Great Britain. However, British actors do not agree with the estimated British contribution to the lake acidification.

Multilateral negotiations that aim at agreements to decrease environmental stress are not seldom fed by national interests that are not merely concerned with the environmental needs.

In November 1979, the Convention on Long-Range Transboundary Pollution was signed by 32 European countries, the European Economic Community (EEC), Canada and the USA. The Convention does not entail binding commitments to undertake measures but "to limit and, as far as possible, gradually reduce and prevent air pollution, including long range transboundary air pollution" (article 2). By article 3 the Contracting Parties "shall by means of exchange of information, consultations research and monitoring develop without undue delay, policies and strategies which shall serve as a means of combating the discharge of air pollutants." From all the pollutants covered by the convention, priority was given to sulfur compounds. In July 1985 a protocol was added to the Convention to reduce sulfur emissions or transboundary fluxes by at least 30% of the 1980 levels at the latest by 1993.

The effect of such or other kind of policies can be evaluated by RAINS, thus making it an instrument to compare negotiation results. Figure 7 displays the deposition of sulfur in Europe in 2000 as a result of a 30 percent reduction of the emission figures listed in Table 1.

Compared to Figure 4 it can be concluded that areas with a deposition higher than 10 $g/m^2/yr$ are reduced (by approximately 70%). This policy agreement is one of many that may internationally be obtained.

In Figure 8 the European deposition pattern in 2000 is displayed when every country would install its best available control technology taking each country's national cost function into account.

Compared to Figure 7 it is clear that this maximum reduction scenario leads to a significant decrease of the deposition. Of course the abatement needed would be too costly for most countries and thus infeasible from a national point of view. Such a conclusion however, is only possible in a multilateral negotiation

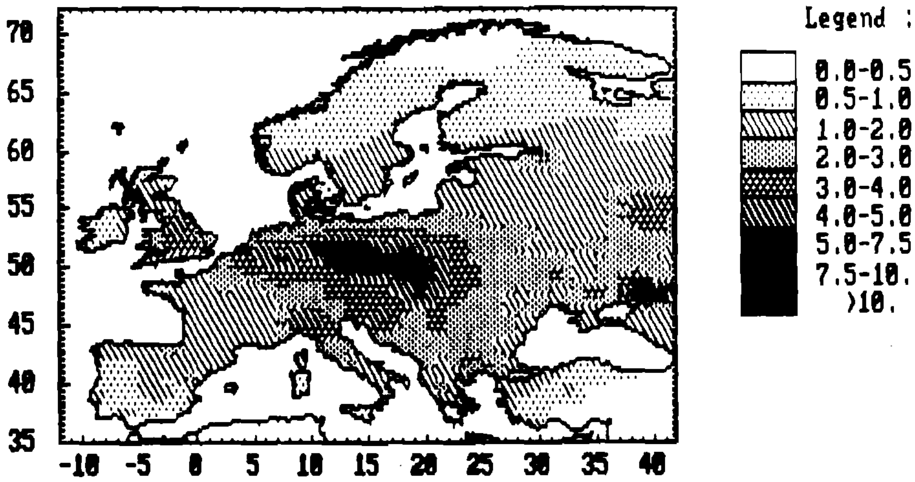

Figure 7. Sulfur deposition in Europe in 2000 assuming a 30% reduction of 1980 emissions.

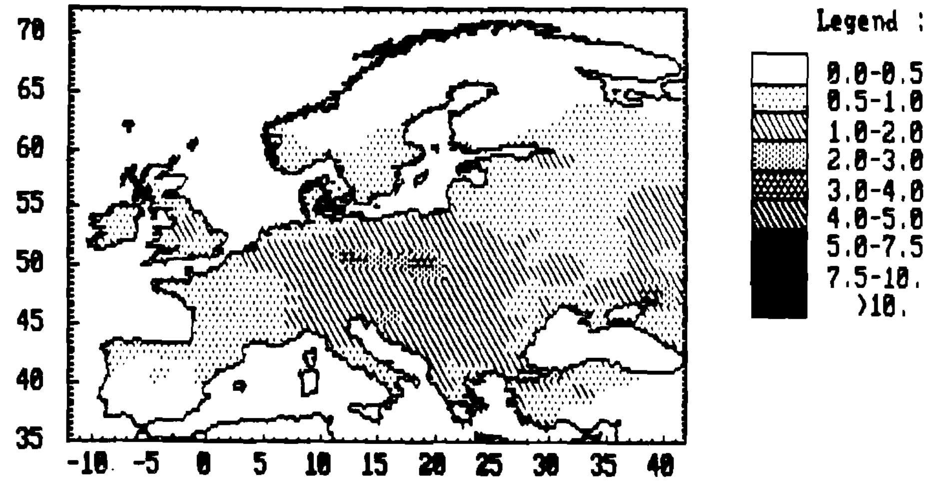

Figure 8. Sulfur deposition in Europe in 2000 due to the introduction of technically maximal feasible abatement techniques.

framework when all actors are using the same measurement tool. As a further consequence other policies than the 30% reduction goal, can be measured and negotiated leading to the next agreement of which the urgent need is evident in the light of the ongoing forest dieback and other serious environmental damages. The result of such an international agreement may be better than the aggregate of the different national policies separately. An example could be the creation of a European financial fund. It could enable the redistribution of national pollution abatement budgets, leading to a more efficiently targeted international policy. This kind of multilateral policy should aim at harmonizing national and international policy- and environmental interests, to be evaluated in one coherent framework.

4. Conclusions and Final Remarks

Acid Rain is due to pollutants that are transboundary in nature, and thus leads to environmental impacts that should be treated in a multilateral policy context.

In this paper the spatial, temporal and policy aspects of the acid rain problem are briefly reviewed. In order to treat such a problem we argue that transparency of its components is needed through disaggregation of the scales into manageable parts. This disaggregation should be ongoing in a consistent, internationally comparable way aimed at a continuous tuning of international environmental policy. The tool used to evaluate the policy to reduce acid rain should support a similar disaggregation.

The modular structure of the RAINS model provides a frame of reference that allows the evaluation of an abatement policy in terms of deposition, soil acidity, direct forest impacts, groundwater acidity, and costs of abatement strategies. The spatial scale ranges from grid squares (100 km^2) to entire Europe while the temporal scale covers the period 1960 to 2040.

A recent feature of RAINS is to evaluate national cost optimal strategies to reach predefined target deposition loadings in regions of Europe (Batterman et al. 1986, Amann and Kornai 1987). The results of RAINS provide an internationally comparable evaluation of the causes of acid rain, its effects, and costs of control.

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3.4 DENDROCHRONOLOGY – AN INSTRUMENT TO MEASURE ENVIRONMENTAL CHANGES

D. Eckstein
Institute for Wood Biology
University of Hamburg
Federal Republic of Germany

1. Introduction

Regional systems are not stable in time but instead experience a variety of disturbances which may be natural and/or anthropogenic. Since such disturbances influence the outcomes and responses of the system, we must have knowledge of their potential quantity and quality. But in order to estimate the effects of such fluctuations for the future, better knowledge of their frequency and intensity in the past is necessary. Since instrumental observations do not extend far enough back in time for this purpose, tree-ring series can be taken into account as proxy data. So it may well be possible that dendrochronology can act as an instrument to measure such changes in regional systems.

Dendrochronology is a biological science with a wide spectrum of applications. In the following, two sub-disciplines will be considered, dendroclimatology and dendroecology. In dendroclimatology, the dated annual increments of trees (tree rings) are analysed to clarify present and past climatic conditions; in dendroecology present and past local environmental changes are considered (Fritts, 1971). Both sub-disciplines may become increasingly important for regional resources management.

2. Concept of Dendrochronology

The annual increments of trees can be measured and analysed regarding their width, density, and chemical composition. From this kind of research, information on environmental and climatic changes can be derived with wave lengths of years to decades. How does this information get into a tree? The leaves and the roots of a tree are in close contact to the environment due to their morphology and anatomy, and thus act as entry points (Figure 1). According to Fritts (1981) a tree is considered to be a 'filter' by which a given input set of climatic influences is transformed into a visible and measurable output (tree-ring width, wood density, chemical composition); this transformation is performed through metabolic processes within a tree which need not be known in detail. Trees of different species and from various regions have different 'filter' properties, which should be characterised at the beginning of any dendrochronological study. This is

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buracas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

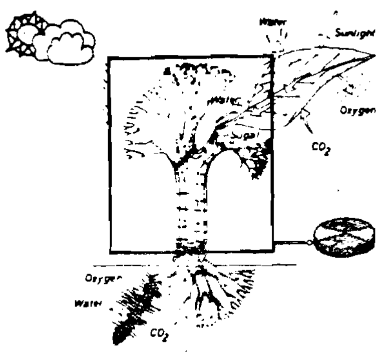

Figure 1 The black-box concept of dendrochronology: various factors enter a tree where they are integrated and converted to tree rings whereas the underlying metabolic processes are concealed within the black box.

usually done by multivariate methods to find a statistical relationship between a set of environmental variables and the contemporarily formed tree rings.

With this concept it has been possible, for example, to reconstruct past air pressure (Fritts et al. 1979), precipitation (Fritts, Gordon 1982), sea surface temperature, lake level changes, drought occurrence (Cook, Jacoby 1979), and other parameters. The present state of knowledge is summarized, for example, in Hughes et al. (1982), Schweingruber (1983), Bitvinskas (1986), Stockton et al. (1985), and Fritts and Swetnam (1986).

3. How to Extract the Recorded Information?

In principle the information we are looking for is recorded in all trees living now or which lived in earlier times and can now be found excavated by archeologists and geologists, used as building timber in old houses, or in wooden art-historical objects. Complete cross-sections of trees or beams provide the best possible material, but mostly one is restricted to cores removed from the trunks with an increment borer. Further technical evaluation depends on the underlying question and varies from a pure ocular observation of tree-ring features (Stokes, Smiley 1968) to highly sophisticated procedures such as x-ray densitometry (Schweingruber, 1973), automatic image-analysis (Sell, 1978), or mass spectometry (Stuiver, Burk 1985). But the most common technique still is the measuring of the widths of tree rings using a binocular microscope in combination with a traveling stage and interfaced with a computer (Robinson and Evans, 1980, Aniol 1983).

The result of the measurement of any tree-ring feature is a time series where the annual values vary in relationship to time. This variation contains the information one is interested in (signal), but it also includes variability caused by other influences (e.g. ageing, microsite etc.) (noise). The signal usually can be enhanced by a careful selection of trees. For example, trees growing on shallow soils free from the influence of groundwater record variations in precipitation; trees from a polluted site record the pollution history; and trees influenced by periodically occurring insect attacks record variations in insect populations. The enhancement of the signal is further achieved through replicate sampling in order to average out the random indifferences within and between individual trees. The number of trees that should be sampled is 10 at a minimum and should be increased to 30 or more per site if possible. In the long run a network of sites on regional and transregional scales is always to be envisaged in order to consider the spatial dynamics of the natural and anthropogenic disturbances in question.

4. Case Studies for the Reconstruction of Environmental History

In order to make the aforementioned theoretical principles and considerations understandable, a few case studies will be described. They demonstrate the diversity in both the techniques and the problems to be resolved.

4.1 Reconstructed stream flow for two rivers in Argentina (from Holmes et al. 1982)

The Rio Neuquen and Rio Limay drain a large area in the foothill of the Andes Mountains in western Argentina. From the point where they meet the river is named Rio Negro and flows into the Atlantic Ocean. Knowledge of past variation of riverflow may be of interest to administrators, planners and decision makers for the planning of projects such as dams, hydroelectric power stations etc. The upper basins of the two rivers contain a dense network of tree-ring chronologies for *Araucaria araucana* and *Austrocedrus chilensis*; both tree species turn out to have good qualities for tree-ring analysis. At the same time there are continuous gauging records beginning in 1903 for the annual runoff data. The trees grow on well-drained sites where they receive moisture only from precipitation. The approach to reconstruct stream discharge assumes that the trees respond to the same climatic input that influences discharge. After this was demonstrated the runoff was reconstructed back to 1601 AD; only the record from 1880 to 1966 is shown in Figure 2. The correlation between the measured and reconstructed series is 0.73, although in the years of extreme low and high flow the measured values are mostly more extreme than the estimated ones. It seems feasible to extend runoff records back as far as the tree-ring chronologies go, which at that time was the year 1140 AD. Such long runoff records may be useful as an estimator for future water resource planning.

4.2 Dendroclimatological reconstruction of the summer temperature for an Alpine site (from Eckstein and Aniol 1981)

The tree-rings widths of larch, spruce and stone pine in Tyrol (Austria) were used. The chronologies contain tree-ring series from living trees as well as from building timbers going back as far as 1471 AD. The climatic data were supplied by a weather station about 10 km from the tree sites, with records for the average monthly temperature starting in 1851.

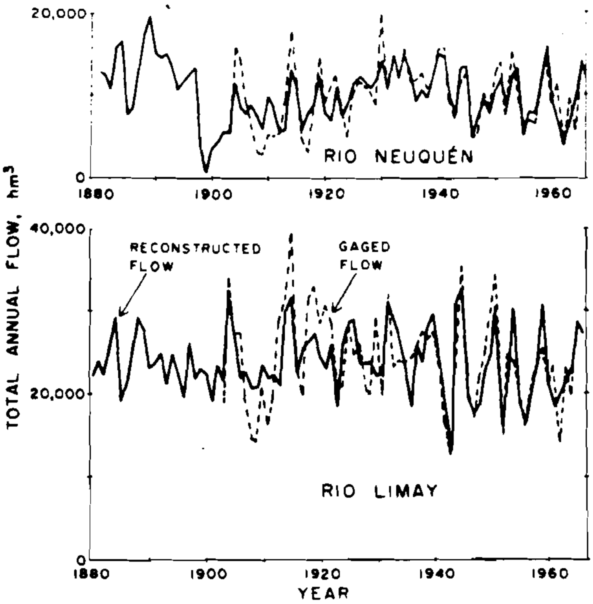

Figure 2 Total annual riverflow, Rio Neuquen and Rio Limay, as gauged 193011967 (dashed lines) and as reconstructed from tree-ring series 1880-1968 (solid lines) (from Holmes et al. 1982).

The three tree species respond to summer temperature, whereas precipitation is of minor importance. Consequently summer temperature was reconstructed as far as tree-ring series were available (Figure 3). In addition to the annual values of summer temperature the low frequency fluctuations have also been calculated; below average values are plotted in solid color.

Periods of below-average summer temperatures correspond reasonably with the more or less known intervals or glacial advances and retreats. But extreme single years such as 1627/28, 1673, 1675 etc., and above all 1816 ("the year without a summer") could also be confirmed, for example by documents on the dates when tithes were paid in grain in Switzerland (Pfister 1979). Thus, the dendroclimatologically estimated summer temperatures for the Alpine region appear to be realistic and merit our confidence, if they are to be considered as a disturbing factor of a regional system.

4.3 Large scale variations of climatic variables during the last centuries as reconstructed from tree rings

For the reconstruction of spatial and temporal variations of a specific climatic variable, dense networks of tree-ring sites and of climatic observations are necessary. Fritts et al. (1979) used 65 ring-width chronologies from western North America which span 1601-1963, together with meteorological records of seasonal temperature and precipitation as well as sea-level pressure. Multivariate transfer functions converted the past spatial variations in the network of tree-ring records into estimates of past variations in the meteorological series. The reconstructed winter and summer temperatures during the 17th through the 19th centuries differ from the 20th century means. Extreme winters were more

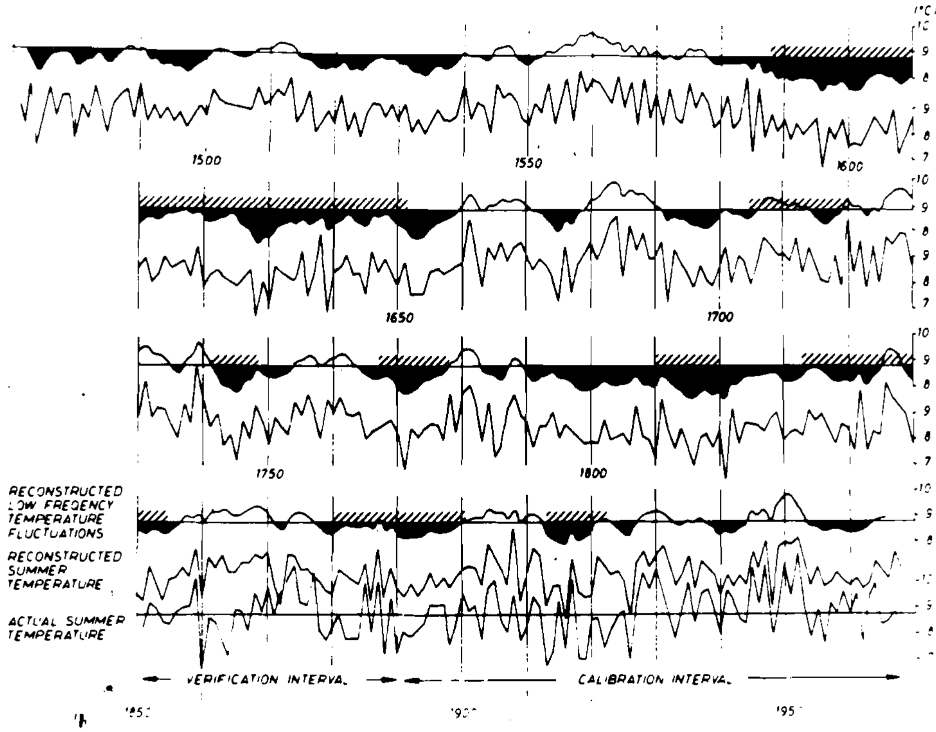

Figure 3 Summer temperatures for an alpine region in Tyrol, Austria, reconstructed from tree rings back to 1471; hatching symbolizes known glacial advances in the Alps (from Eckstein, Aniol 1981).

frequent in the 17th century. As an example Figure 4 illustrates the reconstructed air pressure, temperature, and precipitation for each decade from 1801 to 1850 expressed as departures from the 20th century averages.

Variations in the latewood density of conifers from cool, moist locations and from sites in the vicinity of the alpine and boreal timberlines (Schweingruber et al. 1987) allow the reconstruction of spatial annual temperature patt for the months from July to September for extensive areas in Europe. Figure 5 shows two rows of maps of Europe where in the upper row the areas with July-September temperature below the long-term average are in solid color and the areas with a respective above-average temperature are blank; in the lower row the same is done for above and below average tree-ring density from a network of 22 regional tree-ring chronologies. These two parameters were chosen since earlier studies revealed a good relationship between latewood density and July-September temperature for those ecological sites selected. A visual comparison of these maps year for year reveals a high similarity between the patterns of deviation of temperature and wood density. Thus, a large-scale estimation of summer temperature for the last four centuries seems to be possible.

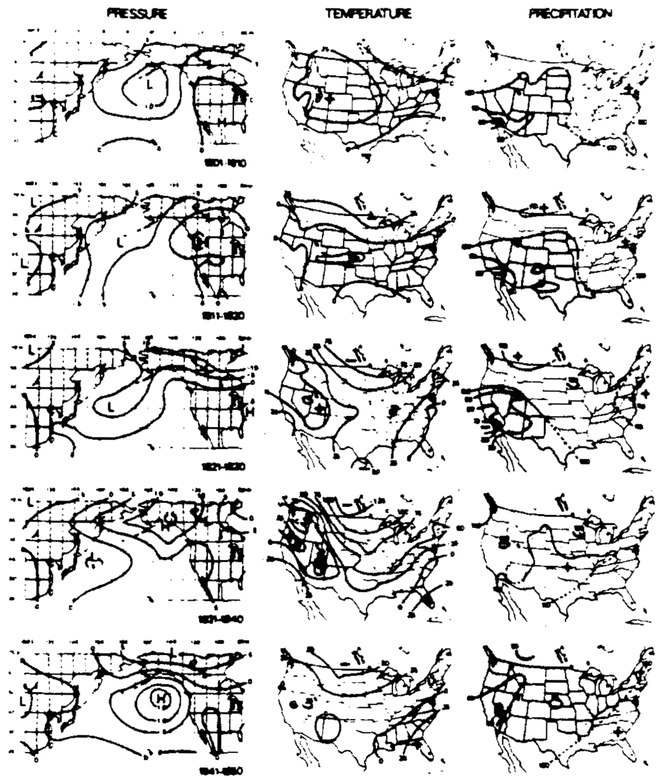

Figure 4 Reconstruction of mean annual surface pressure, temperature, and precipitation from 1801 to 1850 for North America, plotted as departures from the 20th century averages; shaded areas are warm, dry anomalies (from Fritts et al. 1979).

4.4 The application of dendrochronology to the evaluation of forest damage

More than 100 years ago tree-ring analysis was already used to recognize and quantify forest damage caused by industrial fumigation.

Forest damage caused by *pollution from the vicinity* can often be attributed to a single pollutant. Comparing the tree-ring series of diseased and of healthy trees, it is possible to determine the damage area and also to derive information on the temporate development of air pollution (e.g. Vins, 1961; Pollanschütz, 1962). In order directly to quantify the pollution influence on tree growth, sufficiently long time series of pollution data would be necessary. Since pollution has been recorded for only a few years, the production data of factories are sometimes used in the growth model as proxy data.

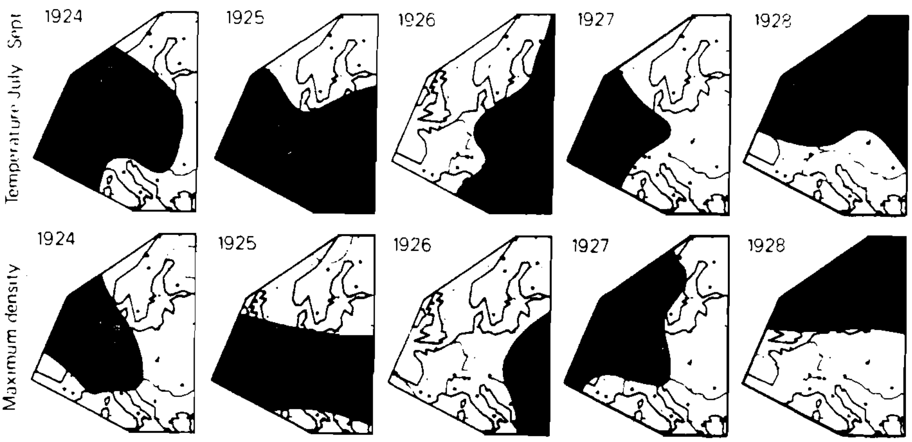

Figure 5 Comparison of the mean temperature for July to September from 23 stations (top) and of maximum tree-ring density from 22 regional tree-ring chronologies (bottom): black – temperature and density below average, blank – both parameters above average (from Schweingruber et al. 1987).

In the case of *far distant sources* the influence of air *pollutants* on the growth of trees is more difficult to recognize. A simple but powerful tool was introduced by Schweingruber (1986). Severe growth reductions are directly dated on discs or cores of thousands of trees from Switzerland and the results mapped geographically and chronologically. As can be seen from Figure 6, the onset of injury varies from region to region and from species to species. Some growth reductions seem to coincide with dry years, e.g. 1921, 1944, and 1976. In the 1950's pine and spruce have recovered, and at present all three tree species live in a phase of recovery, presumably because of a reduction of fluoride pollution. The studies furthermore reveal that there is often a poor correlation between the production of photosynthetic tissue of a tree and its radial growth. Consequently, the question of how far crown assessments really reflect the actual condition of trees in general and in the European forests in particular needs further investigation.

But what can be done when the trees do not show visible symptons of damage in their crowns at all. It is impossible to recognize large-scale pollution loads only by comparing tree-ring mean growth curves of different sites. Often climatic and orographic influences obscure the effects of small but long-lasting pollution, and unaffected control samples are difficult to obtain or nonexistent. In such a situation the influence of air pollution and acid rain on the radial growth of tree species may indirectly be made evident (e.g. Puckett, 1982; Fox et al., 1986). A recent example will be of interest.

The case study deals with a beech dieback in Western Germany (Eckstein et al. 1984). Some extremely narrow tree rings occurred simultaneously in the whole study area, but in 1976 the growth is more reduced than in any previous year. Missing rings subsequent to 1976 give an additional indication that the trees have been affected more seriously than ever before. The tree-ring widths

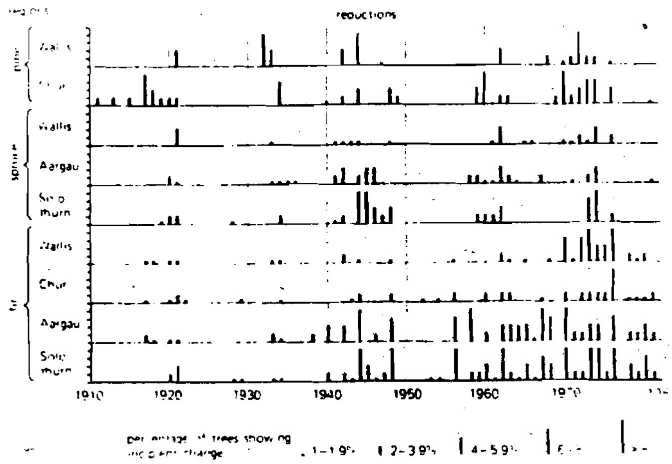

Figure 6 Onset of growth reductions in pine, spruce, and fir in various region of Switzerland (from Schweingruber, 1986).

of some 300 trees were cross-dated with each other and precisely placed in time. Then non-climatically caused tree-ring variations were statistically eliminated as far as possible, e.g. variations caused by ageing of the tree or by silvicultural treatments, and all tree-ring series of a site averaged. These mean tree-ring chronologies together with the records for the contemporary monthly precipitation and temperature were used to elaborate a statistical relationship between tree-growth and climate according to the methods of Fritts (1976) and co-workers. Such a multivariate relationship was calculated for the so-called calibration period, a time span in the early lifetime of the trees in which the damaging factor in question was not yet present. Using this model, tree-ring widths were statistically derived from the climatic records extending from the calibration period up to the present. In Figure 7 the actual and the reconstructed tree-ring series are shown for three group of sites. Within the calibration period and even up to 1970 there is a high similarity between the two curves, but then the measured tree-ring series obviously deviate from the reconstructed ones. Can this deviation merely be explained by the dry summer of 1976? Several dry summers occurred during this century which were at least of the same severity. Therefore an additional stress factor must be considered to be responsible for the recent beech decline.

This approach of using climatic response models of tree rings in the analysis and prediction of forest decline has recently been applied also by Cook (1987).

5. Conclusions

Dendrochronology may be able to contribute answers to some of the present-day serious problems such as the anthropogenic impact on the biosphere and the resulting consequences for the renewable resources of forestry and agriculture. But for this it is necessary that specific biological preconditions be fulfilled and the methodological tools capably applied. According to the biological principles of dendrochronology only those environmental elements that limit some

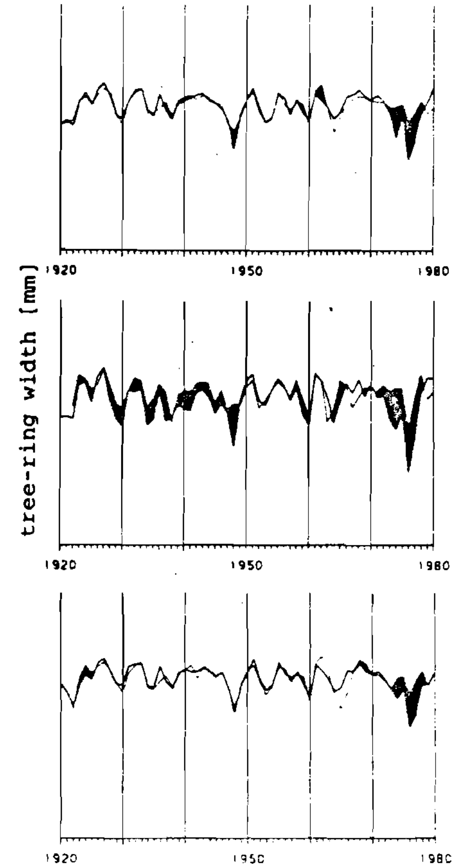

Figure 7 Comparison of actual average tree-ring series of beech in West Germany and constructed tree-ring series for three groups of sites; black areas indicate intervals where the actual tree-ring widths are smaller than the constructed ones (from Eckstein et al. 1984).

physiological process of the trees can affect growth and consequently are recorded in the tree rings. That means, for the analysis of a regional system it can happen that the needed information on disturbances cannot be supplied from the tree rings since the trees did not respond to the element in question. But one cannot simply take phases of reduced tree growth as indicators for a disturbance of the regional system as long as the causes for such a reduction are not known; because what is detrimental to a tree may not also be a disturbance in a regional system. Consequently, the cause effect relationship has in any case to be sought. As the case studies should have been illustrated, dendrochronology is well adapted to looking into the past. Only then is it impossible to predict future developments. Whether such auognosis will allow a statistical statement, for example, on the probability of the occurrence of climatic extremes, or direct annual forecasts (e.g. Kairiukstis, Dubinskaite 1986) is still an open question which must be discussed by the representatives of both points of view. The applications of dendrochronology may be of local and regional nature or they deal with large scale, continental, hemispheric or global areas and thus are adaptable to the scales of regional system analysis.

For future studies some major lines should be followed:

- good quality tree-ring chronologies from East and West should be brought together;
- all areas possible should dendrochronologically be worked;
- apart from tree-ring widths additional features should more intensely be taken into account, such as density, chemical composition of wood, and vessel size;
- methods should be developed in divers directions and at the same time there should be agreement on standardisation and unification;
- dendrochronological studies should be undertaken to enable us to distinguish man-made from natural environmental changes.

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3.5 ECOLOGICAL ASSESSMENT OF THE INFLUENCE OF PHYSICAL FIELDS ON LIVING ORGANISMS*

G. Buracas
Institute of Semiconductor Physics
Lithuanian Academy of Sciences, USSR

Until recently it was common to consider that the main abiotic factors influencing organisms are temperature, atmospheric pressure, the composition of the air, moisture, and light.

Technical progress provided a possibility to include into the list of these factors physical fields of a different nature, such as geomagnetic, electric, electromagnetic, and seismic fields.

Three important aspects can be distinguished in the influence of physical fields on living organisms:

- energetic impact on biosystems;
- influence on the temporal organization of biosystems;
- physical fields as information carriers.

The energetic impact of natural and man-created fields is being widely explored; and the effects are widely applied in medicine, agriculture, and other fields.

But the two last aspects of physical fields' influence on biosystems are still obscure. The ecological importance is also in need of assessment.

The gravitational field of the Earth is omitted in ecological studies. There are two reasons for this: firstly, it is commonly considered that the geogravitational field is actually stable and biosystems are fully adapted to it; secondly, there are great technical problems of gravitational wave measuring. Only recent investigations [5] with gravitocompasses and cockchafer (Melolontha vulg.) have led to a hypothesis about the existence of vortical gravitational waves and the capability of insects to perceive them by means of gravitoreceptors.

Other physical fields of biological importance are electric, magnetic, electromagnetic, and cosmic rays.

As is well known, cosmic rays are composed of particles with energies ranging from 1 to 10-15 Me V and accompanying magnetic fields. The interaction between those particles and the atmosphere yields secondary particles—nucleons and mu-mesons. The variation of natural radioactivity near the Earth's surface even during the strongest activity of the sun is not high and the biosphere is considered to be adapted to it.

The geomagnetic field exerts a much greater influence under changes in the sun's activity. There are several large periodic variations in the geomagnetic field, with periods of 27 days (that coincides with the sun's rotation period); of 14 (or 7, or 5) days, depending on the number of magnetic sectors round the sun—

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refer to Figure 1 from [6].

Also, there are considerable variations in 0.0001-5 Hz frequencies. As can be noticed in Figure 2, geomagnetic micropulsations coincide with physiological rhythms in a rather broad band [4].

The origin of electric fields on Earth is partially thought to be due to the ionizing action of cosmic rays, due to atmospheric processes, for instance, the evaporation of water. The tension of electric fields on a sunny day reaches 130 V/m near the Earth's surface. Electric fields also undergo rhythmic variations. The most significant rhythms are the following:

- 2-year variation;
- circaannual;
- 27-day;
- circadial oscillations.

There exist several powerful nonperiodic sources, for instance, storm clouds, the field tension in which can reach 1 MV/m. The electromagnetic field (EMF) radiated by the sun ranges from 5 Hz up to gamma-rays (refer to Figure 3 from [3]).

As is well known, the maximum energy radiated is in the visual band of EMF. In Figure 4, windows of atmosphere transparency to EMF are presented.

As mentioned, these fields are characterized by more or less periodic fluctuations. Some experimental observations lead to the supposition that these oscillations act on biological systems as *Zeitgebers* in most hierarchical levels beginning from cell and tissues up to ecosystems and the entire biosphere. The thresholds of sensitivity of biosystems to EMF, electric and magnetic fields usually are comparable to or are even lower than the amplitudes of natural fields (Figure 5).

Biorhythms, as self-sustaining oscillations, can be described by a nonlinear differential equation. A general model by Wever is:

$$y'' + e(y\hat{}2 + y\hat{}(-2) - 3)\, y' + \omega\hat{}\ 2(1 + 0{,}6y) = \omega\hat{}\ 2(x'' + x' + x)\ ,$$

where e indicates the amount of energy exchange and is a function of the oscillator *eigenfrequency*:

$$e = 0.5\ \omega\hat{}\ 1.25\ ,$$

y is a self-sustained biological rhythm; x is environmental change acting as *Zeitgeber*; sign ^ is an exponent [2]. Constant conditions, which as a rule are only possible in experiments, make the right-hand side of the equation constant.

Nowadays in our highly technological society, a variety of sources of artificial EMF are distributed over large territories, making their impact on ecosystems. Furthermore, modern building materials, which are highly electrically insulating due to the generation of electrostatic charges, also cause the formation of electric fields.

The electric charging processes resulting in voltages up to a few kilovolts, which are particularly noticeable in synthetic materials, can lead to spark discharges. Low-frequency electric fields can be generated due to the change in geometry of charge carriers. High voltage lines up to 100 kV of alternating current in frequencies of 50 Hz, telephone lines with 20 Hz frequencies, and buildings are all powerful generators of EMF.

Periodically alternating artificial EMF acting as *Zeitgebers*, can substantially influence such bioprocesses as the electrical dipoles of the brain, the synchronizing work of brain tissues over some narrow band of frequencies, thus affecting total functioning of the organ.

The importance of artificial EMF as a potential redistributor of natural biorythms still awaits ecological assessment.

Another aspect to be discussed is the informational content of electromagnetic fields. It is evident that a signal with a constant amplitude or constantly changing amplitude cannot transmit information.

Simple bursts of field or lack of them can transmit binary information. Continuous changes of some parameters of a field can transmit analogous information.

The informational importance of physical fields is obvious in the electrocommunication of insects, plants, etc. For example, bees are able to maintain an electrostatic charge on their body. Every electrostatically charged body produces a defined alternating field when moving relative to a fixed point. If this alternating field has a stable frequency over a long period of time, as it has during the dance of a honey-bee, the possibility exists of transmitting information by means of code. Large flocks of starlings are capable of carrying out complicated flight maneuvers in less than 5 msec. Heppner and Haffner have formulated the hypothesis whereby flight maneuvers are coordinated by means of electromagnetic signals. This hypothesis gains added significance from the fact that birds are charged electrostatically during flight [2].

Many other observations, such as magneto-orientation of birds, interaction of trees in forests, sensitivity of fish to electric and magnetic fields, etc., could be mentioned as evidence of the bioinformational importance of EMF.

A completely different approach to the functioning of EMF as bioinformation carriers is applied in the millimeter range of wavelengths. As is shown in Figure 4, millimeter waves of cosmic origin are almost fully absorbed by the atmosphere making this range of EMF free from noise. This fact has led to the hypothesis, sustained by N.D. Devyatkov, that millimeter waves can be a potential channel transmitting information among organisms. The content of this information, as can be deduced from recent experimental data [1], is likely to relate to the general state of an organism.

Recent work by V.P. Kaznacheyev [3] showing the possibility of transmitting biological information by quanta of optical EMF also raises new questions about informational pathways in ecosystems and the impact on them by means of human technological activity.

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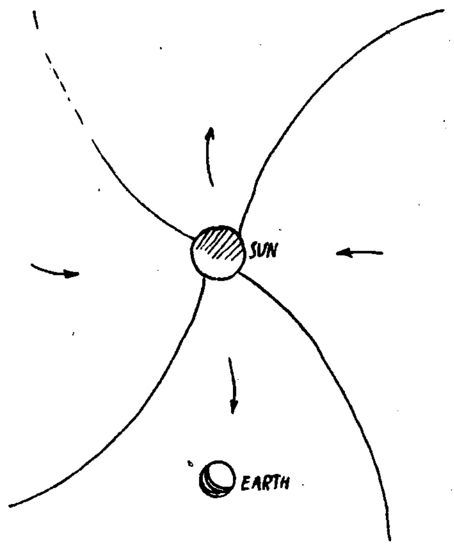

Figure 1 · Structure of interplanetary mangnetic field

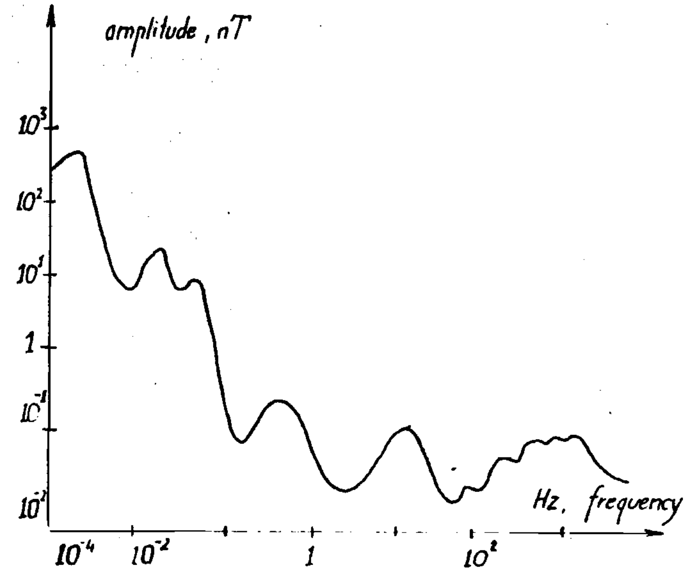

Figure 2 Geomagnetical micropulsations: interdependence between amplitudes of quasisinusoid pulsations

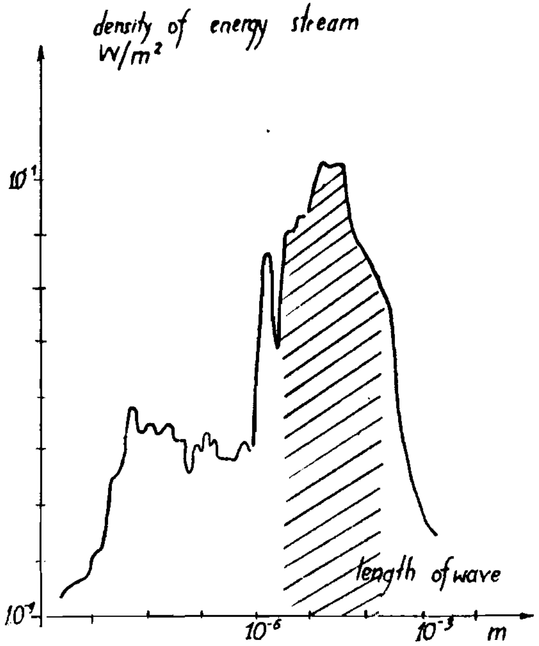

Figure 3 Energy distribution in solar spectrum

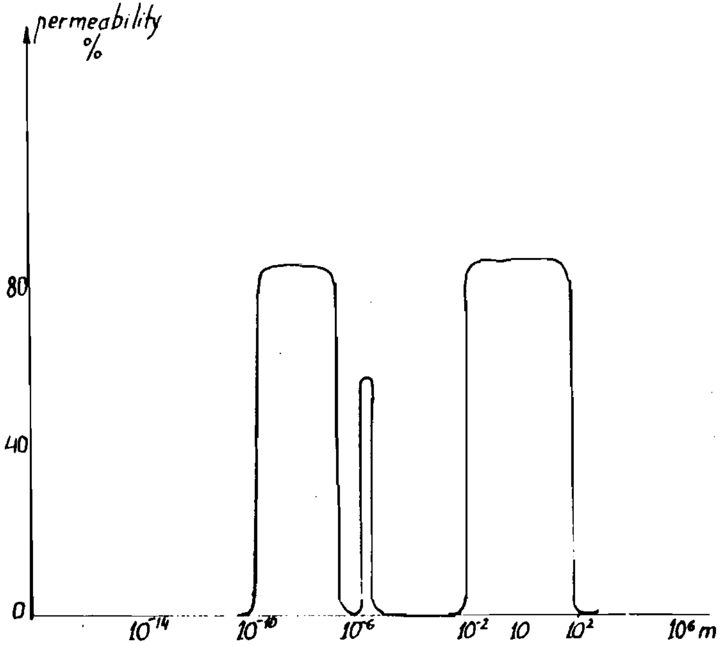

Figure 4 Windows of atmosphere

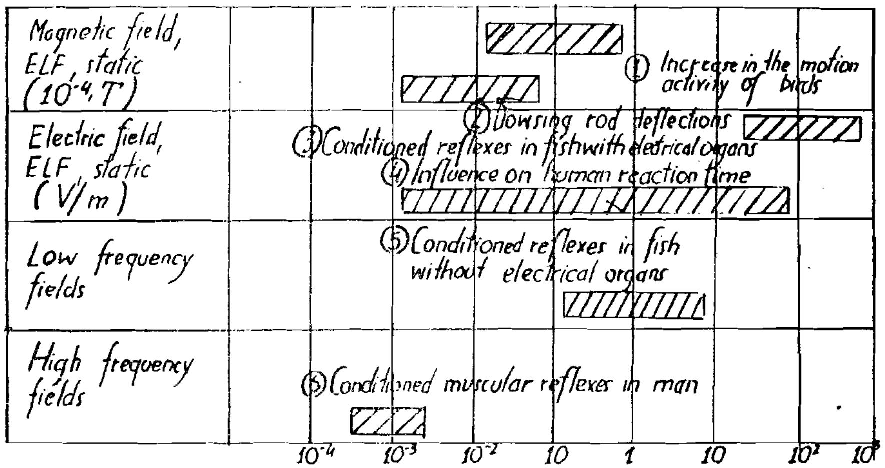

Figure 5 Intensities of natural EMF and lowest thresholds of reactions by biosystems

PART IV

METHODOLOGIES FOR ECOLOGICAL ASSESSMENTS

4.1 EVALUATION AND METHODS OF THE RATIONAL USE OF NATURAL RESOURCES*

V. Malisauskas
Head of Department, Evaluation of Natural Resources
Academician, Institute of Economy of the Lithuanian Academy of Sciences
Pozelos 52, 232600 Vilnius, Lithuanian SSR, USSR

With the development of industrialization, adverse anthropogenic influences are increasingly exerted upon the environment. In this connection it is necessary to foresee ways and to work out appropriate measures aimed at a more rational use of natural resources and environmental protection.

Natural resources fall into three major groups: 1) conventionally-permanent (land, water, climatic conditions, solar radiation); 2) renewable-biological (vegetation, wildlife); and 3) exhaustible (oil, coal, ore, and other mineral resources). An analysis of the above classification brings us to the conclusion that human society will be in a position to develop normally as long as the quality of the conventionally-permanent resources is maintained while exhaustible resources are replaced [4].

A more rational use of natural resources is facilitated by: the integration of new waste-free technologies, the creation of reserves for all kinds of natural resources, and improvement in the economic effectiveness of natural protection

Over billions of years, the evolutionary process on Earth has created a closed-loop, waste-free cycle of matter. The wastes of some organisms are consumed by others. Man-created technologies are far from being perfect, which results in large waste dumps and environmental pollution. So far, man has not learned to work without waste. Therefore, it becomes a matter of high priority to introduce on the very largest scale a multistage, waste-free cyclic technology of production, to expand biological industrial processes, and to implement utilization of manufacturing wastes. The ecological economic effectiveness of the aforementioned measures is determined not so much by the gains received from waste utilization, as by its validity for environmental protection.

The Soviet Union and its republics have accumulated substantial experience for the economic evaluation of natural resources and its practical application.

The economic evaluation of any natural resource can be undertaken using elaborated evaluation criteria. It is desirable to have all natural resources evaluated by a common criterion which is indispensable for comparing different evaluation indices. The USSR Academy of Sciences suggests that the indicator of the national-economic (operating and nature-protective) value of natural resources should be used in the capacity of such a common criterion. The value is determined as the differential rent which is estimated as the difference between the value of production calculated by limit costs (i.e., socially-necessary

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costs under worst production conditions), and direct discounted costs for its acquisition. The proposed criterion is well-grounded in broad generalization. Yet, due to the fact that different evaluations pursue different goals, the evaluation of separate species of natural resources warrants the use of other evaluation criteria as well.

On the recommendation of the USSR Ministry of Agriculture, the following three criteria are used to evaluate farm lands: 1) productivity (crop capacity, value of gross output); 2) recoupment for expenses (value of gross output per unit of expenses); and 3) differential profit (extra net profit in soils of superior quality and favorable location) [3].

All the calculations based on the aforementioned criteria are conducted in common terms for the Soviet Union land prices for plant-growing production. This makes it feasible to compare the evaluation points of lands under different production conditions. For instance, among the Union republics, the land evaluation point in terms of production value in prices per hectare of farm lands fluctuates by 9.3 times, in terms of recouping of expenses by 2.3 times, and in terms of differential profit by up to 135 times. Consequently, differences in land evaluation points predetermine the range of applicable measures for land improvement, protection, and procurement of differential rent.

There are considerable differences in the evaluation points of farm lands not only among the Union republics, but also within each of them. Because of this, it is necessary to have an evaluation point which meets local conditions, since the all-Union evaluation conducted on the basis of common land prices deviates from local purchasing prices and is too generalized and conditional to be of practical use.

The evaluation of farm lands in the USSR was conducted by the Lithuanian Scientific Research Institute of Agricultural Economics and the Republican Land-Tenure Design Institute.

In applying the evaluation scale, fertility of agricultural crops, expressed in conventional units (the basis of which is made up of fodder units), was taken as the evaluation criterion in the Lithuanian SSR. There are approximately 720 varieties of soils in the Republic. There is no need to subject all of them to evaluation, as long as their fertility does not differ greatly. For this reason, 37 conglomerate groups have been formed to evaluate arable lands, and 39 to evaluate meadows and pastures. The data of 1971 through 1977 have been used to determine the fertility of the conglomerate groups. The scales for arable lands, meadows and pastures have been drawn up on the basis of fertility data of 626 and 320 typical farms, respectively [3].

The evaluation scale is based upon the genetic properties of soils and their mechanical composition (Table 1).

Table 1 Extract from the evaluation scale of arable lands (points) [2]

Soils	Not drained	Drained	Irrigated
1. Sod - podzolic weakly podzolized loamy sands	48.4	53.2	121.4
2. Sod - podzolic weakly podzolized loams	52.3	57.0	127.0
3. Sod - podzolic weakly podzolized clays	51.8	58.9	127.0
4. Sod - podzolic gleysolic loamy sands	28.0	43.0	106.4
5. Sod - podzolic gleysolic loams	30.9	48.6	120.7
6. Sod - podzolic gleysolic clays	32.0	50.4	120.7
7. Sod - gleysolic loamy sands	36.6	55.7	127.7
8. Sod - gleysolic loams	36.6	60.2	146.8
9. Sod - gleysolic clays	35.7	60.9	146.8

In farm-to-farm soil evaluation, the index is rendered more precise by taking account of the attained level of land cultivation (the reaction of acidity and quantity of mobil phosphorus is taken into account). If these indicators are higher than in typical farms, the evaluation point is increased, if lower - decreased). When conducting an economic evaluation of farm lands, correction factors reflecting the territorial-geographic and technological conditions of production (the quality of road network, farm location, climatic conditions, landforms, location, stoniness, relative soil resistance to tillage, etc.) are applied.

In the Lithuanian SSR, for region-to-region evaluation of farm lands, the index varies from 27.7 to 53.4; while for farm-to-farm evaluation of farm lands, the index varies from 15.2 to 63.9 per hectare [3].

Considerable variations in land evaluation necessitate taking measures to even out the economic conditions of management and to obtain differential profit. In this connection, a new more precise differentiation of state purchasing prices for livestock production was executed in 1983, breaking them down in accordance with five groups of agricultural enterprises. Milk prices in the fifth group, as compared to the first, are higher by 8 percent, cattle prices by 24 percent, and pig prices by 31 percent. The economic evaluation of land is widely used in analyzing, planning, and managing agricultural production.

A critical analysis of the differentiation of purchasing prices according to the five enterprise groups makes it relevant to point out that from a purely scientific viewpoint, it would have been better to adjust prices on the level of socially-necessary costs under worst production conditions (i.e., on the level of the fifth group of agricultural enterprises). In this case, the differential profit obtained in other groups of agricultural enterprises might have been obtained by means of fixed rental payments in accordance with the economic evaluation of land and other production conditions. In this case, however, the purchasing prices would have been too disconnected from retail prices; thus it would have been necessary to review the whole system of price formation and pay for work, which is time-consuming. .

The possibilities to develop new lands are constantly decreasing. Therefore, the principal way to further accumulation of food resources is to raise the quality of lands and to enhance the intensification of production. To more rationally utilize the Republic's land, plant, and animal resources, the following procedural framework has been mapped out:

1) to increase forest areas at the expense of low-crop farm lands and to afforest them with premium-quality plantings;
2) to recultivate all disturbed lands;
3) to increase the area of protected territories;
4) to adopt the worked-out measures to combat water and wind erosion of soils;
5) to consistently decrease the acidity of precipitation which diminishes land fertility and fish-yield of water reservoirs;
6) to preserve the whole existing gene stock of the plant and animal world.

An original ***methodology and scales for the economic evaluation of forest resources*** [2] have been developed by joint efforts of various specialists and are widely applied in production in the Lithuanian SSR. The value of basic and collateral production yielded at normal management as well as the usefulness of the protectional and recreational functions of forest have been taken for the criterion of this evaluation.

To evaluate forest resources, four scales have been drawn up concerning: 1) wood; 2) nonarboreal products of the forest; 3) soil- and water-protective functions; and 4) recreational functions of the forest.

The evaluation of forest lands in terms of wood is based upon the genetic classification of soils (Table 2). The complete scale takes into account the types of soil, its physicochemical characteristics, acidity reaction, landforms, the degree of marshland, and the specific conditions facilitating the growth of certain types of forest tracts. This scale consists of two parts: the first one provides the average evaluation point of forest lands, the second – the evaluation point of separate tree species. A comparison of the evaluation points of forest lands and forest tracts reveals the available reserves for the improvement of generic composition and the increase in the productivity of forest tracts.

In evaluating the nonarboreal products of the forest (fungi, berries, herbs), alongside with land fertility, an important role is played by forest-tract valuation indicators: composition, age, density, etc. For instance, at a forest-tract density of 0.3, cowberries can yield up to a few hundred kilograms of production per hectare, while they are totally unproductive at 0.8. All this is taken into account in forest management projects.

The usefulness of soil- and water-protective functions of the forest is determined by the efficacy of retarding soil erosion and decreasing the washout of nutrients from soils. This scale consists of two parts: the evaluation points of natural conditions fall into the first part, the state-of-the-art of protective forests into the second (Table 3).

Three factors have been considered relevant to the first part of the scale: landforms, slope declivity, and the mechanical texture of soils. In the second part, forest tracts are classed into three groups by their composition and density. Purely coniferous forest tracts do not perform their protective functions as well as mixed or leaf-bearing ones do. Forests on a hilly terrain and light

Table 2. Extract from the evaluation scale of forests and forest lands in terms of wood (compiled by V. Malisauskas, V. Vaicys, S. Mizaras, I. Lukosius) [4]

Type of site conditions*	Land evaluation point	Tree species evaluation points							
		P,L	F	O	A,M	Bal	Br	As,Po, Li	Gal a.o.
1	2	3	4	5	6	7	8	9	10
nm Sa	35	35	-	-	-	-	-	-	-
Sb	50	55	-	-	-	-	30	-	-
Sc	60	65	65	-	-	-	40	40	-
Sd	65	65	65	70	70	-	45	45	20
Na	45	45	-	-	-	-	-	-	-
Nb	65	70	70	65	-	-	40	40	20
Nc	75	80	80	80	-	-	50	50	25
Nd	80	-	85	90	90	-	55	55	30
Ne	85	-	80	95	100	-	60	80	30
Ta	45	45	-	-	-	-	-	-	-
Tb	65	65	70	60	-	-	40	40	20
Tc	70	75	75	75	-	50	45	50	25
Td	75	-	80	90	90	60	50	55	30
Te	80	-	80	90	100	70	55	60	30
Ha	30	30	-	-	-	-	-	-	-
Hb	40	45	45	-	-	30	20	-	-
Hc	45	60	65	-	-	40	30	40	20
Hd	50	-	60	-	75	50	35	45	25
He	60	-	60	-	85	60	40	45	25
Wa^d	20	20	-	-	-	-	-	-	-
Wb^d	35	40	40	-	-	-	15	-	-
Wc^d	45	55	70	-	-	35	20	-	-
Wd^d	55	-	70	-	75	55	25	-	-
Wa	10	10	-	-	-	-	-	-	-
Wb	20	20	20	-	-	25	10	-	-
Wc	30	30	35	-	-	35	15	-	-
Wd	40	-	40	-	-	50	20	-	-

* **Symbols:** S - soils on steep slopes; N - soils of normal moisture; T - temporarily overmoistened soils; H - heavy swamp soils; W^d - drained swampy peaty soils; W - nondrained swampy peaty soils; a - very infertile; b - infertile; c - fertile; d - very fertile; e - extremely fertile. P - pine; L - larch; F - fir; O - oak; A - ash; M - maple; Bal - black alder; Br - birch; As - asp; Po - poplar; Li - lime; Gal - gray alder.

Table 3. Extract from the evaluation scale of the protection functions of forest (compiled by G. Pauliukevicius and V. Malisauskas) [4]

A. Evaluation of natural conditions				B. Evaluation of forest tract								
				Composition								
Landforms	Slope declivity	Mechanical texture of soils* (within the range of roots)	Evaluation point	coniferous			coniferous and leaf-bearing			leaf-bearing		
				Completeness								
				0.5	0.5–0.9	0.9	0.5	0.5–0.9	0.9	0.5	0.5–0.9	0.9
				evaluation point								
1	2	3	4	5	6	7	8	9	10	11	12	13
even, rolling	5°	Gr, S	26	15	20	18	15	26	22	20	26	26
		LS, LM, LM_1	18	13	16	16	15	13	18	15	18	18
		LM_2, C	14	10	14	14	10	14	14	12	14	14
		organic matters	12	8	12	12	10	12	12	8	12	12
hilly	6–10°	Gr, S	28	18	25	23	17	28	25	26	28	25
		LS, LM, LM_1	24	13	20	17	15	24	22	22	24	22
		LM_2, C	20	10	17	14	12	20	16	18	20	20
	11–15°	Gr, S	32	15	25	20	18	30	25	28	32	30
		LS, LM, LM_1	28	12	22	17	16	25	22	22	28	28
		LM_2, C	24	9	17	13	15	25	22	20	24	24
	15°	Gr, S	44	20	35	30	24	40	36	38	44	40
		LS, LM, LM_1	40	16	25	20	20	35	28	36	40	40
		LM_2, C	36	14	24	18	17	30	26	30	36	36

* Gr – gravel; S – sand; LS – loamy sand; LM – light loam; LM_1 – medium loam; LM_2 – heavy loam; C – clay

soils are more highly valued. In the given case, the optimal density of forest tract is rated at 0.5–0.9. A comparison of the two evaluation points shows to what extent the existing forests perform their protective functions.

The suitability of forests for recreation is determined by the intensity of their use. Forests located in the vicinity of water bodies are more frequently used than those at a distance of two or more kilometers.

The evaluation scales that have been drawn up on the basis of the outlined data are widely used in carrying out forest management projects. Each forest area which is subjected to evaluation is treated in terms of all four scales. The evaluation index obtained makes it possible to zone forests according to their functions and to increase forest resources. The major management direction is established with due account of the function with the highest evaluation point. The economic evaluation of forest lands may be successfully used in planning forestation projects, land transformations, in working out forest supervisory measures, and in analyzing and planning activities of separate production units (e.g., forestries).

Not only forests are used for recreational purposes but also the seashore, city and village parks, water bodies (lakes, storage reservoirs, rivers), city gardens owned collectively by workers and employees, ski areas, recreation in agrarian surroundings, etc. An applicable methodology and scale have been developed to subject all of these to evaluation. Their attendance, measured in man-days per hectare of recreational areas a year, has been taken for the evaluation criterion (Table 4).

The evaluation point of separate recreational areas on the scale ranges from 5 to 1500 man-days per hectare. Currently, the use of forests for recreational purposes is relatively extensive (their average evaluation index is 13.7 man-days per hectare a year), water bodies are more intensively used (33.7), and the seashore, city parks, and collective gardens are used most intensively.

All the recreational areas have been evaluated with 33.4 percent of the Republic's territory being used for this purpose. The quantity, quality, and intensity of the use of recreational areas differ greatly in various localities and range from 11.4 to 65.5 man-days per hectare. Consequently, ample opportunities exist to expand recreational activities, especially in forests and at water bodies. For this purpose, lands are reserved in forests for campgrounds (spaces for tents, fireplaces) and parking sites, furniture-supplied shelters are constructed, drinking water supply is laid on, and tourist trails and paths are built. Beaches are built at water bodies with boat jetties, bathing-huts and children's playgrounds. Assuming that the value of one man-day of recreation is estimated at 1.5 rubles, the costs of these facilities will be recovered on average in the course of one year.

The evaluation point of recreational resources may be successfully employed in locating and supplying recreational areas with the necessary inventories, in expanding their network, and in taking measures to intensify recreational activities.

Complex problems to be overcome in evaluating and protecting water resources. The role of water resources is diverse in various sectors of the national economy. Irrigation water helps increase crop yields, in the fishing industry water is the medium for breeding fish, in industry and water transport, it amounts to only a small part of the created value. These differences complicate the issue of choosing a common criterion and evaluating water resources. The most reasonable sequence of steps to be taken in bypassing these difficulties is the following: 1) to evaluate water resources at their source, and 2) to separately determine the efficiency of their utilization in various sectors of the national economy.

To effect the evaluation of water resources at their source, the idea of applying the criterion of discounted costs for one m^3 of water in use is proposed. Tariffs are imposed on the intake water drawn by industrial users from water bodies. For example, in accordance with the government enactment of 1979, payments of 0.10 kopecks per m^3 are exacted from industrial enterprises into the budget for water drawn from the rivers and lakes of the northern and eastern regions of the USSR, and 2.72 kopecks per m^3 for the Dnieper–Donbass canal water. The payments for water taken from other basins are within these limits. On the basis of these data, it is possible to calculate the differential profit obtained by enterprises which use cheaper water. The volume of the differential profit designates the economic evaluation point of water resources at their source. There are considerable divergences within evaluated large water basins. For example, within the Nemunas (Lithuanian SSR) river basin, the differential

Table 4. Evaluation of recreational natural resources
(compiled by V. Malisauskas and A. Koncius)

Category of recreational areas	Area (thous. of ha)	Evaluation index: man-days/ha per year	Overall evaluation (thous. of man-days)
1. Sea coast:			
a) Palanga	7.1	1200	8520
b) Neringa	9.3	90	837
2. City and village parks	1.7	1500	2550
3. Forests at a distance of up to 0.5 km from water bodies:			
a) dry	75,7	75	5678
b) humid	20,0	25	500
4. Forests at a distance of 0.5 to 2 km from water bodies:			
a) dry	138.9	40	5556
b) humid	36.3	15	544
5. Forests at a distance of upwards of 2 km from water bodies:			
a) dry	1082,1	10	10821
b) humid	553,0	5	2765
6. Lakes and storage reservoirs:			
a) assigned to the Society of Hunters and Anglers	44.0	70	3080
b) used for other kinds of recreation	116,7	20	2334
7. Rivers:			
a) assigned to the Society of Hunters and Anglers	14,4	50	720
b) tourist routes	3.8	80	304
c) used for other kinds of recreation	21.8	15	327
8. City collective gardens	9.1	1500	13650
9. Automobile tourist routes	3.6	90	324
10. Skiing routes	8.0	45	360
11. Recreation in agrarian surroundings	34.6	60	2076
Total:	2180.1	28	60946

rent among its tributaries ranges fivefold, which should be allowed for in situating enterprises which incorporate water into their product.

The economic efficiency of the utilization of water resources in separate sectors of the national economy is heavily dependent upon a multiplicity of production conditions. For instance, the economic efficiency of irrigation is determined by:

1) the type of water source;
2) the proximity of irrigated sites to water sources;
3) the area of irrigated sites;
4) landforms;
5) the fertility of irrigated sites;
6) the selection of crops.

An analysis of the above indicators revealed that the construction of irrigation systems based on lake water and man-made storage reservoirs is costlier, respectively by 19 and 63%, than the construction of systems fed by river water. The construction of large storage reservoirs is less expensive ($y = 4994 \div 26534 : x$, where y – estimated cost per hectare in rubles; x – area in hectares). The farther the irrigated sites from the water source, the higher the capital investments needed for constructing the main water-supply system (1 m^3 of which costs on the average 2 rubles). Construction of large-scale irrigation systems is less expensive, which is evident by the correlation between the cost of the irrigation system (y) and its area (x), ($y = 2778 \div 13868 : x$). Plains and slightly rolling areas afford more intensive production, while irrigation here costs less than on hilly stretches of land. The selection of crops to be irrigated depends upon their response to water. Most effective is the irrigation of vegetable crops.

A scale for the evaluation of natural-economic irrigation conditions has been worked out subsuming all the aforementioned factors (Table 5). The transfer from poor to good irrigation conditions secures a fourfold increase in economic efficiency. The evaluation index can be successfully employed in selecting economically more effective irrigation objects and schemes.

Considering the case where water resources are used in the fishing industry, fish productivity, expressed in natural (one species of fish bred) and value (a few species of fish) units per hectare of ponds, has been drawn upon for the evaluation criterion. The following factors have been analyzed to determine fish productivity under different production conditions: 1) landscape (pond location, shape, surface area and depth, bed condition); 2) soil (mechanical texture, pH, biogene content); 3) water (general mineralization, oxidization, biogene content); 4) climatic (precipitation, air and water temperature, sunshine duration) [1].

After the mathematical-statistical processing of the factual materials of the Lithuanian SSR fish farms, applicable evaluation scales for hatcheries, nursing, spawning, and wintering ponds have been drawn up, taking into account the published data. These scales can be successfully adopted in planning fish productivity, analyzing the attained results and further enhancing fish-pond productivity.

Scales for the economic evaluation of lakes which are used as fisheries have been developed in the Lithuanian SSR as well. All lakes have been classed into groups according to the intensity of fish-farming, taking account of their suitability for breeding separate species of fish. This evaluation renders it possible to more effectively combine the bred species of fish with their food reserves and to obtain maximum fish production at relatively low cost.

Table 5. Evaluation scale of irrigated lands (points)
(compiled by V. Malisauskas) [6]

Water sources	Distance of irrigated lands from water sources	Economic evaluation index of irrigated lands	Irrigated area of up to 100 hectares, landforms: up to 5°	Irrigated area of up to 100 hectares, landforms: upwards of 5°	Irrigated area of more than 100 hectares, landforms: up to 5°	Irrigated area of more than 100 hectares, landforms: upwards of 5°
Storage reservoirs	up to 1 km	up to 35	25	30	30	35
		36–45	32	37	37	42
		45	40	45	45	50
	upwards of 1 km	up to 35	32	37	37	42
		36–45	40	45	45	50
		45	50	55	55	60
Lakes	up to 1 km	up to 35	40	45	45	50
		36–45	50	55	55	60
		45	60	65	65	70
	upwards of 1 km	up to 35	50	55	55	60
		36–45	60	65	65	70
		45	70	75	75	80
Rivers	up to 1 km	up to 35	60	65	65	70
		36–45	70	75	75	80
		45	80	85	85	90
	upwards of 1 km	up to 35	70	75	75	80
		36–45	80	85	85	90
		45	90	95	95	100

Rational use of water largely depends upon its quality. Currently, water bodies are so heavily polluted that their self-purification is insufficient. This problem is so acute that it has become a matter of top priority to reduce water pollution by introducing recirculating systems in the technology of water use, intensifying the treatment of effluents, and adopting waste-free technologies.

An extensive application of the recirculating system of water supply in the Soviet national economy resulted in an overall annual saving of up to 240 m^3 of pure intake water, which made up approximately 40% of the whole amount of utilized water. In 1985, in the Lithuanian SSR the saving ran as high as 83%. Generally, these systems are operational in different sectors of the national economy. In future they will be applied on a larger scale. Together with these measures, however, it is necessary to more widely apply purification of wastewater discharges, especially in public services and in many sectors of the economy.

A whole range of the worked-out and adopted methods is available to determine the economic efficiency of the protection of water resources [5, 6]. Their essence is in estimating the damage inflicted upon people's health and the national economy, with due account of the toxicity of separate kinds of pollutants. Since no regular record of all pollution ingredients is kept, these methods are to be extended to adjust to local conditions.

A fairly high quality of water resources offers ample scope for their diversified utilization (for fish breeding and recreation purposes, in industry, etc.), which substantially raises the economic effectiveness of their application. A more rational use of water resources is greatly facilitated by the regulation of river flow with the help of storage reservoirs, accretion of groundwaters by surface waters, expansion of the network of industrial water-supply systems, and construction of zonal water-supply systems and refineries. Appropriate projects have been worked out concerning those issues.

A whole complex of air-protective measures has been developed in the Lithuanian SSR, including:

1) gradual switch-over to cleaner fuels (natural gas and nuclear energy instead of coal and fuel oil, diesel fuel instead of gasoline);
2) wider adoption of waste-free technologies and more sophisticated gas- and dust-absorbers;
3) elimination of small boiler-houses and installation of a centralized heat-supply system;
4) creation of a network of compressor gas-filling stations;
5) construction of highway bypasses eliminating transit traffic from cities;
6) systematic motor vehicle emission control;
7) increasing use of land near highways for raising cereals, which are less absorbent of hazardous automobile exhaust components than other crops;
8) setting the maximum permissible discharge limits for the main industrial polluters and establishing legal prosecution in case of noncompliance;
9) supplying the public transport of large cities and health resorts with unleaded automotive fuel;
10) taking measures to reduce industrial noise in enterprises and traffic noise in cities and health resorts.

Taking account of increasing anthropogenic influences upon the environment, the Lithuanian SSR's protected and reserved territories will be expanded by 2.4 times. Measures are taken to protect rare and endangered species of flora and fauna.

Investigations into the field of the economic evaluation of mineral and raw resources are also pursued in the Republic. A qualitative and quantitative registration of these resources has already been carried out, their evaluation scales, optimum transportation and processing projects are being drawn up.

Having completed the economic evaluation of all natural resources, a common approach will be developed which will help utilize them more rationally and effectively.

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4.2 THE APPLICATION OF ECOLOGICAL STRATEGIES TO TERRITORIAL PLANNING*

V. Stauskas
Department of Landscape and Recreational Architecture
Lithuanian Scientific Research Institute
of Architecture and Construction
Kaunas, Lithuanian SSR, USSR

In developed countries, territorial planning designs are based on certain scientific-theoretical concepts and special scientific tests that refer to regional and town planning theory. If one admits some ecological mistakes in the concept of planning or concrete design proposals, these mistakes will emerge to the full while realizing the design. Thus, a territorial planning design is the first and, at the same time, one of the most important elements in the optimization of the future human environment.

In working out a territorial planning design, a number of specialists working in various fields, such as economists, geographers, sociologists, foresters, experts in agriculture, transport, etc. should take part. Nevertheless, the most important role of coordinating and synthesizing these elements is, as a rule, played by architects – specialists in regional, town or landscape planning.

The aim of any contemporary architect, including a landscape architect and a town planner, is not only to create his "own object" and use the site as an input for his ideas in the existing environment, but, having taken into consideration all the requirements, to work out a complex environment of a new quality. The range of 20th century architectural involvement has become wider and, consequently, the responsibility of architects has grown.

Our friends from the International Union of Architects have stated that "architecture is the unity of art and science, forming the life environment of man."[1] This means that we should be aware of the inevitable unity of the objective and the subjective. In other words, one must realize the integration of the natural and the artificial. The goal of a new complex environment is its convenience, ecological stability and beauty. Although landscape architecture is usually perceived as art, I am of the opinion that it is an applied art. That is why the categories of "beauty" and "ugliness" of a landscape are always related to functional land use. I suppose that "beauty of agricultural landscape," "beauty of industrial city" and "beauty of preserved natural landscape" cannot be opposites. They are not different *grades* of beauty. They are rather different *kinds* of beauty.

There are four fields of activity that contemporary landscape architect is concerned with. They are, basically, four levels of environmental planning:

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*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buracas, and A. Straszak (Eds.), 1986, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

[1]I.U.A. World Congress. Declaration of Architects. Warsaw, 1981, p. 7.

1. state level of planning (coincides with state boundaries);
2. regional level (planning of large-scale areas);
3. planning of separate towns, settlements;
4. site planning level (a building, park, etc.).

Activities at these levels are carried out in the USSR in all 15 republics, including the Lithuanian SSR, the Scientific Research Institute of Architecture in Kaunas being the Republic's center of scientific coordination. A new approach to so-called ecological planning has been worked out and put into practice. A completely new approach is based on the following main theoretical propositions:

a. on the extension of traditional (mainly visual) interrelationships between nature and architecture to the complex functional and aesthetic dependence on "man–nature–architecture;"
b. on the priority of natural landscape components that are the most important from the ecological point of view over all the types of planning, because human life and health are values having no adequate correspondence;
c. on the principle of necessary differentiation of functional types of landscape and also the principle of preservation of the most beautiful scenic spots, rejecting any building development, even the most advanced from the architectural point of view.

This approach suggests the necessity to clearly differentiate between three main frameworks of planning:

a. the framework of natural landscapes under particular preservation (valuable from the scientific, historical or ecological point of view);
b. the framework of landscapes for recreation, including routes for tourists and the infrastructure of recreational services valuable for health;
c. technogenic framework of roads, the network of urban centers and engineering communications. Territorially, they are adjacent and intersect each other, but they serve different purposes.

The initial planning begins with surveys. Theoretically, each of the frameworks is a system of areas, lines and points (Figure 1). Blank spaces between these frameworks are zones of intensive agriculture, forestry and water economy. The result is a complex model for the formation of the whole human environment at a given area. The method has been carried out in the following scientific publications: *Complex Scheme of Nature Protection in the Lithuanian SSR* (1983), *The System of Recreation in the Lithuanian SSR* (1978), and others.

Each framework or element of the complex environmental model will include its own scale of values, existing or perspective. For instance, the recreation system of the Baltic republics provides six types of recreational environment. The types differ in planning, means of landscape architecture, types and even forms of buildings (Table 1). At the same time, we notice a difference in visual impact, i.e., different emotional impact of the environment on man.

The above-mentioned principles have been almost fully realized in the system of environmental planning of the Lithuanian seaside. The differentiated landscape has been created along the 100 km belt of the Baltic Sea and the area of the Curonian Bay (Kursiu Marios) at the delta of the river Nemunas. To the north (the Palanga resort), in the middle (Klaipeda) and to the south (Neringa and the area of the Curonian Bay), landscape regions have been formed. Intensive public recreation and new recreational centers serve in excess of about 60–80 thousand people each summer; new architecture has been created in the nearly monotonous natural landscape of the Palanga area. The Klaipeda area is the landscape of ports, industry, and large-scale new residential areas. The Neringa region reflects the beauty of preserved natural landscapes, restoration of small-scale fishermen's villages (at present they are converted into recreational villages) are characterized by ethnographic architecture. The policy of landscape differentiation has been pursued for over 15 years there and it will be continued in future.

The theoretical model shown in Figure 1 might be computerized. There are so many components, including emotional and psychological ones, in territorial planning that final results are, as a rule, obtained by synthesizing objective data and subjective thinking.

Table 1. Main types of recreational environment of the Baltic area.

Type of recreational environment		Model of landscape management		
Index	Characteristics	Index	Functional features	Visual features
I	Natural environment. No facilities.	R_1	No motor tourism. Excursions only.	Contact with virgin nature. Absolutely natural landscape.
II	Slightly changed natural environment. Insignificant facilities.	R_2	No motor tourism or limited motor tourism. New campings, shelters, beaches.	Same contact; some traces of man's interference.
III	Same environmental change. Moderate use of facilities.	R_3	As above + vacations on the basis of existing villages.	Contact with natural landscape and rural-type architecture.
IV	Partly changed environment.	R_4	As above + vacations at new small-scale centers for recreation. No health service, weekend streams.	Contact of new architecture with natural landscape.
V	Considerably changed environment. Large-scale use of facilities.	R_5	All kinds of recreation, including motor tourism and health resorts. Heavy streams.	Balance between nature and architecture.
VI	Greatly changed (including artificial) landscape. Greatly developed facilities.	R_6	Very intensive recreation of all types. Heavy weekend streams. Large-scale resorts.	At the centers of concentration – predominance of architectural landscape. Balance of nature and architecture.

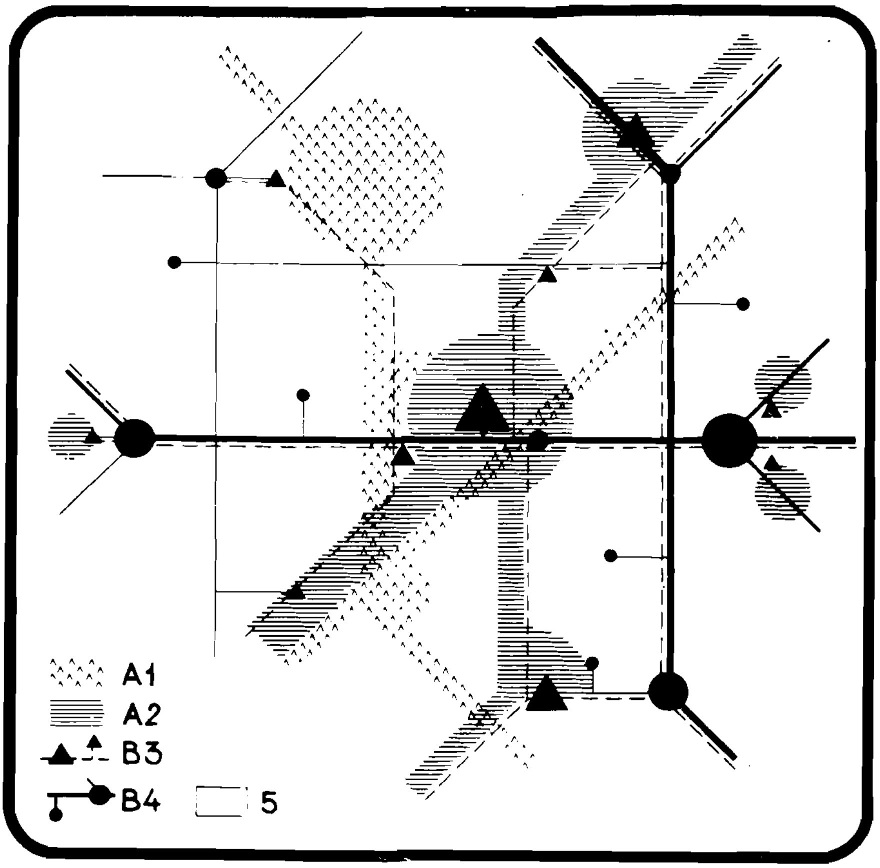

Figure 1. Interrelationship of three main frameworks of complex environmental planning (theoretical model).

A_1 – Framework of natural landscapes under particular preservation

A_2 – Framework of recreational landscapes

B_3 – Infrastructure of recreational service and routes for tourists

B_4 – Technogenic framework of urban centers, roads and engineering communications

B_5 – Blank spaces between these frameworks – zones of intensive agriculture, forestry and water economy

4.3 HIERARCHY OF PLANNING LEVELS AS A BASIS FOR OPTIMIZED REGIONAL ECOLOGICAL MANAGEMENT*

H. Loik
Ministry of Forest Economy and
Nature Conservation of the ESSR
200101 Tallinn, Estonian SSR, U.S.S.R.

The analysis of the relations between man and nature starting with global and regional systems and ending with an ecosystem, population or species is necessary for the following reasons:

- to get a global picture of the world;
- to direct the process of nature management and protection correctly;
- to guarantee the use of natural resources and environmental conditions necessary for man's existence for a long time.

Systems analysis seems to be the only branch of science having prerequisites for solving environmental problems. Up to the present time traditional branches of science have set up more problems than have been solved. Results of different scientific studies are often in conflict.

The achievement of synergetic effects is most necessary but probably possible only on a regional level. The problem has been dealt with for a longer period and more concrete results could be obtained in the near future if

- cooperation in marine investigations amongst the countries surrounding the Baltic Sea were to be extended to the land territories of these countries;
- better contacts were to be established amongst corresponding scientific and administrative nature protection agencies.

The Estonian SSR is a republic with relatively high industrial concentration and intensive agriculture where the stress of human activities on nature is considerable. The influence of anthropogenic activities is enhanced by the republic's location on the northwestern border of the USSR where the quality of water and atmosphere greatly depends on the situation in Central and North-Europe (the Baltic Sea, transboundary transmission of atmospheric pollution by prevailing winds from the west and southwest). This is the reason why a territorial unit has been used as the basis for solving our environmental problems. Those units are the following:

- *macroregion* which embraces the Baltic republics, the Karelian ASSR, the Leningrad territory and the countries surrounding the Baltic Sea, particiularly Central Sweden and South-Finland;
- *mesoregion* which embraces the territories mentioned above except Sweden and Finland;

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- *region* – the ESSR which in its turn is divided into 5 subregions.

It is natural that up to the present time the main attention has been paid to our own republic, that is to the region. Since 1968 zoning projects on the level of subregions, administrative areas and the whole republic have been elaborated for nature management and protection, including the following:

- inventory of natural conditions;
- registration and prognosis of anthropogenic load (mining of mineral resources, land improvement, agricultural production, industry, human settlements, communications);
- synthesis, resulting in suggestions for the improvement of environmental conditions which will be taken into consideration in plans of national economy;
- elaboration of ways and means to maintain the natural ecological potential.

The activities mentioned above make up a specific hierarchical system of planning levels:

1. The complex scheme (on the scale 1:200,000) of the management and protection of the republic's natural resources. Polarization of the republic's territory into intensively and extensively used (or compensation) areas was carried out within the framework of the scheme. Compensation areas embrace state nature reserves (7% of the whole territory), wetlands to be preserved, forests which are not to be managed intensively, cultivable lands (habitats of rare and endangered species) which are being preserved in their natural state.
2. The complex scheme (on the scale 1:50,000) on the level of subregions and administrative regions.
3. The scheme (on the scale 1:10,000) of preservation and recreational areas on the level of agricultural and industrial enterprises in which a network of compensation areas between large field expanses, on the banks of waterbodies (especially rivers), sanitary-protective forests of industrial enterprises has been taken into consideration or will be projected.

Special complex programs which provide the necessary means for the rational use of natural resources and environmental protection and fix the dates for their application are being worked out for industrial areas.

Perspectives for the development of the national economy on a territory are being developed in the form of so-called district planning projects in which natural conditions have been considered and perspective development of industry, agriculture and settlements envisaged.

On the level of industrial and agricultural enterprises (especially in the case of those influencing nature), the extent of use of natural resources (natural matter), components of technological processes which have an essential influence on nature and emissions into all media (air, soil, water, biological circulation) in natural as well as in monetary terms are being envisaged. The economic use of resources and reduction of emissions are being stimulated.

The territory as a whole and the resources located there remain the basis for decision making. On this level it is impossible to consider components such as an ecosystem although they are essential in forming environmental conditions.

At present it is important to integrate models of ecosystems developed abroad and in the ESSR with territorial models. In our republic the work of building an ecological-economic model of the Matsalu State Nature Reserve which embraces the Matsalu Bay, the Kasari River and its catchment area (somewhat over 300 thousand hectares) is nearing completion. The model consists of several territorial subsystems (the bay, river, tributaries, dry land communities). The aim is to find such economically justified ecolevels which can most easily be influenced to achieve improvement in water quality. It is planned to "extend" the model to the open Baltic Sea. A monograph describing the model will soon be ready. Analog models are to be constructed on the subregions of Northeast Estonia and Lake Peipsi. Elements of ecological-economic models are already being used in decision making in the field of nature management.

Forests which comprise 53.2% of the whole territory of the republic function as the most important natural resource guaranteeing the stability of environmental conditions. In the ESSR, nature protection and forest management form an administratively integral system; therefore, the principles mentioned above have been carried out within the framework of the forestry ecology program.

When elaborating the management regime, information about forests (soil, undergrowth, forest type, secondary resources) has been used as completely as possible. All environmental and resource characteristics as well as related resources (minerals, water, wild animals, etc.) have been taken into account. The practical management of the smallest territorial forest units – allotments (average area is 3 ha; total number in the state forest fund is 423,000) will be based on standards which have been worked out for all stages of forest management starting with afforestation and finishing with clear-cutting. Ecological as well as economic standards have been elaborated for each habitat.

The main conclusions based on the application of ecological principles in forest management at the present stage are the following:

1. Complex management of forest resources (timber, berries, mushrooms, honey, game, fish, recreation) guarantees maximum success.
2. Forest management which takes into consideration ecological aspects, not only guarantees preservation of ecological conditions (water resources, wild animals, natural vegetation) on forest lands but also compensates for the negative results of anthropogenic influences outside these areas.

On less fertile forest lands, the value of by-products surpasses the value of timber; intensification of management may result in a decrease of by-products as well as of total production.

Proceeding from the above-mentioned, the concept of the environmental maturity of a stand which is considerably lower than the maturity of the stand has been developed.

Because of the variability in the environmental maturity of a stand (20...30 years depending on the forest type), forest management may be limited to forest protection and supervision only.

Integral administrative system of forest management and nature protection is justified if forests occupy over 30% of an area. In this case, the forest functions as a stabilizing natural complex and forest protection inspectors act as specialists to guide the long-term process of renewal of natural resources.

The above-mentioned was a short survey of the requirements and possibilities (ways) of how the hierarchical system "territory – ecosystem" ought to be analyzed and directed in the practical work of nature protection. There are lots of obscure and unsolved problems but the necessity of changing technocratic attitudes towards nature into collaboration with nature has become evident. When modeling technological processes, natural ones must be used as examples.

4.4 INTEGRATING ECOLOGICAL DATA INTO LOCAL AND NATIONAL MANAGEMENT OF WETLAND ECOSYSTEMS IN THE WILLIAMSTOWN, MASSACHUSETTS AREA*

W.R. Moomaw and A.D. Southworth
Center for Environmental Studies
Williams College
Williamstown, MA 01267, U.S.A.

1. Introduction

To most people the term "wetland" conjures up images of a mosquito breeding ground or a convenient site for disposing of garbage. At best it is synonymous with inexpensive land that can be readily filled and converted to more economically productive use. As early as the 11th century, Dutch engineers were actively converting coastal wetlands to agricultural purposes, and a short time later their descendents were draining the freshwater fens of East Anglia in England. The availability of improved technology has led to a global acceleration in wetland drainage during the last century as nations have sought to improve public health and gain additional land for agriculture, housing, manufacturing and commerce. Since the settlement of North America there has been an estimated net decrease of 40% in the wetland areas of the New England states (New England Wetlands Seminar 1980), and the U.S. Soil Conservation Service predicts a continuing annual loss of 0.4% (Dawson 1983). The loss of original wetlands is substantially higher, but is in part offset by new impoundments that have been created for flood control or water supply. The benefits of filling wetlands have been fairly obvious, but what have been the costs? Writing about the Dutch experience, the American historian, Lynn White, Jr., stated the issue in the following manner:

> "In their epic combat with Neptune have the Netherlanders overlooked ecological values in such a way that the quality of human life has suffered? I cannot discover that the questions have ever been asked, much less answered." (White 1967)

Since White wrote these observations two decades ago, both policy makers and the public have become more sensitive to just these kinds of questions. During the past twenty years, as wetlands have disappeared, an awareness of their value has grown in the United States, and laws have been enacted at the national, state and local levels to protect inland and coastal wetlands and to regulate their development. In attempting to implement these new laws, regulators, developers and the public are often confronted with an inadequate ecological database and sharply divergent views on the relative values of the wetland and the proposed development project. While it is quite straightforward to calculate the economic value of new construction, it is far more difficult to determine the cost of the wetland which it displaces. Flood protection, groundwater production, absorption of both toxic and nutrient chemicals, wildlife and plant habitat, education, recreation, aesthetics and open space are some of the wetland values which will be considered here.

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As the legal framework for wetlands protection has evolved, lawmakers have had to address difficult legal and technical issues. 1) What legally constitutes a wetland requiring regulatory attention? 2) Which wetland values deserve protection? 3) How should wetland values be weighed against property rights and the economic benefits of a proposed project? 4) What ecological and economic data are needed for regulatory purposes? 5) What is the appropriate governmental level for a given regulatory action, and how flexible or prescriptive should the regulations be?

To establish an adequate ecological database for regulatory purposes, one of us (A.D.S.) in 1986 carried out an extensive inventory of the wetlands of Williamstown, Massachusetts, a 12,500-hectare university town of 9000 people, located in a mountainous, rural area of the northeastern United States (see Figure 1). All wetlands within this geographical region were located and visited, and their wetland values were cataloged and assessed. Each wetland was then ranked in terms of importance, and priorities were recommended for protection or development.

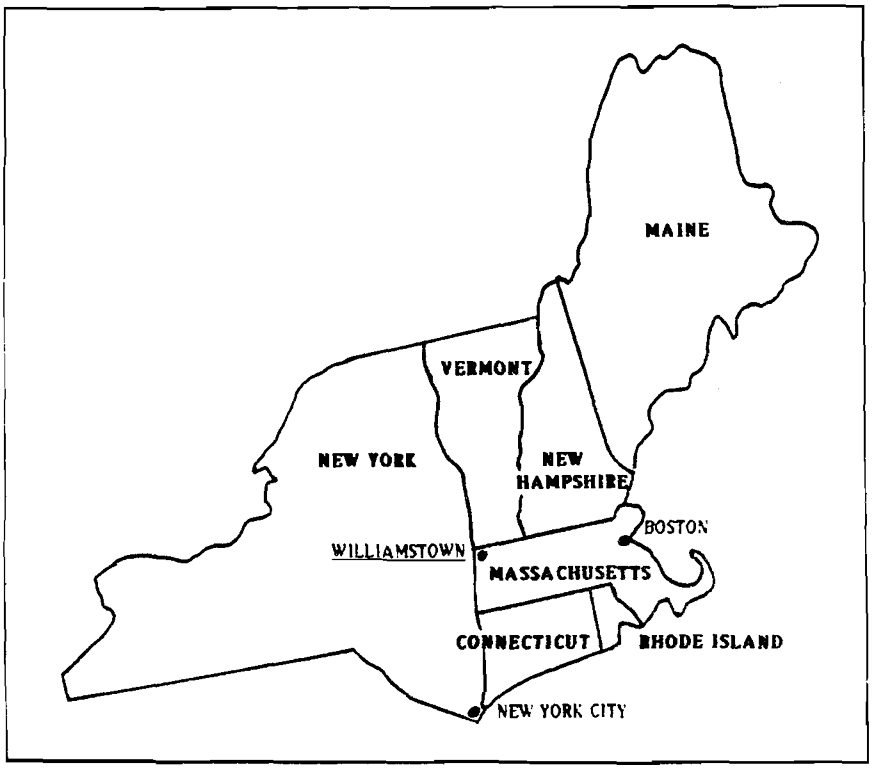

FIGURE 1 Map of the northeast United States locating the study area, Williamstown MA

In this paper we will utilize the Williamstown example as a case study to illustrate the range of issues that arise when a society attempts to respond to economic development pressures while wishing to retain important ecological values. We will describe current United States laws which try to maintain some degree of regional and national consistency while allocating decision making for individual cases to the most appropriate local level. Several recent cases of local and national significance will also be described.

2. Wetland Definitions and Values

2.1 Wetland definitions

Before considering the values of wetlands, we will first look at their multiple definitions. Geologically and hydrologically, wetlands occur wherever surface drainage flows to a low depression of impervious soil or bedrock, or where the underground water table reaches the surface. Ecologically, wetlands may be described in terms of the water-dependent plants, animals and microorganisms that live in the waterlogged soils and in and on the water itself.

Legal definitions may be quite arbitrary, but they must be precise, and in the United States different government agencies have chosen definitions which, while not always compatible with one another, serve their own mission and purposes. For example, the national Clean Water Act, which is described later, defines wetlands vegetatively as "those areas that are inundated by surface or groundwater with a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (40 CFR 230.3).[1] Precise boundaries are essential for planning and in executing legal procedures. For this law, wetland boundaries are determined by an analysis of where wetland plants grow as determined by "a specialist familiar with the local environment." Wetland plants are in turn defined as "plants that require saturated soils to survive (obligate water plants) as well as plants, including trees, that gain a competitive advantage over others because they can tolerate prolonged wet soil conditions and their competitors cannot" (40 CFR 230.41). If vegetation is dormant at the time of assessment or has been removed, then the wetland area is defined by "hydrological and physiological characteristics of the environment." The State of Connecticut has chosen soil criteria to define wetlands, while Massachusetts relies on a combination of geological and biological factors which specify wetlands as areas "where groundwater, flowing or standing surface water or ice provide a significant part of the supporting substrate for a plant community for at least five months of the year," lands supporting "emergent and submergent plant communities in inland waters," and "that portion of any bank that touches any inland waters" (G.L. Chapter 131 s 40).[2] These varying definitions do not create as much confusion as they might since they are usually used to regulate different activities. When conflicting interpretations arise, the courts are called upon to resolve the disagreement.

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[1]This is the designation of the appropriate section of the U.S. Clean Water Act.

[2]This is the designation of the appropriate section of the Massachusetts Wetland Protection Act.

2.2 Wetland values

Let us now examine which wetland values may be important and deserving of consideration by land-use regulators. The values listed are of course generally applicable to wetlands anywhere, but we will illustrate them using as examples the freshwater wetlands of Williamstown. These include the seasonally flooded plains of the Hoosac and Green Rivers and their many small tributary streams, several small open water ponds (4 hectares or less) and their adjacent wetlands, and numerous isolated marshes, swamps and wet meadows.

Flood protection. It is now generally recognized that floodplains along the banks of rivers play an important role in reducing damage from potential floods. This is particularly important in Williamstown which sits in a narrow river valley surrounded by steep slopes that can produce rapid water runoff during snowmelt or heavy summer thundershowers. With the abandonment of cleared agricultural land and its return to forest (Williamstown is now approximately 75% forested), flooding is not so intense as it was in the past. However, much of the floodplain has been lost to development. In the late 1950s the U.S. Army Corps of Engineers eliminated large amounts of floodplain by channelizing the Hoosac River for several kilometers upstream to protect industrial buildings that had been constructed on the floodplain during the late 19th century. Some more recent construction has occurred on the floodplain within Williamstown near the downstream terminus of the flood-control channel, creating a potentially serious hazard when floods do occur. In the 1970s, about one-fourth of the wooded Hoosac floodplain was filled right to the riverbank with garbage, trash and construction materials before another site further from the river was selected. The remaining floodplains along the downstream banks of the Hoosac and the Green Rivers have therefore become even more important in reducing flood damage (Ogawa and Male 1983). These floodplains also help to stabilize the banks and keep the river in its natural channel by slowing river velocity, capturing sediments and holding soils among the roots of wetland vegetation. Williamstown's isolated ponds and marshes also reduce the extent of flood damage by absorbing surface runoff before it reaches stream channels.

While no quantitative study of the value of floodplains for flood protection has been made for Williamstown, a 1972 study of the Charles River basin near Boston concluded that a 40% loss of wetlands there would raise peak flood levels about one meter and increase annual flood damage by $3.2 million, i.e., $8.5 million in 1987 dollars (U.S. Army Corps of Engineers 1972).

Groundwater recharge and discharge. Some of Williamstown's palustrine (shallow, nonriver) wetlands are filled primarily by surface water runoff, but many appear to be connected hydraulically to underground aquifers. Recent studies have found recharging of underground aquifers in Massachusetts to occur during the late summer months, while groundwater discharge may occur throughout the year (Motts and O'Brien 1981). As upland recharge areas became paved or covered with buildings the groundwater recharge value of Williamstown's wetlands has increased. Although a complete study of the hydrology of our area has not been undertaken, 76% of Williamstown's wetlands were found to be underlain by soil types associated with primary recharge areas (Southworth 1986, Berkshire County Regional Planning Commission 1984). The water supply value of wetlands in Massachusetts was estimated to be as high as $6800 per hectare (Gupta and Foster 1973). In current dollars this would give a value of approximately $3 million for the water production capability of Williamstown's wetlands.

Water quality improvement. Wetlands improve water quality in three distinct ways, by absorbing sediments, nutrients and toxic chemicals. Marshlands adjacent to ponds have been shown to be capable of removing 80–90% of suspended sediments from inflowing surface waters (Larson and Newton, undated) thereby protecting fish and bottom-dwelling organisms, and substantially extending the life of open bodies of water.

The vegetation and microorganisms of marshes, swamps and wet meadows have been shown to be extremely efficient in removing nitrogen and phosphorous nutrients from agricultural runoff and septic field leachate. An artificial shrub swamp, constructed elsewhere in Massachusetts, was able to remove 62% of the 4782 kg/ha/yr of nitrogen introduced into it (Yonka and Lowery 1979). Later studies of a variety of wetland ecosystems have found removal efficiencies to range between 40 and 97% (Sather and Smith 1984). Phosphorous removal in the same artificial swamp cited above was found to be 76% efficient for a loading of 859 kg/ha/yr, and other plants such as cattails (*typha spp.)*, reeds and sedges can remove 300–800 kg/ha/yr (Chun 1982). The removal of nutrients is important not only in preventing eutrophication of ponds and streams, but also for protecting underground drinking water supplies especially in agricultural regions.

The effectiveness of wetlands in holding toxic chemicals has been amply demonstrated by local examples. Before new laws were enacted during the 1970s local chemical and leather-tanning industries dumped significant amounts of cadmium and chromium into the general waste disposal site near the Hoosac River. Leaching of these chemicals has been noted and some have been absorbed by adjacent ponds and marshland preventing them from reaching the river. One recent study found that depending on the metal, vegetation and soils type, wetlands were capable of removing 20–100% of heavy metals (Sather and Smith 1984). The U.S. Environmental Protection Agency has reported annual wetland removal potentials as 0.001–0.38 kg/ha for cadmium, 0.007–1.58 kg/ha for copper, 0.13–103.4 kg/ha for iron, 0.026–1.01 kg/ha for lead, and 0.001–1.714 kg/ha for zinc (Chun 1982). Highly toxic and persistent polychlorinated biphenyls (PCB's) were dumped into the Hoosatonic River south of Williamstown by a manufacturer of electrical transformers. Downstream contamination has been significantly reduced by the absorption of these chemicals in the sediments of Woods Pond and adjacent marshland through which the river flows. Recent reports by the company even suggest that the pond's bacteria have begun to break down this chemically stable material.

While it is difficult to place a monetary value on such public service functions of wetlands, these removal efficiencies compare extremely favorably with those of expensive secondary sewage treatment plants which typically remove 70% of heavy metals and toxic organic compounds, 50% of nitrogen and only 30% of phosphorous.

Ecological values. Wetlands are extremely efficient converters of solar energy into biomass, typically rivaling cornfields in productivity per hectare. Wood swamps and sedge marshes produce 7–14 metric tons of biomass/ha/yr, while a cattail marsh produces 20–34 metric tons/ha/yr (Chun 1982). In addition to the common plants expected in the New England states, seven of Williamstown's wetlands currently are known to host six rare species, while historical records exist for five others.

The great variety of plants found in these wetlands provides a range of habitats for migratory and native birds, and for several species of mammals, reptiles, amphibians, fish, insects, and other invertebrates. We have used the ecologically based scheme of Golet and Larson (1974) to classify Williamstown's wetlands by vegetation type and water depth into seven classes: *open water* (1–3 meters depth), *deep marsh* (0.15–1 m average depth), *shallow marsh* (less than 0.15 m during the growing season, but water may be absent at other times), *meadows* (saturated soil during growing season, never more than 0.15 m of water at other times, few woody plants), *shrub swamp* (woody plants less than 2 m in height covering more than 50% of wetland, water depth less than 0.3 m), *wood swamp* (similar to shrub swamp, but woody plants exceed 2 m in height), and *seasonally flooded flats* (river floodplains). Depending on vegetation type, these classes are further divided into twenty-two subclasses. These categories may be directly compared with the classification system used by the U.S. Fish and Wildlife Service (Cowardin *et al.* 1979) since the wetland boundaries determined in this study were superimposed on the National Wetlands Inventory Map (Figure 2).

While the ecological importance of each wetland has been assessed in this study, there do not appear to be any models available that can convert this information into economic value.

Educational and recreational values. The ecological richness of wetlands make them ideal outdoor laboratories for teaching field science to elementary and secondary school pupils and as subjects for serious research by university students and faculty. These areas also provide less formal opportunities for nature study, bird-watching and nature photography for both residents and tourists. Other recreational activities suitable for wetlands include hunting, fishing, trapping, hiking, boating, ice skating, cross-country skiing, and picnicking. Some economists have determined a monetary value for wetlands' educational and recreational worth by estimating the cost of travel and recreational equipment, including binoculars, cameras, field guide books, and hunting, fishing and sports equipment.

Aesthetics, open space and land-use planning. Wetlands can provide open space and aesthetically pleasing visual contrast in otherwise crowded developed areas. The extensive use of artificial ponds in public parks in Europe and North America and their heavy use by the public suggest that policy makers are aware of their appeal. In the United States, the cost of land adjacent to and overlooking wetlands is generally higher than for other building lots. Development costs associated with the provision of proper drainage as land becomes covered by paving and buildings can often be reduced by incorporating an existing wetland into a land-use plan. Models for assessing visual, cultural and other land-use values have been developed by Smardon (1983) and Smardon and Fabos (1976).

3. Wetlands Inventory of Williamstown

3.1 Methodology

The inventory of Williamstown's wetlands was carried out as part of the thesis research of Anne D. Southworth in Environmental Planning at the Center for Environmental Studies, Williams College, between September 1985 and May 1986. Three previous reports prepared for the Town since 1963 recommended that plans be prepared to identify, locate and protect those wetlands of particular significance to Williamstown. Although there has been strong support for such a program, this study represents the first comprehensive examination of this resource. Because of the variation among legal definitions discussed earlier, we chose a broad definition of wetlands that would be inclusive of most of them. We gathered data on all open water bodies and any land more than 50% covered by wetland plant species that exceeded 0.04 ha in area.

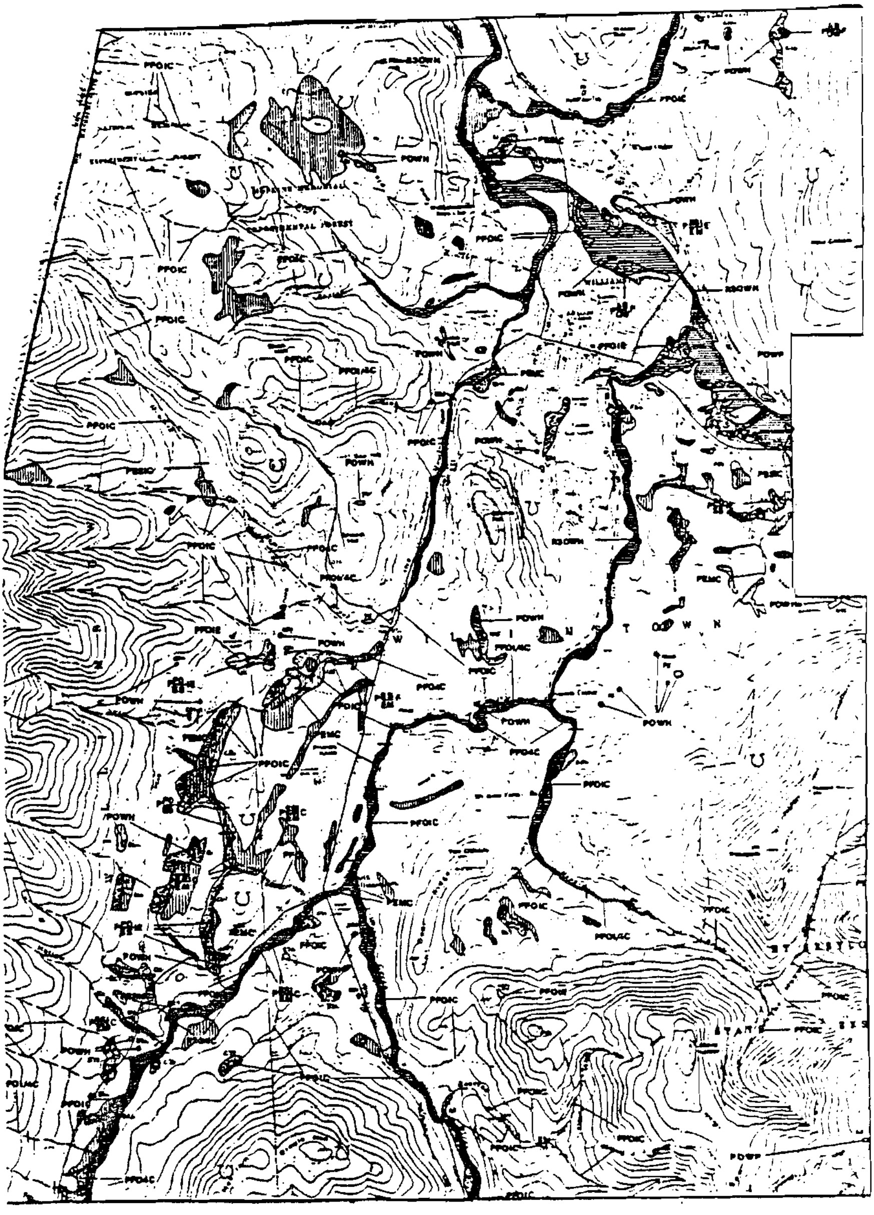

FIGURE 2 Wetlands map of Williamstown MA Both the wetland boundaries reported in this study and the designations from the National Wetlands Inventory Map are shown Dark contour lines are spaced approximately 30 meters apart and the highest elevation of just over 1000 meters above sea level occurs in the southeast corner
100 year frequency flood plain Wet soils not necessarily wetlands

It was found necessary to consult a variety of unusual sources in order to locate *all* wetlands in the study region. The more prominent wetlands were found by examining earlier reports. Soils that might support wetlands were identified from a 1973 U.S. Soil Conservation Service map, and 100-year floodplain boundaries were taken from federal flood insurance maps. Additional areas were located through interviews with landowners, knowledgeable citizens and town officials. All potential sites were located on a set of stereoscopic, infrared aerial photographs taken in August 1985 and then were visited in the field. All wetlands chosen for inclusion were photographed (210 photos were made and cataloged) so that visual information about vegetation and wetland type would be readily available for both assessment and regulatory purposes. After first identifying wetland plant species, wetland boundaries were drawn on a topographic master map (Figure 2).

In order to rank the wetlands in terms of the values cited earlier and to assess the development pressure on each, data were collected at each site and assembled into tables for ready reference:

1. "General Wetland Parameters" includes common name, location by map coordinates, size (determined using an electronic digitizer), land-use zone in which located, present use of surrounding land, and type of ownership;
2. "Soils Classification and Hydrology" includes site type, soils, a comparison with two previous aerial surveys (MacConnell and Niedwiedz 1975) and groundwater recharge potential based on the Soil Conservation Service map and recent information prepared by the Berkshire County Regional Planning Commission (1984);
3. "Vegetation" describes the wetland class and subclass, pattern and extent of vegetative cover, indicates presence of rare plant species and presents specific comments about the vegetation at the site;
4. "Wildlife" lists animal species recently observed in twenty-five of the wetlands, and is based upon records of scientists, bird-watchers, hunters, trappers and fishermen as well as upon direct field observation;
5. "Rare Plants" lists historical and current records for Williamstown's wetlands;
6. Additional tables of plant and wildlife expected in our region were also assembled (Clark and Carlozzi 1976).

It was assumed that the last three pieces of information in the first table were the most sensitive measure of development pressure. Towns may divide themselves into land-use zones so as to assure orderly development of public services, to protect public health and safety, and to promote the general welfare. Williamstown has chosen to create two rural zones, a conservation-recreation district, largely confined to the upper steep mountain slopes, in which no dwelling units may be built, and a rural residence district which encourages agriculture and forestry, but limits building density to one house per hectare. Higher density housing and apartments are permitted in the more urban general residence districts. The business zones provide for shops and hotels, while industry is confined to the remaining urban district. We determined adjacent land use since it has proven to be a strong predictor of future development trends. Finally, land ownership plays a decisive role in economic development since private owners are able to initiate any project permitted under the land-use laws, whereas state- and town-owned lands may only be used for designated purposes.

3.2 Description of identified wetlands

A total of 59 wetlands were located in the field. Wetlands in the same vicinity having a common water source were considered as a single unit. Total wetland area was 254 hectares, exclusive of river and stream channels, or about 2% of the total area of Williamstown. Individual wetlands ranged in size from 0.04 ha for a small farm pond to 28.5 ha for a large wood swamp. Earlier estimates which were based solely on aerial surveys were found to underestimate significantly the actual wetland area. Three separate studies reported only 23, 74 and 180 hectares of wetlands, in part because aerial photography could not distinguish shrub and wood swamps from their dryland counterparts (Southworth 1986). Discrepancies were also found in wetland boundaries, demonstrating the importance of on-site field investigations for obtaining accurate measurements of wetland boundaries.

Forty of the wetlands (162.5 hectares) are located in the rural residence district and only four are in the conservation-recreation district (1.7 ha). Nine are found in the general residence districts (44.3 ha), two lie exclusively within the business or industrial zones (0.8 ha), and four are shared among the urban districts (44.6 ha). Forty-eight (81%) of the wetlands are in private ownership and eight are at least in part owned by the Town or the State. Eighteen wetlands are directly associated with streams and one third of these are created by dams (the largest being the 1.2 ha Williamstown Reservoir). Most of the river floodplain is in private ownership except for a Town-owned park along the lower Green River and a section along the Hoosac that is used by Williams College for sports. Twenty wetlands consist of one or more small, artificial ponds usually 0.1 hectares in area or less that were created for agricultural purposes. Only three open water bodies of 3.9, 1.7 and 0.5 hectares are classified as lakeside environments. Each is associated with a substantial and ecologically important marsh of 9.5, 7.4 and 2.0 hectares respectively, and all are in close proximity to the Hoosac River floodplain.

4. Evaluation of Wetlands

As indicated earlier, wetlands provide a variety of benefits to society, which are difficult to assess quantitatively. Property owners seldom receive direct economic returns from their wetlands, so that economists have had difficulty in calculating monetary values for such lands. Several models have been proposed including 1) the "wetland replacement value," 2) the "income generation potential" and 3) the "market value of comparable wetlands." Such models have produced values that range from $335 to $200,000 per hectare (Southworth 1986) for the same wetland. Current undeveloped land prices in Williamstown range between $6000 and $50,000 per hectare. These values should be compared with the estimates for other specific benefits cited under **Wetland values**.

Given the uncertainties inherent in such economic analyses, we chose not to attempt a quantitative economic model for Williamstown's wetlands. Instead, each wetland was first evaluated qualitatively for its contribution to flood control, streambank stabilization, water quality, groundwater recharge and discharge, and aesthetic-cultural values. Then a two-stage evaluation of each wetland was carried out using a procedure developed by the Wetland Research Team at the University of Massachusetts (Larson, Ed. 1976). This model places its greatest emphasis on ecological values that are important for educational, recreational and conservational purposes. Each wetland was first assessed to determine if it met one or more of eleven specific criteria:

1. The presence of rare, restricted or relic flora or fauna;
2. The presence of infrequently occurring flora possessing high visual quality;
3. The presence of flora or fauna near the limits of their range;
4. The presence of a vegetational gradient from submergent to forest vegetation (hydrarch succession) indicative of a rich range of habitats;
5. A high production of native waterfowl species;
6. The use by a large number of migrating waterfowl, and other birds;
7. The presence of outstanding or unusual geomorphological features in or associated with a wetland;
8. The availability of reliable scientific information concerning the geological, biological or archeological history of the wetland;
9. The presence of outstanding archeological evidence;
10. Wetland classes that are relatively scarce in a physiogeographic region or that provide distinctive visual contrast;
11. Wetlands that are integral links in a system of waterways or which dominate the landscape of a region.

While some of these criteria require subjective judgement, they were found to be relatively easy to apply in practice. Ten wetlands met one or more of the criteria. The large, College-owned Eph's Pond and marsh met four of the criteria (1,4,6,8). This wetland is home to three rare plant species, one of which is endangered within Massachusetts, and a second which is on the threatened list (criterion 1). Historical records exist for two additional species which are not currently known to exist in Williamstown. Records exist for the sighting of 175 bird species at this site including 46 species that are wetland-dependent. Among the latter are 15 species of both migratory (criterion 6) and breeding ducks and geese, 16 wading or shorebird species, and 15 other species including the nationally rare osprey *(Pandion haliaetus)*. The area is also home to two species of reptile, five amphibians, one crustacean, one fish and two important fur-bearing mammals, muskrat *(Ondatra zibethicus)* and racoon *(Procyon lotor)*. This wetland is among the Town's most productive sites for wildlife, in part because of its full range of plant succession (criterion 4) and the nearby open fields and floodplains. Its easy accessibility has also made it a research site for faculty and students (criterion 8), a sampling site in the statewide acid rain monitoring program, and a favorite bird-watching location for amateur naturalists. This site was also judged to provide visual contrast to the surrounding landscape and hence to contribute both aesthetic and open space values. The nearby Town-owned Bridges Pond and marsh met two of the same criteria (1,6), and is a favorite local recreational area. One of the only upland wetlands in the area met criteria 1 and 7 as the home of two rare plant species and for its unusual geological setting in a deep depression between two mountain peaks. The other seven wetlands met criteria 1,4,7,8 and 10, and include three areas that support rare plant species, a water chemistry research site and the only Williamstown's wetland located in a boreal forest, a 3.3 ha wet meadow, and a cluster of three "kettlehole" ponds formed when large blocks of ice were separated from the front of a retreating glacier at the close of the last Ice Age.

The remaining 49 wetlands were evaluated for their wildlife potential using a numerical scoring system that is based upon the class and subclass (described earlier), ecological richness, size, site type, surrounding habitat and current land use, vegetative cover pattern and closeness to other water resources. These factors were weighted so as to give class, richness and size the most importance and closeness to other water resources the least (Larson, Ed. 1976). Possible scores range from 32 to 96, and seven areas scored in the moderately important range of 64.5 to 75.5. Several of these higher scoring areas were found to support additional species of native fish, amphibians, reptiles, birds and fur-bearing mammals such as beaver (*Castor canadensis*), mink (*Mustela vison*), red fox (*Vulpes fulva*) and the regionally rare otter (*Lutra canadensis*). The twenty-one farm ponds tended to score much lower (average 44.9) since their open surroundings and lack of vegetation do not provide adequate food and habitat for much wildlife. Nevertheless these ponds serve agricultural needs, recreational and aesthetic purposes and provide water supply and fire protection in rural areas. The lowest wildlife score of 38.0 was received by an isolated seasonal marsh surrounded by houses and apartments, which does, however, provide open space and reduces local flooding by capturing surface runoff.

5. Regulating Wetlands Under United States Laws

Wetland use in the United States is regulated under a complex set of laws that originate at different levels of government. Larger wetland resources such as rivers and lakes and their associated floodplains, swamps and marshes, and those wetlands which span state boundaries are subject to regulations at the national level. Filling of any lake greater than four hectares, or stream having a flow greater than 0.15 m^3/second or their associated wetlands requires a permit from the Army Corps of Engineers and a review by the U.S. Environmental Protection Agency and the U.S. Fish and Wildlife Service. In the case of most larger projects there is also an opportunity for testimony by the public. The authority for this legal process is section 404 of the Clean Water Act which requires that officials must "consider whether the proposed activity is primarily dependent on being located in, or in close proximity to the aquatic environment and whether feasible alternative sites are available." When deciding whether to permit the filling of a wetland, regulators must consider the following factors: "conservation, economics, aesthetics, general environmental concerns, historic values, flood damage prevention, land use, navigation, recreation, water supply, water quality, energy needs, safety, food production, and in general, the needs and welfare of the people" (42 Federal Register 37136). Because of its emphasis on water quality, the law regulates the filling but not the draining of wetlands. It is important to note that this law like most others requires a balancing of economic and environmental values by government agencies, but does not dictate the exact conditions under which a permit must be granted or withheld. In 1986 a precedent-setting ruling by the Environmental Protection Agency substantially strengthened wetland protection under this act. A developer proposed to build a large shopping center by filling a 40-ha wood swamp in Attleboro, Massachusetts. To offset the loss of the swamp, he offered to replace it with an artificially-created wetland of comparable size in an abandoned gravel pit several kilometers away. Such compensation for lost wetlands is encouraged by the law, but few projects have been attempted on this scale. He was denied a permit on the grounds that the proposed project did not need to be in a wetland, and alternative, dryland sites were available even though he did not own them. Many critics of the proposal also argued that the wetland was hydraulically linked to the underground aquifer, and was a complex geological and ecological system that could not simply be picked up and moved to another location. As noted in the Williamstown study, a substitute wetland is also less likely to provide as rich a wildlife habitat as is a natural area. Although this particular project was halted and one wood swamp has been at least temporarily saved, approximately 20,000 ha/yr of U.S wetlands are filled after undergoing similar review (Office of Technology Assessment 1984).

Both state and federal governments have enacted additional laws to cover other actions affecting wetlands. For example, under executive orders 11988 and 11990 promulgated by President Carter in 1977, federal agencies are ordered to avoid construction on floodplains whenever practicable, and to minimize destruction, loss or degradation of wetlands through federal activities. Other federal laws that might protect some wetlands are the Endangered Species Act, which protects habitat, and the National Environmental Policy Act, which only requires review of the environmental consequences of actions by federal agencies (but not by state or local governments or by private citizens). Two additional federal laws provide strong incentives to individuals not to destroy wetlands in the pursuit of economic activity. The National Flood Insurance Program provides government-subsidized flood insurance for property owners provided that their local community requires all new housing construction to be raised above the level of the 100-year flood. Perhaps the most far-reaching legislation is a provision in the 1985 Farm Act which denies federal agricultural price supports, crop insurance, crop storage loans, or any other federal agricultural loans including those on homes if farmers produce *any* crops on newly converted wetlands. Farmers may reduce existing debt on their homes by placing a conservation easement on their wetlands to insure that they will not be drained or filled for any reason. These provisions not only protect wetlands, but also discourage the production of surplus agriculture products. Massachusetts also provides tax reduction benefits of 75% to any landowner who guarantees that his or her wetlands will remain in an undeveloped condition.

The major tool for regulating wetland use within Massachusetts is the State Wetlands Protection Act of 1972 (G.L. Chapter 131 s 40). Under this legislation, primary responsibility for regulating wetlands rests with a five-person citizen board appointed by elected local government officials. Proposals to alter a wetland must be presented to this Conservation Commission in an open, public meeting at which any citizen may speak. Some activities are exempt such as wetland changes associated with 1) cranberry farming, 2) normal maintenance and improvements associated with active agricultural land, 3) small-scale forestry for one's own use, 4) forestry associated with a prefiled plan, 5) alteration of small extensions of a wetland less than 50 m^2 in area or an open body of water less than 1000 m^2, or 6) work done in connection with mosquito control. Otherwise the Commission may set conditions or deny an owner the right to alter a wetland in order to protect public or private water supply, groundwater, fish and shellfish, or to reduce water pollution or prevent damage from floods, erosion and storms. Notably absent from this list of environmental values to be protected are aesthetics, recreation and wildlife other than fish. An attempt is currently underway to amend the act to include wildlife as a value to be protected, and some towns have added all three values to local wetlands protection laws. The state law provides for criminal penalties for those who fail to obtain a permit or to abide by the conditions established by the Commission of up to $1000 or imprisonment of one month for each day of violation. Such severe punishment is seldom used, and appeal to the State Department of Environmental Quality and Engineering is always possible, but the presence of such penalties does encourage developers to comply with the conditions of their permit.

6. Economic Development and the Sustainability of Wetlands

The economy of Williamstown has centered primarily on its largest employer, Williams College, and on dairy farming and light manufacturing. While population in the region has declined recently, Williamstown continues to grow at a rate of about one percent per year (Berkshire County Regional Planning Commission 1984) thanks to its rich cultural life and its attractive natural setting and location. Being just 200 km west of thriving Boston and 250 km north of the massive population center of New York City, Williamstown has begun to attract urban people for vacations and retirement. There is pressure to construct additional houses, apartments, hotels and shops in the general and rural residential districts where most of the unprotected wetlands lie.

Fortunately some of the most important wetlands are protected because they were purchased by the Town, are owned by conservation trust organizations or belong to the College. The College and the Town have, however, also been responsible for wetland losses in recent years. Both the old waste dump on the Hoosac River floodplain as well as the new disposal site and sewage treatment plant are close to the river and have preempted some wetlands. There have been incremental losses in the neighborhood of the wildlife-rich Eph's Pond as some of the adjacent forest was removed by the Town to construct a housing project for the elderly, and by the College to develop parking lots and sports fields.

Williamstown's wetlands are not in danger of disappearing overnight, but they are threatened by incremental loss as the benefits of each economic development are weighed against the cost of surrendering one small wetland. While none of Williamstown's wetlands is extensive enough to be considered "regionally important" according to a 1977 Massachusetts Water Resources Commission Report, the kind of detailed study report here demonstrates that particular wetlands do possess significant and irreplaceable values. Taken as an aggregate, these lands are found to possess economically important values such as flood protection, drinkable groundwater production and water quality improvement. They also provide ecological benefits by protecting endangered flora and fauna and by enriching the variety of both native and migratory wildlife. Finally, they are found to contribute indirectly to the economic and population growth of Williamstown by adding significantly to such aesthetic and cultural values as education, recreation and open space. At the same time there are worthwhile development projects that may encroach on these lands. The issue then is how best to cope with these competing demands.

In developing a proposal to protect Williamstown's wetlands it is important to remember that these lands comprise only about 2% of the total town area (or if one excludes the steep highlands and includes river and stream channels as wetlands, perhaps 5% of potentially developable land can be classified as wetland). Second, most land-use decisions in the United States are made by local officials according to criteria that must balance the health, safety and general welfare of the public against the economic rights of the property owner. Finally, given the kind of detailed knowledge needed to make judgments about both specific development projects and local environmental values, it seems most practical to have decision making at the most local level possible. On the other hand, wetlands often possess qualities that transcend the boundaries of local government. For example, a wetland may be connected hydraulically to a river or large underground aquifer, chemically as the sink for acid deposition, or ecologically to a distant region through migratory birds. It seems most appropriate, therefore, for national and state governments first to determine the wetland values that need protection, and decide which economic and environmental factors must be weighed. They must then be certain that their own activities do not violane either the substance or process of the established principles and laws. These higher levels of government need also to be the responsible decision-making agent for larger-scale projects that affect more than one community or which have international implications. As demonstrated by this study, state and federal natural resource agencies can contribute significantly to informed decision making by gathering and providing information such as soils maps, and economic, ecological and hydrogeological data to local officials. State and federal officials should also hear appeals from developers, towns or the public who disagree with a locally-made ruling, and monitor decisions to be certain that they were fairly arrived at, and are compatible with broader policy principles. In addition to regulating the use of wetlands, local governments should also have the freedom to enact more stringent wetlands protection laws if they feel such action to be desirable.

We have recommended that Williamstown enact a stronger zoning law to reduce future development in the remaining floodplain, and that additional values such as wildlife, recreation, aesthetics and open space become grounds for restricting wetland destroying activities. If implemented, these factors would reduce the number of economic projects judged to be of sufficient importance that wetlands should be sacrificed to accommodate them. In the case of several wetlands having exceptionally important environmental values, development pressures were found to be currently or potentially high. To protect them, we have recommended the purchase of these particular wetlands or their development rights by the Town. This option is feasible since the data to make such judgments are now available, and one is dealing with a relatively small amount of land so that costs are not likely to be too high. Finally, local officials should inform farmers and other landowners of the financial benefits they may receive under various state and federal laws for protecting their wetlands. By using these multiple approaches, Williamstown should be able to continue enjoying both its wetlands and economic development along with the benefits that each provides.

Universities and research institutes also have an important role to play in gathering data which decision makers at all levels can use. The study of Williamstown's wetlands described here has been given to Town and State officials, to the Water Resource Center at the University of Massachusetts, to the State Association of Conservation Commissions and to other environmental centers. It is our hope that it will supply specific data for decisions about Williamstown's wetlands, provide a model for the other 358 cities and towns in Massachusetts and perhaps suggest approaches that will be useful for other nations represented at this Conference. In any case, we can respond to historian, Lynn White, Jr., that the questions have now been asked, and with data in hand, we are currently working on the answers.

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4.5 THE DATA BASE FOR FOREST MANAGEMENT IN LITHUANIA*

L. Kairiukstis, J. Grigaliunas, S. Mizaras
Lithuanian Research Institute of Forestry
Kaunas, Girionys, Lithuanian SSR, USSR

1. Introduction

Forests occupy 27.6% of the territory of the Republic of Lithuania. They perform a nature-protecting role, supply industry with timber and other materials, and they are of recreational and aesthetic value. Optimal multipurpose utilization of forest resources requires a very skillful approach in planning and performing silvicultural activities. Rational utilization of resources is organized on the base of a system approach. The system includes systematic registration of forest resources and determination of the level of their utilization, planning and performance of all types of forest cutting, afforestation, amelioration, and other activities.

The core of the forest management system lies in the data base of forest (inventory) plots. The questions of data base compilation, updating and some aspects of application are reviewed in this paper.

2. Compiling and Updating the Data Base of Forest Plots

Periodical forest inventories (one per 10 years) of the Republic serve as input to the data base. The parameters of each stand are measured in accordance with visual estimation of some of them. About 130 various indices are used to characterize each stand and nonwooded sites. Bearing in mind that the data base includes wooded and nonwooded sites, and that stands may be of different structure and state, each plot is characterized by indices.

In an automated search of information, each of the plots has its coordinates: forest enterprise code, forest division code, quarter and plot numbers. Also included are: plot area, forest and land categories, administrative region, relief, exposure, slope, erosion type, etc. A stand is characterized by wood species code; species composition coefficient; quality class; forest type; soil group; mean age, height, diameter; absolute and relative basal area; volume on 1 ha according to storeys, origin and so on. Also included are characteristics of the health of a stand and the extent and kinds of silvicultural activities undertaken.

The characteristics of individual forest plots of the Republic (about 630,000) take approximately 212 megabytes of computer memory. Information is brought together into 13 files. Management of the data base is performed by means of the standard program complex SETOR, and a series of special programs.

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The precision of the information in the data base of forest plots can be maintained by updating. This is done every year. During updating of information, each of the plots is evaluated from the point of view of changes related to forest felling, artificial afforestation and also a series of anthropogenic and nonanthropogenic influences on forests. All the changes are accepted in a very strict order. The last operation of acceptance of changes is the prognostication of natural stand growth. The block scheme of updating is presented in Figure 1.

The greatest problem in updating is the prognostication of natural stand growth. The main indices, such as standing volume, height, diameter, relative basal area are prognosticated. The following models are used:

$$M_{T+1} = M_T(1 + P_M/100) \; ;$$

$$P_M = a_1 + a_2/T + a_3/T^2 + S(a_4 + a_5/T + a_6/T^2) + (B - 4)\, a_7\, T \exp(a_8) \exp(-a_9/T) \; ;$$

$$D_B;H_B = (a_1 + a_2B)[1 - \exp((-(a_3 + a_4B)T))] \exp[1/(a_5 + a_6B)] \; ;$$

$$S_{T+1} = M_{T+1/M_N} \, .$$

Indices:

- M_{T+1} – volume at age T + 1;
- M_T – volume at age T;
- P_M – percent of volume increment;
- S – relative basal area;
- B – number of site indices;
- D_B, H_B – mean diameter and height;
- M_N – volume of standard stand.

3. Application of the Data Base of Forest Plots

The data base helps in solving many tasks of forest sector management in the Republic of Lithuania, e.g., evaluating the state and dynamics of forest, controlling intermediate felling, determining optimal harvesting, planning the extent of silvicultural activities, evaluating the level of forest land usage, etc. Some of the tasks are discussed below in detail.

3.1 Assessment indices of productivity and utilization of forest land

The assessment of forest land is based on an assessment scale, a mathematical model and a computer program. The assessment enables us to estimate the shortcomings of using potential possibilities of forest land productivity and to ascertain activities and ways of overcoming them in order to raise forest productivity.

The scale of forest land assessment is given in Table 1. Forest land is distributed into 27 types (forest growth conditions). The indices, S, N, L, U, P show the level of water regime (S – dry, P – wet). The indices a, b, c, d, f represent productivity (a – land of low productivity, f – land of high productivity).

Forests are divided depending upon the dominant tree species: pine (P), spruce (E), oak (A), ash (U), birch (B), black alder (J), aspen (D), and grey alder (Bt). The average increment of forest volume at the age of final cutting is considered to be the criterion. The increment is assessed in terms of wood realization costs.

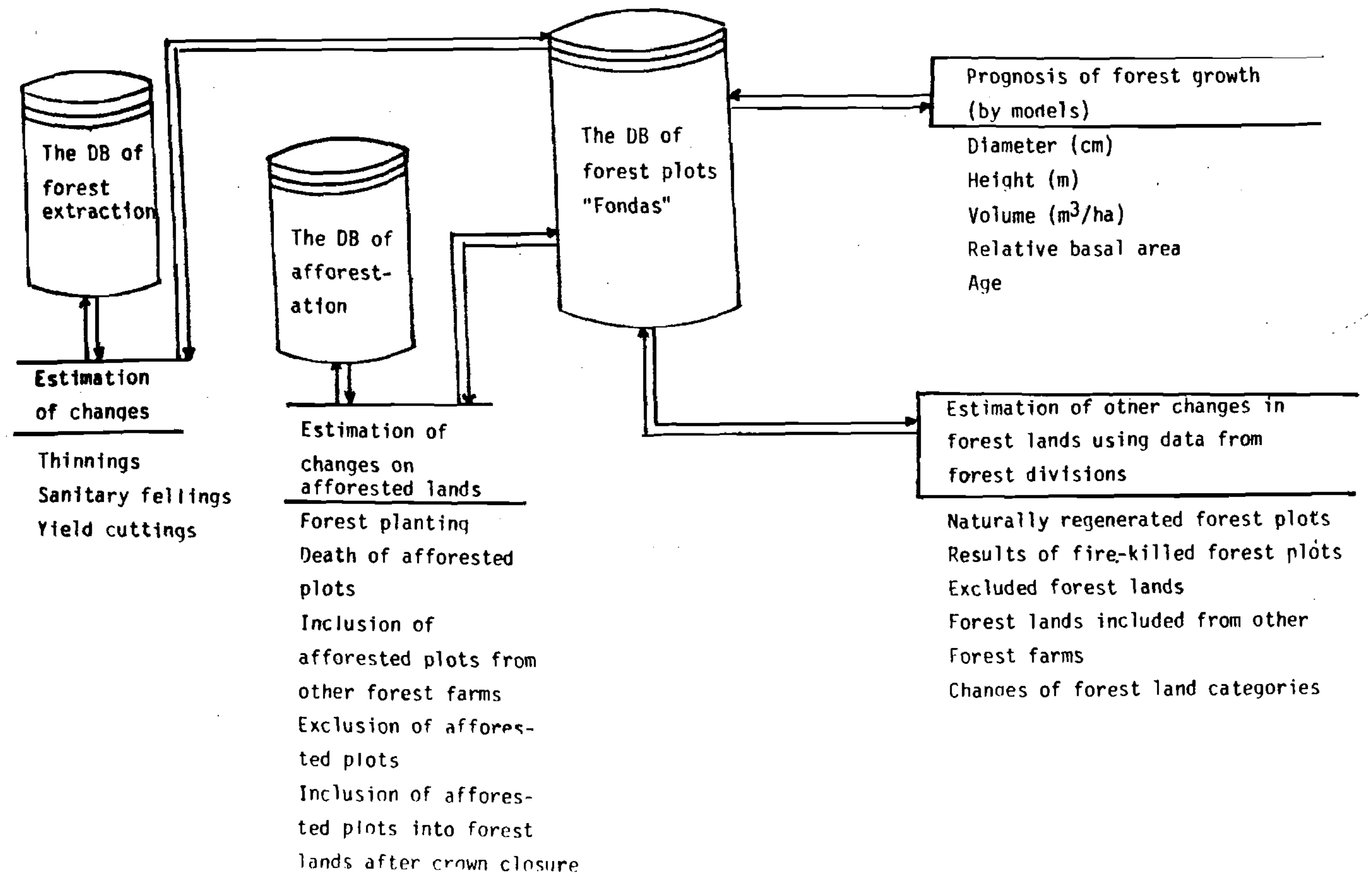

Figure 1 Schematic representation of up-dating of the data base of forest plots in Lithuania

Table 1 Scale of forest land assessment indices in the Lithuanian SSR

Type of forest growth conditions	Assessment indices of stand species, grades							
	P	E	A	U	J	E	D	Bt
Ša	35*							
Šb	55*					30		
Šc	65*	65	65			40	40	20
Šd	65	65	70*			45	45	20
Na	45*					30		
Nb	70*	70	65			40	40	20
Nc	60*	60	60		50	50	50	25
Nd		65	90*	90	55	55	55	30
Nf		80	95	100*	60	60	60	30
La	45*					30		
Lb	55	70*	60		40	40	40	20
Lc	75*	75	75		50	45	50	25
Ld		80	90*	90	60	50	55	30
Lf		80	90	100*	70	55	60	30
Ua	30*					15		
Ub	45*	45			30	20		
Uc	60	65			40	30	40	20
Ud		60		75*	50	35	45	25
Uf		60		85*	60	40	45	25
Pa	10*					5		
Pb	20*	20			25	10		
Pc	30	35			35	15		
Pd		40			50	20		
Pa^n	20*					10		
Pb^n	40*	40			25	15		
Pc^n	55*	70			35	20	20	
Pd^n		70		75	55	25	25	

)* - land assessment indices according to stand species of maximal productivity.

Our model of forest land assessment is:

$$O_z = \sum_{i=1}^{n} S_i B_i \ , \quad i = 1,2,\ldots,n \ ;$$

$$O_m = \sum_{i=1}^{n} (M_i : M_i^o)\, S_i \sum_{j=1}^{m} \frac{b_{ij} k_{ij}}{10} \ , \quad j = 1,2,\ldots,m \ ;$$

$$y = O_m 100 / O_z \ .$$

Indices:

- O_z – assessment index of forest land in grades;
- S_i – area of i-th site, ha;
- B_i – assessment index of land of i-th site in grades;
- n – number of sites in a separate management area;
- O_m – assessment index of a stand in grades;
- M_i – standing volume on i-th site in m^3/ha;
- M_i^o – optimal standing volume on i-th site, m^3/ha;
- b_{ij} – assessment index of j-th species on i-th site, grades;
- k_{ij} – coefficient of j-th species' part on i-th site;
- m – number of species on i-th site;
- y – index of land utilization level, %.

The forest lands of Lithuania have been assessed since 1978 according to the given method. The level of forest land utilization by individual forestry enterprises fluctuates within the limits of 61–77%.

3.2 Calculation of optimal volume of intermediate cutting

The second activity in seeking to raise the productivity of forests is the calculation of optimal volume of clear-cutting.

In order to grow highly productive stands, a model of maximal stand productivity has been constructed in the Lithuanian Forest Research Institute. As a result of our investigations, standards for clear-cutting for every ten years have been worked out. The standards are represented by equations. Optimal volumes of cutting wood are calculated for every separate stand by the computer. The size of cutting volume is estimated as the difference between standing volume and volume left after cutting. The difference is found by using equations. The equations (totaling 29) approximate the relation between average height (H) and (standard) volume (M_N) on 1 ha after cutting. The relation between these indices is represented in most cases by parabolic equations of the second and third degree. The equations have been constructed for pure one-layer, two-layer and mixed soft-leaved – hard-leaved or hard-leaved – soft-leaved stands. In mixed stands, the difference between heights of hard-leaved ad soft-leaved species (ΔH) is taken into account. An example of this relation is as follows:

$$M_N = [1/(a_0 + a_1\ \Delta H]\ H^{1/(a_2 + a_3 \Delta H)} \ .$$

The algorithm includes 4 main blocks: selection of an equation for every individual stand by analyzing its structure; calculation of the volume remaining using the selected equation; determination of the sequence of cutting; and prognosis for height and stock volume.

The structure of a stand is analyzed in terms of species' composition, number of layers, existence of undergrowth, main species, age, height, relative basal area and origin. The sequence of cutting of stands at the age $T > 10$ (three levels of the sequence have been accepted) depends also on their structure.

3.3 A model of optimal final cutting

The third main activity in the system of managing forest resources is optimization of final cutting. The greatest quantity of wood is supplied by the final cutting. For calculation of optimal cutting volume, it is necessary to achieve a uniform distribution of forest area according to age classes. This is done by using the model OPTINA:

$$L_r^k = \frac{1}{r} \sum_{i=1}^{r} f_i^k + \alpha f_{i-1}^k \; ;$$

$$\alpha = 0.9 \div 0.1 \; ; \quad r = 1 \div T_k - 1 \; .$$

The first step is calculation of a minimal cutting area for a ten-year period for all age classes:

$$L_k = \min \left\{ L_r^k \right\} \; ;$$

$$r = 1 \div T_k - 1 \; .$$

The cutting area from one ten-year period to the next is limited by the following restrictions:

$$1. \text{ If } N_k \geq f_{T_k}^k \; ; \; N_k = \frac{F_k}{T_k} \; .$$

then:

a) if $L_k \leq N_k$, the cutting area is L_k ;

b) if $L_k > N_k$, the cutting area is N_k ;

2. If $N_k < f_{T_k}^k$, the cutting area is N_k ,

3. If $f_{T_k}^{k'} \geq \beta L_k$, $\beta = 0.1 \div 0.5$, the cutting area is L_k ;

$$f_{T_k}^{k'} = f_{T_k}^k + f_{1_{k-1}} - L_k \; .$$

The coefficient β limits cutting of exploitable stands. The minimal area of exploitable stands makes up one yearly cutting area of a previous ten-year period ($\beta = 0.1$). The limits of β are $0.1 \div 0.5$. Having made calculations for the first ten-year period, cutting areas for the second and subsequent periods are estimated. But after calculations, the cutting area of every next ten-year period L_{k_i} is compared with the cutting area $L_{k_{i-1}}$ of the previous one. If $L_{k_i} < L_{k_{i-1}}$, then α must be reduced by 0.1 and calculations for $L_{k_{i-1}}$ are repeated until inequality $L_{k_i} \geq L_{k_{i-1}}$ is obtained, and so on.

At the end of each ten-year period, each element of the matrix of areas passes into the next age class.

Indices:

- L_k – calculated minimal cutting area for a ten-year period;
- F_k – total area of all age classes of k species;
- T_k – rotation period (a number of ten-year age classes in the k tree species rotation);
- N_k – area of even utilization;
- f_i^k – area of i-th age class, ha ($i = 1,2,\ldots,T_k$); numeration begins with exploitable age classes;
- α – inclusion coefficient of area of a senior age class ($\alpha \leq 0.9$).

Tables of area distribution of tree species according to age classes and volumes of exploitable stands on 1 ha are used as input information. Calculations indicate that a normal cutting area in our republic will be accessed by the year 2025.

4.6 THE GREAT LAKES: EXPERIENCE IN INTERNATIONAL RESOURCE MANAGEMENT*

Valdas V. Adamkus
Administrator, Region 5,
US Environmental Protection Agency
230 South Dearborn Street,
Chicago, Illinois 60604, U.S.A.

Growth and development are among the primary functions of any nation, regardless of its size. Whether an established, industrialized society moves into new areas of sophisticated technology, or an emerging country struggles to develop a stable economic base, growth is taking place. Although each nation has its own unique set of factors that influence its development – such as differing political and economic systems, cultural values, and natural resources – the goal is the same: to improve the quality of life of a country's citizens, who form the basis of their nation's strength.

And yet it is this very quality of life that can suffer if growth is not managed responsibly. No development takes place in a vacuum. Instead, natural resources are converted into other forms, people are moved around, the face of the landscape is often changed, and wastes are produced. In short, the environment is affected.

It is only recently that the cumulative effects of development on our global resources have received real attention. Incidents in the world press have made clear that civilized nations have not properly planned for the impacts of growth, impacts that range from the destruction of whole ecosystems by rampant overuse, to contamination of air and water by incompletely processed wastes.

Our planet still suffers from man's frontier mentality – one that excuses an abuse of natural resources in the belief that "there's always more where that came from." Perhaps this attitude is more entrenched in newer or larger nations. Yet it can be said that we all are somewhat guilty of an "environmental myopia." This dangerous nearsightedness occurs either when we refuse to recognize potential pollution problems or when we insist on believing they have only a local, short-term effect.

As we are painfully learning, pollution respects no territorial boundaries. The great global streams of wind and sea that moderate our climates also convey air and waterborne contaminants that affect the quality of life hundreds, often thousands, of miles from their source. While the degree of sophistication of a nation's technology frequently can be used as a measure of the complexity of its environmental problems, it does not matter whether a country's inhabitants live in huts or in high-rises – without adequate pollution controls, the end result will be the same: wholesale degradation of air, water, land and habitat resources.

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However, I believe that it is possible, while respecting each nation's individual mandate for growth, to find a way to guide development in a manner that places man in a position of caretaker, rather than conqueror, of his environment. This attitude of stewardship is not an idealistic one; rather, it is born of hard-headed necessity. We share only one planet. At this point in our history, there are no worlds beyond this one, that are accessible to us for a fresh start. To survive as a species, we must protect and conserve what we have.

I believe that the industrialized nations, with their financial and legislative institutions, should take the lead in promoting this attitude of respect for the environment and translating it into action. I would like to suggest a multifaceted approach, which includes:

- fearlessly admitting environmental processes;
- recognizing their international aspects;
- isolating the sources of pollution, including industrial processes;
- researching and monitoring pathways of pollutants through the ecosystem;
- looking for potential repositories or end points where pollutants might collect;
- developing a regulatory framework for cleanup, enforcement, and prevention;
- reassessing cost-effectiveness in the long rather than the short term;
- working for the support and understanding of the public.

My own experience in North America leads me to use the case of the Great Lakes as an example of how such a process can be undertaken.

The Great Lakes are an intensively used and internationally shared and managed resource. As part of the border between the United States and Canada, they extend some 4,000 km from their western shores to the Atlantic Ocean on the east – a distance comparable to a transatlantic crossing from North America to Europe. The Great Lakes have been called "America's fourth seacoast," because they add almost 17,000 km of shoreline to North America.

As a resource, the five Great Lakes are a continental treasure. They are the largest body of fresh water on Earth. They have a combined surface area of more than 296,000 km^2, and they drain an area of 650,000 km^2. Their importance as a source of fresh water for drinking water and high-quality industrial use can also be estimated by their capacity. The Lakes contain about 65 trillion gallons of fresh water – 20 percent of the world's supply, and more than 90 percent of the USA's fresh surface water.

The Great Lakes region is home for approximately 20 percent of the US population and 60 percent of Canada's. One fifth of all US and about half of Canadian manufacturing industries are located in the basin and are, to a great extent, dependent upon Great Lakes water.

The contribution of Great Lakes shipping to the regional economy is estimated at over $3 billion annually. Recreation and tourism based on the Lakes generates another $8–12 billion annually. Sport and commercial fisheries account for another $1.5 billion.

Historically, the Great Lakes have supported the prosperity of the two countries that border on them. They were the foundations of our industry, agriculture, and cities. We relied on them for our recreation, our drinking water, our energy, our economies, and our welfare. But, by the late 1960s, we began to take them and their contribution for granted.

We seemed to feel that smoggy skies, dead fish, and polluted water were the price we paid for our prosperity. No one realized that these might be the warnings of environmental and economic disruption, that so vast a resource could be degraded.

And so the situation worsened. Air pollution was, and has been, a particular problem around the Great Lakes. Unfortunately, many of the region's industries also had a high pollution potential – including steel, primary metals and automobile manufacturing, paper, and electrical generation. The skies of the area were darkened by their emissions. Water pollution problems were also widespread. Discharges of industrial effluents, inadequately treated sewage, and runoff from urban streets and rural fields caused massive fish kills, beach closings, and algal blooms, which impaired both recreational uses of the Lakes and their biological diversity. The suitability of the Great Lakes for drinking water, and even for industrial processes, was threatened. The industries and cities were destroying the very resources upon which they depended.

This was the state of the Great Lakes environment when the US Environmental Protection Agency (EPA) was formed in December 1970 to provide an overall national programmatic approach to the environment. Many states also reorganized and expanded their environmental control agencies, aided by grants from EPA. EPA's Region 5 office in Chicago was also created to provide jurisdiction over most of the Great Lakes states and, through the Great Lakes National Program Office, over all of the Great Lakes themselves.

The US Congress quickly passed a series of landmark environmental laws These laws mandated national programs for what had previously been a state-by-state regulatory design. They also gave the EPA broad powers in approving and rewriting state plans, and provided for direct federal enforcement of them.

The message soon spread in the industrial community that EPA was a force to be reckoned with. This was the beginning of the institutionalization of industrial environmental control in the United States. Similarly, when communities realized that they were being held responsible by the federal government for their own pollution, but that EPA's Region 5 had billions of dollars available for wastewater treatment plant construction, we became a permanent fixture of American government.

EPA's next steps were to fulfill our broad mandate for environmental protection. In Region 5, we placed a special emphasis on the Great Lakes. We held public hearings and then issued permits that had stringent limits for conventional pollutants. We assisted the states as they developed regulations to control air emissions. We began sampling and analyzing Great Lakes area air and water to support our technical determinations and programs decisions.

We took special pains in Region 5 to assure that municipal wastewater treatment plants were operating properly. We also sent several research vessels out onto the Lakes to analyze their physical condition. Over time, the Great Lakes environment changed. We saw significant improvements – water quality improved, rivers no longer caught fire, the fish kills virtually ended, and many beaches reopened. But we soon learned that there were problems in the Lakes that we had never envisioned.

We quickly realized that the environment was much more complicated and interconnected than we had thought. Our analyses had shown elevated levels of PCBs (polychlorinated biphenyls) in fish tissue, which were accumulating at an alarming rate in fish – and in the people who ate them. At that time, there was no regional role in toxic substance control.

In November 1975, Region 5 sponsored an international conference in Chicago on PCB contamination. The conference attendees recommended to the Agency and to Congress that PCBs be banned. EPA issued a warning and phase-out order in 1976, and Congress amended the Toxic Substances Control Act in 1979 to outlaw their manufacture and restrict their use. Canada cooperated fully in this effort.

Later, Region 5 expanded analytical investigations and control efforts to include tributaries to the Lakes. Runoff controls were started, limits on toxic discharges to treatment plants and to waterways were added to permits, and some pesticides were banned. But even this did not control the problem. We have now realized, our regulatory focus must be broader yet. Leaking hazardous waste landfills, slowly released toxic chemicals from contaminated sediments, and other indirect discharges have forced us to look at the entire Great Lakes basin and watershed – and beyond.

For a while we worked to control both conventional and toxic discharges to the entire Great Lakes basin, and we began to realize that more toxic materials were entering the Lakes than could be accounted for by discharges within the basin. We now realize that as much as 80 percent of the current toxic load on the Lakes is through air deposition -- some of it transported long distances. As our understanding of the environment has grown, so has our recognition of the control area – from direct discharges, to tributaries, to the watershed, to the airshed, and now to the entire globe. That is how we came to realize, as an institution and as individuals, how inextricably linked the local environment is to larger global factors.

During this time, the Canadians were engaged in similar efforts. New environmental laws were passed, new control agencies at the federal and the provincial levels were organized. They also began a massive grants program to fund municipal treatment plants. They launched a fleet of Great Lakes research ships and began the same sort of sampling and analyses as the EPA. They made similar progress with their understanding of toxic substances in the environment.

The British North America Act assigned authority for navigable and international water to the federal government. Pollution control and natural resources management were primarily provincial responsibilities. The Federal Canada Water Act provided for agreements to establish the responsibilities of both levels of government. The leading federal agency was Environment Canada. Its major focus was to establish environmental objectives under the Great Lakes Water Quality Agreement, while the major responsibility for implementation activities was with the Ontario Ministry of the Environment. The Canada/Ontario Agreement provided for joint funding of activities under the Great Lakes Water Quality Agreement and joint funding of municipal wastewater treatment facilities. .

Canada and the United States recognized their joint responsibilities very early. In 1909, they established the Boundary Waters Treaty, which created the International Joint Commission (IJC) to monitor and evaluate Great Lakes environmental issues and coordinate efforts for rectification. In 1972, the United States and Canada saw a mutual advantage in entering into the Great Lakes Water Quality Agreement under the Boundary Waters Treaty. This agreement was a major milestone in international pollution control and environmental management. It established true international governance of such environmental resources management issues as hydrological regimes, lake levels, river flow diversions and consumptive uses, and effects of navigation on the Lakes and tributary channels. The new agreement also set the stage for a new approach to managing the total Great Lakes resource – the ecosystem approach. This approach considered man and his economic activities as a fundamental component of the ecology of the Great

Lakes. One of the most notable examples of American-Canadian cooperation in joint ecosystem management has been in phosphorus control. Eutrophication was a significant problem in several lakes, especially Lake Erie. While neither the US Clean Water Act nor Canada's Water Act specifically mandated phosphorus control, both countries made it a priority in both the 1972 and the 1978 Great Lakes Water Quality Agreements.

In the United States, limits on the amount of phosphorus that could be discharged per unit of wastewater were added to permits. In Canada, control orders were issued to industries and municipal discharges to achieve the desired reductions. Both countries spent millions of extra dollars to fund additional phosphorus control measures in grants for municipal sewage treatment plant construction. Also, both countries began seriously to look at the phosphorus coming from nonpoint source runoff. EPA, in cooperation with other federal agencies, funded agricultural demonstration projects to control runoff from fields. EPA also started an urban runoff control program to demonstrate phosphorus control technology for combined sewer overflow and storm water runoff.

States and cities rapidly realized the water quality benefits of phosphorus control. Many began building urban runoff collection and control devices. Two Canadian provinces and five states either banned or severely limited phosphorus in laundry detergents.

On the local level, Great Lakes governors and premiers gathered in 1985 to sign the Great Lakes Charter, which commits the states and provinces to developing their own water management programs and to regional cooperation in managing the Lakes, especially concerning water diversions to other areas facing water shortages. The charter also commits the states and provinces to share information and consult with each other before taking actions that affect the Lakes.

Another agreement was reached in early 1986, when the governors of the eight Great Lakes states signed the Great Lakes Toxic Substances Control Agreement. It covers cooperative study, management, and monitoring of the Lakes. It also aims to reduce toxic substances as much as possible and to maintain public health and environmental priorities ahead of economic ones. The premiers of both Ontario and Quebec supported the agreement.

These programs are not yet sufficiently developed to adequately control all our environmental problems. For instance, most Great Lakes harbors remain contaminated by toxic sediments generated by previous industrial activities. Cancerous tumors are still being found in Great Lakes fish; health advisories warn against eating the flesh of certain species. Acid rain generated by smokestack emissions from the regions damaged northern lakes and forests; control programs are still in their infancy. User interests clash as shoreline property owners seek to reduce erosion by lowering Lake levels, a move opposed by shipping and hydroelectric industries.

On the other hand, new federal legislation in the 1987 amendments to the Water Quality Act mandates strict control of toxics in both industrial and municipal discharges, as well as requiring programs for control of nonpoint source pollution. Unfortunately, local governments have been delegated more responsibility with less funding to carry it out. The private sector will undoubtedly show some resistance to new pollution control requirements, but in the long run they will come around to realize that their improvements will help make the region more attractive, livable and, therefore, economically viable.

Meanwhile, the joint effort continues to protect this great international resource. In my opinion, sharing the Lakes with Canada offers a distinct advantage: The two countries act as a support, a spur, and a check upon each other, pooling resources, sharing information, and reviewing each other's progress. The process is far from smooth or perfect, but it is working.

Translating such a model to the European arena is difficult. The multiplicity of sovereign countries, with their differing languages, cultures, and social and economic systems, often acts as a barrier to reaching a consensus about pollution control. However, the close proximity of the members of the European community can act as a unifying influence. Rivers, seas, and forests are not just historic boundaries but shared resources, as is the air and groundwater. From this perspective, international cooperation in the setting of common resource protection goals is not only desirable, but possible, regardless of how each nation chooses to meet those goals. If we, who take pride in our cultural technological and social developments, cannot accept responsibility for the impacts of our growth on the environment, how can we expect this of developing nations?

The Third World has entered only lately into the global environmental equation. While richer nations look upon the destruction of South American rain forests or the desertification of African grasslands as a tragedy restricted to local developmental problems, we fail to realize that much of the air we breathe is recycled and purified by the extensive vegetation now endangered on these continents. Countries searching for food and fuel for hungry populations are destroying the very resource base that, with better planning and management, could help to sustain them. Ignorance and desperation in these nations achieve the same ends as greed and shortsightedness do in more educated societies.

Yet, it need not be this way. If viewed in the long term and as part of an international cooperative effort, environmental protection and wise use of resources can be perfectly compatible with economic development. The focus must be on the quality, rather than just the quantity, of growth – quality in the sense that man's presence does not have to detract from the overall value of the environment. What is needed is a shared vision, and a shared commitment. When considering the limited resources of this planet, we must realize that we have no other choice.

4.7 POLISH CASE STUDY: REGIONAL IMPACT OF LARGE-SCALE MINING AND ENERGY DEVELOPMENT*

K. Holubowicz
Field Research Station,
Institute for Environmental Engineering
Polish Academy of Sciences, Piotrków Trybunalski

and

J.W. Owsiński and A. Straszak
Systems Research Institute,
Polish Academy of Sciences
Newelska 6, PL-01-447 Warsaw, Poland

1. Introduction

Large-scale lignite strip mining and related power generation development in a predominantly agricultural region of Poland has brought important changes to the socioeconomic and natural resource environment. This paper reviews some problems related to long-term consequences of the development mentioned.

The case considered here received much attention in terms of research undertaken and executed, as well as in terms of media coverage. A special Field Research Station of the Institute for Environmental Engineering, belonging to the Polish Academy of Sciences, was created especially for this case. In view of the obviously systemic nature of problems at hand, the Systems Research Institute was involved over several years. Some of the results from the studies performed at the Systems Research Institute have already been presented, also through common undertakings with IIASA: see Owsiński and Holubowicz (1985), Owsiński and Zadrozny (1986), Owsiński (1986 a,b), and Owsiński, Jakubowski and Straszak (1986). The present paper covers the subsequent analyses, in which many of the results obtained to date will serve to establish the starting point.

The Case Considered

2.1 The general problem: stability and sustainability

A large-scale development of finite time horizon – at most 50 to 60 years with the anticipated level of intensity – is introduced into a relatively weakly developed region. This gives rise to a number of questions, related primarily to the short-term and long-term stability of the regional ecological, social and economic trajectory. The questions of long-term stability of course involve

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buračas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

consideration of sustainability. In fact, one is dealing with a clinical case in which these two notions are closely interconnected.

Thus, if we consider a system to be sustainable if it continues over a very long, possibly infinite, time, a predetermined nonzero value of some variable characterizing it, then sustainability is assured by enhancing stability of the system, this stability being defined with respect to a perhaps otherwise perceived system.

In the case at hand, shorter-term considerations refer from necessity to stability of the regional system during the build-up and then abandonment phase, the latter leads directly to the question of sustainability: how to ensure open-ended development of the living basis of regional population? This question concerns resources, jobs, infrastructure and environment.

2.2 Regional characteristics

The area in question is located in central Poland. It is characterized by traditional family farming, with farm sizes typical of Poland, i.e., small, with production based upon rye, potatoes and milk. Soils are light and precipitation is low – 55 to 58 cm per year. Agriculture, although less intensive than in most of the surrounding areas, provides, due to low urbanization of the region in question, important regional exports and an important share of jobs. The forest area is slightly lower than the national average, although it is somewhat higher than this average in the close vicinity of the strip mine, and wood quality is not too high.

Industry is much less developed than in surrounding areas. There are no important urban centers and no university tradition. In fact, this region was, but for a short period, an underdeveloped part of Poland throughout history, although in its geographical center.

Delimitation of the area considered is defined by the influence of a large-scale lignite strip mine and power generation related to it. There are a number of such influences, environmental, economic and social. Some of them will be mentioned later. Each of them covers a different geographical area.

It is, therefore, convenient to take certain proxies in order to represent the region. Thus, the maximum area of the envisaged drop in groundwater table, resulting from strip mining, of at least 1 meter, as located against the regional administrative boundaries could be used for this purpose. This area will be referred to as "groundwater crater." The rest of the area, in which approximately 85% of the crater is located, does not differ substantially in its features from the crater area. Some of the characteristics given at the beginning of this section are illustrated with data for the Piotrków region in Table 1 (Piotrków region may, for some purposes, be also taken as a proxy for the region in question).

When assessing the data of Table 1, one should remember that Poland is a flat central-European country, relatively developed, with the most industrialized and densely populated areas surrounding the Piotrków region.

Table 1 Some indicators relating Piotrokow region to Polish averages, as of 1984.

Item	Polish average	Piotrkow crater	
		average	as % of natl. average
1. Urban population share	59.1%	43.1%	73%
2. Population density, persons per sq. km	115.3	97.8	84.8%
3. Employment in state economy per 1000 inhabitants	333	301	90.3%
4. Value of capital assets per capita, in 10^3 zlotys	214	207	96.7%
5. Global value of annual state-controlled proeuction per capita, in 10^3 zlotys	66	57	86.4%

2.3 Strip mining and related developments

Because of lack of other carriers, Polish energy is oriented towards coal. Poland is a traditional exporter of anthracite, which is a very important export item. In conditions of shrinking coal resources and increasing costs of exploitation, it becomes expedient to find and put in operation new reserves. Luckily enough, the Central European Plain, stretching from the Rhine beyond the Vistule has several rich lignite fields in its upper part. These lignite fields are exploited as strip mines in the Federal Republic of Germany, the German Democratic Republic and Poland.

The opencast mine in question is one of the biggest in Europe. Its depth reaches 300 m, while its total length will be near 20 km. It is composed of two parts, of which only the first is now in operation. This part is supposed to contain more than 10^9 tons of lignite, while the second – a little more than 0,5 x 10^9 tons. It is anticipated that, under presently assumed operation conditions, the lifetime of the whole mine will reach approximately 40 years. It is likely that, after the operation is finished, some part of the mine surface will be covered by lakes. Meanwhile, the "brown hole" draws water from the surrounding aquifers.

In the vicinity of the mine, a lignite-fueled power plant is in operation. Its capacity is 4200 MW. Another power plant is planned to start generating electricity when the second part of the mine starts producing coal. The capacity of the other power plant is envisaged at 1500–2100 MW.

Direct employment in power generation and mining is envisaged to grow in the next few years from the present 5 thousand to 8 thousand. This would account for approximately 10% of the overall industrial employment in the area and proportionately more for the area directly influenced.

The "groundwater crater" surface is now approaching 450 km^2. Its envisaged maximum is 1300–1800 km^2, i.e, some 20–30% of the region.

2.4 Problem structure

There are a number of regional effects, observed and potential, resulting from the introduction of the large strip mining and power generation developments. The most important may be listed as follows:

1. Agricultural land appropriation and landscape changes.
2. Employment in industry and service.
3. Development of downstream and complementary industries.
4. Diversion of labor from agriculture.
5. Lack of water and "groundwater crater."
6. Increased personal income.
7. Crop decrease.
8. Specific ecological deterioration.
9. Crop quality decrease.
10. Changes in human habitat environment.

Beside the question of evaluation of the present and imminent outcomes of the dynamical system composed of the effects listed, there is the problem of the long-term perspective. Mining, as mentioned, will go on for approximately 40 years. This implies long-term dynamics of quite a specific nature.

It becomes obvious that the effects listed have to be taken in the analysis over the whole cycle of development. It should be mentioned that although some of the effects may have a reversible character, e.g., groundwater level in the vicinity of the mine, most of them are hardly, if at all, reversible.

Groundwater will approximately return to its previous level when the mine is filled with water. Some areas may even become more humid than before. Soil quality, however, (especially peaty areas) may deteriorate in an irreversible manner. For the best soils, which can thus degenerate, located within the mine or close to it, it may turn out to be cost-effective to transport them to other locations or use them for greenhouses. Pollution will certainly diminish at the end of the cycle, but its consequences will linger quite some time afterwards.

Within the domain of socioeconomic effects, if abandonment of agriculture occurs on a greater scale, so that neither the labor force, nor the productive infrastructure can any longer be found afterward, a return to the original condition, if wished, may be difficult. (Abandonment itself inflicts large social costs of income and job provision, as well as production substitution and transportation increases.)
On the other hand, the most practiced reforestation policy, in view of ecological conditions, may prove quite inefficient during the cycle.

Thus, a problem arises of securing a smooth and loss-minimizing change during the cycle, and a feasibility of return, if wished, afterward. The policies undertaken should, of course, not be incompatible with a possible profile shift of the region.

2.5 Studies, concepts and policies

In the actual decision process, a compromise was reached, according to which the mining operators were obliged to supply water to villages located next to the "brown hole" and pay direct mining damage compensations to farmers.

Additionally, important overall compensation was to be paid by the mining and energy sectors to regional authorities with the purpose of introducing special agricultural operations and policies.

One of the major motivations for the particular study reported here was the realization, gained through previous experience, that clearly formulated hypotheses concerning the regional system in fact already existed, although not quite pronounced, within the institutional setting related to the development and local authorities. These hypotheses concerned not only conditions for, but also outcomes of, the future course of events, and they could be relatively easily attached to particular actor types within the institutional setting. They can be described as follows:

Hypothesis No. 1. Through diversion of the surplus labor force from agriculture and the market expansion (higher incomes and bigger urban population), development induces (forces) an agricultural technological shift thereby helping agriculture which, anyway, suffers little otherwise.

Hypothesis No. 2. The above can occur provided additional investment capital is made available for agriculture over the coming period of time.

Hypothesis No. 3. In order for Hypothesis No. 1 to come true, not only additional capital would be necessary but also the diversion of labor would have to be accompanied by an important reallocation (or flow) of the labor force among the farm types.

Hypothesis No. 3 was added by the study team.

3. Regional Agricultural Policy Model

The regional agricultural model is meant for analysis of medium-term development alternatives, for choice of best structures and for evaluation of conditions of agricultural operations and changes.

The time horizon of the model results from its linear form. In fact, it is a linear programming (LP) construct, relatively detailed, allowing quite precise balancing of resources and products. Thus, the model can presently help in policy setting for the initial stage of the development cycle, taking into account such effects of mining developments as labor force diversion from agriculture, water deficit, land availability decrease and crop yield decrease, and their consequences.

Hence, the model can represent most of the processes related to the development/agriculture interface. Furthermore, if the model is run for the end-of-cycle scenario, it can also be used for long-term policy analysis.

The model, called furtheron SEMORA B, is constructed as a two-level LP problem. The lower level, composed of 7 submodels, represents individual subregions of the area. Subregions are delineated according to administrative breakdown, contiguity and location with respect to the mine.

Each submodel describes in a detailed way the agricultural economy of a subregion. The submodels contain approximately 1700 variables and 500 constraints each. The main groups of variables describe:

1. Crops grown.
2. Livestock kept.

3. Sales of crop products.
4. Consumption of crop products within region.
5. Crop products for livestock feeding.
6. Sales of livestock.
7. Sales of livestock products.
8. Consumption of livestock products within region.
9. Livestock slaughter.
10. Purchase of crop products for human consumption.
11. Purchase of crop products for livestock feeding.
12. Purchase of livestock products.

These variables are subject to the following groups of constraints:

1. Land, crop rotation and secondary crop.
2. Crop product balances.
3. Herd balances.
4. Livestock product balances.
5. Feed balances.
6. Labor force balances.
7. Pulling power balances.
8. Fertilizer balances.
9. Water balances (annual and peak period)
10. Sales and purchase balances.
11. Capital investment limits.
12. Minimum income requirements.

Two main objective functions were maximized alternatively:

1. Total agricultural net income from subregional agriculture.
2. Total agricultural subregional production value.

The variables and constraints were classified according to the following aspects:

a. crop types (16 types of crops considered),
b. soil quality types (4 + permanent grassland),
c. crop technologies (3),
d. farm types (5),
e. animals (7),
f. husbandry technologies (2),
g. fertilizer contents (4),
h. sales and purchase markets (3).

The master model, smaller than the subregional ones, contains descriptions of the subregional resource efficiency functions and certain constraints on regionally balanced resources, such as: infrastructural and productive investments, credits for credit schemes, and water. It is with respect to these resources that coordination is primarily performed. Solutions of SEMORA B on the subregional level specify optimal production structures and product destinations. On the master model level, values of "policy variables," i.e., certain resource allocations, are determined.

4. Model Results and Policy Indications

For the sake of brevity and clarity, only the main features of the solutions, policy indications and chosen directions of analysis are presented.

One of the main objectives of analysis, in view of the impact envisaged, was establishment of adequate agricultural income conditions. Their level is decisive for local agriculture. Several scenarios were tested, differing by assumptions as to potential water deficit, crop decrease, etc. It must be emphasized that simple maintenance of the present income levels is not sufficient to effectively limit the impact, i.e., labor force diversion from agriculture to mining, since wages in new industries are, on the average, 2–3 times higher than agricultural incomes. It was shown with SEMORA B that some farm types may attain income levels comparable with those of industrial employment, while others cannot. Attainment of lower income levels does not imply that labor diversion will occur automatically. The greater the difference, however, the more important this diversion. On the other hand, attainment of comparable incomes by some farm types is conditioned by adequate increase of capital investments in these farms, i.e., appropriate credits. For an overview of results, see Table 2.

Table 2 Numbers of farm types, out of a total of 5, in which incomes comparable to those in industry jobs can be obtained under optimum conditions A: water cost increase with no deficit and crop decrease; B: cost increase and water supply cut by 30%; C: as A, with slight crop decrease, esp. in permanent grasslands; D: as B, with slight crop decrease, esp. in permanent grasslands.

Description of scenarios	Capital investment in farms		
	Present level: 100%	150%	200%
Water deficit and crop decrease			
None	2	2	4
A	1	2	4
B	0	1	2
C	0	0	1
D	0	0	0

The counterpart of the income situation is that of the labor force. Analysis of this aspect of the regional agricultural system is important insofar as the labor force diversion, already mentioned, is positively evaluated not only by the mining lobby, but also by some representatives of local authorities and by some agricultural economists; see *Hypotheses* mentioned. These opinions are formulated on the basis of a global assessment of labor force number, its theoretical productivity and actual productivity. The SEMORA B model applied the same parameters as those used in global assessments. Since, however, the model solutions represent optimal rather than average conditions, it could be justly suspected that "idle manpower" would come out in these solutions even greater than in the global economic assessment. This would provide arguments for those who claim that labor diversion helps in the rationalization of agricultural production. Actual results are schematically outlined in Figure 1.

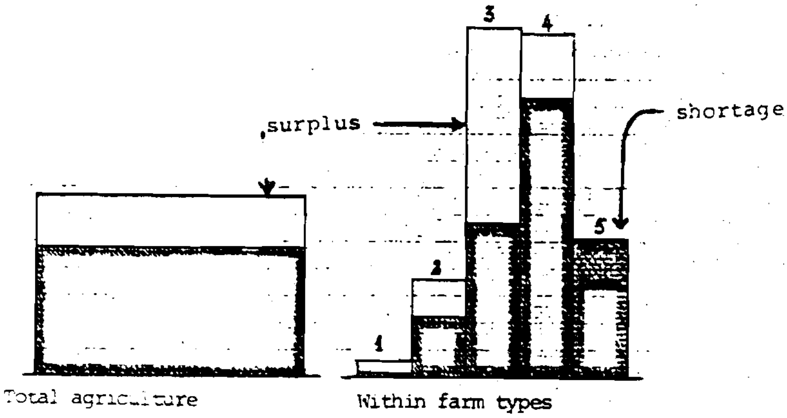

Figure 1: Relation of actual manpower requirements in regional agriculture, according to SEMORA B results. Farm types 1. state farms; 2. cooperative farms; 3. private farms < 5 hectares; 4. private farms 5 to 10 ha; 5. private farms > 10 ha.

The diagram shows that virtually the whole labor margin comes from one farm type, i.e., small private farms, while the most promising farm type (No. 5 in the diagram) is already suffering from an important lack of manpower. Furthermore, quite a share of manpower from farm type 3 consists of so-called double-professionals, i.e., people also employed outside agriculture, due to income shortages on small farms. Thus, even the indicated margin may in reality be less.

Hence, while it seems almost sure that diversion will occur over the years to come unless appropriate policies are undertaken, this diversion would have a negative effect on local agriculture.

Work with the model allowed formulation of general policy outlines countering these effects, the policies proposed referring to capital investments and to labor force "reallocation" among farm types through the farm market and otherwise.

5. Further Study and Discussion

5.1 The cross-impact study

In order to elaborate the previous study and to uncover more general longer-term trends within the regional system, a cross-impact analysis was performed, reported in Owsiński, Jakubowski, and Straszak (1986). This analysis was based on an *à priori* identification of the problem structure, starting from the list of processes as in 2.4. Then a full-day computer-aided session was convened with participation of 15 major experts from mining, power generation, regional and local authorities as well as outside ("neutral") specialists. The structure of the dynamic system thereby established allowed us to make a qualitative forecast, whose main features could be summarized as follows:

- in spite of the shrinking resource base (including, e.g., water), there is high probability that development will result in the location of subsequent resource-consuming, capital-intensive industries in the region;
- such momentum will not be sufficient to establish long-term economic stability of the region;
- the importance of agriculture in regional economy will drop from the present level to slightly below the national average across the region and will not recover;
- a low probability is attached to implementation of the policy of environmental reconstruction in the region if things are "left to themselves."

5.2 Other studies

In view of the importance of this region, both directly and as an example, a large number of studies were undertaken referring to a variety of natural, economic and social questions. In particular, special attention was devoted to studying the potential and actual crop yield decreases due to a drop in groundwater level and other influences. While opinions differed concerning potential crop changes, studies of actual crop yields showed no significant decreases in field crop yields and only very limited decreases in pasture and meadow productivity.

This, in the eyes of many specialists, was a sufficient basis for stating that agriculture would ultimately not be affected negatively by the development at hand, thereby corroborating Hypothesis 1.

Still, Table 2 in this paper indicates that even under conditions of no change, especially no productivity drop ("None") and only a water cost increase ("A"), only a minority or even a small minority of farms can secure incomes comparable to those in industry. Since, however, this Table was a result of an *à priori* study and it was meant to indicate the policy path, an effort was undertaken to analyze the position of regional agriculture on the basis of actual data.

5.3 Factor analysis: correlations

Data was collected describing in an aggregate way the agriculture of 30 basic administrative units ("gmina," equivalent roughly to county) of the region. Of these 30, only 14 were to some extent touched by the direct effect of mining in terms of a drop in groundwater table. Thereby, a background control situation could be studied. Furthermore, the gminas considered formed a contiguous area, allowing a spatial analysis.

Each gmina was characterized by the following variables:

1. Agriculture intensity, an aggregate assessment in points (0–100), average for the years 1983–85, so as to get rid of climatic fluctuations.
2. Percentage of surface outside the groundwater decrease area; for 16 gminas this variable was 100%, for 12 gminas between 0 and 100%, and for 2 gminas it was 0%.

3. "Neighborhood distance"[1] from the mine, ranging from 0 (gmina where the mine and power plant are located) to 4 for the farthest gmina.
4. Share of agricultural land, in %.
5. Share of permanent grasslands in agricultural land, in %.
6. Soil quality, on the 0–100 scale.
7. Fertilizer use, in tons of NPK per ha.
8. Manure fertilization, in tons per ha.
9. Labor resources, in full time equivalents per 100 ha.
10. Traction power per 100 ha, tractors and horses.
11. Traction power per 100 ha, tractors only.

In the modest data analysis exercise undertaken for this data set, factor analysis was first performed. At the outset, a correlation matrix was calculated, as shown in Table 3. Then, Table 4 shows, for each row variable, ranks of other variables according to the absolute values of the correlation coefficients with the row variable, starting with rank = 1 for the column variable which has the strongest correlation with a given row variable.

On the basis of this Table, the following conclusions can be drawn:

- agricultural intensity clearly increases with distance from the mine;
- this can be mainly attributed to the fact that the share of permanent grasslands increases with distance from the mine, this share being negatively correlated with soil quality;
- furthermore, mechanization and/or traction power also increase with distance from the mine;
- on the other hand, the use of fertilizers slightly decreases with distance from the mine, but it clearly does not influence the intensity index;
- the influence of labor force resources, although quite low, amplified this picture since these resources slightly increased with distance from the mine and had a positive, though low, influence on the intensity of agricultural activities.

Two further phenomena should also be noted, namely:

- low, but negative correlation of the agricultural land share of the total land surface with the share of permanent grasslands in agricultural land;
- very high – 0.956 – correlation of total traction power with that for tractors alone (although the latter variable constitutes less than 72% of the former at the aggregate regional level), which means that substitution plays quite a secondary role here.

We shall come back to these conclusions later.

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[1]Calculated as follows: once distance 0 is allotted to a unit, those adjacent it are allotted distance 1, then all their neighbors distance 2,...

Table 3 Coorrelation matrix for variables describing agriculture subareras of the region considered.

Variable No.	2	3	4	5	6	7	8	9	10	11
1	.53	.67	.50	-.61	.62	.86	.53	.28	.60	.52
2		.67	.35	-.30	.29	-.12	.32	.24	.46	.40
3			.13	-.55	.42	-.29	.31	.22	.47	.31
4				-.30	.44	.20	.39	-.25	.47	.56
5					-.62	.34	-.18	.04	-.46	-.37
6						-.09	.58	.07	.67	.58
7							.06	.04	.02	.13
8								.17	.69	.69
9									.16	.03
10										.96

Table 4 Ranks of column-variable correlation coefficients with appropriate row variables. *- negative correlatio; **- correlation between -.25 and +.25; ***- both.

Variable No.	2	3	4	5	6	7	8	9	10	11
1	6	1	8	3*	2	10**	5	9	4	7
2		1	4	6*	7	9***	5	8**	2	3
3			8**	1*	3	6*	5	7**	2	4
4				5*	3	7**	4	6***	2	1
5					1*	4	5***	6**	2*	3*
6						4***	3	5**	1	2
7							2**	3**	4**	1**
8								2**	1	1
9									1**	2**
10										1

5.4 Factor analysis: factors

It was interesting to look at the factors in order to see whether their shape would corroborate previously formulated partial conclusions.

Two examples of factor analysis results are cited here, see Table 5. Both were calculated for the shortened set of variables, namely 9 out of the total of 11, where variables Nos. 4 and 11 were omitted. In the first case two factors, and in the second case three factors were sought.

Table 5 Two cases of factor analysis results. Asterisks denote the "factor-forming" variables.

Variables	Case 1		Case 2		
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 3
1	.74*	-.39	.63*	.52*	-.19
2	.44	-.44	.23	.72*	-.20
3	.45	-.76*	.29	.69*	-.51*
4					
5	-.41	.60*	-.53*	-.09	.68*
6	.71*	-.28	.85*	.06	-.28
7	.12	.44	.06	-.02	.50*
8	.80*	.09	.71*	.29	.22
9	.21	-.06	.07	.37	.11
10	.84*	-.15	.77*	.34	-.12
11					

For the sake of brevity, only a few results are shown. This portion, however, is quite sufficient to see full agreement with correlations discussed previously. Thus, in the first case, when two factors are established, they represent, verbally

Case

Factor 1: Intensity and soil conditions

Factor 2: Distance from the mine and permanent grassland share,

while in the second case:

Case

Factor 1: Intensity and natural conditions

Factor 2: Performance and distance from the mine

Factor 3: Distance from the mine, permanent grassland share and fertilizer use.

Hence, dependence upon the distance from the mine appears again to be related to grassland share. Looking at the results for Case 2, one can distinguish the following:

- agricultural intensity (1) is closely connected with grassland share (5), soil quality (6), manure use as fertilizer (8), and traction power available (10);
- on the other hand, (1) is also connected with distance to the mine (3) and groundwater drop (2);
- the linkage between those two is provided by the dependence of mineral fertilizer use (7) and grassland share (5) upon distance from the mine (3).

Three questions clearly arise:

a) is it really true that lignite deposits happen to be located in the local center of bad soils and grassland farming?

b) assuming this, to what extent does this explain the decline of agricultural intensity toward the mine?

c) how does this relate to the labor force analysis, whose results were presented before?

Before commenting upon these questions, let us take another look at the region

5.5 Cluster analysis

The same set of data was subject to several runs of cluster analysis as described, e.g., in Owsiński (1984). The runs were meant to reveal some of the geographical relations within the region.

First, runs were performed taking also into account variables 2 and 3, i.e., those related to distance from the mine. The results obtained indicated, obviously, such groups of gminas in the region that were to a large degree concentric with respect to the mine. Then, a number of runs were tried without these two variables. The optimum partition for one such run is presented schematically in Figure 2.

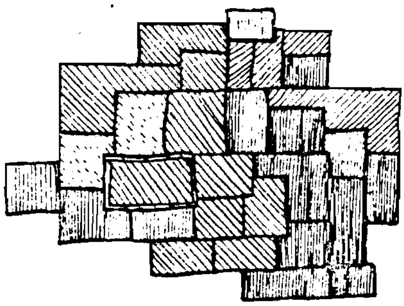

FIGURE 2. Results of cluster analysis for the run without dis-
tance-from-the-mine variables.
group 1 -
group 2 -
group 3 -
group 4 -
Double boundary denotes "gmina" in which [illegible]
located.

Thus, the results of cluster analysis clearly corroborate previous conclusions related to geographical shape of agricultural activity characteristics. These results provide a striking image of the spatial distribution of territorial units in the absence of variables expressing somehow the distance from the center of the mine.

Still, however, the question of the ultimate dependence is left unresolved.

6. Regression Analysis

A further step towards clarification was made with regression analysis, again using the same data set. The analysis was intended to yield only a qualitative insight into the structure of the phenomena. Thus, only linear models were tried. Their forms were as follows:

$$
\begin{aligned}
I_0 \cdot x_1 &= b_0 + b_3x_3 + b_5x_5 + b_6x_6 + b_{10}x_{10} \\
I_1 \cdot x_1 &= b_3x_3 + b_5x_5 + b_6x_6 + b_{10}x_{10} \\
II_0 \cdot x_1 &= b_0 + b_3x_3 + b_5x_5 + b_6x_6 + b_8x_8 + b_{10}x_{10} \\
II_1 \cdot x_1 &= b_3x_3 + b_5x_5 + b_6x_6 + b_8x_8 + b_{10}x_{10} \\
III_0 \cdot x_1 &= b_0 + b_2x_2 + b_3x_3 + b_5x_5 + b_6x_6 + b_8x_8 + b_9x_9 + b_{10}x_{10} \\
III_1 \cdot x_1 &= b_2x_2 + b_3x_3 + b_5x_5 + b_6x_6 + b_8x_8 + b_9x_9 + b_{10}x_{10}
\end{aligned}
$$

In addition, each software run was made in two variants: without elimination of variables appearing in the model, and with elimination of these variables, elimination being performed on the basis of a t-Student test critical value. Thus, it was in principle possible to obtain similar models for all cases with elimination of only those variables used in cases I_0 and I_1, i.e., those with highest correlation with x_1 (variables No. 2,5,6 and 10, see Tables 3 and 4) proved to be significant for the agricultural intensity model. This, however, proved not be the case, as can be seen from Table 6.

As indicated, the best results were obtained for cases I_0, II_0, III_0 with variable elimination. On the basis of these results, the following conclusions can be formulated:

- the decline of agricultural intensity toward the development center of the region is only partly due to the correlation with grassland share distribution, other variables having equal or even greater weight (see, e.g., variable 8, i.e., use of manure as fertilizer, which, surprisingly, influences variable 1 in the opposite direction to variable 5, grassland share); models imply a "disembodied" influence, not fully contained in the variables used;
- model of III_0 with elimination clearly indicates the influence of labor force resources, equaling that of the grassland share, corroborating the findings of labor force analyses, commented upon previously.

Case / Variable no.	I_0 No. elim.	I_0 Elim.	I_1 No. elim.	I_1 Elim.	II_0 No. elim.	II_0 Elim.	II_1 No. elim.	II_1 Elim.	III_0 No. elim.	III_0 Elim.	III_1 No. elim.	III_1 Elim.
C	55.109	51.695	-	-	53.496	55.21	-	-	43.72	49.98	-	-
3	1.725	2.092	2.354	3.302	1.602	1.593	2.691	2.704	1.163	1.39	1.531	1.722
5	0.116	-	0.849	0.895	- 0.227	- 0.276	0.617	0.615	- 0.274	- 0.306	0.237	0.246
6	0.177	0.321	1.008	1.168	0.063	-	0.777	0.781	0.059	-	0.542	0.533
10	0.163	-	0.250	-	0.026	-	0.0189	-	- 0.005	-	-0.0336	-
8					0.452	0.538	0.7501	0.766	0.443	0.510	0.639	0.627
2									0.016	-	0.135	-
9									0.259	0.274	0.868	0.875

Table 6 Coefficients of the agricultural intensity for 12 cases considered. All models were significant. Lowest significance was for case "III_1. No elimination", and generally for cases I_1, II_1, and III_1 without elimination, while the highest was for case "I_0 Elimination", and generally for cases I_0, II_0, III_0 with elimination. The lowest error value was obtained for "III_0 Elimination".

Concluding Remarks

In a complex regional setting, contradictory justifications and arguments can be raised regarding a development undertaking and its consequences. For the sake of regional sustainability, especially when such an undertaking is important for the region, influences, if not necessarily causes and effects, have to be clarified. Only then can really rational long-term policies be formulated.

The case considered here is a clinical one. The institutional setting around the development in question has generated certain hypotheses, research results and policies. Our study indicates that these constitute only a partial response. The situation is illustrated by Table 7 below.

Table 7. Research and policy generation situation for the case considered.

Area	Research	Policy
Environmental protection	Abundant	Partly adequate
Capital needs vs availability	Little	Partly adequate
Labor force	Little	Inadequate

In order to ensure sustainability of this region, proper policies should be generated and implemented aiming at the mechanism causing agricultural decline around the mine.

4.8 IMPROVEMENT OF THE ORGANIZATIONAL STRUCTURE FOR MANAGING THE NATIONAL ECONOMY OF A UNION REPUBLIC TAKING INTO ACCOUNT TERRITORIAL AND BRANCH INTERESTS*

B.S. Bairiev and N.S. Kozerskaya
Central Economic and Mathematical Institute
of the Academy of Sciences of the USSR
Moscow, USSR

The intensification of development of the national economy of a republic, the aggravation of the problem of rational, comprehensive utilization of all kinds of resources, the smoothing out of the levels of economic and social development of various regions call for substantial improvement in the organizational forms of management. "It is high time to start improving the organizational structures of management, to eliminate superfluous links, to simplify the apparatus, and to raise its efficiency."[1]

A considerable improvement is obtained by a rational location of the facilities of various branches in one territory – the territorial and production complexes (TPC). However, the organization of management of the territorial and production complexes at present leaves much to be desired. It is necessary to have a rational pattern of organizational structure of management (OSM) of the complex, optimally economically effective TPCs, the MPCs (multibranch production complexes), and also of the State Planning Committee and the Council of Ministers of the Republic. Here under OSM we mean the totality of subsystems interacting with each other, forming a single whole for the achievement of planning targets.

Proceeding from the long-term goals of managing the national economy, the rapid change of technological processes, the means and methods of management taking place under the impact of the scientific-technical progress, and the optimal combination of branch and territorial interests, it is planned to include the following complex of models into the system of the long-term planning of a republic (Figure 1).

Let us explain Figure 1. The first task in improving the organizational system of management of the national economy of a republic is elaboration of the scheme of development and location of productive forces of the republic, which must include a comprehensive assessment of the natural and socioeconomic prerequisites for further development and location of productive forces: environmental protection and rational utilization of natural resources, and also the principal directions of production specialization and comprehensive development of the economy, including location of the productive forces of the republic. In particular, the issue must be resolved concerning the rational direction of economic development of the territory and formation of the system of TPC of the

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[1]Materials of the Plenary Meeting of the CPSU Central Committee, Moscow, Politizdat Publishers, 1985, p. 12.

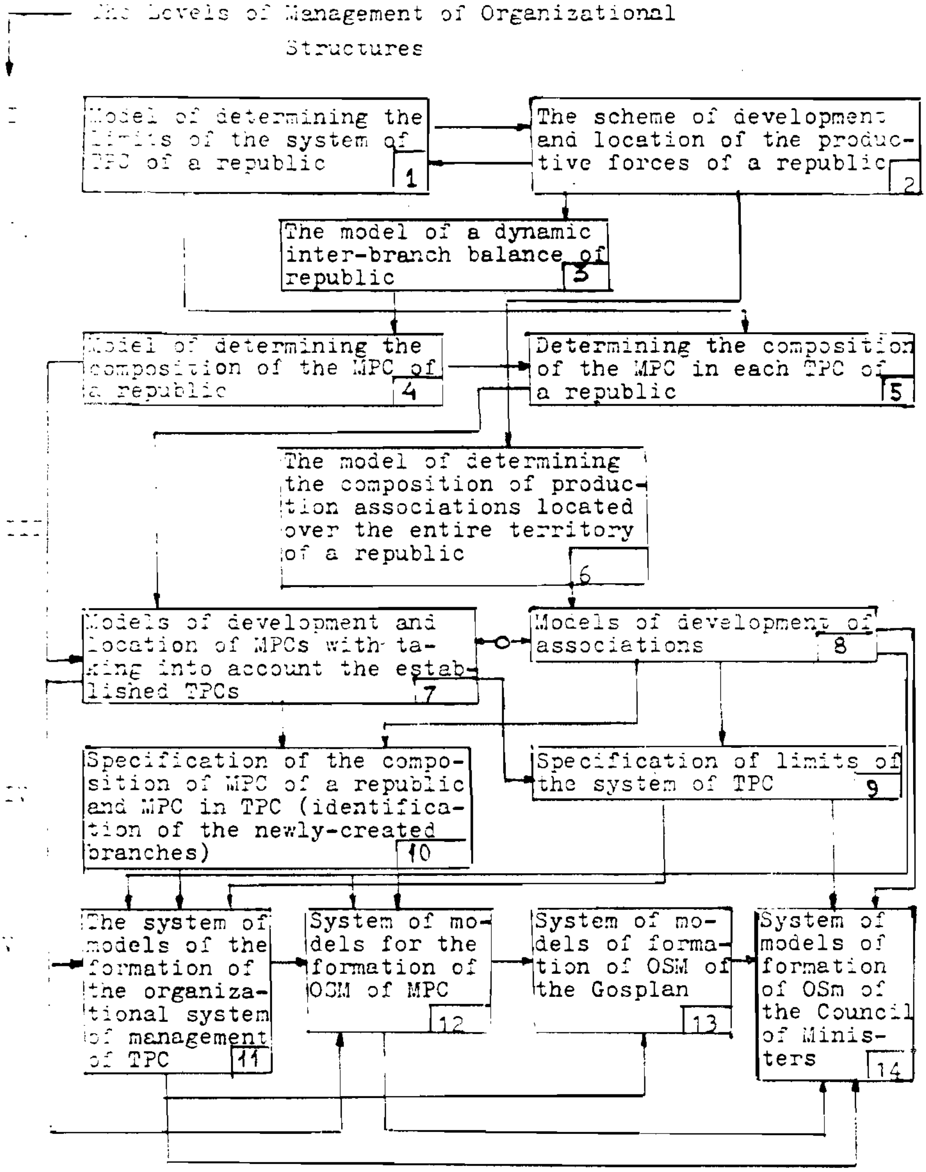
The Levels of Management of Organizational Structures
I
Model of determining the limits of the system of TPC of a republic 1
The scheme of development and location of the productive forces of a republic 2
The model of a dynamic inter-branch balance of republic 3
III
Model of determining the composition of the MPC of a republic 4
Determining the composition of the MPC in each TPC of a republic 5
The model of determining the composition of production associations located over the entire territory of a republic 6
Models of development and location of MPCs with taking into account the established TPCs 7
Models of development of associations 8
Specification of the composition of MPC of a republic and MPC in TPC (identification of the newly-created branches) 10
Specification of limits of the system of TPC 9
V
The system of models of the formation of the organizational system of management of TPC 11
System of models for the formation of OSM of MPC 12
System of models of formation of OSM of the Gosplan 13
System of models of formation of OSm of the Council of Ministers 14

Fig.

union and republic. Here the task of determining the system of TPC is most important at each stage. The solution of the task of determining the limits of the system of TPC is implemented on the basis of evaluation of labor, land, water, raw material, fuel, energy resources, transport conditions, construction, the existing locations of economy and population, the possibilities of cooperation, combination and economic purpose of production concentration. If limits of the system of TPC do not coincide with the administrative frontiers, then the latter should be revised so that the compact single economic task would be resolved within the limits of one administrative unit, according to a single plan, with a single management.

At the second level the task of building a dynamic interbranch balance of the republic is being resolved. Here one should take into account both the development of the existing branches and the emergence of new branches. If the solution of that task at the second level is difficult, then for the solution of subsequent tasks (in particular, the task of determining the composition of the multibranch production complexes (MPCs)), it is possible, in our view, to make use of the reports of the interbranch balance of the republic with the subsequent solution of the task of identification for the newly-created branches.

At the third level, on the basis of the results of the solution of the tasks for the first two levels, issues are considered concerning the improvement of the branch structure of the national economy of the republic. In the final analysis the sectoral structure must be such that the efficiency of management should increase in the branch pattern and coordination of the territorial and branch interests should be improved.[2]

In the multilevel system of management, coordination can be simple, if the number of agreed-upon reciprocal ties diminishes. For example, at present to increase the efficiency of enterprises manufacturing and processing agricultural products, regional and district agro-industrial associations have been created. However, these associations for the adoption of managerial solutions should coordinate their activities with all ministries to which the enterprises are subordinated. The relevant integration of branches and the setting up of the organ coordinating the activity of the entire agro-industrial complex of the republic will result, in our view, in a considerable improvement of coordination of territorial and branch interests. This was especially emphasized at the April Plenary Session (1985) of the CPSU Central Committee: "Under the impact of departmental interests, district and regional associations very often cannot in due measure agree upon and resolve the issues of comprehensive development of agriculture and the branches connected with it ... measures should be carried out, which will make it possible to manage, plan and finance the agro-industrial complex as a single whole at all levels."[3] A similar conclusion can be reached in this respect in regard to other multibranch complexes.

The efficiency of the system of management of the multibranch complexes will largely depend on the correctness of its structure, that is, the sectoral composition. Therefore, at the third level, using the results obtained in the solution of the tasks of the first two levels, and the qualitative interconnections of branches of the national economy of the republic, it is necessary to resolve the task of optimization of the sectoral structure of the multibranch complexes.

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[2]The coordination of the activity of a subsystem of a higher level is aimed at the coordination of the reciprocal ties between the subsystems at a lower level.

[3]Materials of the Plenary Meeting of the CPSU Central Committee, Moscow, Politizdat Publishers, 1985, p. 14.

The results of location of the productive forces, the determination of the limits of the system of TPC and composition of the multibranch complexes make it possible at this level to determine which multibranch complexes should be developed in each TPC of the republic. In certain cases, the location of raw material resources, the branch reciprocal ties in the production of a certain type of product and so on call for the creation of associations of production facilities located in the entire territory of the republic. The task of determining the composition of such associations is also being resolved at the third level.

At the fourth level, we practically determine the space and production structure of the republic for the years to come, and the development and location of the multibranch complexes and the development of associations taking into account the established TPCs. According to the results of these tasks, specifications are made of the limits of the systems of TPC, composition of the MPC of the republic and the composition of the MPC in each TPC.

The results obtained at the levels III-IV make it possible to carry out the tasks of molding the organizational structure of management of TPCs, MPCs, the State Planning Committee and the Council of Ministers of the republic. The result of resolving the entire range of tasks of a given system is the structure of management of the national economy of the republic, proceeding from the long-term aims of a given region, formed on the basis of combining branch and territorial principles of management. To determine the efficiency of the system of managing the national economy of the republic synthesized in conformity with the need for development and location of productive forces, and also for determining the dynamics of achieving the set goals, it is necessary, in our view, to build a complex of simulation models of development of the republic's economy.

4.9 BIO-RATIONAL SYSTEM OF FARMING IN THE LITHUANIAN SSR (USSR)

A. Onaitis
Assistant Director of the Lithuanian Order of the
Red Banner of Labour Research Institute of Agriculture
Kaunas, Cirionys
Lithuanian SSR, USSR

The Lithuanian SSR occupies an area of 65,200 sq km, i.e. 6,520 thousand hectares, 3,683.9 ha of which is farm land. Soil and climatic conditions of the Republic are characterized by a great diversity and by a gradual change from west to east.

In the western zone of the Republic covering the Pajuris Lowland and the Žemaitija Upland, winters are moderately cold with frequent thaws, rather cold springs and summers, rainy and long-lasting autumns. The mean annual precipitation varies from 700-900 mm. The sum of temperatures higher than 10°C totals only 1900-2000°. Mineralization of organic matter is hindered in this region. The soils are subjected to rather strong and persistent leaching. The following soils prevail in this zone: sandy soils, sandy loam, loamy soils underlying clay derno-podzolic, derno-podzolic-gleyic, acid soils satiated with mobile aluminium. Intensive farming is hindered if they are not limed.

In the central zone of the Republic running from North to South occupying the Central Lithuanian Lowland, the climate is more continental. In its northern part mean annual precipitation is only 500-600 mm. The sum of temperatures above 10°C totals about 2100-2200°. Water percolates into the soil about 240-250 days per year. In its southern part, about 600-700 mm of precipitation fall, and the water percolation period is 250-260 days. During this period the sum of positive temperatures (higher than 10°C) totals 2200-2400°. In the Southern part of this zone, the vegetation period is nearly two weeks longer than in the Northern part. The following soils prevail: derno-calcareous, derno-gleyic, slightly leached or podzolized, mainly loamy soils, drained with closed drainage. In the central zone the most intensive farming takes place, and the majority of crops are concentrated there. On drained soils, the efficiency of fertilizers is quite high.

In the Eastern zone of the Republic occupying a hilly Baltic Highland and zandric plains, climatic conditions are more continental: winters are snowier, summers are dry and often cool. The mean annual precipitation is about 600-700 mm. The period of water percolation into the soil is 230-240 days; in the Southern part this period is 240-260 days. In the Northern part the sum of positive temperatures (higher than 10°C) is about 2000-2200°, in the Southern part it is 2200-2400°. In the hilly part of the zone, the following soils prevail: eroded sandy loam, loamy soils, skeletal and bouldery soils on the slopes and tops of hills, and marsh-ridden, often peaty soils in the lowlands. In zandric and other plains, dernopodzolic, sandy and sandy loam, prevail often underlying loam, acid

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soils. Mineral fertilizers are highly effective in this zone.

Lithuanian SSR according to its soil-climatic conditions of farming is divided into three zones: Eastern, Central and Western. Agricultural production is organized accordingly.

Because of close interaction of the factors controlled by man, as well as active action of meteorological factors, the farms in the Eastern zone in 1971-1975 produced 15.1, 1976-1980 - 15.1, and 1981-1985 - 18.8 centimeters of plant-growing material annually from a hectare of farming land. In the farms of the central zone the production was the following: 25.1; 27.2; 31.6 centners, and in the farms of the western zone it made up to 14.4; 16.8; 20.1 centners. To one hectare of farming land, 180 kg of nutrient matter NPK mineral fertilizers and 12 tons of organic fertilizers are applied to one hectare of ploughed land. From organic fertilizers, the balance of nutritional matter is replenished by 95-100 kg/ha of NPK. Mineral NPK fertilizers are replenished in the following ratio: 1:0, 4-0, 5:0, 8-0, 85.

As has already been mentioned, derno-podzolic loams and sandy loams deficient in organic matter and in mobile phosphorus prevail in the republic. 28.9% of all soils are very poor in phosphorus. Average provision with phosphorus reaches 11.3 mg in 100 g of soil On the soils of this type, phosphorous fertilizers are very effective, but their deficiency makes up about 20-30%. The provision of crops with nutrient matter makes up only 80% of its need.

Besides, 26.6% of soils in the Republic have a level of acidity which reaches pH 5.5 and less. Liming is very useful on such soils. In the farms of the Republic, more than 200 thousand hectares of acid soils are limed every year. An effective liming system for acid soils was worked out and introduced into production. On the whole area of farm land, an intensive production of plant production as well as of animal husbandry is carried out. In 1986, a year of not very favourable meteorological conditions, the yield of grain crops was 26.4, of potatoes 176, and of sugar beet 259 centners per hectare.

The level of milk production in 100 hectares of farming land is higher than 800 centners, of meat 200 centners. In 1986 76.2% of the winter crops were grown according to intensive technologies in our republic, the average yield of which made up 29.2 centners per ha, 94% of sugar beet, the yield of which was 263.5 centners per ha, 38.5% of potatoes the yield of which made up 202 centners per ha and 68.1% of long-stalked flax, the yield of which was 4.8 centners per ha of fibre.

Intensification is carried out through the improvement of zonal systems of farming, a great part of which occupies improvement of plant nutrition and protection of the surroundings from pollution with chemical materials.

In the process of intensification, not only the problem of yield increment of agricultural crops is studied but also the problems of getting the required amount of protein, carotin, amino acids and carbo-hydrates, as well as the study of ecologically and economically grounded norms and rates of chemical measures, in which fertilizers occupy the leading role.

It is important to note that in 1986 owing to the means and measures of intensification, a notable stability of the yields of grain crops, perennial grasses and sugar beet was revealed. During the last three years, the efficiency of fertilizers was stabilized. In 1983 from 1 kg NPK 4.24, in 1984 - 4.85, in 1985 - 4.59 kg, and in 1986 - 4.7 kg of produce was obtained. The greatest efficiency - 5-8 kg from 1 kg of NPK occurred, where yielding capacity was highest. The efficiency of fertilizers depends not only on the removal of nutritional matter by the plants but also on the influence of a whole complex of factors.

The system of fertilizer application as a component of the whole eco-rational system of farming was worked out for the programmed yield. It consists of organic (application of organic fertilizers) and mineral (application of mineral fertilizers) parts. In the soils of the Republic, the organic - mineral system of plant nutrition is most effective in intensive technologies. In trials carried out on light according to their mechanical composition during two rotations, organic fertilizers secured a yield of 60,400, mineral fertilizers a yield of 64,200, mineral and organic fertilizers together 68,600 of fodder units per ha. Application of mineral and organic fertilizers secured the greatest efficiency of fertilizers and the required safety of the surroundings.

Summing up, with a great number of trials with fertilizers, it was determined that fertilizers among the whole complex of intensification factors, depending on the level of intensity, give the greatest part of grain yield increment (Table 1). But fertilizers alone are not so effective without the interaction of other factors. Thus, fertilizers should be distributed in such a way that they would give maximum yield increment and would secure the safety of the surroundings.

Table 1. Grain yield increment due to the action of different factors of intensification.

No.	Title of the factor	Agricultural crops and the level of yield centners per ha							
		Winter Wheat		Winter Rye		Spring Barley		Oats	
		30	50	25	35	30	45	30	40
1.	Crop rotation and precursors	12	12	11	5	10	10	8	8
2.	Soil cultivation	12	5	15	9	12	10	10	10
3.	Fertilizers	25	25	30	30	25	25	22	22
4.	Sowing time, rate and seed introduction depth	11	5	5	7	10	10	12	15
5.	Seed variety and quality	11	12	8	8	12	15	12	15
6.	Chemical and mechanical weed control	9	1	5	5	11	8	10	8
7.	Pest and disease control	15	14	12	15	13	15	15	15
8.	Chemical measures against lodging	0	10	8	13	0	0	0	0
9.	Harvesting	5	6	6	8	7	7	11	7

Distribution of fertilizers for the programmed yield is carried out through the plans of fertilizer application which are compiled by electronic calculating machines, separately for each farm of the Republic. Distribution of fertilizers begins from the distribution of the resources of organic fertilizers and of the supply of mineral fertilizers for the regions, farms and fields of crop rotation. The main principles of the distribution of the supply of mineral fertilizers are the following:

1. About 3% of a yearly fund of fertilizers is left in the reserve of Agroprom of the Republic and is meant aas help for economically weak regions, for some specialized farms and farms which suffer natural calamities.
2. For crops of state importance, fertilizers are alloted at optimum rates, recommended by the Lithuanian Research Institute of Agriculture and the research station of agriculture in order to get the programmed yield.
3. In order to increase soil fertility and to reach the greatest efficiency of fertilizers, additional amounts of fertilizers are alloted to the soils poor and very poor in mobile phosphorus and in exchangeable potassium.
4. The main part of the fund of fertilizers is distributed among regions; in regions it is distributed proportionally to the nutrient matter removed with an average yield of plant-growing produce during the last three years.

In order to improve the conditions of expanded productivity, according to the method, limits are determined for all the farms of the Republic, which guarantee the minimal amount of fertilizers for them. According to these limits, not less than 45-50 kg of nitrogen are alloted for one hectare of farming land. Phosphorous and potassium fertilizers are alloted according to the ratio of nutrient matter in the republican fund of mineral fertilizers.

The distribution of the supply of mineral fertilizers according to these principles leads to a reduction of the differentiation of regions and farms according to the amount of applied fertilizers, it also improves the ratio of nutrient matter, secures an increase in the level of their assimilation by plants and minimizes the possibility of environmental pollution.

The following distribution of fertilizers increases the efficiency of mineral fertilizers on average by 5% and the productivity of one hectare to 33 fodder units. This helps increase the yield by 117 thousand tons and helps to avoid negative consequences of environmental pollution with nitrates and nitrites.

The next stage in rational distribution of fertilizers for the programmed yield is to work out plans for fertilizer application. This is done in the following way:

On the basis of data on mineral fertilizer applications, the structure of the sowings, results of agrochemical soil inspection, precursors and sequence of crops, fertilization plans are worked out for all farms in the Agrocalculating Centre of the Republic. The Centre distributes soil fertilization plans to farms, in which the rates of fertilizers are indicated for each crop and for equally fertilized plots. This plot must not necessarily coincide with the field of crop rotation, but it must be sown with one crop and have clearly expressed contour boundaries.

In the field, fertilization plans according to the reference calendar application of fertilizers is planned in two periods: spring and autumn. In connection with this, the supplies of fertilizers are divided into two main groups - for spring and autumn application.

Mineral and organic fertilizers are distributed according to average, but not maximum and minimum rates (manure - 40-60 tons per ha) drawn up for every agricultural crop. Depending on soil conditions (Table 2) average rates are adjusted accordingly. The correction coefficient for irrigated soils is as follows: nitrogen fertilizers - 1.3; phosphorous fertilizers - 1.1, and potassium fertilizers - 1.3. In order to avoid environmental pollution with nitrates and nitrites, the rates of nitrogen fertilizers for spring feeding of winter crops are specified according to the results of soil and plant diagnostics. For this reason when vegetation is renewed, soil samples are taken from a depth of 60 cm. The samples are analysed by the central research station for the Republic. Information about specified rates is disseminated by teletype. For the correction of rates of nitrogen fertilizers for subsequent feeding, plant samples are analysed by the "Indam" method. Nitrogen fertilizers at rates higher than 60 kg/ha of nitrogen are applied two to three times. Thus the possibility of nitrate accumulation in water and in other parts of the ecological environment is eliminated.

Table 2. Correction coefficients of the rates of fertilizers depending on soil conditions.

Soil indices		Type of fertilizers		
		nitrogen	phos-phorous	potassic
Groups according to the content (in numerator - $-P_2O_5$, in denominator - $-K_2O$)	I		1.4/1.3	1.3/1.4
	II	-	1.0/1.1	1.2/1.2
	III	-	0.7/0.9	0.7/0.7
	IV	-	0.6/0.7	0.7/0.7
	V-VI	-	0.5/0.6	0.5/0.6
Mechanical composition:				
sand		1.2	0.8	1.2
sandy loam		1.0	1.0	1.0
light loam		0.9	1.1	0.9
average and heavy loam		0.8	1.2	0.8
bog soil		0.9	1.1	1.0
Acidity level pH	4.5	0.8	0.8	0.9
	4,6-5.5	1.1	0.9	1.2
	5.6	1.0	1.1	1.0

Fertilizers feed the weeds as well as the crops. So plant nutrition is integrated with weed, pest and disease control. In the institute, trials are carried out to determine the critical period of competition between crops and weeds, i.e., to determine the period at which crops are most susceptible to weeds, at which weeds require only small applications of herbicides, at which herbicides must be applied and when herbicides can be dispensed with. In these trials, the effectiveness of integration of agrotechnical, chemical and organizational measures is revealed.

Critical periods of weed and crop plant competition have been determined in four integrated situations, including different combinations of sowing rate (2 and 4 million per ha grains) with fertilizers ($N_{90}P_{60}K_{60}$) and without fertilizers. The results of the trials have shown that for soils heavily infested with dicotyledonous weeds, particularly in years with anomalous weather resulting in late sowing, for example, the weed susceptibility of barley (Nadia, Ida, Gintariniai) begins to manifest itself from the 2-3 leaves stage till shotting stage (from 10-20 to 30-40 days after sowing). During this most critical period, the intensive precautions must be taken.

In not so heavily infested soils, the critical period is considered to be from the bushing-out stage to the shooting stage (30-40 days after sowing).

In the thick sowings of these trials (4 million per ha), weeds made up 44-48%; in thinner sowings (2 million per ha) 57-62% of the total number of plants. The conclusion can be drawn that a thick sowing decreases the weed population and thus produces a more abundant yield without additional chemical measures.

According to the data of the trials carried out in our institute, spring barley sown on the tenth of April secured a yield of 54.4 centners per ha. When the barley was sown 15 days later, the number of weeds doubled and the yield of barley was 3 centners less. Barley sown on the 10th May yielded only 40.6 centners per ha or for 14 centners less than the yield of early sowing.

This example shows that by means of precise and timely agrotechnical measures, optimal yield can be secured with a minimal amount of chemical control or even without it.

It is important to note that according to mean data of the XIth five- year period, the increase in yield due to fertilizers was 25-30%, due to biologically active chemical measures of weed control, biological stimulation and regulation of plant growth was 15-20%, and due to introduction of new, more intensive varieties was 12-15%

The conclusion can be drawn that plant-yield intensification measures and measures of environmental contral are practiced in our Republic in an integrated way. This increases their effectiveness and helps in the solution of problems raised by the Food Programme.

4.10 PATH STUDIES OF THE DEVELOPMENT OF AGRICULTURAL PRODUCTION IN THE FEDERAL REPUBLIC OF GERMANY: SYSTEMS ANALYSIS, SCENARIOS, AND COMPREHENSIVE IMPACT ASSESSMENT

Hartmut Bossel
Environmental Systems Analysis Group
University of Kassel
D-3500 Kassel, F.R. Germany

1. Introduction

The objective of the study "Technology Assessment of Alternative Agricultural Production Paths" was the development of a systems analytic instrument suitable for agricultural policy development. The study was commissioned by the West German Federal Parliament (Bundestag). The instrument was designed to assess the bandwidth of the possible development paths of agricultural production in West Germany and of its agricultural, ecological, economic and social consequences under the influence of new technical and agricultural policy developments over a time period of several decades. (The term 'technology assessment' was used in a wider sense to include general policy assessment)

The study therefore had two major objectives:

1. The development of a method of technology assessment for agricultural production.
2. Application of the method in a sample study in order to assess its usefulness

The following is a condensation of the essential results with respect to the following aspects:

- the essential components of technology assessment, especially with respect to agricultural production
- the elements of the instrument and their linkages
- the purpose of the technology assessment
- critical evaluation of the method
- recommendations for further development
- application of the method to three development paths of agricultural production
- preliminary results.

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2. The Essential Parts of a Technology Assessment Study

A technology assessment study for a complex system requires four distinct components:

1) A **systems description** appropriated to the given problem, which must contain all significant system elements and their causal linkages. Normally, the system structure will be translated into a computer simulation model which allows computer simulation.

2) A complete description of the **initial system state** i.e. the initial conditions necessary for starting the calculations.

3) **Scenarios** for the temporal development of external influences over the time period considered. Of necessity, the scenario data will consist of (mutually consistent) assumptions concerning plausible and likely development conditions. Several scenarios characterized by different guiding aspects should cover the total spectrum of possible exogeneous influences in order to assess the resulting consequences and developments.

4) A **criteria system** based on the viability requirements of the system considered, which will be used for comparative evaluation of the different development paths.

3. The Components of the Method and their Linkages

The basis for the assessment approach is the description of a prototype farm by the sum of tis individual processes of plant and animal productionn with their respective material and monetary inputs and outputs. Prototype farms are defined for each productionn region; their development over the time period under consideration is controlled by region-specific scenarios. By aggregating the farm data to the region and finally to the nation, the corresponding regional and national indicators of agricultural productionn and their consequences (e.g. for food productionn and environment) are obtained. The production results are compared with the food demand resulting from the populationn development and nutrition scenarios. The final results are evaluated using a comprehensive set of evaluation criteria, which are chosen to reflect the national supply security and viability interests. We give a brief description of the components of the system model and of their linkages:

Production processes: 23 different processes of plant productionn and 5 different processes of animal production are presently implemented. These also include identifiable future developments (e.g. renewable resources). Each of these processes in characterized by some 30 parameters describing the specific material and monetary inputs and outputs. Since each of these processes can be operated at different levels of intensity, 5 different intensity levels are defined and applied to most processes. For each of these intensity levels the corresponding input and output parameters are defined for each productionn process on the basis of empirical data. It is assumed that these technical and monetary data change with time, and corresponding scenarios for the temporal development are incorporated in the method.

Description of farm prototypes: The regional prototype farm is described by a region-specific mix of productionn processes (and region-specific intensities of productionn) (Figure 1). The data of the prototype farm are defined to be as close a possible to the data of the official agricultural statistics (Agrarbericht 1984 and other sources). These initial conditions are assumed to change with

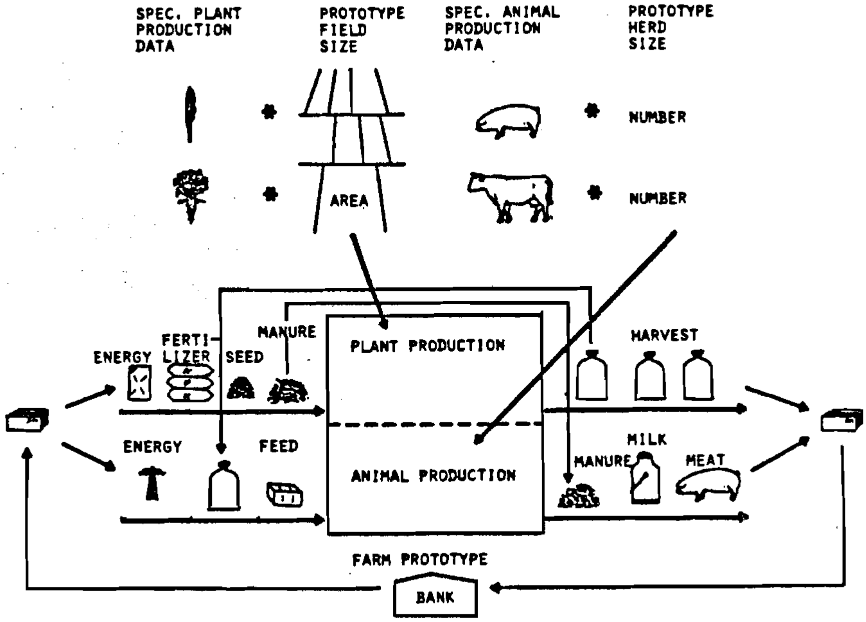


Figure 1 Representation of regional prototype by its productionn processes

time, where the changes in the type and the amount of productionn of each of the prototype farms is laid down in scenarios. At the farm level the material, monetary, ecological etc. consequences of the corresponding agricultural productionn are computed via some 110 intermediate variables, among them a set of indictor variables which are used to evaluate the current system state of the regional farm prototype. The most important results are recorded by some 75 state indictors for each scenario point in time (every 5 years).

Regional productionn: The production results for each agricultural region follow by aggregation of the data of the regional prototype farm via the regional number of farms and the regional agricultural area. The results are collected in some 35 state indicators.

National productionn: The national production data are obtained by summation of the regional data over all of the 15 agricultural regions.

National food demand: The demand for food products is computed via the population development and considering age-specific food consumption data. The results are very much dependent on the scenario assumptions for the average national diet (Figure 2). Comparing these demand data with the productionn data leads to specific hints concerning productionn deficits or surpluses to be expected.

Evaluation method: The results of the computations of the state indicators on the regional and national level are compared to a set of evaluation criteria which were selected to allow a comprehensive assessment of the development with regard to the food supply, and the viability of farms and of society.

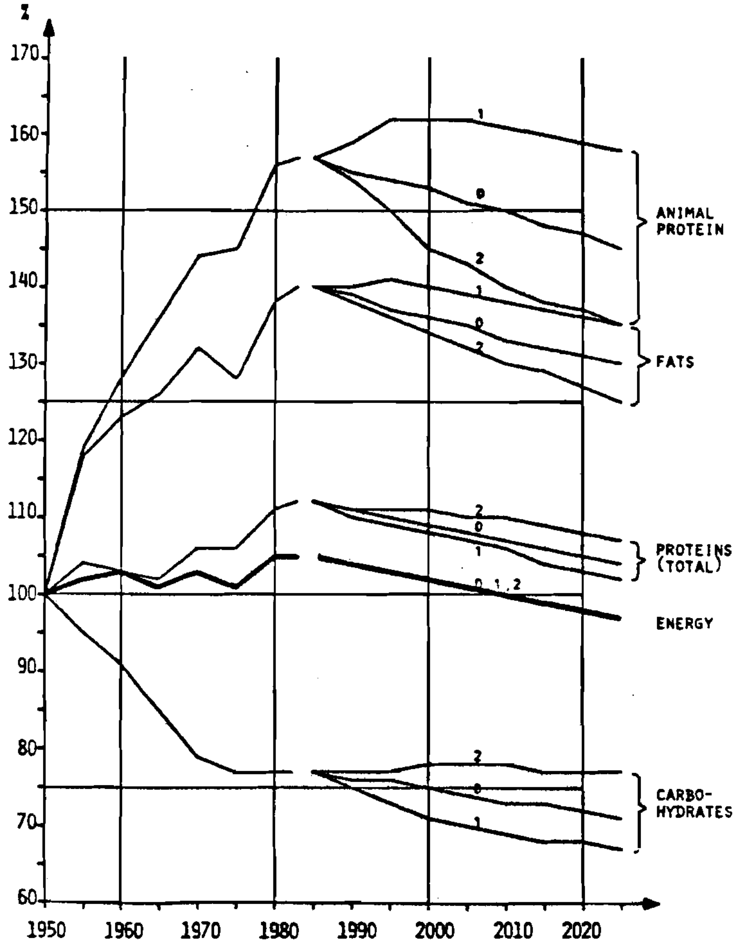
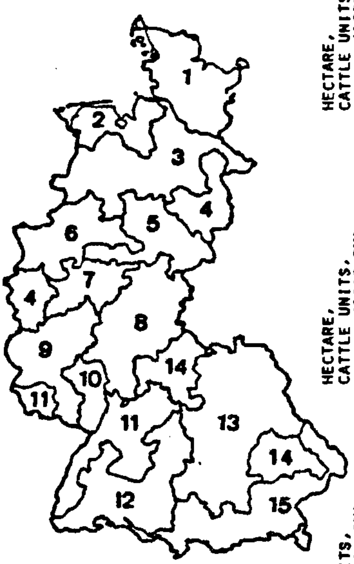


Figure 2 Development of specific food consumption (FRG)

4. Application of the Method

The application of the method requires several preparatory steps:

Regional disaggregation: In order to be able to consider the regional differences based on the natural and historical development in the Federal Republic of Germany, the total agricultural area is disaggregated into 15 agricultural regions (Figure 3, Figure 4). These regions were obtained by aggregation of some of the 42 agricultural areas of the official agricultural statistics. For each agricultural region the initial data of prototypical farm were defined on the basis of the data of the agricultural statistics and other sources.



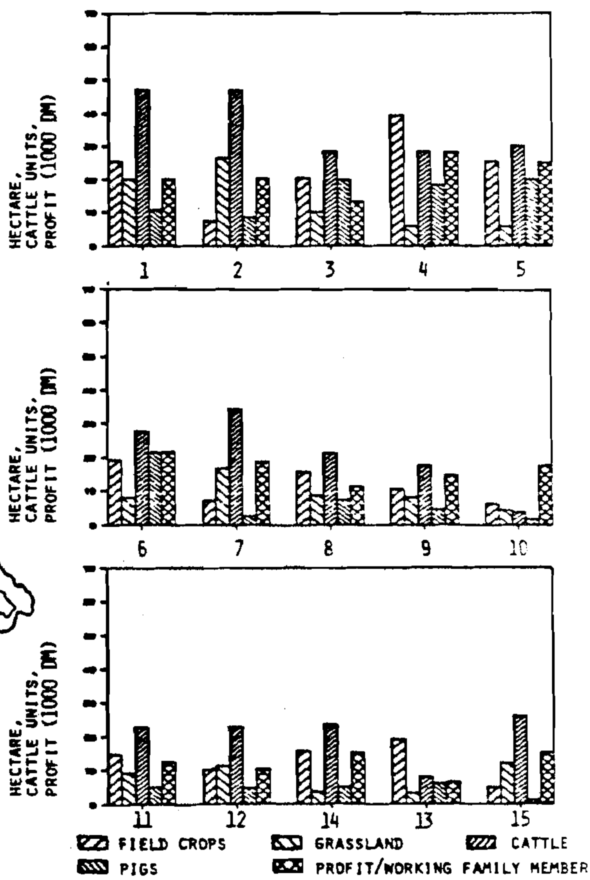


Figure 3 Agricultural Production Regions of the Federal Republic of Germany

Figure 4 Regional Farm Structure in the Federal Republic of Germany

	Scenario A	Scenario B	Scenario C
GRAIN	--	-	-
RAPE SEED	-	+	+
LEGUME CROPS	-	+	+
SUGAR BEETS ETC.	-	O	-
RENEW. RESOURCES	++	+	O
FEED CROPS	-	O	+
GRASSLAND	-	O	+
FALLOW AREA	++	+	O
CATTLE	--	O	-
PIGS	+	O	-

LEGEND:
++ STRONG INCREASE
\+ SMALL INCREASE
0 NO CHANGE
\- SMALL DECREASE
-- STRONG DECREASE

Figure 5 Production trends in the 3 scenarios
(A - Intensification
B - Business-as-usual
C - Ecological)

General development scenario: In order to describe the systemic alternatives and their consequences, the spectrum of the possible external developments (technical progress, agro-economic conditions and agro-political policies) must be collected in corresponding plausible and consistent scenarios. We collect the most relevant development perspectives in three scenarios (A - 'intensification', B - 'business-as-usual', C - 'ecologization') (Figure 5).

Technical scenarios: The verbal scenario descriptions have to be translated in corresponding quantitative parameters or time functions to allow computation. For the technical and economic parameters, identical conditions were assumed for all of the regions for a given scenario.

Regional scenarios: For the regional farm development, certain parameters must be quantified and specified specifically for each region and for each scenario (farm production area, volume of each production process, introduction of new processes etc.).

Following the prescription and quantification of the scenario assumptions, the temporal developments of production data and production consequences are computed for each regional prototype, aggregated to the region al and national level and compared to the demand data, and finally evaluated using the comprehensive set of criteria.

Purpose of the Technology Assessment: The Description of the Development Spectrum

There are certain limits of application to the method which should be mentioned. The **technology assessment** developed here is **not a forecasting method**. Its sole **purpose** is the identification of the **spectrum of possible future development paths and their likely consequences**. The approach used can only be used for crude assessments at the level of the individual agricultural region and can therefore not be used for regional detailed analysis, unless several regional prototypes are introduced. In addition, the approach can only be used to obtain crude estimates concerning the future situation of the different production processes. More exact results could be obtained by more detailed analysis. Finally, not much weight should be attached to the monetary calculations at the farm level, at the regional level and at the national level, because price and cost data can only be estimated with very great uncertainty. However, these analyses should provide relatively accurate assessments of problem areas to be expected in the future.

On the whole, the technology assessment should be judged in the same way one looks at a good cartoon:

The important point is not the precision of the description but the validity of the results. We hope to have reached a reasonable compromise for dealing with a complicated problem.

6. Critical Evaluation of the Method

We do not restrict our use of the word 'technology assessment' to merely the technical aspects of agricultural development. Rather, we also include the corresponding organizational, agro-political, economical etc. developments.

The validity of the technology assessment approach for agricultural production is judged by us to be as follows:

1. The approach is **structurally valid** for the resolution given (farm level, regional level, national level). Structural validity follows as a consequence of the approach, which is based on the real system structure.
2. The **behavioral validity** of the examples computed by us so far is problematical, since behavioral feedbacks were not included in the assessment. This aspect can easily be improved by changing the instrument used (i.e. interactive scenario development and impact assessment, working in timesteps). This is possible without changing the instrument.
3. The method does not produce forecasts, but it rather describes developments which can be expected in response to certain external conditions. No assessment of the probability of these conditions is made.
4. The **empirical validity** is assured by basing the technology assessment on the material flows in the system. However, there is some need to improve the consistency of the data set, which had to be collected from different sources. However, the empirical validity of the monetary factors is a fundamental problem, and not peculiar to the present approach.
5. The assessment approach is characterized by the fact that it is based solely on real farm level data (i.e. material flows). Therefore, there is no need for parameter estimation (by statistical correlations, or regression analysis) of data which have no real counterpart.

6. Using the farm structure as the basis of the approach means that the instrument is more transparent, more easily changeable and testable and that the real parameters used can easily be replaced by more accurate values.
7. The instrument provides **application validity**, since the consequences of arbitrary scenarios can be computed and can be evaluated by applying user-specific criteria weights. The characteristic consequences of different production alternatives and of their impacts on the development of the total system can therefore be assessed and evaluated.
8. The completeness of the impact assessment of development alternatives depends primarily on the completeness of the scenarios considered, since in our representation of the production system, it does not by itself generate any characteristic dynamics.
9. The method allows the identification of problem areas connected with material flows and of their ecological, economic, social etc, impacts.
10. Because of its modular character, the instrument can easily be improved by including additional system variables, and by more detailed description of certain processes or regions.

7. Recommendations for Further Development

On the basis of our experience we recommed the following improvements:

- An effort to improve the consistency of data from different sources in order to remove inconsistencies and certain imprecisions at the farm, regional and national level.
- computation of the technology assessment in time steps of 5 or 10 years, with a careful evaluationn of scenario parameters for the next time step, taking into account the system development so far. In particular, an attempt should be made to include the financial result of the farm operation in the choice of parameters for the future development of the farm and of the number and size of farms in a given region.
- Independent evaluationn of the scenario results by representatives of different interest groups, who should also use their own criteria weights in the assessment procedure.

8. Application to Three Development Paths of Agricultural Production

The objective of the study was the development of an instrument for technology assessment in agriculture and its exploratory application to three development scenarios. The first priority was to find out whether for a technology assessment in connection with the development of agricultural production a suitable instrument could be developed which would allow the reliable assessment of important impacts and consequences. Our research focussed on this side of the study in particular.

Since the suitability of the instrument had to be tested by application to concrete scenarios, we also report some results for the scenarios A 'intensification', B 'business-as-usual' and C 'ecologization'. These results should not be taken too seriously at this point since we fully recognize certain inconsistencies of the data set used and of the noniterative scenario procedure. Both points should be reworked in follow-up-studies. However, we are certain that with some small improvements a relatively reliable instrument for technology assessment in agriculture will be available.

Despite these reservations we feel that several of the assessments of this preliminary application of the instrument are certainly valid, even though they do not deviate fro results being discussed now in other agricultural policy studies. In particular, the instrument allows the testing of many current assumptions and speculations. In this regar, basing the assessment on material flows is a crucial and essential feature.

The system study based on material flows is augmented by the comprehensive evaluationn with respect to the essential criteria of the development of the agricultural system. This means that crucial problem areas are easily identified.

The instrument was applied to three development scenarios of agricultural production:

In **scenario A 'intensification'** the essential element is the reduction of trade restrictions and market distortions which would lead to a stronger intensification of agricultural production in particular regions for economic conditions are taken out of agricultural production.

In **scenario B 'business-as-usual'** the major theme is the assurance of continued operation of the most productive farms in their current form. This means that markets cannot be liberalized in the way planned in scenario A. For this reason, a similar intensification and concentration of production cannot take place.

In **scenario C 'ecologization'** the major impulse is a more conscious orientation of agricultural production towards decreasing ecological impacts and supporting natural nutrient cycles, coupled with an attempt to support the traditional small family farm structure.

9. Preliminary Results

Despite the preliminary nature of the study, we present here some important results, which we feel to have some general validity. Figure 6 shows the trends of agricultural land use in the three scenarios for all of the Federal Republic of Germany.

1. Food consumption in the Federal Republic of Germany will drop by some 20% in the next decades, mainly as a result of demographic development.
2. Demand reduction for animal products has disproportional effect on agriculture, since this affects the grain production (for feedstock) significantly.
3. It is not possible to secure the operation of the current numbers of farms under the conditions of free agricultural market, with increasing yields and decreasing demand.
4. There are only a few possibilities to alleviate this dilemma: to reduce the acreage for plant production and the number of farms significantly, or to intensify production, or to subsidize production and its subsequent destruction, or to subsidize food exports, or to decouple the internal market prices for agricultural products form the world market, bringing them to a level high enough which would guarantee the continual existence of a greater number of extensively producing farms.
5. The scenario 'intensification' which assures survival only for the most productive farms using intensive production, while large unproductive areas

would be taken out of production, certainly has the most severe social and ecological impacts. On the other hand, this is a scenario which under the current conditions seems to have the best economical and political chances. Here, a problem with high decision pressure becomes obvious if the development of socially unacceptable conditions is to be avoided.

6. The scenario 'business-as-usual' which assumes only incremental policy changes to avoid the most obvious negative impacts also must be assessed as having overwhelmingly negative consequences. In this case, subsidized production of agricultural products continues to be a necessity.
7. The scenario 'ecologization' in which an attempt is made to preserve the current small farm production pattern as much as possible by exentsivation does not show the most favourable ecological and social impacts, but it also has to deal with difficult problems of economic and political acceptance. The technology assessment for this scenario again shows the necessity for timely decision and action in order to favour desirable developments by switching policies, and by blocking unwanted developments in time.

The results of the comprehensive impact assessment for the three scenarios, using 16 relevant orientors, are show in Figure 7.

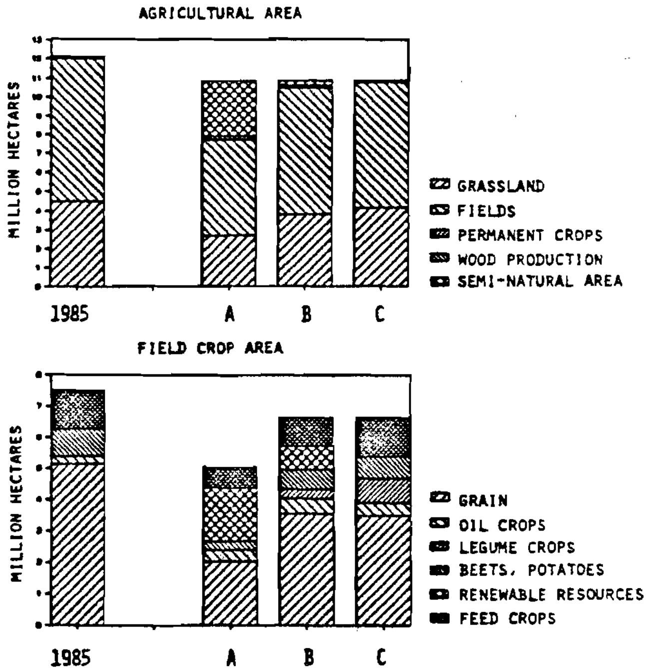


Figure 6 Field Production area Scenarios for the Federal Republic of Germany

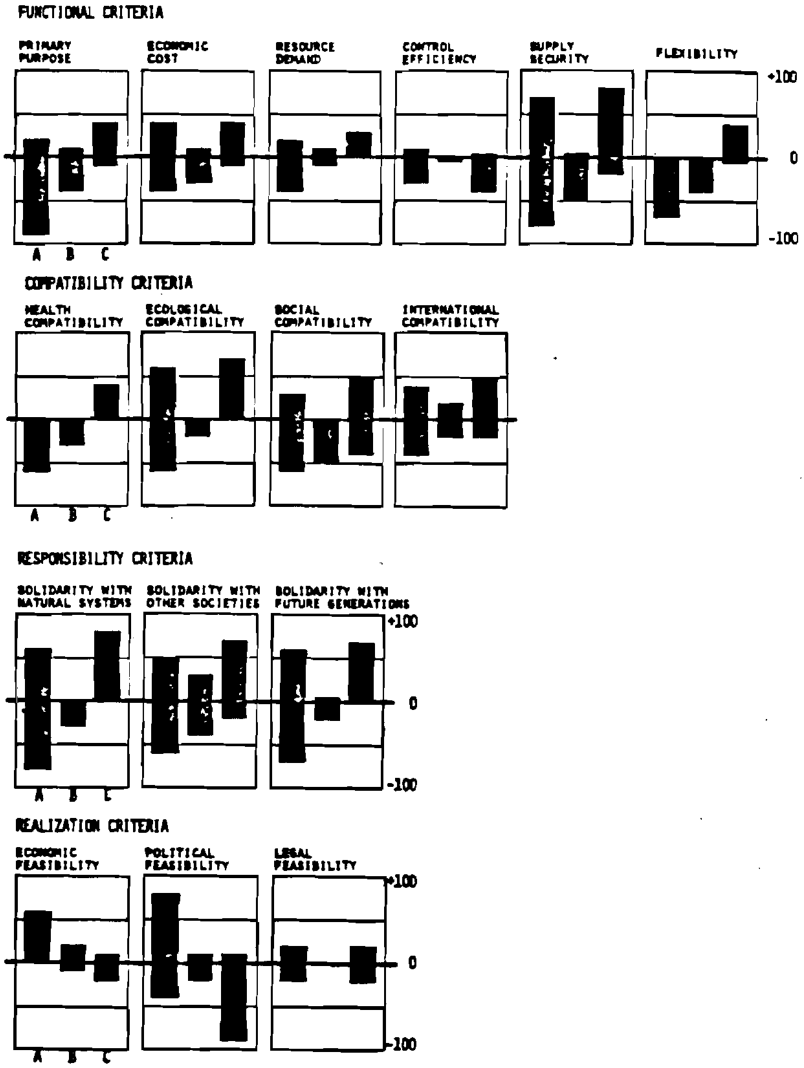


Figure 7 Results of Comprehensive Viability Assessment Using Basic Orientor Approach

4.11 MANAGEMENT OF FOREST RESOURCES IN LITHUANIA*

V. Antanaitis and R. Deltuvas
Lithuanian Academy of Agriculture
Kaunas, Girionys, Lithuanian SSR, USSR

Forest resources. The forest land in Lithuania amounts to 2134 thousand ha, including 1882 thousand ha of forested area. About 69% of the forest land is managed by state forest enterprises under the supervision of the Ministry for Silviculture and Forest Industry; 19% of the forest land is in the charge of collective farms and the rest is run by state farms and various ministries. The forest land comprises 27,9% of the Lithuanian territory. It is to be extended to 30% by the year 2005 at the expense of land unsuitable for farming.

The most widely distributed tree species are the conifers (pine and spruce) amounting to 57% of the forest area; 40% is occupied by birch, alder and aspen, and 3% by hardwood tree species (oak and ash).

A characteristic feature of Lithuanian forests is the inadequate distribution of age-class. The average age of Lithuanian forests is 40 years, with only 4.9% of mature stands, an extremely low percentage. The surplus of younger stands is a result of post World War II reforestations of huge clear-cuttings. However, today's premature stands are growing and after 20 years, there will be no lack of mature stands. The timber volume per ha is also increasing. In 1956 it consisted of just 78 m^3/ha but in 1983 it had already reached 164 m^3/ha. The average volume of the mature stands in the state forest enterprises is equal to 219 m^3/ha, but in the collective farm forests 111 m^3/ha only. The mean annual volume growth is 3,6 m^3/ha and the current annual growth is 6,8 m^3/ha. The mean site class is 2,1 (by the M. Orlov system) and the mean stock density is 0,7.

Site classification. Site evaluations in Lithuania have been developing in two ways. S. Karazija (1977) in the Lithuanian Forest Research Institute has worked out a site classification based on forest types, based on the concept of a forest stand type by Sukatshev and the ecogenetic forest vegetation development principle of Kolesnikov. The following three methodological approaches have been used:

a) estimation of the most essential and obvious indices of the forest types;
b) study of the ecological and economic attributes of the forest types;
c) elaboration of the silvicultural systems on the basis of forest type.

Using soil characteristics at measuring sites, two other scientists, M. Vaitshys and B. Labanauskas (1966), modified and expanded the edaphic net by P. Pogrebnjak. So, a second site classification scheme based on soil characteristics has been worked out. It is known as the soil typological classification.

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buracas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

Since 1966 forest inventory and silvicultural planning have been carried out on the basis of soil typology. Both site classifications mentioned above – that of the forest types and that of the soil types – are complementary and they constitute a united ecological-geochemical classification of Lithuanian forests. The silvicultural systems worked out on the basis of that classification take into account the leading forest function for the given area and contribute to forest management improvement.

Multiple-use organization. Society desires many goods, services and qualities (timber, water and soil protection, game, recreation, berries, mushrooms, etc.) produced simultaneously by forests. Because of the ability of the forest to provide multiple services, management activities can be implemented to produce more or less any particular product. Multiple use is intended to produce a set of forest services. All goods and services produced by the forests are called functional forest resources (FFR) to separate them from the forest resources as a whole. Forest resources as a whole are considered as a territorial totality. All the forest qualities are considered to be natural factors with and without social use. The natural factors with social use are called functional forest resources because they result from the forest functions. The number of the FFR on a given territory and at a given time determines the quantity of the silvicultural targets and the quantity of forest-use types.

The various uses made of forest land reflect the relative importance that society attaches to alternative purposes for which forests can be protected and managed. The forests in Lithuania are divided into two groups according to their functions: the first group, which involves many specific categories, serves mainly recreational and protection purposes whilst the second one is intended for timber production. It should be mentioned that these forest groups are characterized by different tree species, rotation and silvicultural treatment systems. The area of the first group of forests is 36,3% or 575 thousand ha; the rest of the forest land is occupied by forests of the second group. Among the categories of the first group, one can mention so-called green belts surrounding our towns and cities (357 thousand ha), parks, health resort forests, forests for water protection (80700 ha), forest belts along roads and railways (63700 ha), etc.

There is an important trend in the use of forest land in Lithuania. Reservation of forest land for noncommodity purposes is gradually increasing. Examples of such actions include the creation of the Lithuanian National Park (1974) on an area of 291 km^2, and various reserves. 70% of the National Park territory is covered by forests. There are three total reserves, 35 landscape, 27 landscape-historical, 15 geological, 6 ornithological, 10 botanical-zoological, 24 botanical, 13 ichtyological, 2 entomological, 4 hydrological, and 32 cranberry partial reserves in Lithuania. The total area of reserves is more than 2000 km^2. In all types of reserves, forests play an important role.

The forests of Lithuania are managed on the basis of the sustained yield principle. We consider this principle from the biological viewpoint of a productivity process in forestry, for it is always necessary to have a certain growing stock present to promote the renewable, multiple use of the forest (timber, recreation, soil and water protection). In certain periods of human life, one or another forest product, or function, may prevail, but all the changing demands can be met only when there is a continuously producing stand complex.

The least unit for multiple-use management on the sustained yield principle in Lithuania is a forest enterprise, the mean size of which is 30000 ha. Each forest enterprise consists of 8–10 forest districts, which have an average area of 3000 ha. A compartment is the smallest permanent subdivision of a forest. As a rule it is rectangular and has an area of 40–50 ha. The smallest unit of inventory, planning and treatment is a subcompartment (a stand; *Teilflaeche*). As a result of intensive and silvicultural activities, the mean size of a stand in our forests has decreased to 2,0 ha. This is considered to be a negative phenomenon.

Introduction of the sustained yield principle into practical forestry is the main task of the special forest survey and planning service (*Forsteinrichtung*), which is responsible for carrying out inventories on a stand basis, preparing forest treatment plans and drawing maps at the level of each forest enterprise at ten-year intervals. During stand inventories, forest soils have been described and characterized since 1966 in order to acquire more foundations for silvicultural planning. After the inventory has been performed, a special soil map is prepared. Naturally, many of the stand foundations do not coincide with the different soil types.

Sustained yield on the multiple-use basis is a perfectly regulated state. The concept of a target forest is an expansion of the normal forest concept. The target forest is an object of interdepartmental and intradepartmental regulation. It should be mentioned that such a system is more suitable under a centrally planned economy. The target forest must be composed of target stands and a target stand must meet the requirements of the corresponding forest group or category.

The functional structure of the target forest depicts the territorial integration of forest husbandry purposes worked out on the FFR study basis. Theory and research suggest that forest husbandry purposes can be independent, complementary or competitive. These relationships are important guides to decision making.

The main feature of the forest spatial division to meet the requirements of the multiple-use husbandry is the timber volume level. There are three timber volume levels in the target forest: maximal, reduced, and "other." Maximal timber volume is intended for timber production, water and soil protection. In forests intended for recreational services, game, berries, and mushrooms, timber volume should be reduced as a result of the lowered stand density. Other timber volume levels may be appropriate in forests intended for scientific and cultural purposes (reserves, national parks, forests of historical importance, etc.) Scales have been developed to evaluate forest land and growing stands according to their suitability for timber production, game, berries, recreation, etc. in Lithuania.

For final yield regulation, some area methods are used. They are based on rotation and age-class distribution of the management classes. These are combined on the level of a forest enterprise after the stand analysis has been carried out and they are characterized by the dominant tree species, rotation and areas of age-classes in ten-year intervals. When estimating the allowable cut for such a management class, we seek a normal age-class distribution to ensure a sustained yield. The rotations of the main tree species are given in Table 1.

Problems. For many years the small size of the stands and administrative units has been considered to be of benefit. The sequence and distribution of stands and administrative units have been exclusively determined on the basis of biological requirements. The main problems facing our forestry today are: decreasing labor resources in forest enterprises on the one hand, and growing demands for timber on the other. Such a situation has made it necessary to introduce industrial production methods into forest husbandry, to change management forms and units, and to revise the principles of timber production planning.

Table 1. Tree species rotation (years).

Tree species	Forest group	
	Group I Protection forests	Group II Exploitation forests
Pine, ash	120	120
Spruce	120	100
Oak	160	160
Aspen	80	50
Alder, birch	80	70

Maps of our forests depict a mosaic of small stands due to the variety of soil types and intensive silvicultural activities. In many cases, they show erratic forms. Such a structure makes the introduction of modern logging machinery both difficult and uneconomic. There are two approaches where effort should be concentrated in order to solve this problem: enlarge the clear felling areas and minimize the distance between them.

The first method gives us the opportunity to improve the form of the stands by making them right-angled. The optimal form of a stand is considered to be a rectangle, the long side of length of about 1000 m, facing the direction of prevailing gale winds (west) in Lithuania. One realizes that, in such a case, the nonobligatory clear felling follows the boundaries of an existing mature stand. Slight differences between soil types have no importance and, therefore, rather than cultivate mature stands characterized by different tree species, as is the case with some mature stands, we aim to regenerate a pure stand. The width of a clear felling area, i.e., that of a future regenerated stand, is limited. The width of a felling strip depends on the soil type, tree species being regenerated, and the group of forests; the width is usually 150–200 m. One of the decisive factors limiting the width of the stands is the threat of windblow, the damages from which are greater, the broader an even-aged stand is. This problem is especially acute in spruce forests situated in the western part of Lithuania and bordering the Baltic Sea. This is why the clear felling strips are commonly aligned from east to west, i.e., against the main wind direction, because it is known that younger and lower stands have a greater resistance to wind and, therefore, should shield the older and higher trees. Investigations carried out in the areas of severe windblow have proved that the most effective protection against frontal wind attack can be afforded by having a 5 m height difference between two neighboring stands. This is especially important when stands exceed an age of 40–50 years. Subsequently, adjacent clear felling strips must have an age separation of, at least, 6–10 years. The goal is, therefore, to create a stepped stand series from the first age-class stand until the cutting age stand and to force the wind to travel up these steps, thereby gradually losing strength. We would like to point out that when concentrating the logging operations, increasing the felling areas and the stands to make the most of the particular machines introduced, we do not forget that the forest is a biological entity, the structure of which should be brought into accordance with the new economic situation in forestry.

The second step in the logging concentration process is a correct placing of the felling strips in the area of a forest enterprise. This serves to minimize the distance harvesters have to move among those stands which are scheduled for cutting in the same year and to maintain the average annual timber hauling distance as a constant during the planning period. This is a complicated task due to the many limitations to be taken into account in each forest enterprise:

- position of mature stands according to the dominant tree species;
- position of worker settlements;
- road network intensity and quality;
- terrain type of the felling strips;
- annual yield (allowable cut) from each tree species management class (constant for each ten-year period).

Thanks to such a methodology, in recent years we could increase the average clear felling size to 3,5–4,0 ha. This is a basis for increasing the average area of future stands.

A new problem we are facing nowadays in Lithuania is the worsening environment. Westerly winds bring acid rain and sulphur dioxide while some of our own factories and traffic are heavy sources of air pollution. In some places dying or dead trees, and even dying stands, can be seen. To get a real picture of the situation, we are going to implement a forest monitoring system on the whole territory of Lithuania. In fact there will be three forest monitoring systems, each designed to meet special goals.

Forest inventory based on the complete stands survey makes available a wide range of data-based information on stock volume, volume increment, damages, health of the stands, cutting quantity, reforestation, site quality, network of roads, silvicultural measures, etc. Each inventory takes one decade.

Forest resources monitoring is concentrated on the main tree species of Lithuania. Stands are selected along a 4 km grid. Ninety trees of dominant species and predominant importance will be numbered and permanently marked. Defoliation and timber quality will be assessed by a specially trained team every year. The survey in the sampling stands will include the assessment of the vegetative cover, insects, diseases, anthills, birds of prey, and damage by game. Chemical needle-analysis of identical trees will be carried out. In such a way indicators of the latest situation, trends and regional distribution of air pollution will be gathered.

Silviculture quality monitoring's objectives are to evaluate the silvicultural measures carried out in the forest enterprises by the local foresters. A special control system has been worked out aimed at comparing the characteristics of planned and actual stands.

For example, the plantation quality can be estimated on the basis of the following characteristics (Table 2).

Table 2. Plantation quality control.

	Index	Quality mark			
		I good	II satisfactory	III bad	IV dead
1.	Quantity of dead plant seedlings, %	25	25–50	51–80	80
2.	Quantity of unpromising seedlings among the viable seedlings, %	25	25–50	51–80	80

Modeling and forecasting. All decisions on resource management involve some form of forecasts. The main tool for forecasts is modeling. The forest is a complex biological entity. So it is quite difficult to model all processes taking place in the forest. The importance of modeling can be summarized as follows:

1. Models clearly demonstrate characteristics and regularities of the phenomena investigated.
2. Models contribute to the optimal strategy of forest management.
3. Models help us determine those parts of the system which need further investigation.

Quite considerable success has been achieved in Lithuania in modeling volume increment, growth and stand productivity characteristics, taking into account anthropogenic impacts. Some models have been developed for final and intermediate yield regulation. All models are based on the lessons learned from past forest productivity experience, based on regularities of volume increment, growth and stand productivity, and descriptions of these processes in mathematical form. This work is summarized in a monograph by V. Antanaitis, G. Wenk, and S. Smelko, which is to be published in Russian, German and Slovak (USSR, GDR, CSSR). The most essential models are collected in a book *The Laws and Regularities of Stand Growth and Structure* (by V. Antanaitis, A. Tebera, and J. Skepetiene, 1986).

Modern models intended for the stand growth and productivity description take into account the following factors:

1. Climatic conditions.
2. Site types.
3. Level of environmental pollution.
4. Calendar year.
5. Tree species composition.
6. Age.
7. Density.
8. Tree species' genetic characteristics.
9. Provenance of the stands.
10. Silvicultural measures.

However, existing models are incomplete from the following points of view:

- models are insufficiently coordinated with the environment;
- various tree species are subjected to research of different intensity;
- models are empirical and do not reveal the causal relationships;
- anthropogenic impacts are insufficiently reflected;
- the total biomass dynamics of the trees is not reflected;
- models are not linked to dendrochronology;
- accuracy of the models is not known.

If we are seeking to define the stability of forest ecosystems and to establish forest monitoring systems, we cannot be satisfied with the models based on an equilibrium concept (as generally assumed). Models have to include irreversible processes and have to be linked to dendrochronological rhythms since these rhythms influence both the process of biomass formation and the duration of succession.

Main development goals.

1. An increase of the land forested by 2–3%.
2. An increase of stand productivity and quality through tree species optimization.
3. An increase of small-sized wood production by 300 thousand m^3 for the furniture industry.
4. An increase of the labor force by 1000 in the silvicultural sector.
5. Keeping the forest sector supplied with highly productive tools and machinery.

4.12 ANALYSIS OF THE FOREST SECTOR IN REGIONAL DEVELOPMENT (ON THE PATTERN OF LITHUANIA, USSR)*

L. Kairiukstis
IIASA, A-2361 Laxenburg, Austria

and

S. Mizaras, L. Balcevic & A.V. Rutkauskas
Lithuanian Research Institute of Forestry
Kaunas, Girionys, Lithuanian SSR, USSR

1. Introduction

The forest should be considered as a basic component of the regional system where forestry consists of regional economic sectors. Air pollution, water and soil contamination having an adverse influence on the growth and productivity of forests are concomitant of intensive regional economic development. In turn, the state forests in many respects determine the volume of timber harvesting and the development of the forest sector as a whole. Therefore, the maximum annual allowable timber cutting must be analyzed in close interrelationship between the development of the environment and national economy as a whole.

Let us consider management of the forest sector in the framework of regional development on the pattern of the Lithuanian SSR.

The optimal variants of development of different regional economic sectors (including those of the forest sector) have been established according to accepted criteria. A system of models for regional development analysis has been used (Figure 1).
In the analysis of regional productivity (the model), these variants are based on different scenarios. Simultaneously, the volume of possible emissions into the environment (an ecological block) are assessed depending on the volume of production and on non-productive activity. Expenses for air and water purification and for damage due to environmental contamination are ascertained in this block too. The model describes regional economics and its interrelation with the environment. The anthropogenic impact on single recipients is analyzed more profoundly on the basis of models at the following levels. They enable greater detail of the characteristics according to single recipients to be obtained and the model of regional productivity specified. Some of the indices from model I of the higher aggregation level are used to assess the characteristics of air pollution causing deterioration of forest growth. Some forests are even killed. The reduction of increment and the killing of forests changes the magnitude of timber harvested.

Feedback occurs through the influence of the changed volume of timber harvested in the model of regional reproduction. Firstly, the volumes of production and the values related to them in the wood-processing economic

*In: Proceedings of the Workshop on Ecological Sustainability of Regional Development, Vilnius, Lithuania, USSR (22-26 June, 1987), L. Kairiukstis, A. Buracas and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

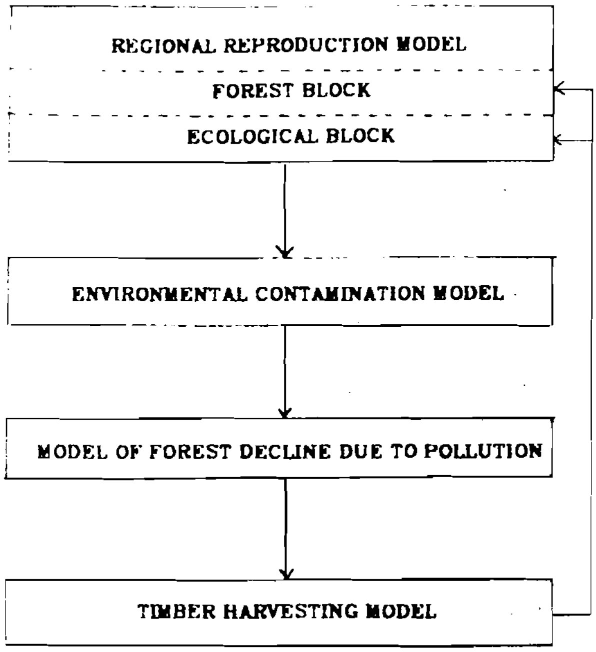


Figure 1. Modelling scheme of the forest sector in the framework of regional reproduction.

sector vary immediately. Secondly, a change in the volume of wood processed affects the production process within the sector and wood consumers. Thirdly, information on changes in wood processing under the influence of this or that amount of pollution allows us to estimate economic forest damage due to air pollution according to one kind of recipient (wood). The same approach is feasible to estimate the impact on other recipients too. Thus, ecological consequences of the previous variant may be considered in the subsequent step of the iterative calculations.

2. Regional Productivity-Model of the Lithuanian SSR

2.1 Major principles of model construction

An integral characteristic of an economic activity in a region over a certain period is the total sum of indices representing the processes of creation and distribution of gross national product (GNP) (Buracas and Rutkauskas, 1984). A production phase of the given processes in the economy sector may be described by the following balance equation:

$$X_i(t) - M_i(t) - Z_i(t) - B_i(t) - \Pi_i(t) = 0 \ , \quad t = 1,2,\dots,\tau \ , \quad i = 1,2,\dots,n \ .$$

where:

$X_i(t)$ = gross output of i produced in a region in year t;
$M_i(t)$ = volume of expenses of product i for productive consumption of all sectors of the regional economy in year t;
$Z_i(t)$ = volume of expenses of production i for productive capital investments in all sectors of the regional economy (the increment of the main productive funds, that of unaccomplished construction and other productive capital investments);
$B_i(t)$ = expenses of production i for reproducing all kinds of ecological resources and for eliminating the consequences of environmental changes;
$\Pi_i(t)$ = other kinds of consumption of product i and its losses.

The correlations of reproduction are given in the system of "submodels" characterizing the items of the balance equation. We will briefly describe each item.

1. Establishment of the volumes of gross output depending on the factors of production.

The volumes of production and their determining factors are compared on the basis of linear production functions:

$$X_i(t) = \alpha_0 + \alpha_1 \bar{F}_i(t) + \alpha_2 D_i(t) + \alpha_3 t \ ,$$

where

$\bar{F}_i(t)$ = mean annual volume of the main productive funds in sector i in year t;
$D_i(t)$ = average annual number of workers in sector i;
$\alpha_0, \dots, \alpha_3$ = parameters of the variables.

2. Assessment of the overall volume of production consumption in a sector.

In order to determine the necessary flow of production from sector i to sector j, the coefficients of direct material expenses a_{ij} being predicted in an exogenous way are applied. Then the flow will be:

$$X_{ij}(t) = a_{ij} \cdot X_j(t)$$

The overall volume of production sector necessary for the productive consumption in all sectors will be the following:

$$M_i(t) = \sum_{j=1}^{n} X_{ij}(t) \ , \quad i,j = 1,2,\dots,n \ .$$

3. Determination of the volumes of productive capital investments.

The volumes of the requirement of the productive capital investments in sectors are calculated by the models describing the process of productivity funds. The models are based on the following assumptions:

a) the funds assigned for the start of a year change towards the end of it proportionally to coefficient $\beta_t = 1 - \alpha_t$, where α_t is the coefficient of elimination of the main productive funds in year t;

b) the volume of fund input is a result of the productive capital investments of the given year and previous years l. Besides, each unit of fund input in year t contains a certain part of $U_p(t)$, $p = l, l-1, \ldots, 1, 0$ which is a result of the capital investments of year t–p, where

$$\sum U_p(t) = 1;$$

c) input of the main productive funds is carried out yearly in conformity with the coefficient of uniformity of fund input. The coefficient is accepted for a sector in an exogenous way. The average annual funds are assessed according to the formula:

$$\bar{F}_t = \frac{F_t + F_{t+1}}{S_t} ,$$

where
- $\bar{F}_t$ = mean annual funds in year t;
- F_t = volume of funds for the start of year t;
- S_t = coefficient of uniformity of fund input.

Let Δt be the volume of input of the main productive funds in year t. It is then possible to calculate the mean annual values with the aid of the fund elimination (α_t) value and the known fund value for the end of base year (F_o). The following scheme is then used:

$$\bar{F}_1 = \frac{(1+\beta_1)F_o + \Delta_1}{S_1} ,$$

$$\bar{F}_2 = \frac{\beta_1(1+\beta_2)F_o + (1+\beta_2)\Delta_1 + \Delta_2}{S_2} ,$$

$$\bar{F}_k = \frac{(\prod_{b=1}^{k-1} \beta_6)(1+\beta_k)F_o + (1+\beta_k) \sum_{p=2}^{k-1} (\prod_{b=p}^{k-1} \beta_b)\Delta p-1 + (1+\beta_k)\Delta_{k-1} + \Delta_k}{S_k} ,$$

$$\bar{F}_T = \frac{(\prod_{b=1}^{T-1} \beta_6)(1+\beta_T)F_o + (1+\beta_T)(\prod_{b=p}^{T-1} \beta_b)\Delta_{p-1} + (1+\beta_k)\Delta_{T-1} + \Delta_T}{S_T} .$$

The annual values of the necessary volumes of main funds ($\bar{f}_t$) are established from the productive functions. The annual increment values of fund (Δ_t) are calculated by applying $\bar{f}_t$ instead of $\bar{F}_t$. For the first year of the period predicted

$$\Delta_1 = S_1\hat{f}_1 - (1+\beta_1)F_o .$$

The values for subsequent years are ascertained according to the same principle.

Further, the volume of capital investments in the main productive funds is determined allowing for condition (b). These funds are necessary to provide a desirable level of the average annual funds:

$$Z_t = \sum_{k=0}^{1} U_{t+k,k} \frac{1}{\beta_{t+k}} [S_{t+k} \hat{f}_{t+k} + (1+\beta_{t+k})$$

$$\times \sum_{p=1}^{t+k-1} (-1)^p S_{t+k-p} \bar{f}_{t+k-p} + (-1)^{t+k} (1+\beta_{t+k}) F_0] \quad ,$$

$$t = 1,2,\ldots,T \quad .$$

The value of the demand of the corresponding products are assessed on the basis of the calculated values of the demand for the capital investments and on the matrices of material structures:

(

for all j). The formula is the following:

$$\hat{Z}_{ij} = \sum_{j=1}^{n} W_{ij}^{Z} Z_{jt} \quad .$$

4. Assessment of the expenses for reproduction of the ecological resources and damage caused by air pollution.

The given calculation is based on the following scheme:

- determination of emissions
- establishment of the level of expenses for reproducing (purifying) natural resources (air, water);
- ascertaining the level of damage as a function of the non-reproductive part of the resources exploited;
- assessment of the total level of ecological costs.

Emission volumes are determined by means of statistical evaluation according to the results of observations of X_i and P_{ij} the parameters of function P are estimated:

$$P_{ij} = p_{ij}(X_i) \quad ,$$

where

P_{ij} = emission volume j in sector i;
p_{ij} = emission j in sector i per unit of activity intensity;
X_i = index of activity intensity in sector i.

The emission strength is divided into a purified (P_{ij}^{o}) and an unpurified (P_{ij}^{H}) part.

$$P_{ij} = P_{ij}^{o} + P_{ij}^{H} \quad .$$

The expenses for purification of ecological resources (B^o_{ij}) consist of capital investments in the funds for nature protection and exploitation expenses for these funds (3^e_{ij}):

$$B^o_{ij} = Z^e_{ij} + 3^e_{ij} \ .$$

The volume of funds necessary for purification (F^e_{ij}) are ascertained as a function of fund capacity (f_{ij}), which is established according to the standard or statistically:

$$F^e_{ij} = f(P^o_{ij}) \ .$$

The volume of capital investments necessary for the funds of nature protection are determined in the same way as those for productive funds:

$$Z^e_{ij} = z(F^e_{ij}) \ .$$

The volume of expenses for exploitation are assessed by the volumes of funds for exploitation:

$$3^e_{ij} = Z(F^e_{ij}) \ .$$

Damage induced by emission (Q_{ij}) is expressed by abatement costs of the consequences of emission activity in environment deterioration:

$$Q_{ij} = q(P^H_{ij}) \ .$$

The total value of ecological expenses (B_{ij}) is obtained by the formula:

$$B_{ij} = Z^e_{ij} + 3^e_{ij} + Q_{ij} \ .$$

Minimizing ecological costs is an optimization criterion of the development of the regional economy.

5. *The value of other kinds of consumption in the given modification of a model established as the final item.*

When necessary, it is possible to differentiate the given value. The task of optimizing regional development on the basis of the correlations described is set forth below.

Indices:

$i = \overline{1,n}$ = index of sector-producer;
$j = \overline{1,n}$ = index of sector-consumer;
$\tau = \overline{1,4}$ = index of period calculated (five-year periods);
X^τ_i = volume of production of i in period τ;
a^τ_{ij} = coefficient of direct expenses of production sector i to produce a product unit in sector j;
C^τ_i = volume of an intermediate product of sector i;
F^τ_i = mean annual volume of main funds in sector i;
D^τ_i = number of working population in sector i;
t = time;
y^τ_i = final product in sector i;
$\alpha^{x\tau 1}_i, \ldots, \alpha^{x\tau 5}_i$ = parameters of production function;

b_i^τ = parameters of funds for production;
Z_i^τ = volume of capital investments in sector i over period τ;
W_{ij}^τ = coefficient of a matrix of material structure of capital investments;
v_i^τ = volume of production of capital investments in fund-creating sectors;
$\bar{y}_i^\tau$ = volume of net final product in sector i;
d_i^τ = labor productivity in sector i;
φ_i^τ = funds for labor in sectors i;
m_i = value set for labor productivity;
S_i^τ = values set for the funds for labor;
K_i^τ = limitation set for volume of capital investments;
$\bar{y}_i^\tau$ = structure of net final product;
P_i^τ = volume of emission in sector i;
$\alpha_i^{p\tau 1}, \ldots, \alpha_i^{p\tau 3}$ = parameters of the function determining emission strength;
$P_i^{o\tau}$ = quantity of pollutants purified;
$P_i^{H\tau}$ = quantity of unpurified pollutants;
$F_i^{e\tau}$ = volume of funds for nature protection allocated for pollutant purification;
$\alpha_i^{F\tau 1}, \ldots, \alpha_i^{F\tau 3}$ = parameters of the function determining the quantity of funds for nature protection;
$Z_i^{e\tau}$ = volume of capital investments in funds for nature protection;
$b_i^{e\tau}$ = parameters of nature protection fund productivity;
W_{ij}^τ = coefficient of a matrix of material structure of capital investments in funds for nature protection;
$v_i^{e\tau}$ = volume of production of capital investments in funds for purification;
$З_i^{e\tau}$ = exploitation expenses for natural protection funds;
$\alpha_i^{e\tau 1}, \ldots, \alpha_i^{e\tau 3}$ = parameters of the function determining the volume of exploitation expenses;
Q_i^τ = economic losses for the regional economy due to unpurified emissions into the environment;
$\alpha_i^{Q\tau 1}, \ldots, \alpha_i^{Q\tau 3}$ = parameters of the function determining the volume of economic losses.

A model:

Interrelation between the volume of production and its determining factors:

$$X_i^\tau = \alpha_i^{x\tau 1} F_i^\tau + \alpha_i^{x\tau 2} D_i^\tau + \alpha_i^{x\tau 3} t + \alpha_i^{x\tau 4} .$$

Correlation between the gross output, intermediate and final product:

$$\sum_{j=1}^{n} a_{ij}^\tau X_j^\tau - C_i^\tau = 0 \ ;$$

$$X_i^\tau - C_i^\tau - y_i^\tau = 0 \ .$$

Equations of dependence of the capital investments on production volumes and productivity fund parameters as well as on the dynamics of capital investments:

$$Z_i^{\tau} = z(X_i^{\tau};b_i^{\tau}) \ ,$$

$$\sum W_{ij} \cdot Z_i^{\tau} = v_i^{\tau} \ .$$

Equations forming net final production in the set structure:

$$y_i^{\tau} - v_i^{\tau} = \bar{y}_i^{\tau} \ .$$

$$\sum_i \bar{y}_i^{\tau} = \bar{y}_i^{\tau} \ .$$

Limitation for production, labor funds and volume of capital investments:

$$d_j^{\tau} \geq m_j^{\tau} \ ; \quad \Phi_j^{\tau} \geq S_j^{\tau} \ ,$$

$$Z_i^{\tau} \leq K_i^{\tau} \ .$$

Dependence on the volume of pollutants on that of production and other factors:

$$\alpha_i^{P\tau 1} X_i^{\tau} + \alpha_i^{P\tau 2} D_i^{\tau} + \alpha_i^{P\tau 3} F_i^{\tau} + \alpha_i^{P\tau 4} t + \alpha_i^{P\tau 5} = P_i^{\tau} \ .$$

Correlation between the purified and unpurified part of pollution:

$$P_i^{\tau} = P_i^{o\tau} + P_i^{H\tau} \ .$$

Dependence on the volume of nature protection funds on the quantity of pollutants purified:

$$\alpha_i^{F\tau 1} P_i^{0\tau} + \alpha_i^{F\tau 2} t + \alpha_i^{F\tau 3} = F_i^{e\tau} \ .$$

Dependence of capital investments in nature protection funds on the volume of productivity conditions of those funds as well as on the dynamics of capital investments:

$$Z_i^{e\tau} = \Psi(F_i^{e\tau};b_i^{e\tau} \ ,$$

$$\sum_{i=1}^{n} W_{ij}^{e} \cdot Z_i^{e\tau} = v_i^{e\tau} \ .$$

Equations of expenses for exploitation, nature protection and economic losses:

$$\alpha_i^{e\tau 1} F_i^{e\tau} + \alpha_i^{e\tau 2} t + \alpha_i^{e\tau 3} = 3_i^{e\tau} \ ,$$

$$\alpha_i^{Q\tau 1} P_i^{H\tau} + \alpha_i^{Q\tau 2} t + \alpha_i^{Q\tau 3} = Q_i^{\tau} \ .$$

Overall volume of net final product maximized in the set structure without ecological expenses:

$$\sum_{\tau=1}^{4}\sum_{i=1}^{n}\bar{y}_i^{\tau} - \sum_{\tau=1}^{4}\sum_{i=1}^{n} Z_i^{7\tau} - \sum_{\tau=1}^{4}\sum_{i=1}^{n} 3_i^{e\tau} - \sum_{\tau=1}^{4}\sum_{i}^{n} Q_i^{\tau} \to \max \ .$$

In the above case, the ecological expenses are estimated for one kind of pollutant. Calculation of several kinds entails no difficulties.

In the first step of the iterative calculations, the volume of economic losses induced by emission (Q_i^{τ}) may not be included in the criterion. Subsequently, it is established in other models and entered into the criterion of optimization of the following iterations.

Input data of the model:

1) quantity of economic sectors presented in the model;
2) volume of main productive funds for the start of the period predicted;
3) lag of capital investments;
4) coefficients of safe keeping of main productive funds;
5) lag coefficients;
6) coefficients of uniformity of fund input;
7) coefficients of capital investment distribution in five-year periods;
8) values of parameters a of functions linking endogenous values in the model; for each sector of the regional economy, 2–8 values are set; values 2–7 are non-production fund parameters;
9) matrix of coefficients of direct material expenses:

$$(a_{ij};\ i,j = 1,2,\ldots,n) \ ;$$

10) matrix of coefficients of material structure of capital investments:

$$(W_{ij};\ i,j = 1,2,\ldots,n) \ ;$$

The matrix must meet the condition:

$$\sum_{i=1}^{n} W_{ij} = 1 \ , \quad j = \overline{1,n} \ .$$

One matrix is entered into each five-year period;

11) vector of the final product structure; one vector is entered into each five-year period predicted.

Information obtained as a result of a decision (according to the sectors of the regional economy):

- volume of gross output (million roubles);
- number of working people, (thousand people);
- intermediate product, (million roubles);
- final product, (million roubles);

- volume of capital investments in the main productive funds, (million roubles);
- material elements of capital investments, (million roubles);
- volume of the main productive funds, (million roubles);
- net final product; (million roubles);
- volume of emission in the air (or in the soil, in the water) due to production (thousand tons/year);
- purified emission (thousand tons/year);
- funds for nature protection (for protection of air, water, etc.) (million roubles);
- capital investments in the funds for nature protection, (million roubles);
- material structure of the capital investments in nature protection funds (million roubles);
- exploitation expenses for nature protection funds (million roubles);
- damage induced by air pollution (million roubles);

Because of different settings of the task, changes are possible in indices obtained.

A scenario on the development of sectors in the forest sector has been created and the tendencies of the effects of management activities on the environment determined. The scenario is based on the aforementioned model.

2.2 An intersector analysis of the development of the forest sector

A variant of calculations for predicting regional economic-environmental development has been applied by singling out 30 economic sectors (products). Of these, 5 relate to the production of the wood-processing industry:

1) the production of the wood-processing industry;
2) the production of wood sawing;
3) furniture;
4) other kinds of production of wood-processing industry;
5) the production of the pulp and paper industry.

The development of single sectors in the system of the whole economy of a region may be analyzed along these lines:

1) assessment of the variants of production volumes for sectors in the forest sector. They must balance with the development of all other sectors in the period predicted;
2) establishment of the resources, volumes necessary for production (capital investments, the number of working population, the volumes of productive consumption, etc.);
3) evaluation of the effects of regional economic development (different variants) on the rate and proportion of the development of sectors in the forest sector.

The analysis of sector functioning tendencies in the forest sector and the necessity of achieving a certain situation in prospects, enabled the dynamic variants of the sector to be worked out. The necessity of an essential increase in gross output and significant limitation of the resources were considered in the analysis. For instance, the number of working people must not increase due to augmentation of labour productivity etc.

Some characteristics of the dynamics of sectors (one variant obtained as a model output) are presented in Figure 2.

The given variant of the development of five sectors is balanced with the development of the whole regional economy and with necessary resources for a long period in the future. As shown in the diagrams, the increment of gross output in the wood-processing sectors is mainly achieved due to an increase in labour productivity and in the volumes of major productive funds. The latter tendency is typical of the development of the regional economy currently in Lithuania, USSR. However, it is not dispensable for a long period in the future. Other correlations between the reproduction funds allows variants with decreasing fund capacity to be obtained.

The main value of the model lies in the feasibility of multivariant analysis of different tendencies.

2.3 The analysis of the impact of anthropogenic activities on the environment.

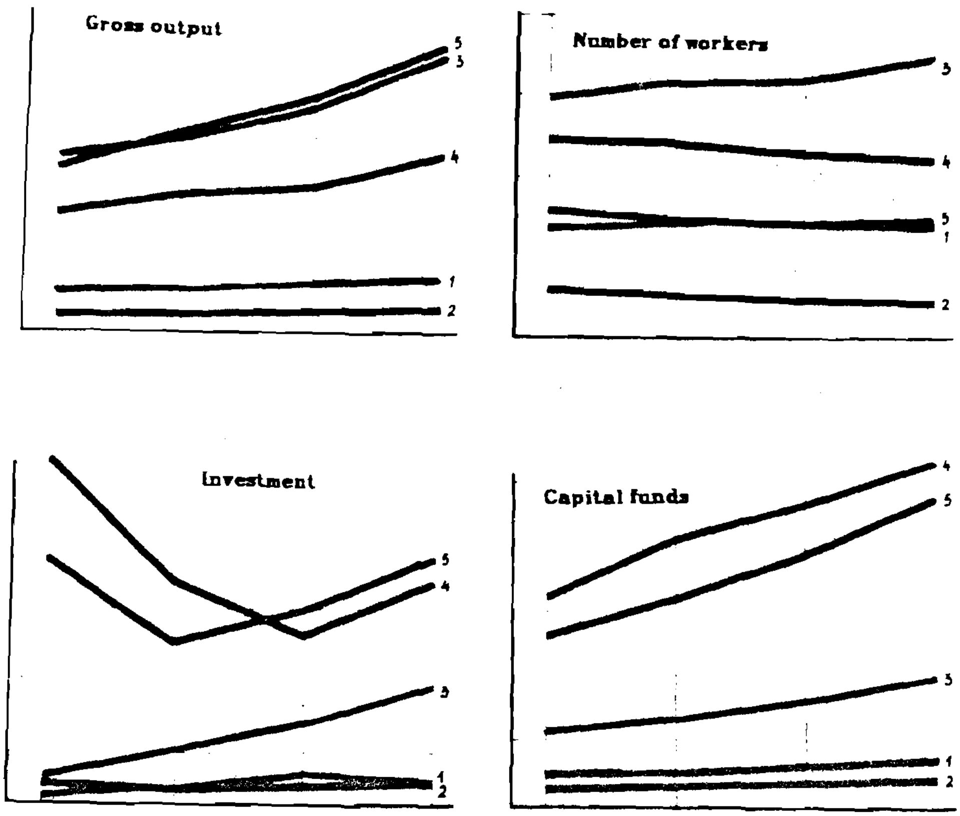
Source emissions depend on the intensity of productive and unproductive activity of people. Prevention of air pollution requires certain expenses. In the model of prediction of regional productivity, the expenses for purification of the ecological resources are considered as a sum of capital investments in the funds for nature protection and expenses for their exploitation (B^o). The remaining unpurified pollutants cause adverse consequences. Apart from the ecological costs (B^o), economic damage (Q) due to these consequences ($B^o + Q$) is another component.

The two components of ecological costs are interdependent: the greater the one, the lesser the other. Hence, a question of optimal correlation between the two parts arises. The dependence between the expenses for nature protection (B^o), damage due to pollution (Q) and the level of environmental contamination calculated according to the model is presented graphically in Figure 3. A minimal value of the total ecological costs ($B^o + Q$) is achieved at a certain level of environmental contamination P_o^B. In the model of regional productivity minimizing ecological costs under other conditions is one of the criteria of optimal socio-economic development of a region.

One of the possible dynamic variants of atmospheric pollution under concrete conditions of economic development of the region is shown in Figure 4. The upper diagram characterizes the dynamics of the cost for air protection, while the lower one indicates changes in the volumes of noxious emission, in their purified part and in air pollution depending on the magnitude of production and the presence of funds for air protection.

3. Establishment of the Indices of Environmental Contamination

The indices of environmental contamination were calculated according to the model for ecological productivity which was elaborated at the All-Union Research Institute of System Investigations of the State Committee of Science and Technics at the Academy of Science of the USSR (Krutko et al, 1982; Pegov et al, 1985).



1 - logging
2 - wood cutting
3 - furniture
4 - other wood products
5 - pulp and paper industry

Figure 2. Scenarios of forest sector development tendencies.

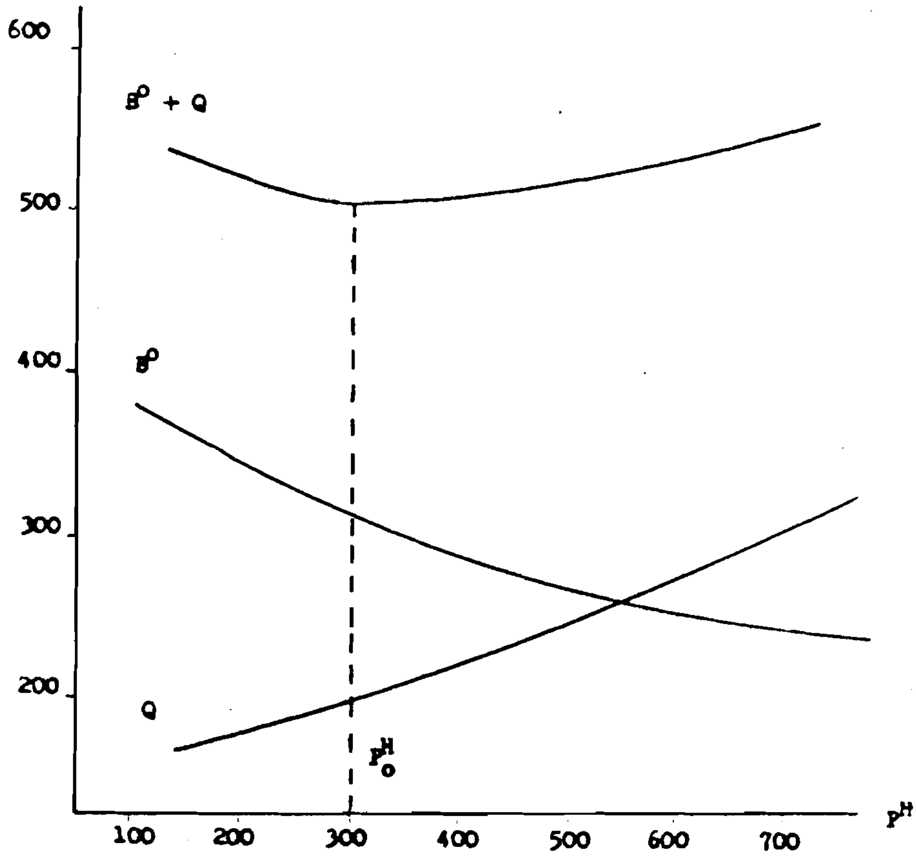
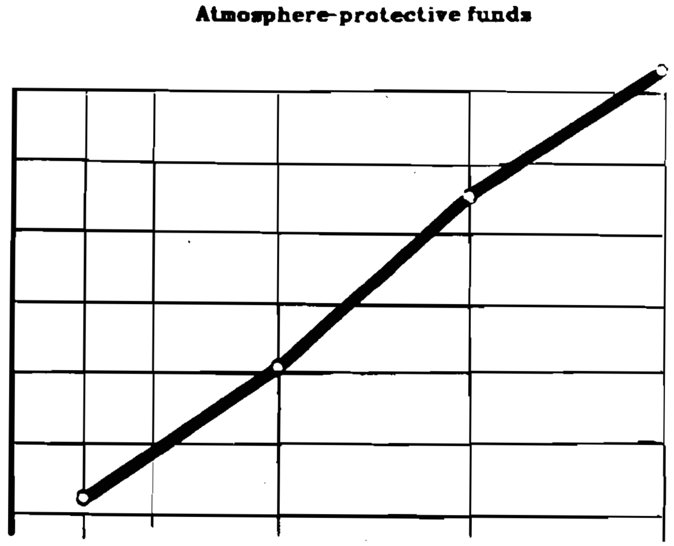


Figure 3. Dependency of atmospheric emissions (P^H) upon atmospheric protective investments (B^O) and dependency of damage (Q) upon emissions (P^H).



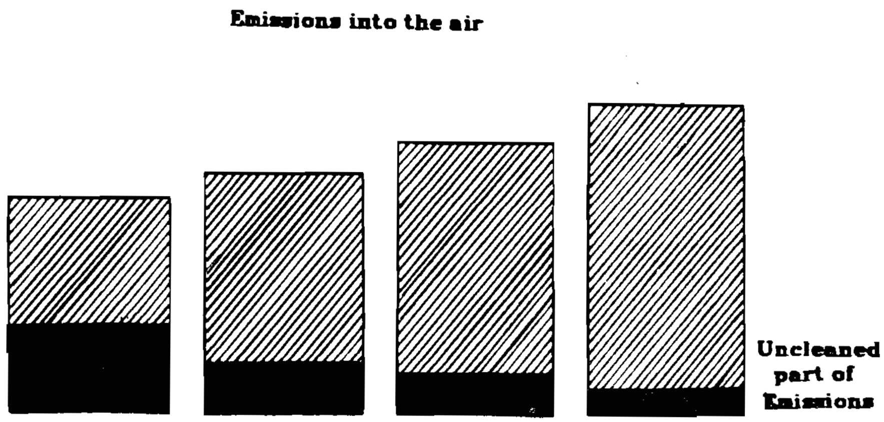


Figure 4. Scenarios of atmospheric emission volume changes depending on increase of atmosphere-protective funds.

The parameters of redistribution and transformation of pollutants with the aid of auxiliary variables, such as the coefficients of pollutant transformation were allowed for in the model. The transformation coefficients establish the part of pollutants of the given type processed as a result of absorption, precipitation, decomposition, etc. In general, pollutant transformation is described in the following way. Industrial emissions enter the air and water. In the water the pollutants, together with agricultural fertilizers, are partly deposited in the process of flow. Part of them decompose under the influence of micro-organisms. Air pollutants are carried away by the wind beyond the boundaries of a region. Within the air shed of a given territory, the remaining pollutants partly decompose under the influence of ultra-violet radiation. During the process of decomposition the pollutants are absorbed by vegetation. The remainder get into soil where they accumulate. Additionally, pollutants' get into the soil together with leaf fall and needle shedding. Some of the pollutants are carried away with the harvest.

The model provides three ways of setting the region being simulated: direct, automatic and standard. We have adapted the model with automatic setting of the region. The following indices characterizing Lithuania, USSR are entered into the model:

1) Geographical belt - moderate
2) Geographical zone - mixed forests
3) Relief - a plain
4) Soil - sandy loam
5) Swamp formation - moderate
6) Filtration from transit rivers - 1.5 mm/km
7) Farming lands - 57% of the area of a region.

One of the scenarios of the model permits the determination of the environmental contamination due to air pollution, on the amount of pollutants in water, and on the quantity of fertilizers applied. We have realized the following scenario of pollutants and fertilizers: in the air, the pollutants comprise SO_2 - 0.075 tons/ha, NO_x - 0.014 tons/ha, C_xH_x - 0.032 tons/ha; in farmlands soil, nitric fertilizers amount to 0.062 tons/ha, while phospheric fertilizers and manure amount to 0.032 tons/ha and 5.7 tons/ha respectively. Some results of the scenario are presented in Figure 5.

4. The Analysis of Changes of the State of Art Forests Attributed to Environmental Changes

For the analysis of the dynamics of forests, taking into account environmental changes, two models were applied: "Pollution and Forest Damage (POLLAPSE)" elaborated by Grossmann (1985) and "Determination of the volume of allowable cut according to long-term dendroclimatic fluctuations and pollution".

The POLLAPSE model which depends on the quantity of pollutants in the atmosphere predicts the indices of air pollution and soil contamination, evaluates changes in the biomass of wood, in leaves (needles), and in soil organisms, etc. The following input data (constants) were entered into the model while adapting it:

$bn = 2.1 \times 10^5$

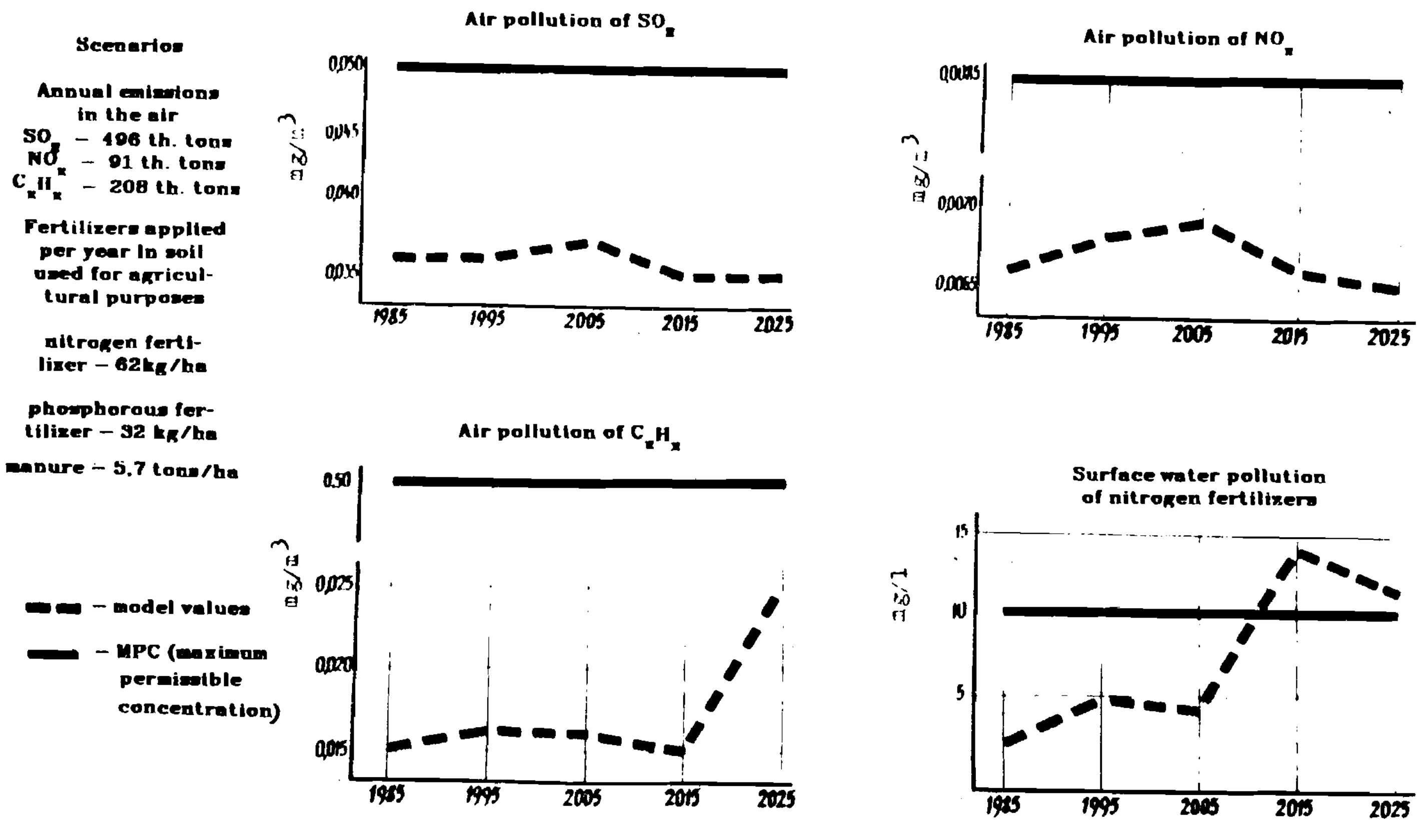


Figure 5. Background pollution of the environment (calculated using the model of ecological forecasting at VNIISI, USSR).

$x_0 = 4.2 \times 10^2$
$wn = 1.46 \times 10^4$
$lbi = 6.3 \times 10^3$
$wf = 18.2 \times 10^2$
$ne1 = 24.3 \times 10^5$
$bci = 5.8 \times 10^5$
$\psi = 22.4 \times 10^5$
$sf = 47.1 \times 10^3$
$x_1 = 12.4 \times 10^2$
$ln = 12.7 \times 10^2$

bn = initial soil contamination, tons;
x_0 = normal value of repeated contamination, tons;
wn = normal biomass of wood per area unit, tons/km^2;
lbi = initial air pollution, tons;
wf = forested area, km^2;
ne1 = initial quantity of needles (leaves), tons;
bci = soil contamination by unstable pollutants, tons;
ψ = stable pollutants over a 20-year period, tons;
sf = non-forested area, km^2;
x_1 = level of air pollution, tons;
ln = normal air pollution, tons.

The following indices of air pollution were used in the scenario (million tons):

1950	=0.0;	1955	0.9;	1960	1.8
1965	3.1;	1970	5.0;	1975	7.0
1980	9.0;	1985	11.5		

According to the POLLAPSE model, there is a possibility to reach different hypotheses on air pollution impact on forest dieback. From the point of view of quantity, this is expressed by entering different values of indices P_1,P_2 and P_3. P_1 = the importance of air pollution by non-phytooxidants for the damage; P_2 = importance of soil contamination; and P_3 = importance of photooxidants. The results of the calculations according to different hypotheses on forest damage are presented in Figure 6 (according to the indices of change in the biomass). Figure 7 shows the data of change in the characteristic of forests (soil contamination, quantity of soil organisms, mass of needles, volume of stands) in conformity with the hypothesis of the forests damage, characterized by indices $P_1 = 3$, $P_2 = 8$, $P_3 = 2$.

Currently, there are not enough monitoring data on forest ecosystems to enable an evaluation of the durability of single hypotheses of the POLLAPSE model. Obviously, according to some of these, the extent of forest decline is increased.

For the evaluation of forest productivity dynamics depending on climatic fluctuations, the dendrochronological method is applied (Kairiukstis and Dubinskaite, 1986; Kairiukstis et al., 1986). It is assumed that long-term cycles are more significant for the magnitude of the volume of mature stands and amount of allowable cutting.

To assess the total impact of several long-term dendrochronological cycles on stand volume, the following formula is used:

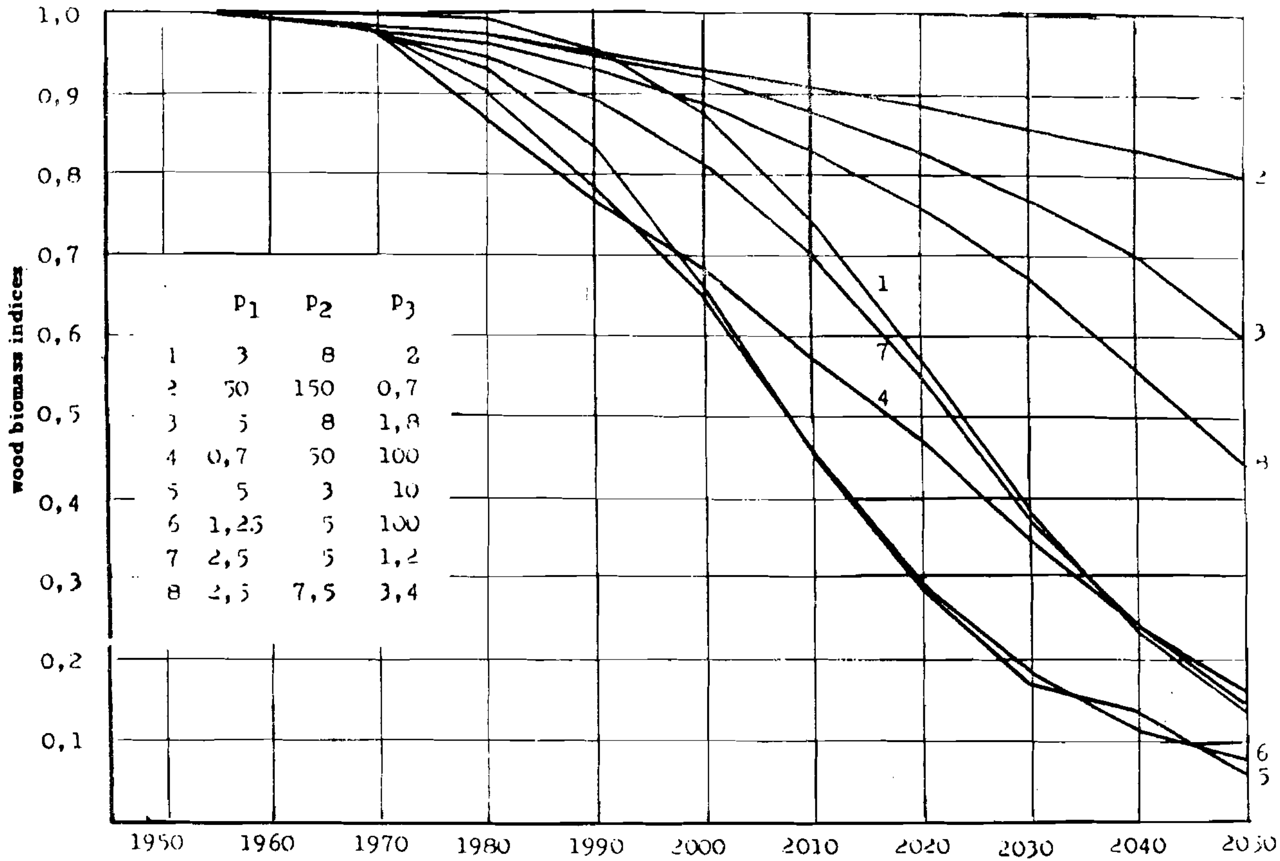


Figure 6. Influence of atmospheric and soil pollutants on wood biomass (8 hypotheses).

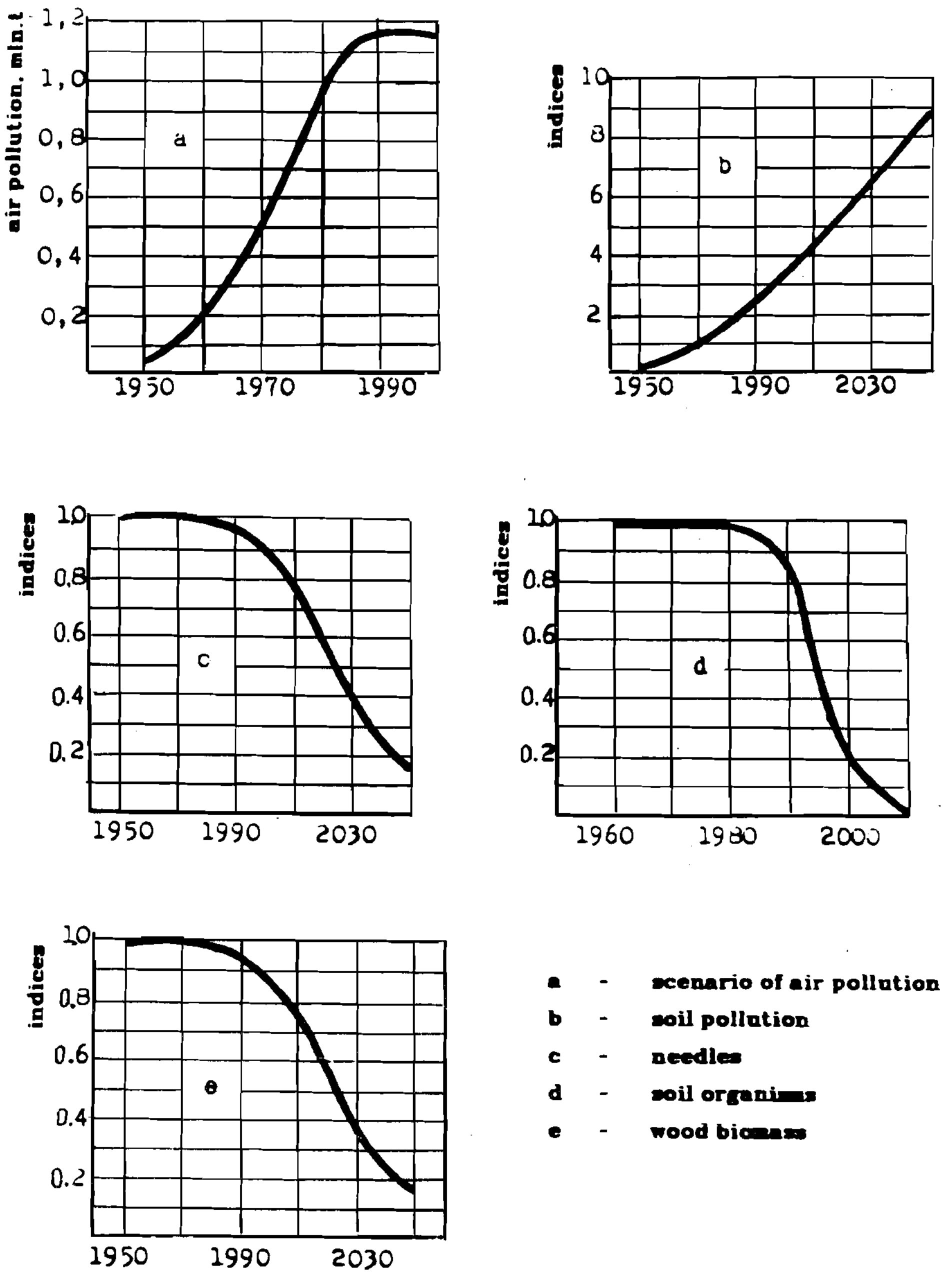


Figure 7. Indices of the influence of atmospheric and soil pollution on the forest.

$$y(t) = \sum_{j=1}^{7} A_j \cos\left(\frac{2\pi(t-1940)}{T_j} + Y_j\right) ,$$

where $y(t)$ = indices of supplementary influence of long-term cycles on the growth of trees; A_j = cycle amplitude; T_j = cycle duration; Y_j = cycle variation phase; t = one year.

Table 1 gives parameters of the cycles. The diagrams of single cycles and their total value are shown in Figure 8.

Table 1. Description of long-term dendroclimatic cycles.

Cycle number	Supplementary influence of cycle indices (amplitude), %	Phase	Cycle duration years
1	0.76	-2.578	39
2	1.08	-2.054	52
3	1.18	-3.037	60
4	1.60	-3.625	78
5	1.82	-0.478	92
6	2.06	-2.149	114
7	2.42	-0.918	171

The dendroclimatic indices over the period of stand growth reflect the change in forest productivity. Hence, the timber volume increment is not constant in time. Therefore, an average index for the cutting rate should be estimated. To achieve this goal, a series of dendroclimatic indices have been formed:

$$A_n(t) = a_1, a_2, \ldots, a_{Nn}$$

$$a_1 = y(t_1),\ t_1 = t-10(Nn-1) ,$$

$$a_2 = y(t_2),\ t_2 = t-10(Nn-2) ,$$

$$a_N = y(t_N),\ t_N = t-10(Nn-Nn) ,$$

where:

- n = tree species;
- Nn = number of age classes (10 years) in rotation period;
- t = calendar year of felling of stands.

The average (within the rotation period) index of change in forest productivity is calculated as:

$$\Delta_n(t) = \frac{\sum_{i=1}^{N_n} a_{in}(t) \cdot b_{in}}{\sum_{i=1}^{N_n} b_{in}} ,$$

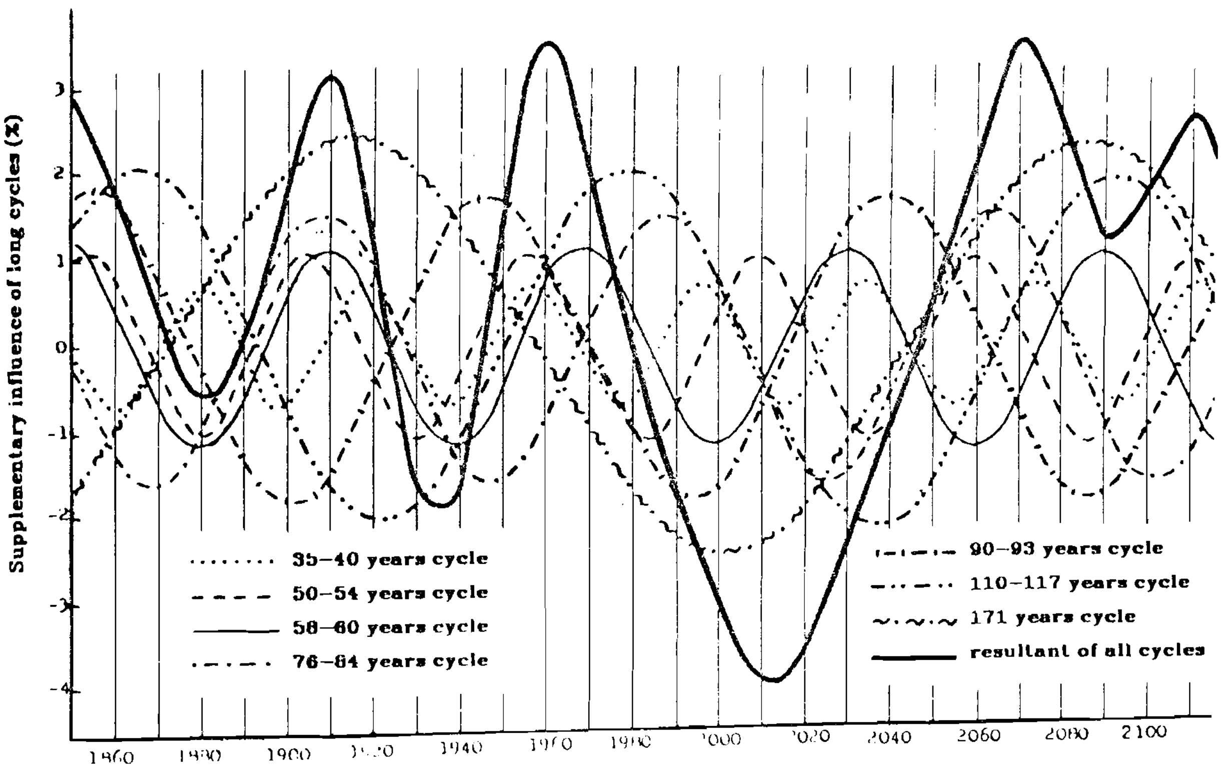


Figure 8. Long-term dendrochronological fluctuations.

where i is the index of an age class.

The allowable cut is estimated using the average real volume of mature stands in Lithuania (forest inventory, 1980). It is affected by climatic fluctuations and therefore the cycle impact on the volume must be eliminated:

$$V_n^* = \frac{V_{n,1980}}{1 + \frac{\Delta_{n,1980}}{100}} ;$$

where:

V_n^* = base volume of stands;

Δ_n = productivity change as a result of the climatic impact on the stand volume, %;

V_n = volume of mature stands in year 1980.

The average volume to be cut in mature stands (m^3/ha) is estimated as follows:

$$V_n(t) = V_n^*(1 + \frac{C \cdot \Delta_n(t)}{100)} ,$$

where C is the coefficient; to estimate the exact value of the coefficient, a special study is necessary; we assume that C = 1.

Table 2 gives the results of estimation of timber volume in the mature stands taking into consideration long-term dendrochronological fluctuations. These data indicate that long-term climatic fluctuations have no essential influence on timber volume of the mature stands. The productivity of stands decreases due to the impact of air pollution. The influence is still greater in periods of short-term fluctuations. Such periods are unfavorable for tree growth. If one assumes a reduction of 30% of normal increment, the mean timber volumes of the mature stands will be at the level presented under the last column of Table 2.

5. Assessment of Timber Harvesting

To determine the rates of allowable cut as one of the main kinds of timber harvesting, the model OPTINA (Deltuvas, 1982; Kairiukstis et al., 1986) was applied. The input to the model is the following: 1) Areas of age classes; 2) Number of age classes in the rotation period; 3) Average volume of mature stands; 4) Timber prices.

The model runs in the following way: for each species, an allowable cut is determined and the minimal one is selected:

$$f = \min\left\{f_1 + \alpha f_2, \frac{f_1+f_2+\alpha f_3}{2}, \ldots, \frac{f_1+f_2+\cdots+\alpha f_n}{n-1}, \frac{f_1+f_2+\cdots+\alpha f_n}{n}\right\} .$$

where:

Table 2. Comparison of scenarios of timber volume dynamics in mature stands.

Years	Volume of mature stands, m^3/ha		
	Scenario 1 (cycles and air pollution are not taken into account)	Scenario 2 (allowing for cycles)	Scenario 3 (allowing for cycles and decrease in forest productivity by 30% induced by air pollution
1985	221	220	
1995	217	216	
2005	219	218	
2015	224	221	
2025	223	220	154
2035	223	219	153
2045	223	218	153
2055	223	218	153
2065	223	219	153
2075	223	220	154
2085	223	221	155
2095	223	222	156
2105	223	224	157
2115	223	225	157
2125	223	225	157
2135	223	225	158

f = possible area yield for a 10-year period;
f_1 = area of the last age class in the rotation period (beginning from mature stands);
f_2 = area of the last but one (premature) age class in the rotation period, and so on;
n = rotation period (number of decades);
α = coefficient.

Further input data (age classes) for the subsequent 10-year period is formed and the allowable cut is determined for this 10-year period.

Supplementary limitations are: the allowable cut for each subsequent decade must not be lower than that of the previous one and it must not exceed the normal cut. The volume to be felled (M) is set by multiplying the allowable cut area (f) by the volume of the mature stands (V).

The output is: the dynamics of the age class areas and allowable cut (ha, thousand m^3, million roubles) in prospects.

Environmental changes are considered in the model by transforming the input data on the age classes and on the volume of mature stands. Changes in the magnitude of allowable cut depending on the impact of air pollution, on the state of forests and allowing for the two hypotheses (section 4) are illustrated in Figure 9:

1. damage of the forests according to the model;
2. decrease in forest productivity up to 30% taking into account long-term dendrochronological cycles;

Both scenarios indicate more or less significant reductions in the magnitude of timber harvested under conditions of environmental contamination. An application of these data for repeated calculations according to the model of regional productivity enables the optimal variants of production to be found. They minimize the total expenses for nature protection and for the losses due to a decrease in magnitude of timber harvested as well as for other kinds of damage induced by environmental contamination.

6. Conclusions

The method presented enables some ecological consequences of the development of the national economy for timber harvesting to be considered. It is based on an intersectoral analysis of regional development. Special methods are applied to determine the state of the environment which impacts on forests as well as timber harvesting.

The method suggested may be improved along the following lines:

1. improvement of the information basis for modeling; and
2. specification of input scenarios for analysis of questions such as rate and proportion of national economy development, scientific and technical advance in forest enterprises and in other sectors, and so on.

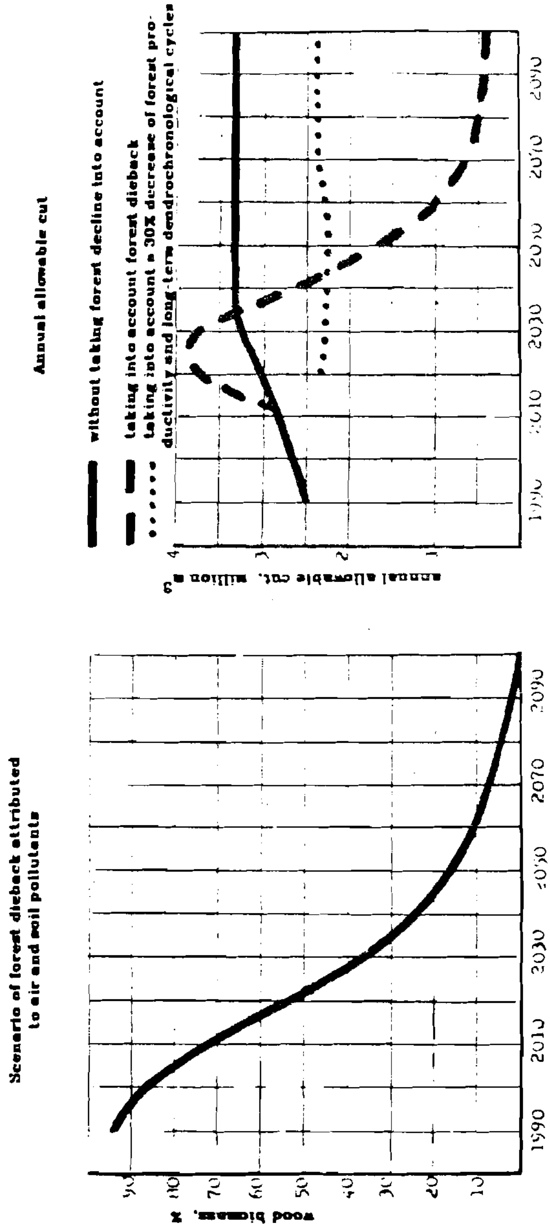


Figure 9. Influence of forest decline on allowable cut.

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4.13 RECREATIONAL FOREST USE IN LITHUANIA, USSR*

E.A. Riepshas
Lithuanian Research Institute of Forestry
Kaunas, Girionys
Lithuanian SSR, USSSR

1. The Basic Factors of Recreational Forest Use

The basic factors of recreational forest use are biological, humanitarian and socioeconomic. Optimizing recreational forest use is not only an important part of the problem of nature protection but it is also a problem of human life on the Earth as a whole. The Program adopted at the 27th Congress of the Communist Party of the Soviet Union enunciates: "Everything for man's sake."

The human requirements embrace not only physical requirements necessary to sustain life, but also physiological ones, including sanitation, the requirements for pure food, water, air and space. Man strives for an ecologically pure recreational environment.

The humanitarian requirements are the following: to know the environment, to enjoy the beauty, the sounds and the odor of nature, to develop one's personality and to strive for intellectual, ideological satisfaction of one's personality.

The demand of the population of the Lithuanian SSR for forest recreation was determined by sociometric methods [2]. The investigations were conducted by us in 1976, 1980 and 1984 with the help of questionnaires (nearly 16,000 questionnaires). They resulted in elucidation of the main tendencies of recreational forest use and in the establishment of the dependence of recreational requirements on the most important natural, socioeconomic and demographic indices of the Republic. These requirements were assessed taking into account the theoretical fundamentals of recreational geography and practical requirements for recreational landscape formation [16, 20]. The observance of these principles is an indispensable condition of interdisciplinary integration of the findings in solving the problem of optimizing recreational nature utilization at large and recreational forest use in particular.

In 1985, the recreational load on a forest in the Republic comprised 14.7 million visitor-days. By the year 2000, it will increase to nearly 23 million visitor-days per year.

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buračas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

2. Factors Restricting Recreational Forest Use

The situation with respect to forest use is mainly determined by the requirements of the national economy, the community and population for forest resources and products (wood, berries, mushrooms, game, resin, etc.) and by forest protective peculiarities (in the broad sense). The intensity of forest management is of importance too.

Currently, 70% of the demand of the national economy of the Lithuanian SSR for wood is met locally [1, 6]. It is impossible to meet the requirements for wood completely due to lack of mature stands (4.2%) [5]. However, the age structure in forests in the very near future (at the beginning of the 21st century, mature stands will increase by 20%) will improve and their productivity will increase (the mean annual volume increment will increase by 0.046 m^3/ha). By the year 2000, the requirements for wood will be met fully from local resources [8, 9].

The demand for byproducts increases. The annual yield of mushrooms in the forests of the Republic comprises on average 54 thousand tons, whilst that of berries 30. Only 15% of the production of mushrooms and 20% of berries are used. However, the intensification of forest management and the increasing recreational load, reduce the yield of mushrooms since the conditions of their habitats will deteriorate. Over the last 20 years the area of berry plantations decreased by 25% [2, 18]. Only 30% of the demand of the national economy for berries and the requirements of the population for herbs are met [1, 2]. Currently, the number of large game (particularly elks) slightly exceeds the allowable rate [11]. The requirements of industry for resin are insufficiently met.

The situation with respect to forest use is rather critical on the whole. Therefore, the increasing recreational requirements will be mainly met through intensification of forest management for recreation. According to our calculations, the area attributed to recreational forests in the Lithuanian SSR will stabilize by the beginning of the 21st century.

The legislative basis for development of recreational forest use is confirmed in the Constitutions of the USSR and the Lithuanian SSR, and in the Program of the Communist Party of the USSR and in a number of Union and republic levels.

Material-technical possibilities for development of recreational forest use are characterized by the following:

1) manpower levels (training of specialists – engineers, technicians and skilled workers);
2) the provision of materials and techniques (with techniques adjusted to the work in forest parks and in other particularly valuable recreational forests, with materials, with means of information and with tools);
3) the provision of technology (specialized regulation of the management of a district, elaboration of projects and techniques for singling out recreational areas for a short period, for designing forest parks, zones of recreation in national and natural parks, in reservations and in other territories with a special function);
4) the provision of workers (the number of permanent and seasonal workers).

Specialists in recreational forest use are not trained in the Republic. Engineers and technicians (of a general nature) in forest management as well as technicians for planting of trees and shrubs in towns and settlements mainly work in these forests.

Provision of materials entails no difficulties. Lack of special techniques and workers has the most restrictive influence on the development of recreational

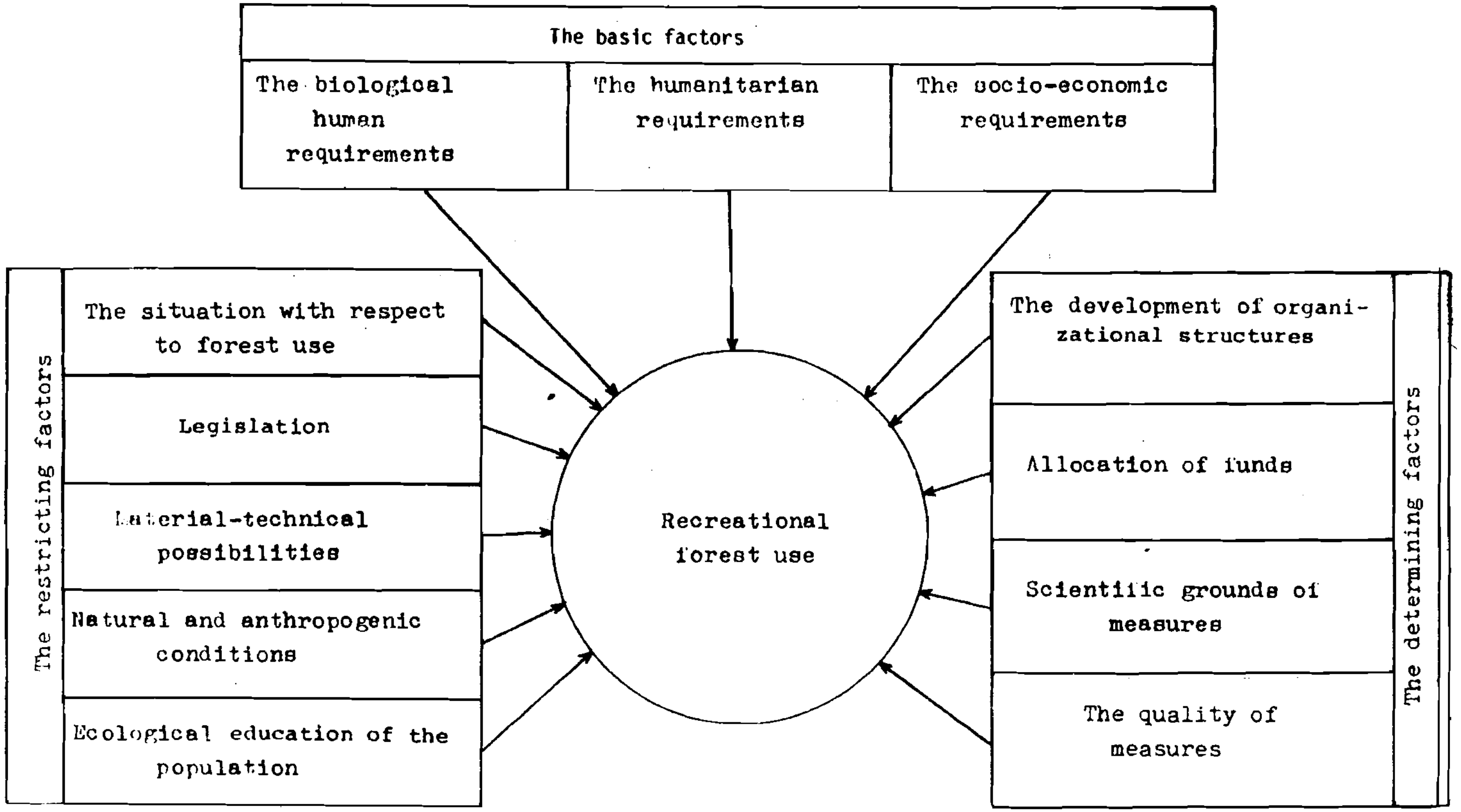

Figure 1 The factors conditioning recreational forest use

forest use. Special small-scale techniques and microtractors are also needed. Large-scale planting is insufficiently mechanized.

The level of provision of technology is rather high. Recreational forests are established by a special division of the Lithuanian forest enterprise of A-U/C "Lesprojekt." The designs of forest parks, short-term recreational sites, sanitation, etc. are elaborated by the experimental project-construction – technological bureau of the Ministry of Forest Management and Timber Industry of the Lithuanian SSR.

Natural conditions in the territory of the Republic are rather favorable for the development of recreation. In summer, 44% of the days are sunny, whilst 78% of the days are without precipitation. A normally dressed person feels comfortable on sunny days in May and September and on cloudy days in July and August. Forest cover constitutes 27.9%. There are 2543 lakes with areas of more than 0.5 ha. 725 rivers are longer than 10 km. The length of the shore of the Baltic Sea in the Republic is 99 km. In winter, conditions are less favorable for the development of recreation since mild winters prevail with insufficient snow and partial thawing. Winters without any stable snow cover also occur.

Forest management for recreation contributes to the development of the road network (514 km/1000 km^2). Recreation centers provide accommodation for nearly 760 thousand people [7]. In 13 of 44 regions, the development of recreational forest use is hindered by environmental contamination induced by industrial enterprises, farming and transport [3].

The recreational capacity of the forests of the Republic was assessed using a method created by us [12]. The results demonstrate that from the standpoint of recreation, the most valuable forests are at Neringa, in the regions of Ignalina and Shvenchioniai (Figure 2). The forests of the Moletai, Lazdijai and Varena regions also have significant recreational value, whilst those of the Birzhai, Akmene, Mazheikiai, Skuodas, Kedainiai, Jonava, Pakruojis, and Kapsukas regions are of less value.

In order to preserve the forests valuable for recreation, it is necessary to use them rationally and to optimize their ecological and recreational capacity. The latter was evaluated for all forests of the Republic according to our methods and standards. The greatest recreational capacity was found in the forests of the Varena and Shvenchioniai regions. The forests of Vilnius, Trakai, Plunge, Shiauliai, Shalchininkai, Panevezhys, and Jurbarkas regions also have great recreational capacity.

The potential ecological recreation capacity for all forests of the Republic comprises 133 million visitor-days per year (conditionally assuming that all visits are attributed to recreation).

Ecological education of the population is of importance in developing recreation. People unaware of ecological factors are not careful enough while making fires in the forest. They litter the ground, damage the vegetation and anthills, destroy forest litter, make noise, contaminate water and soil, and vandalize campground furniture and other objects. The forest loses its attraction and new visitors go to other forest territories. Low ecological education restricts the utilization of protected forest landscapes for recreation and especially those which are valuable and can be readily damaged [4, 14].

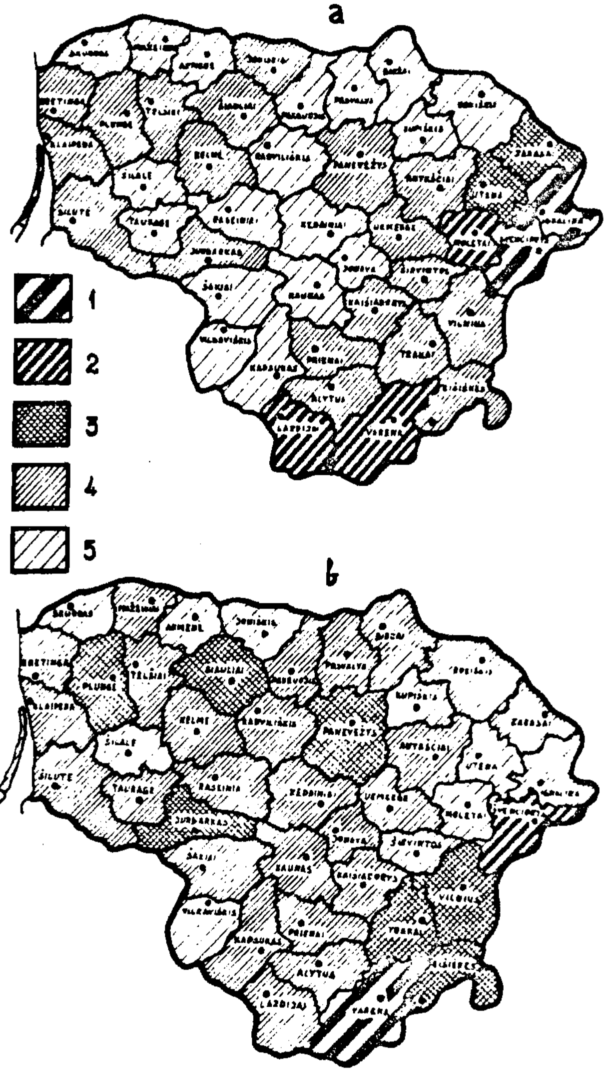

Fig. 2. Assessment of recreational (a) and ecological (b) capacity of forests of the Lithuanian SSR according to administrative regions. Recreational capacity, points: I - >20; 2 - I5.I-20.0; 3 - I0.I-I5.0; 4 - 5.I-I0.0; 5 - ≤5. Ecological capacity, million visitor-days per year: I - >8; 2 - 6.I-8.0; 3 - 4.I-6.0; 4 - 2.I-4.0; 5 - ≤2

3. The Factors Determining Recreational Forest Use

It is necessary to create an organizational structure for recreational forest use on different hierarchical levels of forest management and planning as well as allocation of funds for organizational-economic measures to remove conflict situations. Conflicts arise between the increasing requirements of the population for forest recreation and the degree to which these requirements are met. Simultaneously, the corresponding status for each link regulating their activity in time and space must be worked out.

Special funds for forest management for recreation so far, are insufficient [13, 19].

The funds allocated for constructing and repairing roads and for implementing fire-prevention measures a. e also used to provide recreational amenities and services.

The most important task of forestry research institutes is to elaborate a system of organizational-economic measures. They should include the selection of recreational forests, their assessme: t and projection, forest management (starting with forest plantations and ending with felling) and recreational services and amenities on the territory. Organizational-economic measures must differentiate according to the prevailing recreational activities, according to the intensity of recreational utilization of the territory and according to natural and anthropogenic conditions [13, 15, 18].

4. Elaboration of a System of Organizational-Economic Measures

A system of organizational-economic measures for recreational forests is an interactive complex of forest management, service, amenity and organizational measures. Optimization of recreational forest use means purposeful actions leading to the best combination of existing processes in the forest ecosystems which maximally meet recreational requirements of the population. The cost of protection and development of these forests must be minimized. Two groups of local anthropogenic factors influencing biological mass exchanges, energy flow and the quality of the biota in recreational forests have been singled out (Figure 3): 1) consumption factors (the impact of the recreational load) and 2) economic factors (the effect of economic measures).

Consumption factors affect succession processes adversely. They cause deterioration of the ecosystems with respect to both ecology and socioeconomics. Economic factors conditionally stimulate positive succession processes stabilizing the behavior of ecosystems. They also favor positive successional processes which optimize their utilization for recreation, i.e., with respect to socioeconomics.

Thus, the measures included in an organizational-economic system must regulate recreational load, ensure environmental protection and improve forest recreational conditions (Figure 4).

Organizational measures embrace the creation and development of organizational structures on all levels of forest management. They are also related to the organization of the territory and recreation on the All-Union, regional and local scale.

The major questions of organizing the territory in the Republic and in a region are tackled in a *Complex Scheme of Nature Protection in the Lithuanian SSR* [17]. Methods of mathematical modeling are provided for organizing the

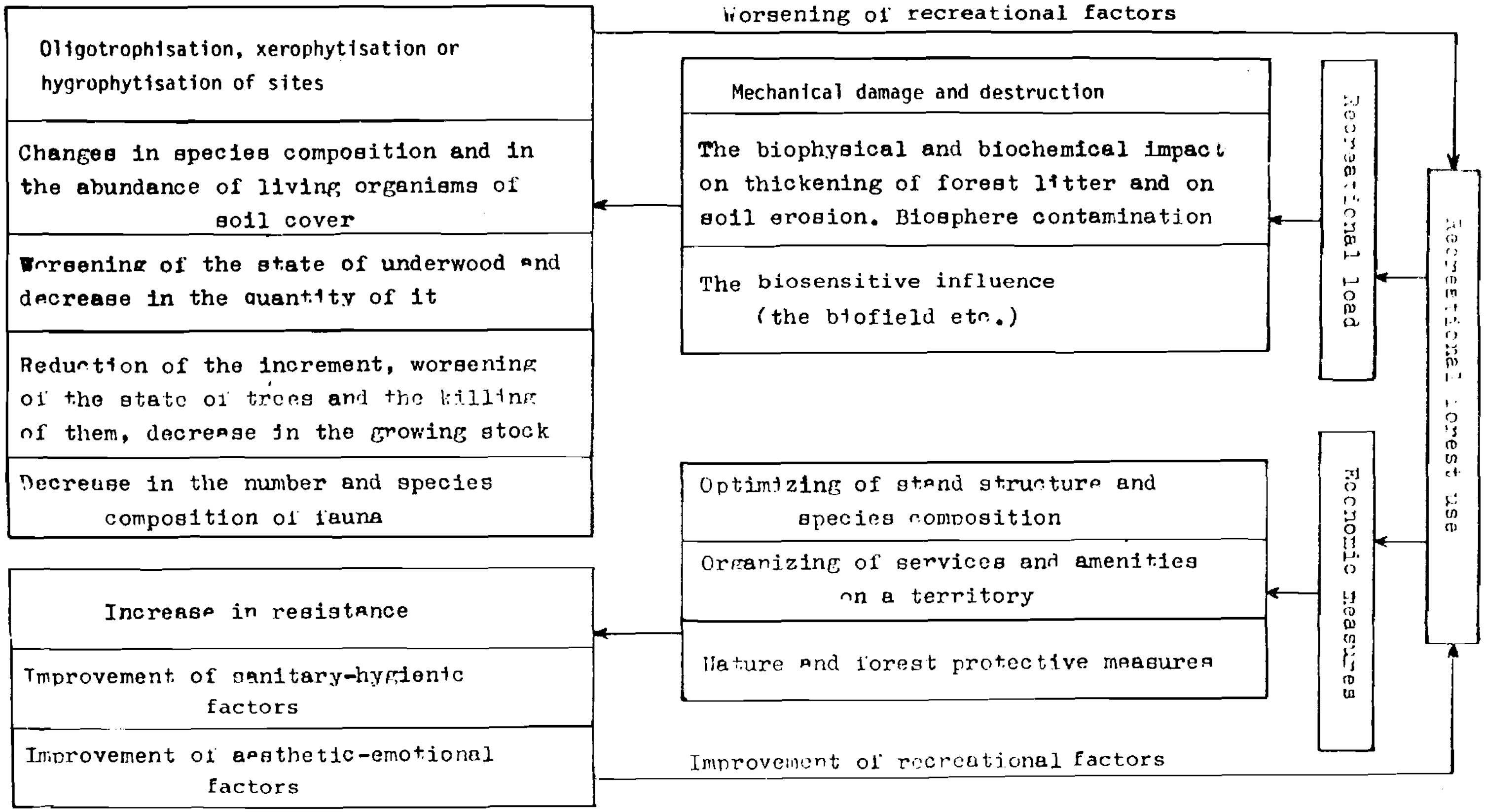

Figure 3. A scheme of interactive processes occurring in recreational forests

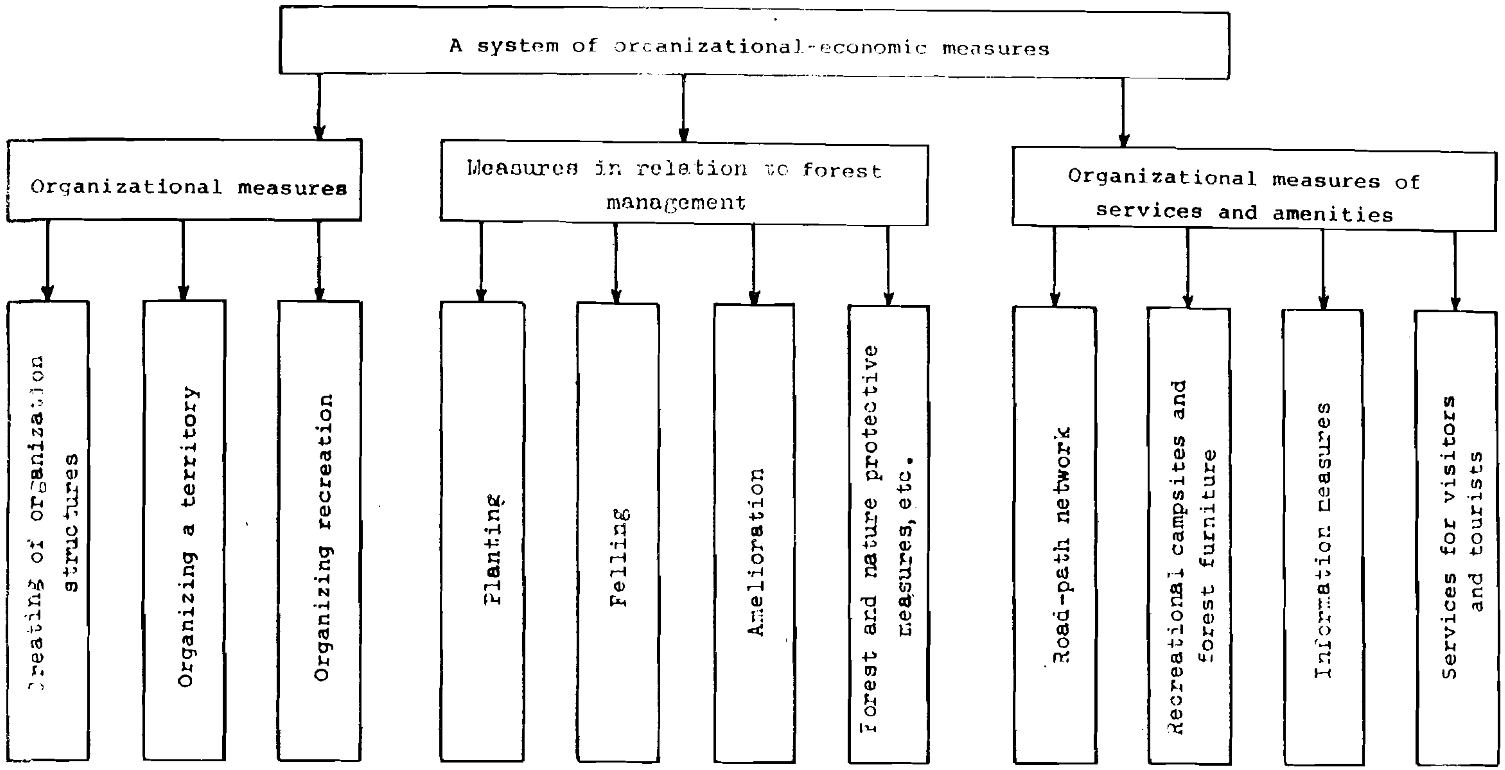

Figure 4 A system of organizational-economic measures for recreational forest use

territory on a local scale. Optimizing of spatial structure, species composition and functional zoning of a recreational forest in a complex way is feasible with the aid of the model, which is based on the integration of medico-biological and aesthetic-emotional requirements of tourists and on the resistance of forest ecosystems at minimal cost.

Organizing recreation belongs to the nonproductive sphere of man's activities. Effective functioning of this sphere is possible only within the framework of an organized, planned and managed branch [10]. Many problems of organizing recreation remain to be solved.

The most important measures of forest management are planting, felling, amelioration and forest protection. The building of roads and paths, recreational campsite construction, the development of a rational information system and facilities for tourists are needed to provide amenities and services. These problems must be solved using modern forest biology applying the newest techniques.

5. Conclusion

The process of optimizing recreational forest use is conditioned by a complex of natural and socioeconomic factors. It is also related to measures embracing the development of balanced and specialized forest management, the improvement of the material-technical basis for management, a decrease in the adverse anthropogenic impact on the environment, the ecological education of people, as well as refinements in the legislative basis for recreational forest use.

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4.14 CONTROL OF A FOREST POLICY SYSTEM AND ITS OPTIMIZING SIMULATION*

Takuro Kishine
Kyoto University,
Faculty of Agriculture
Sakyo, Kyoto 606, Japan

1. Control of a Forest Policy System as a Social System

Forest policy is a method of artificial control which pursues supreme spiritual as well as material values through optimal forest utilization for public service and economy (i.e., timber products) on the assumption that the forest is an indispensable spiritual as well as material resource for the support of human beings. This is because a forest policy system is a social system and the principle of its control is almost the same as the automatic control of an engineering system except for the existence of human beings themselves in the control system. From this point of view, the control theory of the general social system including the forest system is presented in Figure 1.

2. Development of an Optimal Allocation System Model of a Forest Area – OA Model –

Figure 2 shows the contents of a simulation model of the social system in Figure 1 with respect to the forest system. This mathematical model consists of two types of forest system. This mathematical model consists of two types of submathematical models; one is that of a technical system for the optimal zone allocation and optimal working division of forests through principal component analysis: P.C.A. (cluster analysis is also used if it is needed); and the other is that of a political system for the optimal allocation of a forest area for economic and public service use to maximize the combined total forest revenue of the economic forest and the public service forest through econometric analysis

2.1 Optimal allocation system model of forest area by principal component analysis – OA model : –

To attain the optimal allocation of forests of a country, it is useful to make meshes of the total forest area and estimate the general characteristic value, i.e. principal component of each mesh by principal component analysis (P.C.A.), and then arrange the optimal zone and optimal working division according to those

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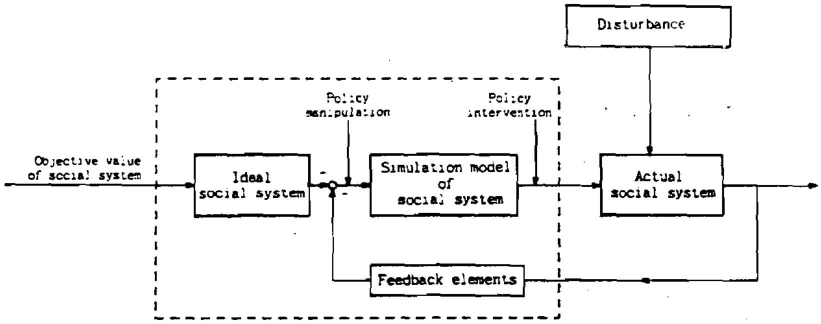

Figure 1. Control of a social system

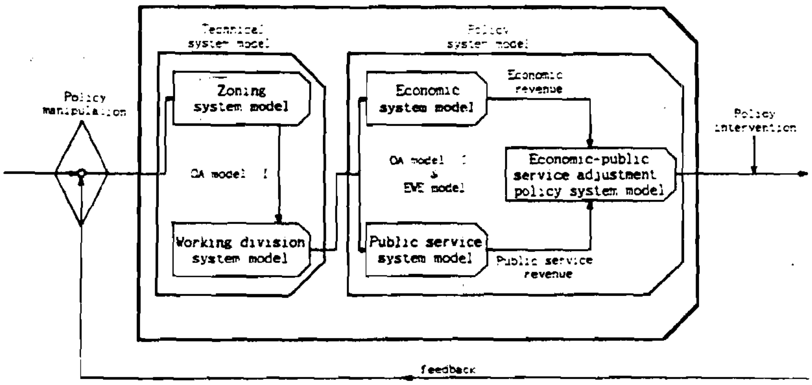

Figure 2. Mathematical models of forestry as a social system

principal components with the highest value. From this point of view, this model may be called Optimal Allocation System model: type I, i.e. OA model: I in short. In this way, the total forests of the country are classified into the forest types of the mountainous interior, the middle zone, and the suburbs; furthermore, each of them is divided, in to the working type, of the economic forest and the public service forests. The details are as follows.

Optimal zoning system model of forest area

By P.C.A., forests may be classified into the forest types of the mountainous interior, the middle zone, and the suburbs according to each mesh which has the indexes based on natural conditions i.e., environmental factors such as temperature, precipitation, altitude, nature of land, vegetation, rivers, lakes, scenery, etc.

Optimal working division system model of forest area

We also set up the working division design of forest utilization about each forest type classified by the allocation of forest according to P.C.A. In concrete terms, we divide the forests of the mountainous interior, the middle zone, and the suburbs into economic forest, public service forests i.e., water reservoir forest, national land maintenance forest, recreation forest, etc., according to each mesh which has the indexes based on economic conditions such as proprietary situation, utilization forms of forests, site condition, etc., and social condition such as village construction, depopulation, urbanization, and historic and noteworthy spots, etc.

In the following, the theory and method of principal component analysis on the "optimal allocation planning of forests", particularly on the "optimal working division planning of forests" is clarified, taking the example of forests of Osaka prefecture in Japan.

Here, the principal component analysis is defined as "theory to reduce various kinds of correlated characteristics to a mutually unrelated small number of general characteristics". Forests have so many kinds of individual characteristics such as geography, soil, vegetation, rivers, landscape and so on, and economical or social conditions like proprietary situation, utilization forms of forest, economic location conditions and historical sites etc. These individual characteristics represent a very complicated ecological and social system, maintaining mutual relations among them. Therefore, it is impossible to grasp the general characteristics of a forest as a whole if we examine each characteristic one by one.

In such a case, if we can summarize these various individual characteristics into a few mutually independent general characteristics or general indexes (which is called a principal component), with these, we may understand the overall or general characteristics of the forest precisely and clearly. This is the reason why we adopt in this study the principal component analysis for the optimal allocation planning of forests. Namely, by the principal component analysis, if we can clarify the peculiar general characteristics of respective forests divided into meshes, through such working division as displaying the peculiar general characteristics of each forest in a mesh, as a whole, we can determine the "optimal working planning" of the concerned forests, that is, in this case, of the whole forests in Osaka prefecture.

Next, let us apply principal component analysis on the forest in Osaka prefecture. The general characteristics i.e. the principal components of the forests of Osaka prefecture are as shown in Table 1. At this point, it is important to clarify which original individual characteristics are represented by the newly determined general characteristic through principal component analysis, because without this check, we cannot understand the content or the meaning of the general characteristics. To achieve this, in the principal component analysis, we should measure the factor loading. Here, the factor loading is defined as "the simple correlation coefficient between certain general characteristics (principal component) and its original individual characteristics", and by measuring this factor loading, we can know which principal component has high correlation with which individual characteristics, and therefore, it is possible to decide precisely the contents of the concerned principal component. Concretely, we can name each principal component.

Table 1: Determination coefficient

Principal component (P.C.)	Determination coefficient	Cumulative determination coefficient
First P.C. Z_1	20.3	20.3
Second P.C. Z_2	15.8	36.1
Third P.C. Z_3	13.5	49.6
Fourth P.C. Z_4	9.6	59.2

From the point of view in this paper, the factor loading is estimated to each principal component in Table 1 which have high coefficients of determination. Here, the principal component with high determination coefficient means the general characteristics with a high degree of explanation. In the case of forests in Osaka prefecture, in the order of first, second, third, and fourth principal component, the determination coefficient is high.

Figure 3 visualizes the results. the factor loading is the simple correlation coefficient between the general characteristic and its original individual characteristics as mentioned above, so that all of them are within the circle with radius 1.0, and the more their positions come near the circle the stronger the correlation between the original individual characteristics and the summarized characteristic i.e. principal component. Therefore, we can give the meaning to each principal component respectively as follows.

Firstly observing Figure 3.1, we can see that Z_1 of the first principal component has strong positive correlation with original individual characteristics No. 3, No. 4, and No. 5. Further, No. 3, No. 4, and No. 5 represent the first stratum factor i.e. water reservoir function, the second stratum factor i.e. soil conservation function, and soil composition factor i.e. water reservoir and soil conservation function respectively. As a result, we can explain the content of the first principal component Z_1 as a summary of various factors of the forest like flood and mountainous disaster prevention functions. For this reason, this kind of principal component may be called "the component of national land conservation function".

Figure 3-1 Z_1-Z_2 factor loading

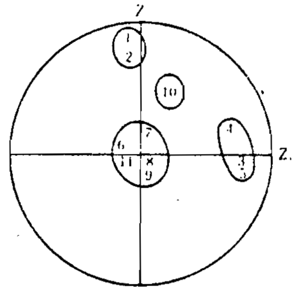

Figure 3-2 Z_1-Z_3 factor loading

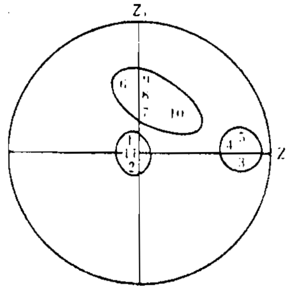

Figure 3-3 Z_1-Z_4 factor loading

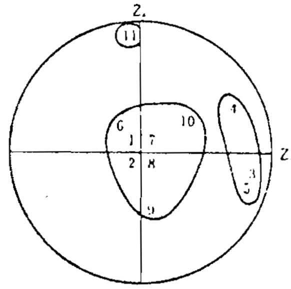

Figure 3: Factor Loading

Next, the second principal component Z_2 has a strong positive correlation with original individual characteristics No. 1. and No. 2. No. 1 and No. 2 are the factors of soil composition and soil productivity respectively; ultimately, the content of the second principal component Z_2 represents those factors such as good soil condition and high productivity which directly effect the timber production. Thus, this principal component Z_2 may be named as "the component of timber production function".

On the other hand, individual characteristics of No. 10 which are located very close to the original point of the coordinate of No. 6, No. 7, No. 8, No. 9, and No. 11, which are so near the original point, that individual characteristics have little or no correlation with the first and second principal components Z_1, Z_2. Some of these individual characteristics, however, have very strong or quite strong correlation with other principal components as is shown in Figure 3-2 and Figure 3-3. That is,.from Figure 3-2, the individual characteristics No. 6, No. 7, No. 8, No. 9, and No. 10 have quite strong correlation with the third principal component Z_3; these five individual characteristics are rivers and lakes, convenience of movement, mixed forest construction, and famous sites; so that the third principal component Z_3 summarizes those various factors of rivers and lakes where people enjoy health and rest in good condition, where it is easy to walk along well arranged hiking routes and the like, and also to see beautiful forest construction and famous sites. Therefore the third principal component Z_3 represents the suitable forest recreation function. For this reason, we may call these kind of principal component as "the component of forest recreation function".

Similarly, from Figure 3-3, seeing that the individual characteristics No. 11 has very strong correlation with the fourth principal component Z_4, and since No. 11 is degree of vegetation, the fourth component Z_4 represents the characteristics indispensable for the maintenance of the ecosystem of the concerned forest. Therefore, we can call this principal component, "the component of ecosystem preservation function".

At this stage, the above four principal components are summarized in Table 2.

Table 2: Naming of the principal component

Principal component	Name
First P.C. Z_1	National land conservation function
Second P.C. Z_2	Timber production function
Third P.C. Z_3	Forest recreation function
Fourth P.C. Z_4	Ecosystem preservation function

The following is the computation of the "general characteristic value" so called "score" of every principal component of each mesh of whole forests in Osaka prefecture. Here, the general characteristic value is the estimated value by substituting each argument on the rightside of the regression equation of the principal component for a respective datum (in this example, evaluated value of the forest function obtained through the mesh investigation). The reason why we calculate the general characteristic values is that, to the respective principal component of each mesh, the value are the respective principal component of each mesh, the higher its computed value, the more precisely the principal component represents the individual characteristic of the forest in the concerned mesh; so if we carry out the forest utilization plan aiming at the principal component with highest value, we can optimize the functioning division i.e. working division of the whole forest. The detail is as follows:

First of all, compute the scores of the principal components with high determination coefficient, and plot the value in the plane decided by two principal components (this figure is called the scattering chart of scores). In this example, as the principal components with high determination coefficient are Z_1, Z_2, Z_3, and Z_4, we are to make three meaningful charts with the combinations of Z_1-Z_2, Z_1-Z_3, and Z_1-Z_4. Figure 4 shows the chart of Z_1-Z_4 plane as an example.

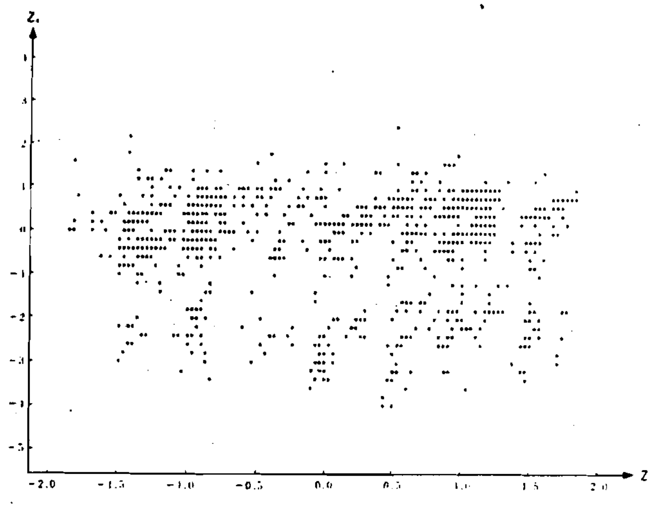

Figure 4. Scattering chart of scores

Next step is the choice of the principal component which represents the concerned mesh, by comparing the scores in three kinds of scattering charts simultaneously. Here, I propose the choice selection procedure shown in Figure 5.

This figure shows a procedure for selecting the representative principal component of each mesh by the scattering chart of scores. The method starts with the division of the coordinates axes of each scattering chart of scores into three equal parts between maximum and minimum values, naming them H (high), M (middle), and L (low) from the top. Then, for example, if the score of a certain mesh falls in the "a" zone, both the first and the second principal components Z_1, Z_2, have strong effects on the mesh, so that the "optimal allocation planning of forest" is either the public service usage as required by the first principal component Z_1 or the economic usage as given by the timber production function represented by the second principal component Z_2. Of course, the principal component with the higher score should be chosen prior to the other principal component in the same mesh. In another case, if the score of a certain mesh is plotted in the "b" zone, this means that the first principal component Z_1 is too strong

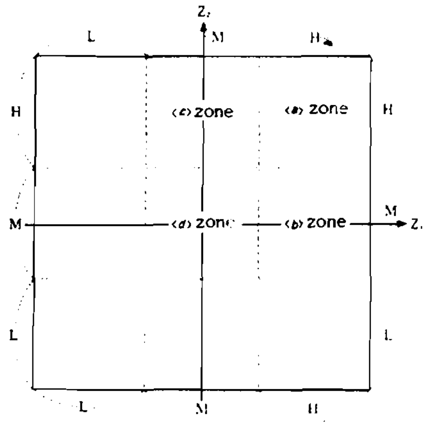

Figure 5. Choice selection procedure of representative principal component.

while the second Z_2 is not so strong; therefore, it is the "optimal working division planning of forest" to choose the public service usage; and vice versa in the case of the "c" zone. If the score falls in the "d" zone, we know that both the first and second principal components Z_1, Z_2 are weak, and therefore these meshes are unsuitable for national land conservation or timber production.

The selection procedure mentioned above holds good in the scattering chart with the axes Z_1–Z_2; however, the procedure differs according to the combinations of the principal components on the axes. As a result, we have to examine all combinations of principal components on the axes in this way. But practically, it is almost impossible to fulfill this kind of operation (2880 meshes in the case of the forests in Osaka prefecture). For this reason, I have developed a substitute method as follow.

In the new method, scores of each principal component of all meshes are first calculated, and then, classified (by color-code) as high, middle, low as shown in Table 3. A color-coded map is then drawn of the concerned forest area by each principal component, and finally on the bases of this map, the principal component is selected with highest score in each mesh to represent the principal component of the concerned mesh.

Table 3: Color-coding of the Principal Component

Principal component Score		Z_1	Z_2	Z_3	Z_4
High	H	blue	ocher	pink	green
Middle	M	purple	purple	purple	purple
Low	L	orange	orange	orange	orange

The "optimal allocation planning of forest" of the concerned area can be attained by selecting the principal component with the highest score. Figure 6 show this process.

2.2 Optimal allocation system model of forest area by econometric analysis — OA model: II —

Prototype of OA model II In this mathematical model, the optimal area arrangement of the economic forest and public service forest is selected to maximize the combined total of economic net revenue and public service net revenue by manipulating the forest age "t" of each growth function of economic and public service forests, that is:

Growth function of economic forest: i.e.

$$Q\Delta = Q\Delta\ (t)$$

$$Q\Delta = K\Delta / (1 + \exp(a\Delta + b\Delta t))$$

Growth function of the public service forest such as the water reservoir forest: i.e.

$$Q_1^* = Q_1^*\ (t)$$

$$Q_1^* = K_1^* / (1 + \exp(a_1^* + b_1^*\ (t)$$

Growth function of the public service forest such as a recreation forest i.e

$$Q_2^* = Q_2^*\ (t)$$

$$Q_2^* = K_2^* / (1 + \exp(a_2^* + b_2^* t))$$

Since the working standard of forest differs among the economic and the public service forests, those growth functions $Q\Delta$, Q_1^*, Q_2^*, too, form respectively different curves according to variation of the parameter "t", as shown in Figure 7.

Therefore, in so far as the growth function of each kind of forest is estimated, the optimal allocation of the economic forest area and the public service forest area which realizes the maximal total net revenue of economic and public service revenue is attained by manipulating the forest age "t" in the following mathematical model. From this point of view, this model may be called Optimal Allocation System model: type II, i.e. OA model: II in short. Here, only the patterns of water reservoirs and of forest recreation are given as an example. See Table 4.

In concrete terms, this mathematical model is such that, with regard to the economic net revenue model, the growing stock per unit area of economic forest $Q\Delta$ is determined so as to each "t" through the growth function $Q\Delta = Q\Delta\,(t)$; the economic net revenue of the whole economic forest area $V\Delta$ is, in fact, the

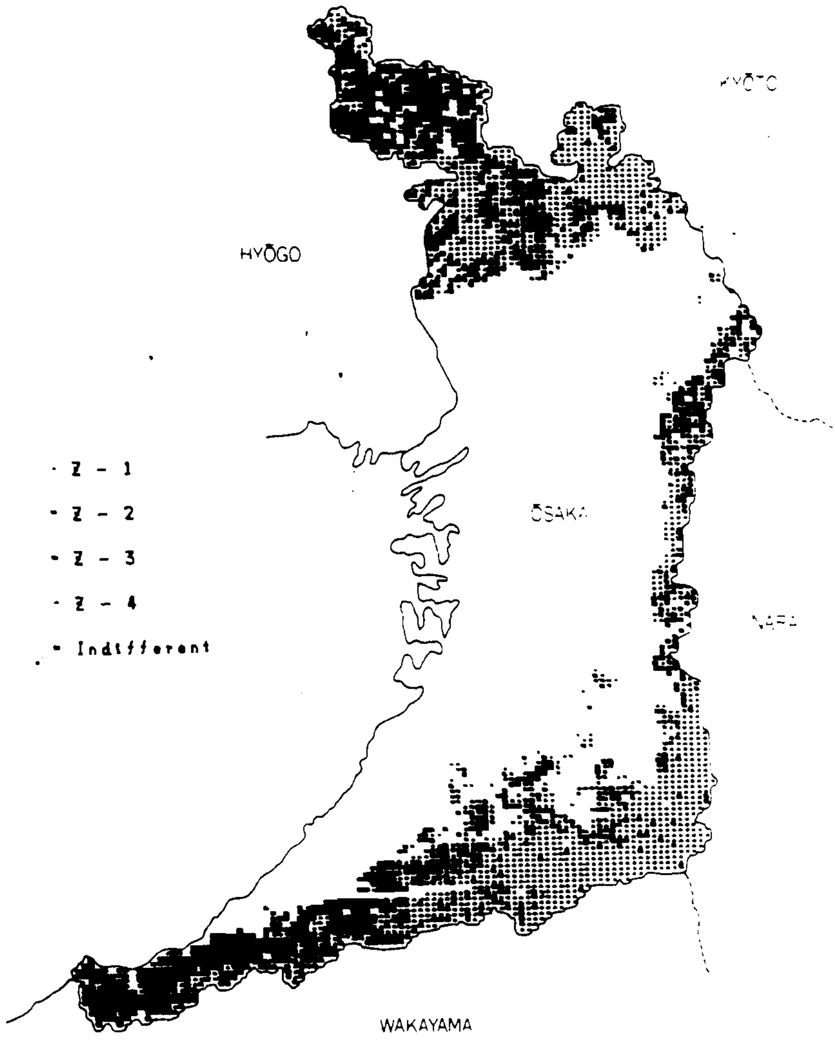

Figure 6. **Optimal working division of forest area in Osaka prefecture**

function of the economic forest area BΔ. Similarly, as to the public service revenue, the growing stocks per unit area of public service forests Q_1^*, Q_2^* are fixed according to every "t" by the growth functions $Q_1^* = Q_1^*(t)$, $Q_2^* = Q_2^*(t)$. This time, too, public service net revenues of the whole public service forest areas V_2^*, V_2^* are functions of the public service forest areas B_1^*, B_2^*, respectively. This mathematical model, therefore, is the t-determining model which maximizes the total revenue V as the objective function under the total forest area in B as the restriction; and those types of economic forest and of public service forest areas BΔ, B_1^*, B_2^* determined under the "t" are the optimal allocated area. In short, the maximal economic-public service net revenue is attained by utilizing the total forest areas in this ratio of economic forest and public service forest area.

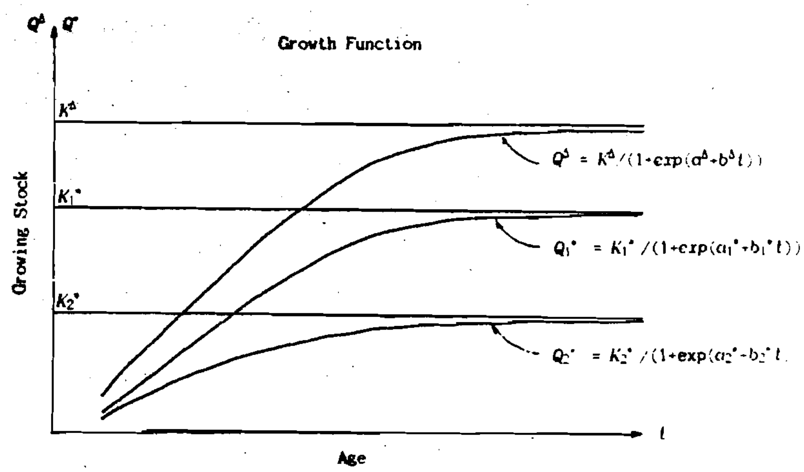

Figure 7. Growth functions of the economic and public service forests

TABLE 4 Prototype of OA model

Ⅰ. **Economic net revenue model**

$$(1)\quad \begin{cases} Q^{\Delta} = K^{\Delta}(1-exp(a^{\Delta}+b^{\Delta}t)) \\ S = Q^{\Delta} \cdot B^{\Delta} \\ V^{\Delta} = P^{\Delta} \cdot S \cdot x - C^{\Delta}(1+r)^{t} \end{cases}$$

Ⅱ. **Public service net revenue model**

Water reservoir net revenue model

$$(2)\quad \begin{cases} Q_1^{*} = K_1^{*}(1+exp(a_1^{*}-b_1^{*}t)) \\ W = k\, Q_1^{*} \cdot B_1^{*} \\ V_1^{*} = P_1^{*} \cdot W - C_1^{*}(1-r)^{t} \end{cases}$$

Recreation net revenue model

$$(3)\quad \begin{cases} Q_2^{*} = K_2^{*}(1-exp(a_2^{*}-b_2^{*}t)) \\ N = n\, Q_2^{*} \cdot B_2^{*} \\ V_2^{*} = P_2^{*} \cdot N - C_2^{*}(1-r)^{t} \end{cases}$$

Total public service net revenue

$$(4)\quad V^{*} = V_1^{*} - V_2^{*}$$

Ⅲ. **Objective function**

$$(5)\quad V = V^{\Delta} - V^{*} \rightarrow max$$

Ⅳ. **Restrictions**

$$(6)\quad \begin{cases} B = B^{\Delta} + B_1^{*} + B_2^{*} \\ S \geqq \bar{S} \\ W \geqq \bar{W} \\ N \geqq \bar{N} \end{cases}$$

Explanation of letters

Q^{Δ} : Growing stock per unit area of economic forest
K^{Δ} : Upper limit of growing stock of economic forest
t : Forest age
S : Log supply
B^{Δ} : Economic forest land area
P^{Δ} : Log price

V^{Δ} : Revenue of economic forest
ι : Ratio of added value of forestry
Q_1^* : Growing stock of water reservoir forest
K_1^* : Upper limit of growing stock per unit area of water reservior forest
C^{Δ} : Production cost of economic forest
r : Interest rate
W : Amount of water reservoir of forest
k : Coefficient of water reservoir of forest (i.e., amount of precipitation storage per unit stock of forest
B_1^* : Water reservoir forest land area
V_1^* : Revenue of water reservoir forest
P_1^* : Unit price of water (water rates)
C_1^* : Production cost of water reservoir forest
Q_2^* : Growing stock per unit area of recreation forest
K_2^* : Upper limit of growing stock per unit area of recreation forest
N : Total number of visitors in forest
n : Number of visitors per unit stock of forest
B_2^* : Recreation forest land area
P_2^* : Unit price of recreation in forest (i.e., rate of visiting forest)
C_2^* : Production cost of recreation forest
V_2^* : Revenue of recreation forest
V^* : Total revenue of public service forests
V : Sum of economic revenue and public service revenue
$\underline{B}$: Total forest land area
$\overline{S}$: Minimum log supply of forest necessitated
$\overline{W}$: Minimum water reservoir of forest necessitated
$\overline{N}$: Minimum number of visitors in forest necessitated

Unknown numbers:

K^{Δ}, K_1^*, K_2^*, a^{Δ}, a_1^*, a_2^*, b^{Δ}, b_1^*, b_2^*, B^{Δ}, B_1^*, B_2^*

Given variables:

Technical variables : k, n, B, $\overline{S}$, $\overline{W}$, $\overline{N}$

Economical variables: P^{Δ}, P_1^*, P_2^*, C^{Δ}, C_1^*, C_2^*, ι

Instrumental variable: t

4.15 FUTURE POLICIES AND INTERNATIONAL COOPERATION IN REDUCING FOREST DAMAGE*

Lennart Schotte
Royal Swedish Academy of Engineering Sciences
Laensstyrelsen, S-79184 Falun, Sweden

Let me begin by stressing the importance of IIASA as an organization of international scientific cooperation and as an organizer together with academies in other countries of meetings such as this one. IIASA serves as a catalyst of international cooperation on the scientific level and, for a project like the Forest Study of the Biosphere Project, also as a link to commercial life, forestry and the forest industry. I believe we need that wide approach.

Let me then try to name a few future policies which I consider to be of significance for the future.

1. The nature of biological science is no doubt such that links and mechanisms of the kinds involved here can scarcely be clarified with 100% certainty. Research and countermeasures in the shape of emission control and forest management must therefore proceed in parallel. International cooperation must take place and responsibility must be accepted on an international basis, with active involvement on the part of forestry and the forest-products sector. On such huge issues as these, our watchword should be to think globally and act locally.

2. We need to establish an overall picture encompassing the entire chain of events from chemistry and ecology to economics and market effects. We have to analyze the economic consequences of emissions – in the case of forestry and the forest-products sector – of each country affected, how air pollutants affect timber supplies and markets for forest products. There will be different effects, of course, in the short and long term. Only a year or two has in fact passed since researchers and international bodies fully realized the significance of this aspect, to the effects of air pollution on vegetation.

3. Funds for basic research about effects of natural stress factors on vitality of trees and stands must be increased. I think we should know more about the nitrogen effects, nitrogen leakage from soil and more about the ozone mechanisms. In that sense it was very stimulating to hear about the environmental program of the Lithuanian Republic and its financing through various sources.

The better understanding and the ability to manage the consequences of forest decline must deal with complete ecosystems with biological, technical, social, economic, and psychological points of view.

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*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buracas, and A. Straszak (Eds.), 1988. Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland

4. Ongoing monitoring of damage to forests by air pollutants must of course continue. Data should be compared annually. Results must be updated; this is a necessity. However, there is a strong need to get an international harmonization of the monitoring. Relevant comparisons due to different or changed monitoring or sampling are to some extent impossible. Funds for basic research must be raised for developing improved large-scale monitoring methods. The use of infrared photography technique and intensive research to improve and complete the method with satellite images should be favored.

IIASA can play an important role here, too, as catalyst and facilitator of development of such improved methods of remote sensing and internationally accepted protocols for ground and remote-sensing data collection for decline estimation.

5. It is important to encourage and make use of the two information centers located in Bratislava and Hamburg. Their unique possibility to take the lead in the process of data communication should be well taken care of. We need early warning systems from ecological as well as from economic standpoints.

6. I would like to underline the importance of a functioning process of knowledge transfer between representatives from science, industry, forestry, and politics. Messages are not always understood and made use of in a proper way. Demands and questions are not always phrased precisely enough. Important results should be communicated until receipt is confirmed. The process must be intensive, open and correct. We have something to learn here. To my mind this is a future policy also in general understanding. International agreements – such as emission control programs – have to be locally accepted. In a situation where the local strategies are not effective or significant, even the best international intentions are not likely to function.

7. Basic risk-management thinking should be adopted also to environmental matters. Forestry and industry must deal with forest decline as a potential risk or threat and not just something that might interfere some time on the markets, something only for environmentalists, politicians and scientists.

I think we have to be more pragmatic. I have already stated that research and action must run parallel. Let us set both targets simultaneously: precise and deep knowledge for scientific understanding and explanation on one side, and a pragmatic utilization of available knowledge and current techniques on the other, as early-warning systems for industry to plan according to and for the policy decisionmakers, the politicians, to react upon after a critical evaluation. Let us aim at both targets.

Also on this pollution matter, it must be accepted in society that action needs to be taken without knowing in advance every detail of the eventual truth.

8. More attention has to be paid to the role of managing or not managing the forests as well as proper management of pollution-damaged forest tracts. Healthy and thriving forests can cope better with stress factors. Through cleaning and thinning operations, unnecessary competition is avoided. Selection of the right kind of seedlings improves resistance. I am aware of the productivity plan for the Lithuanian forests. It represents an important measure for the future.

The forest-damage threat calls for intensified silviculture, better forest hygiene and good soil care, as well as a ground management adapted to local prerequisites.

9. The discussions, observations and policy decisions taken about forest damages should always be linked to the matter of energy supply, raw material costs and methods used. The energy balance is in fact a part of the total picture All political behavior does not seem to be aware of such a linkage or willing to accept it.

10. I think scenarios of different kinds – such as economic ones, harvest ones, or ones to establish, in terms of mean values, what threshold level of injurious effects in different regions would in fact disrupt world trade – should be strongly recommended and encouraged, being asked for by potential users in commercial life. The results, though, must be interpreted in a critical, realistic and professional way! Sensitivity analyses have, e.g., shown that a long-term decrease in forest growth – even at the rate as low as 10% – will as a consequence have reduced production of roundwood and sawn goods. And, a long-term reduction of growth in the forests will decrease the mechanical conversion of wood in western Europe whereas the chemical processing will be rather unchanged. It is also shown that a short-term increase of wood supply through sanitary fellings on the continent would make investments in mechanical wood conversion industries attractive due to lower prices for the raw material. For instance, an increase of the wood supply by 33% would lead to a 20% increase in the production of sawn goods in the region. The primary effect is likely to be more interest for export of timber, thereafter the increased production of converted products after necessary investments. Finally there will develop a shortage situation, when lack of raw material supply appears after finished sanitary fellings and before the positive effect of reforestation.

11. The importance of the current work of the UN Economic Commission for Europe (UN-ECE) should be underlined. That goes for activities concerning emission control, developing an industrial protocol for monitoring, as well as for following the trade in forest products (mainly lumber) with the notion that a freely operating marketplace might result in serious supply and price disturbances in the future. The continuation work of the special market committee of the UN-ECE should be seriously considered. The aim of this committee is to try to identify in an international cooperation possible market disturbances of increased wood supply due to sanitary fellings upon markets for roundwood and converted industrial products, mainly lumber. Twelve countries are at present involved in the committee work. New additional country members are most welcome to take part in the efforts to eliminate possible market problems. Disturbances have not been found to any extent at present – with the exception of some regions – but to my mind they are unavoidable with the present rate of forest damage in Europe unless early precautions are taken.

12. I think with such a background it is important to find methods to increase the consumer's use of wood for different purposes, and to regain market shares lost to alternative raw materials. That would contribute to a more balanced market situation. Open relations and contacts between the Forest Study of the Biosphere Project and representatives of international forest industry and trade should be recommended. For the lumber industry the road to success involves production of value added products for the end consumer. And, a change of management philosophy into a more integrated view is requested. Start at the consumer, convert the market demand to not only the mechanical processing but also to the wood supply. An optimal use of the entire commercial line from the forest and timber production via the sawmill, right to the final customer means an improved rate of use compared to alternative materials.

13. Irrespective of the importance of all these policies and aspects for the future, and irrespective of what rate different kinds of pollutants take in the combined negative effect of stress factors on forests, the main target is emission reduction and the subsequent long-term conversion of damaged forests by advanced planting. Efforts just have to be intensified to reduce emissions by investing in further emission control programs.

It is excellent that we have the international agreements on the reduction of emissions, and more are to be expected. But, I have to say honestly that I am personally very concerned about the rate of improvements of the environment.

Indications from the dose-response investigations in the Nordic countries tell us about too slow a process in the reduction of depositions, and about the unacceptably long period of soil restoration. Five Figures show our results for different parts of Sweden with a comparison between present depositions and critical loads (Figures 1-5) of sulphur dioxide, nitrogen oxides and ozone.

In my personal view, the present situation has to be changed all over Europe and, presumably, North America as well. Something more than today just has to be done!

Again we have to look upon the situation pragmatically. Countries have different financial possibilities to take action fast enough. Priorities taken are, for various reasons not the same. Nevertheless, the threat is there.

With a personal view again, I suggest that an international responsibility of some kind, a financial plan on a large scale with the objective to make intensive emission reduction investments possible at proper places, might have to be established! That is basic risk-management thinking on a high national level! Some countries might consider such a contribution a sort of an insurance to protect threatened resources of their own.

14. It is true that at present, in general only slight effects have been noticed in the marketplaces for roundwood and lumber due to pollutant damages. Some regional effects are, however, quite serious. And with time, an overall considerable risk cannot be ruled out.

I am convinced that another important future policy will be to make the commercial representatives of the forest industry, mainly sawmills, more aware of the threat in terms of volumes and prices for raw material and converted products. The ECE-committee mentioned earlier asked Professor Sten Nilsson at the Swedish University of Agriculture and Forestry – also active part-time at IIASA – to make a study of the extent of forest damage in Europe attributed to air pollutants. An updated report for the situation 1986 has been approved by the committee and will be presented to the Timber Committee at its annual meeting in October 1987. It may be extracted from the report that volumes up to 1500–1700 million m^3 are to some extent damaged in Central Europe, corresponding to 6–7 average yearly harvests. That should be information enough to make the statement that the rate of consciousness today is much too low!

Our decline problem should be taken into account in the future planning of forest enterprises. Very few have done that so far. Too often a comment like "it's just the weather" corresponds to the attitude of today! Even marginal chemical influence, with mainly other stress factors weakening a stand, may have dramatic negative effects. And, in my country there is the fear of the lingering, nonvisible effect on the trees, eventually leading to a possible reduction in growth rate as a consequence! Assuming a 10% decrease in annual growth would mean some 10 million m^3 less wood supply per year. That corresponds to 6 sulphate pulp mills of modern size. With the present dollar rate to Swedish crowns and the price for bleached sulphate pulp the economic effect would be a reduced export earnings of about 6,5 billion crowns. And, of course, consequences in the forests and for the regional employment. Economy considerations are truly a part of the air pollution problems. – And, in addition, how does one interpret the dramatic negative development for deciduous species in the last years?

Beyond doubt, we have warning signals enough to be commercially very careful!

Consciousness of the problem should be our watchword!

15. ***To conclude*** – whether we are talking about emission reductions, ecology or economics in relation to this complex issue of forest decline, the road to success truly involves international cooperation at a variety of levels. The keyword to achieve results is *confidence* among individuals and nations! Conferences with worldwide representation like this one in Vilnius serve that objective.

1. Deposition of hydrogen ions (H^+) and sulphur (S) kg/ha/year	Hydrogen ions	Sulphur
- Southwestern Sweden	1 - 1,4	20 - 30
- Middle part of Sweden	0,5 - 0,7	10
- Northen Sweden	0,2	3 - 5
Critical load kg/ha/year	Hydrogen ions	Sulphur
- Annual deposition	0,1 - 0,5	2 - 7

Figure 1 Deposition of Acid, mainly Sulphur Compounds

1. Deposition of nitrogen, kg/ha/year	
- Southwestern Sweden	20 - 30
- Middle part of Sweden	7 - 8
- Northen Sweden	3
2. Critical deposition level	
Long term, kg/ha/year	10 - 20

Figure 2 Deposition of Nitrogen Compounds

1. Air contents ($\mu g/m^3$)	Country side	Cities
- Yearly average	4 - 7	20 - 60
- Maxima	<100	>250
2. Critical load for forestry damages ($\mu g/m^3$)		
- Yearly average	25	
- Maximum	200	

Figure 3 Sulphur dioxide, SO_2

	Country side	Cities
1. Air contents $\mu g/m^3$		
- Yearly average	4 - 12	60
- Maxima	20 - 50	400
2. Critical load $\mu g/m^3$		
- Yearly average	30	
- Maximum	250	

Figure 4 Nitrogen dioxide

1. Air contents $\mu g/m^3$	
- Summer average	40 - 60
- Ozone episodes	>200
2. Critical load $\mu g/m^3$	
- Summer average	60 - 80
- Ozone episodes	100 - 120

Figure 5 Ozone as Indicator of Oxidants

4.16 LITHUANIA: AN EXAMPLE OF A REGIONAL SYSTEM*

B. Zaikauskas
Chairman, Lithuanian State Planning Committee
Deputy Chairman, Council of Ministers
Lenino 3, Vilnius, Lithuanian SSR, USSR

Nature protection or, as we call it, "ecological equilibrium in human activities" is, at present, an important problem of any developed region. To preserve ecological equilibrium, it appears sometimes necessary to invest large amounts of money, particularly where natural resources are already overused and nature preservation problems have been neglected for a long time.

Lithuania, as a region, is the westernmost Union Republic of the USSR, its territory – 64300 km^2 and population – 3.6 million (56 per km^2). As a socioeconomic system, the Republic still has a comparatively short history of intense industrial and agricultural development. Nevertheless, after World War II, the rate of economic and industrial development in Lithuania was higher than that of other republics in the Soviet Union. Therefore, Lithuanian SSR has become an industrialized region with highly developed agriculture: 67% of its population are living in towns, 48% are working in industry and transport. Food and metal manufacturing industry, engine building, production of mineral fertilizers, oil refining, etc. became important industrial activities. There are large power stations, including a nuclear power station in Ignalina. Production of cement, artificial fibre, excavation of construction materials and peat are developed as well.

The high level of agricultural development (an annual average yield of 2.5 t/ha of cereals) is maintained by soil reclamation, application of mineral fertilizers (197 kg/ha annually) and pesticides. Animal husbandry (about 2.5 million cattle and 2.7 million pigs, etc.) is specialized and concentrated in dairy production units (with no less than 400 cows) and pig-raising units for 12–54 thousand pigs a year.

The network of railways (3100 km) and highways (23700 km) is considered highly developed; passenger turnover is estimated at more than 10 billion passenger-km per year.

Lithuanian nature and its resources can be characterized as follows:

- the climate is transitional between maritime and continental; cyclones and anticyclones are active, on average, during 95 and 117 days, respectively; precipitation: 540–930 mm; temperature: 6.1° C; the length of growing season: 169–202 days;
- the river network represents, on average, 1 km of riverbeds and canals per km^2; there are 2830 lakes larger than 0.5 ha which occupy 1.5% of territory; all cities are supplied with groundwater;

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buračas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

- the predominant types of soils are soddy podzols – 35%, podzol gley soils – 26%, carbonate soddy gley soils – 18%, soddy carbonate soils – 7%;
- there are over 2000 species of higher plants (including 1450 growing by themselves); 436 species of vertebrates: 26 of mammals, 292 of birds, etc.; 28.6% of the territory is under forests (18000 plots), with young stands making up 42% of them; roughly 17% of the territory is taken up by natural grasslands; more than half of the wetlands (6.5% of the territory in the early 20th century) have been drained;
- the nature conservation area amounts to 4.3% of the Republic's territory, including national parks, three nature reserves, 174 landscape and 74 hunting preserves; the state protection also covers 194 parks, 546 old trees, 116 geological sites, 250 species of rare plants, etc.

In recent decades, the negative impact of industrial-agricultural development on Lithuania's ecology has been increasing. Air and water basins become more polluted, erosion, deflation and degradation of the organic layer of soils has become remarkable. Transport of air pollutants, mainly the so-called "Acid Rain" from the southwest, also aggravates the ecological situation in Lithuania. Strong measures become, therefore, urgent for maintaining ecological equilibrium in industrial-agricultural development. Some of the measures being implemented are:

- planning adjustment of development and dislocation of productive forces, with high priority assigned to restriction;
- regulation of landscape development aimed at increasing the surface of conserved areas such as nature reserves, preserves, national parks; recultivation of excavated areas, afforestation, game regulation, vegetation protection, etc.;
- water protection and purification meant to increase by 1.6 times the degree of purification of polluted water, elimination of heavy metals as a water pollutant and planning that the whole body of polluted water flowing into the Baltic Sea will be purified up to standards by 1990;
- transition of all power stations and other industrial pollution sources to gas, reduction of the number of small ineffective heating stations; introduction of lead-free fuel as well as installation of gas-fueled traffic vehicles;
- increase by, at least, a factor of 2 of investments in nature protection and facilitation of implementation of measures which have been worked out in the *Complex Scheme of Nature Protection in the Lithuanian SSR to the Year 2000*.

We are looking with some optimism towards the future. We will do our best to improve ecological equilibrium in Lithuania and to cooperate with other regions for improvement of the ecological situation in the Baltic region and the rest of the world.

4.17 STRATEGY OF NATURAL RESOURCE UTILIZATION IN THE LITHUANIAN SSR*

E. Rusa
Central Research Institute of Town-Building Design
Moscow, USSR

The Complex Scheme of Nature Protection in the Lithuanian SSR to the Year 2000 contains measures and provides a strategy for preservation of dynamic ecological equilibrium and for prevention of the negative environmental trends under conditions of intensive development of the national economy. Moreover, the scheme provides for a favorable solution of existing regional, ecological problems. *The Complex Scheme of Nature Protection in the Lithuanian SSR* consists of 5 blocks:

- urban-ecological analysis;
- the study and prognosis of interaction between the natural and the anthropogenic environment;
- identification and evaluation of ecological problems;
- determination of assumptions for optimization of natural resource utilization;
- an environmental protection strategy.

Special scientific investigations on regional development issues as well as wide-scale application of the general territorial investigation results contribute essentially to each aforementioned block. Thus, for example, issues have been analyzed such as the location of Lithuania in the large-scale Baltic region, demographic capacity of the territory and also the geochemical activity and sustainability of landscapes.

Geochemical sustainability of a landscape is characterized by the ability of the territory to neutralize and utilize the harmful wastes of human activities. It obviously depends upon the rate of chemical transformations, the carry-over of technogenic products from landscapes. On a larger scale sustainability is determined by the type and state of soil, vegetation, water, etc. The quantitative evaluation of landscape, on the whole, amounts to identifying areas having similar response to technogenic impacts as well as prognoses of the extent of possible changes in geosystems.

The most significant indicators of prospective self-purification of landscapes are environmental buffer territories defined by the intensity of carry-over and scattering of technogenic products, the intensity of processing of technogenic substances, and remaining pollution levels caused by chemical substances.

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Evaluation of geochemical activity is carried out on the basis of geochemical inventory and prognoses of behavioral probability of macro- and microchemical elements (particularly heavy metals) in the given areas.

Composition and intensity of technogenic flows are controlled by areas of contrasting migration conditions, the so-called buffer areas. On the territory of the Republic, 25 buffers of territorial and 6 buffers of linear geochemical differentiation and contrast are singled out. The most powerful geochemical buffer is forest vegetation, which accumulates and assimilates a considerable part of the technogenic substances transported by the wind and precipitation. In the forest, through biochemical absorption of the plant root system, the decrease of toxicity, neutralization of alkali, decomposition and mineralization of organic pollutants, transformation of a number of elements into immobile forms takes place.

Complex quantitative evaluation of the landscapes geochemical activity is carried out taking into consideration the main factors conditioning their resistance to chemical anthropogenic impacts: type and structure of predominant landscape-geochemical systems, water-thermal regime, alkaline-acidic and oxidative regeneration conditions, absorptive capacity of the soil, landscape-geochemical buffers, primary content of soil- and biochemically-active chemical substances, and content of organic substances in the water.

All the above-mentioned hydroclimatic, soil and geochemical indices are reflected in the register presenting 400 areas of the Lithuanian nature complex having different sizes and characteristics. They allow one to foresee the probability of self-purification or accumulative processes in the landscape. From the practical point of view, the territories with favorable conditions for self-purification and removal of technogenic substances serve as a basis for the formation of an ecological balance.

Besides, the evaluation of landscape sustainability to physical impacts occurring mainly on sizable areas was carried out with respect to water-erosion and wind-erosion of soils, recreational utilization of the territory, compaction of soils by means of agricultural techniques.

The second block of the scheme mentioned above contains analyses of the impact of economic development on aerial and water basins, soils, vegetation and animals, landscapes and conservation territories of the Republic. For this, account has been taken of the main forms of economic activities such as agriculture and forestry, technical-engineering infrastructure, transport, system of habitation and recreational utilization – which at present influence and will have a great influence in the future upon the state and dynamics of landscape and environmental components. It was ascertained that, in order to assess the ecological situation in the Lithuanian SSR, the following had to be considered: the large ecologically damaging branches of industry (particularly the chemical industry and power production); extremely intensive agricultural use of reclaimed landscapes and a concentration of animal husbandry; the uneven distribution of forests; the highly developed system of transport and the dense network of highways; intensive recreational utilization.

A detailed analysis of these factors made it possible to reveal the basic nature protection problems that were dependent on and resulted from anthropogenic activities. More than 220 conflict situations in terms of nature protection were determined. Most of them are associated with abnormal changes in air quality, biota and/or surface waters. It was admitted that the most critical situations requiring immediate solutions are those in the Baltic coastal region, in the central part of the Republic, in the karstic area of the northern part of Lithuania, etc. By generalization of the present and forecast locations of conflict situations, it appears that they are concentrated into 10 problem areas that have been singled out. Problem areas are ranked according to their importance and requirement for immediate solutions. The areas of the Baltic Sea-shore, Kaunas and Vilnius are acknowledged to be of vital importance.

There is sufficient proof of the current urgency of these ecological problems; the annual economic losses inflicted on the national economy due to pollution and other environmental changes increase every year by 3–5%.

In the *Scheme of Nature Protection*, analyses of alternative natural resource utilization are presented. These analyses include evaluation of current and future forestry management policies, and the identification of a network of conservation territories, as well as territories which can serve as a skeleton for nature protection and self-purification of geosystems.

In this connection, consideration was focused on the ecological function of forest vegetation. Forest influences on the environment were considered in terms of the mechanical filter provided for precipitation, dust, smoke, etc., as well as in terms of the release of energy and matter in photosynthesis, respiration and transpiration.

On the basis of these observations, a quantitative/qualitative assessment was carried out of forest impact on microclimatic regulation, protection of soil, water, air, fauna, and also on the creation of favorable conditions for the growth of agricultural crops. The favorable ecological influence of forest vegetation on the arable adjacent lands is revealed by the prevention of surface runoff, the decrease in wind-speed, the establishment of thermal and water regimes contributing to the growth of agricultural crops and the creation of favorable conditions for fauna, particularly birds.

On these grounds, the following parameters of forest areas in agro-landscapes were determined: maximum sites of open space, appropriate length of shelterbelts (ecotones) and optimal spatial gaps.

A detailed analysis of the existing network of nature conservation territories was carried out and a system of nature conservation territories consisting of 6 reserves, 5 national parks, a number of regional nature parks and reserves was worked out. The *Complex Scheme of Nature Protection* foresees a doubling of the extent of the area of conservation territories to 8% of the Republic in the year 2000.

Particular attention has been focused on the development of nature protection management system, taking into consideration regional and local environmental systems. When working out regional systems, the functional distribution of eco-urbanized territories has been carried out as a means of ensuring ecological equilibrium. Therefore, the following zones were distinguished:

- intensive economic activity – towns and settlements, areas with densely inhabited rural population and expanding agricultural development, communication network, allocation and quarries, etc., i.e., territories strongly affected by human activities;
- ecological equilibrium, i.e., territories for productivity of major natural resources (fresh water and oxygen primarily), with the strictest limits on economic activity, including settlement growth in these territories; extension of the network of nature conservation areas, recreational and touristic facilities, increase of forest cover up to 40–50%, etc. are foreseen;
- buffer zones – expanding forest resources by increasing forest cover by up to 30%, development of a network of conservation territories, etc.

Therefore, an important role is allotted to ecological equilibrium zones separating intensive economic activity zones. At present, the ratios of the aforementioned zones are 1:3:6; however, these numerical values will change to 1:4:5 by the end of this century.

The following zones are distinguished:

- preferable future urbanization;
- limited future urbanization;
- preferable development of forestry and agriculture;
- recreation, tourism and health treatment areas as well as the system of nature conservation territories.

Functional zoning was considered as a specific planning tool to maintain a designated level of ecological equilibrium. By identifying suitable sites for each of the zones and by determining the appropriate regime of economic activity, the decision-maker is able to maintain ecological equilibrium over the whole territory.

The most specific measure in terms of nature protection is the establishment of a land-use plan which can prevent negative anthropogenic impacts over the territory of the Republic. Such a plan has been worked out, taking into account the locations of existing natural resources (large forest areas, rivers, lakes, recreational territories), special characteristics of regional and transregional ecological strategy and future planning and management structure of the Republic. The plan is presented in the form of a surface grid of regional, national and local importance. Notable for their special ecological values are the Baltic Sea coastal and continental regional axes, consisting of well preserved large forest areas. The basic ecological-architectural function of these grid squares lies in the spatial division of areas with intensive economic activity. Forests are characterized by high productivity and environmental protection capacity (underground and surface runoff, oxygen, etc.).

Grid squares of national importance are forming on the basis of small forest area groups, landscape complexes of river-valleys, recreational areas, and natural conservation territories. They provide ecological gaps and ensure ecological stability between environmental grid squares of regional and transregional importance.

Grid squares of a local character are meant to promote further allotment of buffer zones and also to maintain ecological spatial relations between the aforementioned grid squares, i.e., to promote the migration of animal species and plants. Their role is even more important under conditions of intensive formation of agrolandscapes.

Implementation of local nature protection measures is also foreseen, including: technological, technical-engineering, biological, technical-organizational, medical-hygienic, and architectural planning.

By these means, on the basis of considerable scientific data, the *Complex Scheme of Nature Protection in the Lithuanian SSR* has been worked out. It was approved by the national government and became an important tool for developing a strategy of natural resources utilization up to the year 2000.

In 1982, the State Planning Committee confirmed the program for realization of the fundamentals of the *Complex Scheme of Nature Protection* for the 1986–1990-year period. This program serves as a starting point for socioeconomic development in Lithuania. Realization of such a program is carried out at two levels – national and local – which include:

- large-scale measures to be applied on a national level;
- local measures taken by local government bodies.

The realization of the scheme is under the control of the State Nature Protection Committee of the Lithuanian SSR. The fundamental principles of the *Complex Scheme of Nature Protection* are brought to the attention of ministries and departments, local government bodies concerned with a view to raising their competence and role in the process of realization of natural protection development strategies.

It should be noted, for instance, that by 1990 the program of construction of sewage treatment plants will be extended on a large scale.

Consequently, all the water transferred into the Baltic Sea (within the Republic's limits) will be provided with biological sewage treatment and will improve to a target quality. This will meet the requirements set forth in the Convention on Baltic Marine Environment Protection. Besides, special measures for air quality protection, rational land use, protection of forests, vegetation and animals will be worked out. It should be stressed that financing of natural protection measures has doubled in the current five-year period in comparison with the previous one.

In conclusion, elaboration and implementation of the complex natural protection schemes on a regional level offers an opportunity of reducing negative environmental impacts, improving ecological conditions, maintaining the ecological balance of natural complexes and social structures, and working towards ecological sustainability of regional development.

PART V

METHODOLOGIES FOR ECONOMIC ASSESSMENTS

5.1 ECONOMIC DEVELOPMENT AND ECOLOGICAL SUSTAINABILITY METHODOLOGICAL FRAMEWORK FOR CONFLICTS AND COMPROMISES*

Peter Nijkamp and F. Soeteman
Economische Faculteit, Vrije Universiteit
1007 MC Amsterdam, Postbus 7161
THE NETHERLANDS

Framework

This study was initiated by the Dutch Ministry of Environmental Affairs (VROM) with the purpose to outline those aspects of the interrelationship between economic development and environment which deserve high priority for scientific research. The present paper summarizes the first part of this research project.

The second part will consist of a summary of key environmental-economic issues. The third part will describe, in terms of the model presented here, a priority list for economic-environmental analysis.

1. Introduction

The past years have exhibited the need for a sound methodology for analyzing inter- and multidisciplinary phenomena in a more coherent manner. This holds in particular for environmental sciences in which concepts from economics, ecology, demography, geography, ethics, planning and natural sciences have to be incorporated. The pluriform nature of ecological and economic processes can in general hardly be described by means of conventional measurement approaches adopted in an isolated monodisciplinary analysis. Coupling of variables from such different disciplines is hampered by differences in precision of observation, in spatial scale, in time prospective and in adjustment speed (see also Brouwer et al., 1985).

Integrated environmental models have only recently been developed. Such models serve to analyze and evaluate changes in the (a-) biotic environment caused by human activities (for instance, consumption, production of goods and services, recreation, or environmental protection measures). First attempts in this area can be found in the generalized (economic-ecological input-output approaches developed among others by Isard and Leontief. These models were static in nature and did not aim at depicting simultaneously a set of heterogeneous concepts on change processes, but served to provide a consistent accounting system (based on static equilibrium concepts). But the first generation of integrated environmental models was not particularly suited for the analysis of concrete environmental policy issues such as land use planning, land reclamation.

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water resource planning, recreational planning or urban renewal.

From the late seventies onwards however, various attempts have been made to develop operational integrated environmental models in various fields or resource, land use and infrastructure planning. The need for such analytical tools emerged from the growing concern among local and regional authorities about environmental quality (interpreted as a broad multidimensional concept). Furthermore, the advance in the field of integrated systems modeling (based on computer sciences, e.g. led also to an increase in the quality of suitable models for multidisciplinary purposes. Despite this progress however, it has to be admitted that the rise in monodisciplinary environmental models (based on either economic of ecological principles e.g.) is much higher than in the field of integrated environmental models. Attempts at integrating different model types are still unsatisfactory (Jansson, 1984).

In particular it has to be mentioned that many formal attempts at linking economics and ecology, neglect the long-term dynamics of both economic and ecological systems. And it is especially the long-term perspective which determines essentially local and current environmental problems. Therefore, in the present paper, the attention will be focused on structural changes in such systems. This means that in particular the changes in systems parameters will be analyzed, which henceforth requires an analysis of the key factors of the 'laws of motion' of such systems (Bennett and Chorley, 1978). First however, the nature, range and relevance of such structural changes will be described.

2. Global Trends – Local Impacts

The globalisation of environmental problems is one of the most surprising events in the environmental field in the past decade. For instance, poor natural resource management in Third World countries is not only threatening the physical basis of these countries, but destroys also part of the vulnerable ecosystem of the earth to an unprecedented extent. In other cases, over-grazing and deforestation may lead to soil erosion, sedimentation, flooding and salinization. Thus the economy-ecology linkages embody a wide variety of externalities which are pervasive, wide spread in both space and time, and inevitable in the light of a given development level of the economy (Pearce, 1975).

Clearly, the urgency of these problems is increasingly recognized, but economics fail to design an adequate methodology for reconciling economic and ecological principles from a long-term perspective. Conventional approaches, such as marginal opportunity cost principles or shadow cost approaches in alternative accounting systems neglect the qualitative changes in dynamic economic-ecological systems. On the other hand, recent advances in the field of irreversible externalities (based inter alia on alternative discount rates for future generations) lack operationality, so that the actual causes of natural resource degradation cannot effectively be coped with. In view of the global nature of these externalities, which affect essentially all 'commons' of our planet, it appears to be also extremely difficult to pursue policies that can effectively tackle the real causes of environmental decay at a global scale (Repetto, 1986).

In this framework a major problem is formed by the local scale of environmental impacts emerging from global trends. Acid rain, erosion, desertification, ozonization, eutrophication, ocean pollution and resource extraction are taking place at a world-wide scale, but their impacts can clearly be observed at a local or regional scale. Thus the globalization of environmental problems confronts us with qualitative (or structural) long-term changes at almost all places on earth

(Bartelmus, 1986).

Various paradigms have been developed to take into consideration these dynamic processes (such as systems dynamics, zero growth approach or the steady state approach), but the linkage with actual deterioration of environmental conditions at a local or regional level has hardly been established. An integrating framework is lacking so far, although the need for such a framework has been recognized by many scholars (Myers, 1984).

The foregoing observations imply the necessity to seek for a coherent framework in which ecological processes are analyzed in relation to economic processes at a global-regional level. In the next section some key concepts, viz. economic development and ecological sustainability, will be further discussed. It is assumed that key factors of system developments (e.g., demography, technology, agriculture) influence both economic and ecological variables via the structural components of economic developments and ecological sustainability. These factors are partly external, and partly internal to both systems. However, for clarity of presentation we will place them outside both systems.

3. Development and Sustainability

In the context of this paper we will take for granted a formal welfare concept. This means that all phenomena that - directly or indirectly - influence the utility level (or utility perception) of individuals, groups or society as a whole are regarded as arguments of a welfare function, in as far as they lead to need satisfaction from scarce goods and services. Consequently, clean air, a silent environment, or a beautiful landscape are all contributing to somebody's welfare position. Thus, it would be misleading to assume that environmental commodities form a contrast with economic commodities. But it is evident that the production and consumption of many commodities (including environmental commodities) affect the natural resource base of our economic-ecological system (thus causing environmental degradation and vice versa).

Two observations are in order here. First, the ecological system has morphogenetic properties, so that it is capable of regenerating itself within certain limits. And second, various means to increase welfare exist, which do not necessarily have a negative impact on the environment. Welfare can in general be studied at three different (albeit complementary) levels:

- *physical*: here for the economic system the assumption is made that welfare runs parallel to the physical level of production valued at normal market prices. Environmental externalities occur here in both the production and the consumption field. Thus, for the environmental system the ecological opportunity costs of allocative efficiency has to be measured. We suggest to undertake this in physical entities.
- *subjective*: here the assumption is made that welfare is a psychological concept related to needs satisfaction. In this case we are often facing environmental distribution problems (interpersonal, intergenerational).
- *ethical*: here the assumption is made that welfare is co-determined by value systems and norms of individuals, groups or society. Here we are facing inter alia problems of justification of needs.

At all three levels of analysis however, welfare is implicitly regarded as a latent variable, which can only be measured by means of observable indicators. In our paper we assume that both *economic development* and ecological sustainability are the underlying driving forces of welfare change. These two concepts will now briefly be described.

Economic development is a feature of an economic system. Any economic system can essentially be characterized by 3 features.

- economic structure: the parameter structure of the economy
- economic process: the economic evolution in a given structure
- economic foundation: the socio-political basis of the economy (Tinbergen, 1956).

Economic development is mainly concerned with qualitative changes in the *structure* of the economy (or sometimes in changes in transition processes in an economy).

In conventional economics, economic growth (usually measured as the growth in GNP per capita) refers essentially to efficiency increase in economic processes and is not always the most suitable indicator to compare systems changes. In the context of structural changes this welfare measure is problematic, as it neglects social costs emerging from environmental damage and as it cannot provide a full representation of the processes behind resource dynamics and the provision of environmental services (Gilbert and Hafkamp, 1986).

Thus, in a long-term perspective the global trends cause local impacts which can hardly be incorporated in the usual market and price mechanism, so that unbalanced decisions may result. For instance, the construction of a swimming pool at a certain place (meant as a compensation of dirty surface water caused by polluting activities upstream) leads in our accounting system to a rise in GNP, whereas this should from an environmental viewpoint be regarded as a cost component.

In this context, it is interesting to observe that Jänicke et al. (1987) found - in a cross-comparative study among 31 countries - a positive relationship between income on the one hand, and pollution and resource use on the other; a negative relationship between the growth on GNP and that of environmental decay in economies with a well developed sector structure; and a positive relationship between the growth of GNP and the growth of environmental degradation in countries with a poorly developed sector structure.

Now we have to consider the concept of ecological sustainability. Ecological sustainability is regarded as a key factor in resource policy (Clark and Munn, 1987). In delineating this concept, four approaches can be followed:

- the intrinsic value of the environmental system itself
- the emergence of environmental problems
- the need for environmental awareness and policy
- the elements of a control strategy.

Th intrinsic value of the environmental system itself is hard to assess. There is however, one factor which exerts a decisive influence here, viz. scarcity of time. There is no time left to experiment with the environmental system via a trial and error method. This leads to the need for due attention to be given to environmental risk analysis from global to local levels, taking into account the unexpected consequences of synergetic and cumulative effects in the environmental system.

The emergence of environmental problems is closely related to conflicting preferences and objective in our society, in which environmental (i.e. unpriced) considerations have received a low priority, while furthermore the direction of change of the economic system has been to the detriment of the environmental system. In this context, economic aspects have to be dealt with carefully in order to prevent a situation in which in the long run environmental degradation leads to a structural decline in welfare.

The need for environmental awareness and policy is co-determined by the third (ethical) level of analysis discussed above. A major shortcoming here is the difficulty to translate this level of analysis into operational objectives. Therefore, it is sometimes necessary to choose here a pragmatic solution (as will be done in the sequel).

An environmental control strategy serves to assure continuity of the environmental system, but it is evident that here we are hampered by lack of insight. For instance, Clark (1986) states: "... we have learned just enough about the planet and its workings to see how far we are from having either the blueprints or the operator's manual that would let us turn that diffuse and stumbling management into the confident captaincy implied by "spaceship" school of thought" (pg. 11).

In view of the abovementioned uncertainties a risk strategy with respect to the environment might be based on *sustainability*. This concept refers to the maintenance or improvement of a process or activity in the long run. This concept is broader than that of *stability*. Stability as a main ecological objective neglects the morphogenetic properties of an ecosystem, so that fluctuating patterns which might in the long run be desirable for survival would otherwise be excluded. Thus, any control strategy should leave space for self-adjustment of the system. Next to this, it might be necessary to actually improve the system in some quantitative or qualitative aspects, to prevent it from a cataractal motion. The concept of "elastic stability" is more close to our idea of sustainability. In this we mean the ability of the system to recover its original state after some external disturbance.

In the framework of our discussion on ecological sustainability it is interesting to observe that in 1951 already Ciriacy-Wantrup made a plea for a safe minimum standard of conservation: "... a safe minimum standard of conservation is achieved by avoiding the critical zone – that is those physical conditions brought by human action, which would make it uneconomical to halt and reverse depletion" (pg. 253).

In essence, the sustainability objective may be regarded as an integrating objective in which various arguments for environmental care and policy are incorporated. It is a concept parallel to economic development as it is mainly concerned with qualitative or structural changes. Thus the direction of change is especially important here, for instance, recycling (+) versus exhaustion (-), diversification (+) versus monoculture (-), balanced growth (+) versus overgrazing (-). All these phenomena have a global causal background, but manifest themselves especially at a local or regional scale.

As mentioned before, ecological sustainability is a latent variable, but we may use some indicators which may approximate the meaning and aspects of this concept. Some of these proxies will briefly be described here.

- *sustainable yield*: this concept is related to a control strategy for renewable resources in which economic benefit objectives preclude an exhaustion in the long run. It is a well-known strategy in forestry and fishery management models.
- *carrying capacity*: this concept refers to the level of activities of a certain species that can in the long run be maintained given the regional resources. It is a well-known concept in predator-prey models (see e.g., Vincent, 1981).

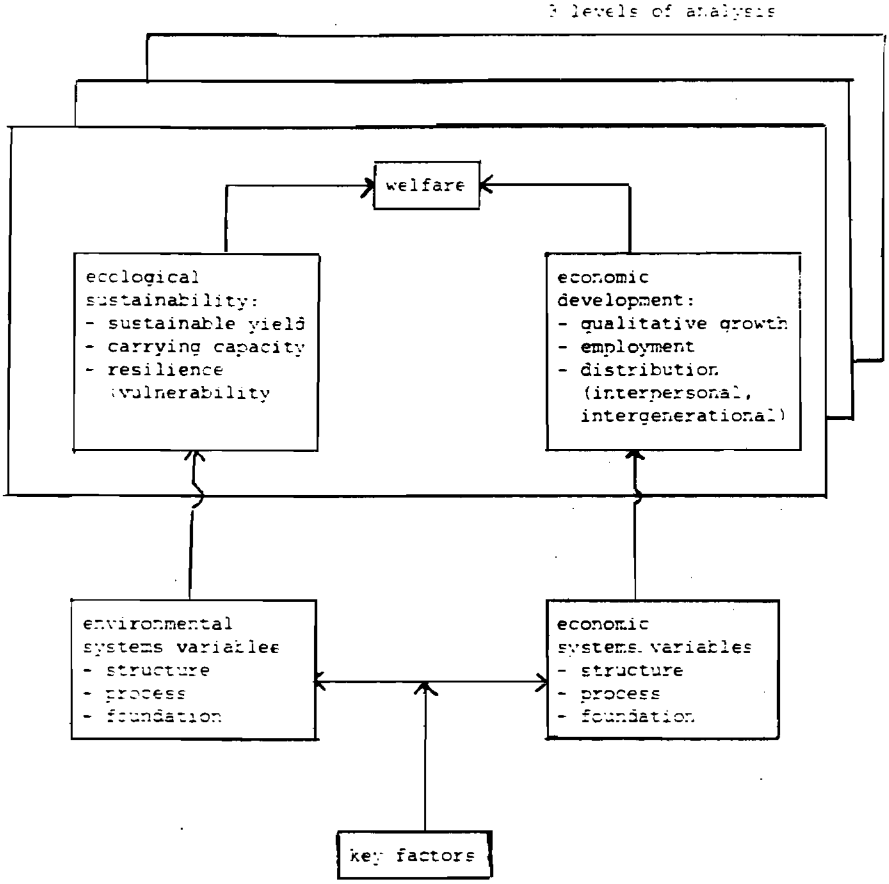

Figure 1 A coherent framework of economy-ecology linkages.

- *resilience*: this concept refers to the vulnerability or the self adjustment of an ecosystem; within certain limits a stable growth may occur, but beyond a threshold level a bifurcation may emerge forcing the system to move a qualitatively different level. In this framework risk assessment models may be helpful (Brooks, 1986).

The present section has shown that at a systems level economic development and ecological sustainability have a parallel meaning, not only at a global level but also at a regional level. The previous observations are briefly summarized in Figure 1. In the next section, an attempt will be made to investigate how current environmental problems – typified by means of a sectoral angle – can be linked to the previous methodological framework.

4. An Analysis Framework for Environmental Problems

In this section we will use a typological approach to environmental problems and confront them with the above mentioned methodological framework.

In the past a great many models have been designed to describe the compound relationship between economic-ecological systems. However, despite the elegance and sophistication of these models, they still exhibited various limitations and flaws;

- the global models from the 1970s appeared to be too less detailed to describe policy-relevant developments at a national or regional scale, so that their relevance was too low to support actual policy decisions;
- micro-analyses of individual behaviour of actor is interesting, but does not provide sufficient insight into compound long-term societal reaction patterns;
- the complicated and manifold long-term feed back relationships from the environmental to the economic system are often neglected;
- the majority of quantitative modelling efforts has an extremely weak data base, so that their validity is still questionable;
- the coherence between economic and environmental systems leads to the need for a compromise rather than a conflict analysis in environmental management (Nijkamp, 1981; Hafkamp, 1984).

In the light of all these limitations we observe increasingly a shift away from both global and micro levels of analysis towards a meso level, particularly the regional level at which the design of an effective and operational framework is more promising, as here distributional and substitution effects can be analyzed in more concrete terms.

5. Prospects

The purpose of our study (see Framework at the beginning) is to outline those aspects of the interrelationship between economic development and environment which deserve high priority for scientific research. An empirical investigation into the most promising or serious subjects in view of the welfare influence, is not our goal. However, for people interested in this research project it will be difficult to propose a priority list of research projects to the Ministry of the Environment without some actual insights into the factual effects on the welfare level. In addition, policymakers will be interested in how economists and ecologists trade off the several indicators of environmental sustainability and economic development.

For this reason we have chosen for a iterative selection process, in which in decreasing level of abstraction the problems will be related to the indicators of both systems (see Figure 2).

The first step of this iterative selection process has taken place in several Delphi-type of meetings with experts on this field. The first-order selection criteria are mandatory. For instance, the subject should have a relation with the Netherlands, practical possibility of inquiry, directed on the future, non overlapping with existing research, the problem should exist because of the interrelationship of both systems, and so on. In the first step several fields of investigation are identified. Among those are: environment and economic development in the Netherlands in relation to Third World countries; technological development

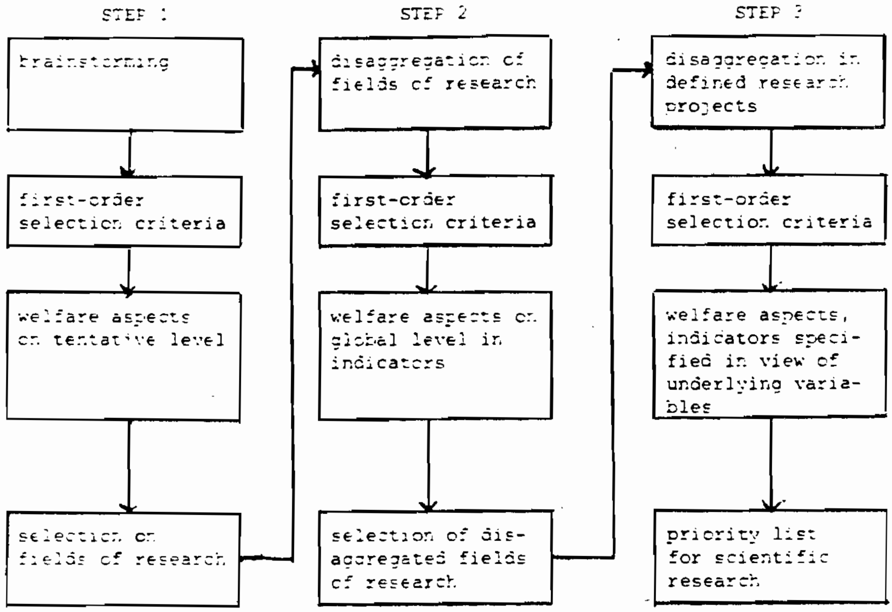

Figure 2 The iterative selection process.

and environment; policy priority for environmental problems in relation to economic development; environmental risk assessment; etc.

The second step of this iterative process is in preparation. Disaggregation on this step means for instance for the first of the abovementioned fields:

a. what is the role of Dutch development aid as a key factor for economic development, and especially what are the impacts on the environment;

b. what is the meaning of trade flows between Third World countries and the Netherlands for development of both systems, and so on.

On the welfare level we aim now at a qualitative judgement of the disaggregated problem area. First of all we should know the key factors of the subjects. For b. this will be the trade flows in qualitative and quantitative sense. On the physical level we should know for the economic system the comparative and institutional advantages resulting into (among others) income and employment. For the environmental system the questions are: how much are these flows related to environmental goods, what about the sustainability of exploiting them, what about the sustainability of the eco-systems in which these goods interfere on the input or output side, what do we know about risk assessment (the assimilative capacity, the vulnerability) of the system.

On the subjective level we add the dimensions of space and time; leading to questions like: what kind of development do we expect for our indicators in space and time. At this level of analysis especially the resilience level of the environmental system and the dynamic interrelations of both systems are important.

Finally we describe on the ethical level the value dimensions which we have to relate to the first and second level of analysis. The ethical level is important for defining the priorities of the problems mentioned so far. Problem fields with relatively many open questions, which however – as we expect – have major implications for both systems on the physical and subjective level of analysis, have a high priority for research programs.

To do this in a coherent, we may use among others a qualitative multicriteria method (see Nijkamp, 1988). The heart of the research is formed by the third step.

Now we have to translate those fields with high' priority onto well defined research projects on the suggested meso-level of analysis (see Section 4). To continue with the abovementioned example, we now have to investigate at the three levels of analysis for instance, ecological and economical consequences of the trade flows between the Netherlands and Thailand of tapioca; the palm oil from Malaysia; and so on. In this step, it will be necessary to have a clear view on actual values of the systems variables to make a balanced decision for environmental priority assessment.

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5.2 INTERACTION BETWEEN SCIENTIFIC EXPERTS AND MANAGERS ON THE BASIS OF SYSTEMS FOR ANALYZING AND FORECASTING PRODUCTIVITY

A.V. Rutkauskas
Lithuanian Research Institute of Forestry
Kaunas, Girionys, Lithuanian SSR, USSR

and

L. Kairiukstis
IIASA, A-2361 Laxenburg, Austria

1. Information

The regional system is a multi-dimensional highly complex human activity system intertwined with a natural system. The basic ecosystem components of a regional system can be classified as land (soil), water, and biota. The basic economic sectors are commonly subdivided into activity or market sectors, e.g., agricultural, forest, manufacturing. The boundaries of the regional system are defined by human and natural geographic, ecological factors. Due to the complexity and vagueness of regional systems, the environmental components within it are still far from an optimal.

As the regional system itself is a human activity system producing economic, environmental, demographic and other transformations that are perceived as relevant to the survival of a specific (micro) population within a defined geographical space over an undefined period of time (Kairiukstis & Espejo, 1986), it is most likely that sustainable resource and environmental management can only be achieved on the basis of an interdisciplinary approach using interactive scientific and manager expert systems and mathematical optimization techniques. As one example of a management support system for regional socio-economic and environmental development in a centrally-planned economy, we shall discuss the experience gained in the Lithuanian SSR.

In a centrally-planned economy, the main strategic objectives for regional development are usually elaborated by scientific experts in cooperation with managers and formulated in a long-term (15-20 years) program of scientific technical progress (STP). The STP program of the Lithuanian SSR, as an example of a regional system, gives a long-term perspective to the development of the following important industrial complexes and economic sectors: natural resources and protection of the environment; a fuel-energy complex; a machine building complex; a chemical complex; a construction complex; an agricultural complex; a forest industry complex; a transport complex; a commercial-industrial complex; a computer techniques and management systems complex; etc. Taking predictions of demographic and energy resources as a starting point for the

*In: Proceedings of the Workshop on *Ecological Sustainability of Regional Development*, Vilnius, Lithuania, USSR (22-26 June, 1987), L. Kairiukstis, A. Buracas and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

development and distribution of productive forces of the region, the STP program also serves in drawing up one- and five-year plans. The structure and elaboration procedures of crucial decisions faced by scientific experts and decision makers on the above problems have been described in an earlier report (Kairiukstis, 1984). In the current report, we shall discuss the regional productivity forecasting system: its purposes, forecasting objects, how to choose the system of models applied to forecast social production processes for the realization of a regional productivity forecasting system itself.

It should be emphasized that in all stages of preparation and realization of decisions concerning the interests of separate economic sectors and interests of the regional system as a whole, the interaction of scientific experts and decision makers causes many conflicts. This concerns not only the choice of construction sites and the setting of the maximum capacity of large structures in the chemical and power industry but also forms of water transport which negatively affect the ecological equilibrium of the environment of a region. It is common knowledge that a number of measures of accelerated technical progress which are being effectively implemented in some sectors of the regional economy are only optimal for that particular economic sector. At the same time, such measures have usually led to a disproportionate exploitation of natural resources of a region. This in turn leads to an adverse impact on the equilibrium between ecological and economic productivity.

To rationalize the use of natural resources and to improve ecological sustainability of regional development, we need a system to establish optimal decisions and technical, technological, managerial, economic and political measures with which to improve the living conditions and development of the social infrastructure on a regional level. In order to realize such measures, it is imperative to accumulate capital from the profits made by the enterprises of each of the economic sectors situated on the territory of a region and direct them to the local planning bodies. Additional finances must be obtained from the centralized transregional economic sectors, which use the regional resources and cause deterioration of the regional environment. Both conditions mentioned above can facilitate solving problems relating to living conditions, purification of water and air, regeneration of recreational zones, formation of an optimal natural landscape following destruction by pollution. All this is indispensable for the micro-population of those living on the territory.

In order to meet the aims above and to facilitate the interactions between scientific experts and managers in solving regional problems, a system of models is currently being used to analyze and forecast regional productivity with regard to technological progress; in addition, environmental management has been developed by the Institute of Economics of the Lithuanian Academy of Sciences and the Lithuanian Committee of the UNESCO "Man and the Biosphere Program."

2. Main Purposes of the System Forecasting Regional Productivity

2.1 The necessity to achieve and support, in the future, the higher rates of socio-economic development, requires the maximum mobilization of the whole productive, scientific, intellectual and administrative potential. In order to solve these strategic problems, a considerable contribution should be made by the system (now formed in the State) forecasting the process of social productivity.

Due to a significant heterogeneity of social productivity conditions, the requirements to forecast separate regional subsystems of social productivity are considerably increased.

The principles used to construct forecasts of regional subsystems are predetermined by logic and the structure of the social production system of the State at large since:

1) the character of interdependence between the development of productive forces and the evolution of social relations is the same for all regions of the USSR; and

2) the aims and rate of development of regions, their scientific and technological retooling growth factors, as well as growth resources for some territorial units, are predetermined by the location and tasks (in economic development) which are allotted to a given region.

Due to the heterogeneity of social production conditions, however, the development of systems providing the analysis and forecast of social production in each region including Union republics, bears many characteristic features. Subsystems which forecast regional production should form an integral system forecasting the social production in the State.

2.2 With an increasing imbalance of resources – both for non-renewable and renewable – as well as an objective broadening of demands to study the lines of long-term development, it is necessary for the the regional forecasting effort to seek to increase the efficiency of all resources utilized in the region and to form an optimum balance (of the whole social production) strategy for technological progress management.

It is necessary to provide such possibilities in order to increase the purposefulness of the regional economy to solve its social problems.

2.3 The systems of the regional forecast should become an active tool used by central planning bodies in searching for the optimum variants used to distribute existing resources – productive, material and financial – in order to provide and maintain higher levels of socio-economic development of the State. Therefore, the ranges of the indicators and variety of analytical forms of their interdependence should also be sufficient to make a choice for extreme variants of development.

2.4 In the study of the problems mentioned above (2.1-2.3), forecasting and planning tools should be used which favor: a) the measuring of interdependence among social, economic, ecological, technological and other processes which form the basis for the development of a region; b) the determination of a region's specialization in order to provide the best conditions to reach the most important economic goals; c) the search for optimal interdependence between creative activities and consumptive behavior of the region's population; d) the search for optimum variants of resource distribution – labor, material, finances, etc. – among national economic sectors; e) the choice of balanced (of the whole processes of social production) strategy of priorities in scientific and technological measures (especially in organizing development of production where a rather high economic effect can be obtained in the shortest time); and f) an interdependence study between economic activities and ecological conditions of a region in order to develop measures providing a desirable state of the environment.

As a whole, it is necessary to have a set of tools favoring the choice of the optimal version of development, from the standpoint of both the parameters controlled within the region and the efficiency of the functioning of the State economy at large.

3. Choosing the Forecasting Method when Constructing a System to Forecast Regional Productivity

3.1 Each region of the State, including a Union republic, is considered as a system of settlements, production units, manpower and natural conditions where material, financial and information flows are integrated into the whole process of social production. There is no single management centre, which controls all the processes of socio-economic, scientific-technological and ecological productivity. Meanwhile, in order to solve many sccial, ecological, scientific and technological, production and organization problems and to choose the strategy with an optimum distribution of existing resources, it is necessary to consider the region as a single entity.

Moreover, the achievement of desirable shifts in social structure, the optimum distribution of active population among the national economic sectors, the organization of complex measures providing the rational use and productivity of nature resources, etc., make up a total complex of regional problems, and in solving them, it is necessary to choose structures which could integrate these tasks into an entity providing their commensurability.

3.2 For such a structure, a system of basic relations of the Integrated Process of Social Productivity (IPSR) should be chosen as a system-forming nucleus. This system is a complex of relations between the productivity of the population and manpower, that of the gross national product (GNP) and capital funds, and that of the natural environment.

On the one hand, the complex of indicators, processes and dependencies included in the IPSR is only a minimum of indicators, well representing the socio-economic, scientific, technological and ecological state of a region and a nucleus, which is very important in integrating all the processes –social, ecological, scientific, technological and economic – occurring in the republic into a single entity. On the other hand, this complex reflects the cause-and-effect relationship in forecasting social, economic and other processes forming, in total, a self-organized system which provides a factor-by-factor balance of forecast parameters for the processes under study.

3.3 Since, under conditions of the planned economy the socio-economic forecast of regional development must represent an integral picture of possible variants of productive forces' growth, changes in the ecological environment of a region and the evolution of productivity relations, the spectrum of possible versions in socio-economic development involved in the forecast analysis should be sufficient to choose alternatives providing harmonious development of a region.

Forecasting studies should be carried out using categories and indicators permitting comparison between qualitative and quantitative changes in social relations, productive forces and the environment, as well as their interdependencies when the results of scientific and technological progress are introduced. On the other hand, these indicators and categories should, in the future, be used as planning and management objectives.

3.4 In the case of the smaller republics, on the basis of territorial autonomy elements and several other aspects, the following were singled out for each subsystem of the IPSR with regard to their interaction, *viz.*:

A. The possibility to divide the total population of the Union republic into several groups which are homogeneous according to life-style;

B the possibility to subdivide (independently of their subordination) all production units located in the republic into several homogeneous industry groups (not only production items, but also the organization of production and its functional efficiency);

C. the possibility to quantify the interdependency of production activity and consumption behavior of the population in the Union republic;

D. the possibility to measure qualitatively the versions of socio-economic development in the republic and the intensity levels of interregional relations;

E. the possibility to evaluate the interdependency of production activity, consumption behavior of the republic's population and the natural environment; and

F. the presence of data allowing a detailed description of the above-mentioned and other socio-economic dependencies.

The assumptions presented above (A-F) are somewhat conventional, although they are present (explicitly or implicitly) in the construction of economic forecasts. For a Union republic, they represent a minimum set of basic forecasting dependencies – social, ecological and economical – and it is most likely that they mutually single out the IPSR as an integrating and guiding nucleus of the system, forecasting the development of a Union republic.

3.5 It is inconceivable that one could make particular forecasts – especially such as those with scientific and technological potential, interregional ties, sector-to-sector distribution of manpower, dynamics of money income and consumer expense – without making an IPSR forecast for the region as a whole and, especially, without considering the region as a component of the national economy of the State. Regional aims, development rates, scientific and technological retooling in the repubiic, growth factors, as well as actual growth resources for some territorial units, depend directly on the place and the tasks of the republic allotted by the development plan worked out for the national economy of the entire State.

4. Basic Principles for Realization of a Systems Forecasting the Regional Productivity

4.1 The IPSR general system is designed to compile quantitative scenarios for long-term development of a Union republic with regard to objective tendencies, real limitations and subjective aspirations. The *Dramatis personae* of such a scenario are as follows: objective regularities of socio-economic and scientific and technological development, subjective aspirations, resource limitations and specialists responsible for the forecast/plan projects.

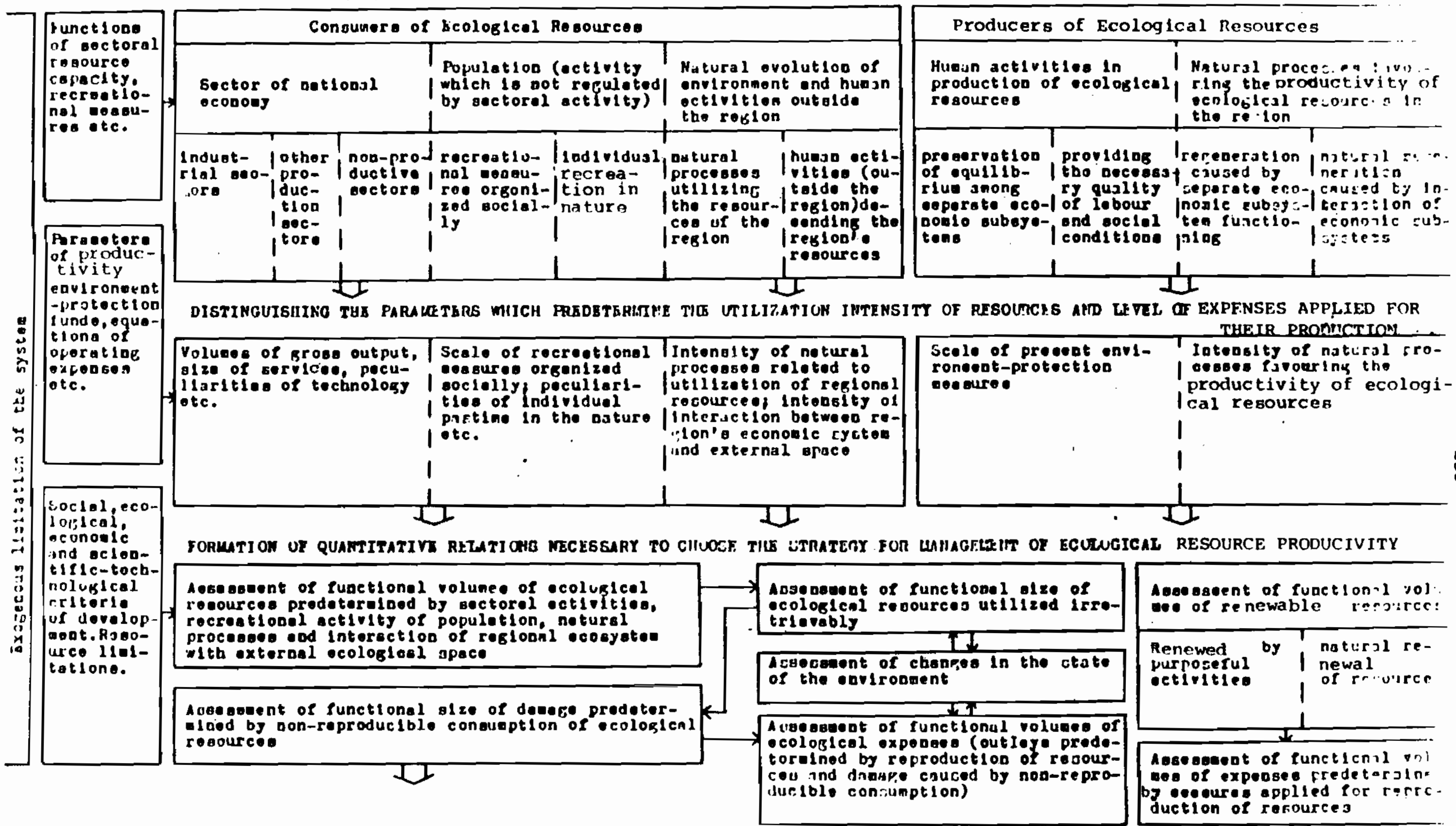
Models of a system suitable for regional development analysis and forecast are chosen on the basis of both the desire to include all basic dependencies of separate components of the IPSR and their interrelations as well as the necessity to link the IPSR parameters with forecast indices of the republic's development.

4.2 As a rule, the forecast indicator is considered to be a spectrum of possible values of the parameter studied with a quantitative measure pointing out the possibility of this spectrum occurrence. However, for large complex systems it is almost impossible to provide a quantitative measure (probability) of the spectrum. Therefore, as a rule in such a case, one should be satisfied with qualitative results. Such a state thus gains the name "forecast state".

FRAGMENT FROM A LARGER SCHEME OF REGIONAL ANALYSIS AND FORECAST OF INTERACTION BETWEEN SOCIAL REPRODUCTION AND CHANGES IN NATURAL ENVIRONMENT

Scheme 1

DISTINGUISHING THE SUBJECTS OF CONSUMPTION AND PRODUCIVITY OF ECOLOGICAL RESOURCES



CHOOSING THE OPTIMUM STRATEGY FOR MANAGEMENT OF CHANGES IN THE ENVIRONMENT AND CALCULATION OF RESOURCES NECESSARY FOR THEIR REALIZATION

Choosing the complex of ecological measures satisfying the criteria representing the efficiency of social, technological and economic development; limitations on materials and resources and finances in a region

Scheme 2

FRAGMENT OF THE DIAGRAM OF THE STP-MANIFESTATION ANALYSIS WITHIN SOCIAL REPRODUCTION

SUBJECTS OF STP

Man's target-orientated activities. Objective laws of social development

OBJECTS OF STP

Population				National (social) wealth			Social relations			
Conditions of labour activity		Population productivity conditions		Productive forces		Natural resources	Production relations		Ideological relations	
Productive forces dislocation principles	Settling principles	Personal consumption	Social consumption	Personal factor of productive forces	Material factor of productive forces	Renewable and non-renewable natural resources	Labour organisation and distribution principles	Distribution and exchange principles	Legally regulated ideological relations	Morally and ethically regulated relations

BEARERS OF STP

Rationality of production and residential dislocation	Population mobility	Fulfillment quality of personal and social needs	Labour educational and skill level	Scientific and technological level of production	Degree of productivity and utilization quality of natural resources	Quality of state of natural environment	Scientific and technological level of production organization	Perfection of distributive relations and exchange	Functioning quality of legal superstructure	Matureness of moral and ethical standards of population's behaviour

Financial resources of STP. STP efficiency indicators. STP-management criteria choice

5. Choosing the System of Models Applied to Forecast the IPSR in a Region (Republic)

5.1 The basis for a system of models applied for the analysis and forecast of the IPSR consists of equations describing the basic interdependencies for population and manpower production, reproduction of the GNP and main funds, as well as productivity of the environment.

5.2 *The subsystem of demographical forecasts and manpower distribution among the national economic sectors.* Forecasts of this subsystem are both an input and an output of socio-economic forecasting. The majority of demographic processes are highly autonomous and therefore, it is possible to obtain approximate indices of a demographic forecast before economic forecasting is carried out.

The aim of demographic forecasts is to obtain indices showing the number of people in a region and their distribution according to age, sex and place of residence. The dynamics of the matrix

$$N = n_{ij} \ ,$$

where n_{ij} is the number of a region's inhabitants having reached age i and belonging to one of j groups: urban women, urban men, country women, country men

is determined according to the following formula:

$$N = N_p - N^b - N^{bH}$$

where N^P is the matrix (calculated) of the region's inhabitants formed under the natural conditions.

N^b is the matrix of migration and N^{bH} is the matrix of immigration.

Data corresponding to the beginning of the period studied, as well as parameters of longevity and birth age are used as basic initial data for the calculation of matrix N^P. The principles used in constructing the matrices N^b, N^{bH} may be considerably changed depending on the peculiarities of a region. Hence, adoption of these principles must be preceded by an analysis of conditions and factors determining immigration and emigration of the regional population.

The detailed demographical forecast obtained serves as an initial basis for determining the actual manpower. In the future, the demand of manpower for economic sectors should be coordinated with its availability according to the criteria showing the increase of socio-economic efficiency of manpower distribution among the sectors.

5.3 *Subsystem to analyze and forecast productivity of the Gross National Product (GNP) and capital funds for production.* This subsystem, reflecting the evolution of a real self-organized subsystem, is constructed on the basis of the necessity to elucidate the levers which control the material productivity of material production with the socio-economic and ecological subsystems. The internal productivity structure is elucidated by determining the dependence of the GNP factors causing it, as well as by defining the principle, tendencies, and sources forming these factors.

5.4 *Choosing the aggregation level of forecasting indices.* In temporal, analytical and functional aspects, detailing the long-term calculations of GNP productivity depends firstly on the aims set before the research is begun and, of course, on the quantification of separate processes and correlations of regional productivity.

However, in order to reflect the internal structure of regional production, it is necessary at least to detail the following description of the GNP among trends of its utilization:

$$X_{t,i} + I_{t,i} - M_{t,i} - Z_{t,i} - K_{t,i} - A_{t,i} - R_{t,i} - V_{t,i} - E_{t,i} - B_{t,i} - \Pi_{t,i} = 0 \qquad (1)$$

where:

$X_{t,i}$ = gross output (or other integral characteristic of economic activities for non-productive sectors) obtained in a region by sector i;

$I_{t,i}$ = volume of imported products (into sector i) necessary for production purposes, as well as those of accumulation and non-productive consumption;

$M_{t,i}$ = output volume (in sector i) spent on productive consumption of all sectors of the national economy in the republic;

$Z_{t,i}$ = output volume (in sector i) spent on productive capital investments into all sectors of the republic (accretion of the capital funds of production, accretion of incompleted construction works, other productive capital investments);

$K_{t,i}$ = output volume spent by sector i on capital investments into non-productive capital funds of all economic sectors in the republic;

$A_{t,i}$ = output volume spent by sector i on the accretion of turnovers, reserves and stocks;

$R_{t,i}$ = output volume spent by sector i on the capital repair of capital funds;

$V_{t,i}$ = output volume spent by sector i on regional consumption;

$E_{t,i}$ = output volume spend by sector i on productivity of all types of economic resources and elimination of consequences caused by environmental changes;

$B_{t,i}$ = is the output volume of sector i exported from the republic;

$\Pi_{t,i}$ = is the remaining types of product i consumed and its losses;

$t = 1,2,\ldots,T$; and $i = 1,2,\ldots,n$.

The complex of indices shown in equation (1) (or in the balance equation which is more detailed) together with a detailed complex of demographic indices and those reflecting the state of the natural environment make up a rather large set of indicators suitable for quantifying different aspects of social productivity in a Union republic.

5.4.1 Simulation of the GNP dependence on factors causing it. The comparison of the GNP output volume obtained in the republic with the variables causing it, is made on the basis of multifactor models. As a rule, the mathematical form of the production function is chosen with regard to several initial requirements based on conclusions made from relevant economic assumptions about dependence of production output on growth factors.

For the material production sector, the output of sector i in year t is as a rule, presented in the production function, as a functional (X) of the number of workers ($D_{t,i}$) and the mean annual volume of capital funds ($F_{t,i}$) with regard to qualitative characteristics, as well as factors specific to a certain sector ($O_{t,i}$):

$$X_{t,i} = x(D_{t,i}, F_{t,i}, O_{t,i}, t) \qquad (2)$$

The analytical form of the function is to be chosen with regard to real possibilities of further assessment and forecasting of its parameters, as well as the possibilities to solve the whole system of multisectoral models numerically. In the case of a multi-dimensional forecast system, special attention should be given to production functions favoring the linearization of a given system.

5.4.2 Models simulating the productivity factors and conditions of GNP production and sources of their formulation. Each structural element of the GNP shown in equation (1) plays a definite role in the production process and satisfies different social requirements.

The regional forecast system described above includes models which determine functional (and numerical as well, if the scenarios of long-term development are realized) valı ɪs of volumes for each structural element of the GNP on the basis of calculations of demands in productive and non-productive consumption and accumulation, as well as the possibilities of achieving them.

Very often, when forecasting the necessary output flow ($X_{i,j}$) from sector i into sector j, the endogenously forec ıst values of coefficient a_{ij} reflecting direct material expenses are used:

$$X_{ij} = a_{ij} X_j \ . \tag{3}$$

Forecast levels of intersectoral flows should be worked out with regard to the main trends and tendencies of scientific and technological progress, as well as other conditions of production. In order to meet the requirements mentioned above, a model of intersectoral interactions[1] can be effectively used; this model is based on the following expression:

$$X_{ij} = a^{o}_{ej} + a^{i}_{ij}x_i + a^{j}_{ij}x_j + a^{ik}_{ij}x_{ik} + a^{ej}_{ij}x_{ej} \ , \quad (ij = \overline{1,n}) \ , \tag{4}$$

where:

a^{i}_{ij}, a^{j}_{ij} = parameters describing the influence in sector i and output volume in j sector, respectively, on the value of output flow;

a^{ik}_{ij} = parameter describing the influence of output volume i delivered to the adjacent consumer (in k) sector taking part in a distribution of this output;

a^{ej}_{ij} = influence of the parallel output flow from sector e in the material outlays of sector j.

The total volume of output (in sector i) necessary for productive consumption will be as follows:

$$M_{t,i} = \sum_{j=1}^{n} X_{ij} \ . \tag{5}$$

5.4.3 The volume of capital investments at a level necessary for social productivity should be calculated using the models which describe the production of funds and allow the linking of balances of capital with those of capital funds. This can be done using the following assumptions:

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[1]See the article on Modelling the Intersectoral Interactions, published in Moscow in 1984.

- the volume of capital funds available in the beginning of the year is changed in proportion to the coefficient $\beta_t = 1 - \alpha_t$, where α_t is the coefficient of the retirement of the capital funds of year t;
- newly introduced funds are the result of capital investments of a given year and previous year k. Moreover, in each unit of funds introduced in year t, there is a certain share which is a result of capital investments of year t−p, (p = k, k−1,...,0);
- the input (introduction) of capital funds of production proceeds every year according to the accepted coefficient of input uniformity S_t; and
- there is a yearly redistribution of funds, the sums of funds transferred and received being the same for all sectors.

If a certain function of fund volume is $f^{-1)}$, i.e., if the expression for assessment of the necessary volume of mean annual funds depends on the volume of gross yield and values of other production factors, the volumes of capital investments can be determined according to the following formula (Rutkauskas and Navickas, 1984):

$$\hat{Z}_t = \sum_{s=0}^{k} u_{t+s,s} \frac{1}{\beta_{t+s}} [S_{t+s} f^{-1_{t+s}} + (1 + \beta_{t+s}) \sum_{p=1}^{t+s-1} (-1) S^{p}_{t+s-p} \tag{6}$$

$$\times f^{-1}_{t+s-p} + (-1)^{t-s} (1+\beta_{t+s}) F_o] \ , \quad (t = 1,2,\ldots,T) \ .$$

On the basis of calculated functional values of sector demands in productive capital investments and matrices of their material and substantial structure ($C^z_{t,i}$), the functional values of demand for the corresponding products are determined as:

$$Z_{t,i} = \sum_{f=1}^{n} c^z_{t,j} \hat{x}_{t,j} \ . \tag{7}$$

As a rule, special methods applied for forecasting the matrices of material and substantive structures of capital investments in separate sectors are based on factor-to-factor correction of account coefficients; this correlation is based on consideration of the main trends and tendencies of scientific and technological progress. Of course this method, if used, should be supplemented with direct count principles with regard to the conditions in a concrete case.

The problem concerning the forecast of matrices of material and substantive structure occurs as well when structural elements of the GNP marked out in the balance management are considered. In many cases, the solution of this problem is based on the utilization of the above-mentioned principles for models of intersectoral interactions.

When forecasting the volumes of production of sector i spent on capital investments into non-productive capital funds ($K_{t,i}$), the same principle for describing the production of funds should be used, as was the case for productive funds. Therefore, the formulae (6) and (7) can be used if equivalents of $F^{-1}_{t,i}$ and $C_{t,i}$ are determined for the non-productive funds.

However, if the principles used in the studies on production of non-productive and productive funds are identical, then in order to assess separate parameters of production, e.g., fund retirement, and to determine further demands in one or another type of funds, it is necessary to apply other principles as in the case of productive funds. In any case, it is necessary to include the principle of direct count, since the behavior of these indicators in future can differ significantly both from that in the accounting period and from their values, for instance, in the USSR as a whole.

5.4.4 The output volumes obtained in sector i from the average material turnover make up rather a small part of the distributed product. However, the indicator showing the volume of the turnover funds and its ratio to the integral characteristics are informative indicators of the sector's efficacy. This makes it necessary to take into account the dynamics of turnover funds, when the productivity of the GNP is being forecast.

The functional relationship between the accretion of average material turnover $\hat{A}_{t,i}$ and integral indicators defining the results of the sector's functioning can be as follows:

$$\hat{A}_{t,i} = a_0 + a_1 \, \Delta\hat{M}_{t,i} + a_2 \Delta\hat{K}_{t,i} \ , \qquad (8)$$

where:

$\hat{A}_{t,i}$ = accretion of material outlays;

$\Delta K_{t,i}$ = accretion of capital investments into sector i during year t.

On the basis of the functional values $\hat{A}_{t,i}$, and the matrix of material and substantive structures of average turnover $C^A_{t,i}$, the functional values of $A_{t,i}$ can be determined as:

$$A_{t,i} = \sum_j C^A_{t,j} \, \hat{A}_{t,j} \ . \qquad (9)$$

5.4.5 The output necessary for repair of capital funds in sectors consists of products which are set aside for the repair of machines, equipment and construction products. The volume of funds requiring capital repairs depends on the total volume of funds and on their physical condition. The account data can be well approximated by regression equations linking the volumes of the capital repair fund $(R_{t,i})$ with the mean annual volumes of funds $(F_{t,i})$ and several characteristics of their age structure $\bar{S}_{t,i}$:

$$\hat{R}_{t,i} = r(F_{t,i}; S_{t,i}; t) \ , \qquad (10)$$

which allows application of these equations in determining the functional values of capital repair funds in the future.

Further, on the basis of capital repair volumes $(\hat{R}_{t,i})$ determined for separate sectors and matrices of repair product structure, the product volumes allotted in these sectors for capital repairs are determined as:

$$R_{t,i} = \sum_j C^R_{t,j} \, \hat{R}_{t,j} \ . \qquad (11)$$

5.4.6 In contrast to the majority of the above-mentioned elements of distributed GNP aimed at increasing the intensity of production activities, the volumes of products destined for non-renewable consumption (as well as the part produced in a region) are direct characteristics showing the efficiency of separate sectors and the national economy of the State. They should always have maximization as a target. Products destined for non-renewable consumption are heterogeneous, as regards their form providing their consumption and the consumption forms themselves. These instances of consumption are well described when the finance and cost aspects of the GNP productivity are studied. Consumption behavior of the republic's population in the system proposed is described by means of a differentiated balance of income and expenses system of the republic's population.

5.4.7 In the "Methodical Instructions" issued to assist in working out State plans of economic and social development of the USSR, there is a proposal to consider the export volume as a share of products made in the region. However, the export volume for a concrete region is caused by several factors, including the following: (a) obligations of a region towards the State; (b) possibilities of a region (output volume X_t); and (c) providing the region with resources from external sources (volume of input I_t). Besides that, a sophisticated interrelationship of these factors causes a rather important analytical form of equations applied for the description of changes in export volumes:

$$B_t = b\,(X_t, I_t, t) \quad . \tag{12}$$

The export structure differs among the regions and responds sensitively to the changes in structure and roduction. Therefore, when the export structure is chosen, it is necessary to compare it directly with the expected changes in the production structure.

5.4.8 The volume of import determined by the balance equation is the last item. Calculations based on the whole system of models can be made with the aim both to determine the volume of import for realization of one or another version of regional development and also to assess the possibilities of regional development under the given volumes of import.

On the basis of the formulated dependencies and calculated (as described in section 3.4) volumes of ecological expenses, the material and substantial interrelationship for the GNP reproduction is assessed.

5.4.9 The volume of expenses necessary for the productivity of resources utilized and the elimination of consequences of their non-productive use is calculated on the basis of the logic shown in Scheme 1. The estimation of ecological expenses for separate products is a particular problem since the components differ in realization type, and their conversion into a vector of products obtained in the specific sector is predetermined by conditions of the concrete region.

A detailed account of the formulation of ecological expenses is given in the following section.

6. Forecasting the Natural Environmental State in a Region Depending upon Human Activity

6.1 General Provisions

6.1.1 The natural environment of any region is to be considered as an integral ecological system serving as a medium for residence and vital activity of the region's population as well as the space for placing productive forces and a source of material wealth for their development.

6.1.2 Hence, considering the productivity conditions of the natural environment, it is necessary to take into account both the productivity of its particular subsystems (atmosphere, water resources, soil/vegetation cover, animal life, the upper part of the lithosphere, residential conditions – such as acoustic, thermal, etc.), and their interaction and the productivity of functional capacities mentioned in section 6.1.1.

6.1.3 Since the state of the natural environment is changed not only by negative human impacts, but also by positive measures providing a certain equilibrium in the environment's state, it is necessary to consider all links of dependence (see Scheme 3):

Further, the term "consumption/production of resources" comprises pollution/ cleansing, production/destruction of potential pollutants, consumption/production and loss/generation of some functional capacities of the resources.

6.1.4 Ecological resources in a region are consumed due to human activities in this region and outside it. Besides that, different types of human activities require a different quality of the ecological resources utilized. Therefore, it is necessary to take into account the following items: human activities, regulated activities in the sectors of the national economy – such as, power industry, productive industries and other industrial sectors, as well as non-productive sectors and their separate types, which are not regulated by the activities in economic sectors, i.e., behavior of people in nature, measures providing defense, etc.

6.2 Purposes of forecast ecological and economic calculations

6.2.1 The main purpose of calculations forecasting the changes in the state of the natural environment (as for all types of social and ecological forecasts) is to find situations which occur in practice on the basis of which one can choose the best (according to certain assumptions) way of changing this state.

6.2.2 The desirable result of further development is such that the concentration of harmful ingredients in some subsystem of the ecosystem does not exceed the maximum permissible concentration (MPC) level, which means that, the environment of a region is practically ecologically undamaged.

6.2.3 Concentration levels of harmful ingredients sometimes depend on natural sources as well as on human activities; it may then not be possible to achieve the standard MPCs practically unconstructive.

In such cases, it is more expedient to undertake the task of meeting the maximum permissible discharges (MPD) which in practical terms leads to ecologically unharmful human activities in the region.

To preserve ecological resources, choosing a strategy which favors meeting the MPCs and MPDs, requires skill in calculating the outlay volumes necessary for these purposes.

6.2.4 It is obvious that in the near future it will not be possible to achieve the standard MPC and MPD for all the natural environmental subsystems and all pollutants under real conditions. Therefore, there is an urgent task to choose a strategy for the sustainability of ecological resources which could minimize ecological expenses (outlays for producing a part of utilized resources plus damage obtained in the case when the resources were not regenerated).

6.3 General scheme on how to choose basic relationships applied to forecast calculations

6.3.1 Basic dependencies used to describe the interrelationship between human activities and the state of the natural environment should be chosen according to the following logical succession (see Scheme 3)·

- single out the subjects of consumption and reproduction of ecological resources;
- assess the rules and parameters suitable to describe the intensity of resource consumption and level of outlays for production of ecological resources; and
- single out homogeneous territorial zones, i.e., judged by the human impact on the environment.

6.3.1.1 An ecological subject should comprise not only all types of human activities in a region, with ecological resources utilized, changed or reproduced, but also natul processes favoring the change in state of the ecological environment in a region. Such a consideration of the ecological subject is dictated by the fact that, in a real case, it is practically impossible to distinguish the general consequences of human impacts on the environment from the results of natural evolution.

When practically considering the interrelationships among social, economic and ecological processes, it is necessary to consider the cases of rather complex subjects, i.e., when a certain type of human activity requires an intensive consumption of ecological resources (e.g., in the case of an enterprise, ministry, industry, village, town, a specific group of the population, etc.).

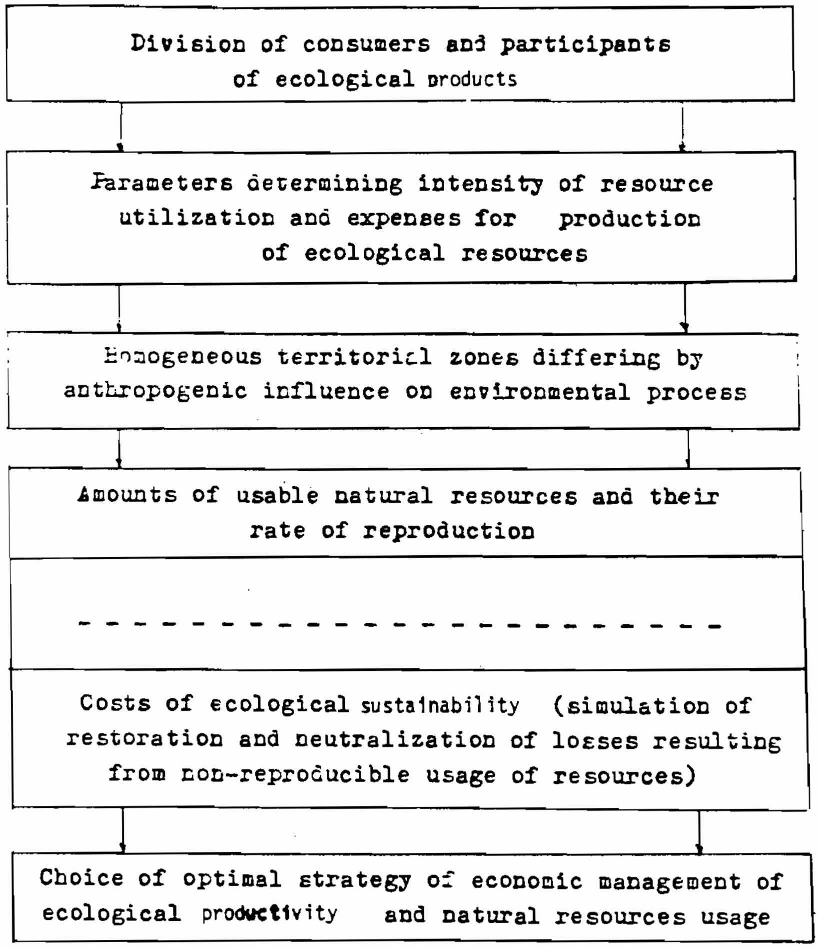
6.3.1.2 A territorial zone is a definite part of the territory in the considered region. This part is relatively (corresponding to a certain function) homogeneous with respect to formation (and hence, calculation) of ecological expenses. For instance, a suburban belt, transport line zone, river basin, etc. are territorial zones.

6.3.1.3 Types of activities in the studied region comprise all sorts of human activities expedient socially and economically and natural evolution processes requiring ecological resources.

6.3.2 On the basis the of logic given in Scheme 1, it is convenient to concretely choose the subjects of consumption and productivity of ecological resources, to single out the parameters predetermining the intensity of ecological resource use (depending on the intensity of subject/consumer functioning) and the level of outlays for their reproduction.

6.3.2.1 When choosing the subjects/consumers of economic resources, it is necessary to meet the following requirements:

- all types of human activities requiring the economic resources are to be covered;
- it is necessary to find the possibilities to theoretically ground the dependence of the resource consumption scale on the intensity of functioning of the subjects/consumers and to statistically analyze the parameters of the suggested dependencies;



Scheme 3. Aggregated scheme of macro-economic management of ecological productivity

- there should be the possibility to determine the addressee of withdrawal of ecologically grounded expenditures for the defrayal of outlays used to regenerate a part of the resources utilized and to eliminate the consequences of non-productive utilization.

6.3.2.2 When distinguishing the territorial zones of negative impact caused by nonregenerative utilization of ecological resources by subjects/consumers, it is necessary to provide:

- completeness in evaluating the total (for the region) damage caused by the nonregenerative utilization of all types of ecological resources;
- the possibility to put the damage down to a definite addressee.

Of course, territorial zones can be superimposed, and as a result, they cannot represent the whole territory of the republic, if there are areas which are not exposed to negative impact.

6.3.2.3 When assessing the volume of ecological expenses, it is permitted to divide the resources used into two parts: the regenerative resource which predetermines the level of outlays spent on production of the resources, and the unregenerative (with regard to natural regeneration) part which predetermines the damage level.

It is possible that resources are regenerated in higher volume than they are consumed.

6.3.2.4 The logic and succession of formation of quantitative indicators necessary for decision making are also represented in Scheme 1.

The status of a forecast indicator is determined on the basis of a generalized criterion for the whole system; and the requirement to minimize the ecological expenses is neturally assumed as a component of this system.

6.4 Succession and Principles of Choosing the Basic Dependencies for Forecast Calculations

6.4.1 In a simplified case, when there is a single subject with a single type of activity, a single resource consumed and a single territorial zone having a single recipient of damage, the succession of formation of dependencies mentioned above is as follows:

- determination of the volume of resource (P) used, depending on the functioning intensity of subject (A);
- determination of the expenditure level (3) for production of the regenerative part of the resource (P^b);
- determination of the damage level (Y) as a certain function y of the unregenerative part af the resource utilized (P^H);
- formation of criteria suitable to estimate P, P^b and P^H into $\bar{P}$, $\bar{P}^b$, $\bar{P}^H$, and hence, the level of ecological expenses V into $\bar{V} = \bar{3} + \bar{Y}$ (the bar over the symbol means that the indicator corresponds to the status of "forecast").

6.4.1.1 For many types of economic activities with a stable technology and levels of utilized power, there is a theoretical possibility to directly calculate the volumes of consumed resources (volumes of utilized water, volumes of pollutants formed, etc.). However, as a rule in practice, it is necessary to consider economically significant subjects, such as large enterprises, entire sectors, towns and even urban agglomerations, transport lines (highways), etc., where the method of direct counting is to be supplemented or even changed by the statistical evaluation method, which evaluates a certain theoretically based function P (based on the results of observations of matched values A_i and P_i):

$$P = p(A) \ .$$

6.4.1.2 The assessment of environmental protection expenses can be divided into two stages: (a) determination of the environment protection fund volume necessary to regenerate the reproductive part of the resource; and b) determination of capital investments and operating outlays necessary to form and operate the environmental protection fund.

6.4.1.2.1 The function expressing the fund volume of resource production (g) can be estimated either by the rules of direct counting of the fund demand or by statistical evaluation of parameters c' the following function:

$$G^7 = g^7(P^b) \ .$$

6.4.1.2.2 Assuming that the resulting efficiency of each component of capital investments (working out new and reconstructing existing environment protection funds, a modification of production technology with a single purpose to decrease its unfavorable impact on the environment, modification of production technology in that part which provides the achievement of environmental protection purposes) is the same, the capital investments (E^7) necessary for environmental protection can be assessed according to the formula, analogous to formula (6) as follows:

$$E^7 = e^7 \, (G^7) \ ,$$

where

$$f^{-1} = g^7 \ .$$

Such an assumption can be made due to an analogous case of production of funds for environmental protection and capital funds. Very often their construction and operation coincide in space and time.

Operating expenses for environmental protection purposes (E^7) are predetermined by the existence of funds for environmental protections and by conditions of their operation:

$$E^7 = \bar{e}(G^7) \ .$$

6.4.1.3 The nonproductive utilization of ecological resources as a rule exerts a negative influence on the regime of productivity for separate subsystems and hence, for the whole ecosystem in a region; functional characteristics become worse, i.e., the conditions for labor activities and life-style of the region's population worsen. In the ecological-economic literature, there is no common methodological approach to the economic evaluation of changes in the state of the natural environment. However, we can say that the following influences of change in the environment to be singled out, are generally accepted:

- direct influence on the factors, and hence on the results of material activity of the population;
- influence on qualitative characteristics of functioning of society

6.4.1.3.1 Calculating material damage, the following methodological formul[illegible] is to be accepted:

$$y_H = \min 3_1, 3_2, 3_3, \hat{3}_{1,2,3}$$

where

3_1 =outlays necessary to achieve the previous state of the environment (m[illegible]e exactly, to reach the state where basic material damage does not incre[illegible]se

3_2 =real gross damage for all recipients;

3_3 =outlays necessary to fulfill previous functional capacities of the environment;

$\hat{3}_{1,2,3}$ =case with partial regeneration of changes in the state and/or reproduction of functional capacities of the environment.

The main recipients should be assumed to be the population, [illegible] public utilities, agriculture, areas covered with forests and [illegible] fisheries, capital funds, recreational resources with the features [illegible]

6.4.2 Under real conditions, we are dealing with complex territorial subje[illegible] utilizing several types of ecological resources bearing an impact on environment of numerous territorial zones in a region. Let us assume that i[illegible] expedient to single out in the studied region I subjects of consumers carrying J types of activities, utilizing R types of ecological resources and exert[illegible] ecological pressure on one or several Z territorial zones.

An alteration of succession in assessing the ecological expenses [illegible] performed in the following way:

- the functions of the resource capacity are determined for all specif[illegible] subjects and for all types of resources utilized;
- outlays to reproduce the regenerative part of the resources utilized a[illegible] determined for each distinguished subject (or their group);
- damage caused by nonregenerative utilization of resources is determined for each territorial zone; and
- total ecological outlays are calculated for all types of regenerati[illegible] resources, as well as total levels of damage for all territorial zones in [illegible] region and the resulting levels of ecological expenses in a region are calculated.

6.4.2.1 The logic of assessing the resource capacity, depending on intensity of the subject's functioning is analogous to that used in section *5.4.1.1*:

$$P_{ijr} = P_{ijr}(A_{ij};\alpha) \quad , \quad i\varepsilon I,\ j\varepsilon J,\ r\varepsilon R$$

where

P_{ijr} =volume of resource r utilized by subject i in case of type j of its activities performed with intensity A_{ij};

α is a constant, reflecting the peculiarities of the subject's technology.

6.4.2.2 Functions determining the environmental protection outlays used for production of the regenerative part of the resource vary in a similar way (as in *6.4.1*):

$$G^7_{ijr} = g^{ijr^7} (P^b_{ijr}; \beta) \ ,$$

$$E^7_{ijr} = e^{ijr^7} (G_{ijr}) \ ,$$

$$\hat{E}^7_{ijr} = \hat{e}^{ijr^7} (G_{ijr}, G^7_{ijr}) \ .$$

Often the resource is produced together by numerous subjects (e.g., water purification, elimination of hazardous industrial wastes, etc.).

6.4.2.3 More characteristic features are formed during the assessment of material damage Y^B_{ijrz} made in zone Z by nonreproductive utilization of resource r used by subject i during the performance of activity type j – R^B_{ijr}. Firstly, damage greatly depends on the zone itself; secondly, it is very difficult, methodologically, to calculate the resulting damage in the territorial zone which is under the impact of several subjects. The resulting damage, as a rule, is a certain complex of damage levels with values which vary significantly: from maximum values of separate components to an arithmatical sum of these components. In practice, however, cases which exceed this sum are possible.

6.4.2.4 If ecological expenses are assumed as a sum of material damage caused by nonreproductive consumption of the ecological resource (y) and outlays for reproduction of the regeneration part of the resource (3) being the sum of capital investments into environment protection (E^7) and operating outlays for the environment protection ($\hat{E}^7$), then:

$$3^7_{ir} = \sum_j 3^7_{ijr} = \sum_j E^7_{ijr} + \sum_j \hat{E}^7_{ijr} \ .$$

where

3^7_{ir} = volume of outlays spent on reproduction of the part of resource r utilized by subject i;

$$Y_{ir} = \sum_{j,z} Y_{ijrz} \ .$$

Y_{ir} = damage caused by nonreproductive consumption of resource r by subject i;

$$U_{ir} = 3_{ir} + Y_{ir} \ .$$

U_{ir} = ecological expenses spent on utilization and rep roduction of resource r by subject i;

$$3^7_i = \sum_r 3_{ir} \ .$$

3^7_i = total outlays spent on reproduction of the part of ecological resources utilized by subject i;

$$y_i = \sum_r Y_{ir} \ .$$

y_i = total damage caused by nonreproductive consumption of ecological resources utilized by subject i;

$$U_i = 3_i + u_i \ .$$

U_i = total ecological expenses connected with subject i;

$$3 = \sum_r y_i \ .$$

3 = resulting ecological outlays for the region;

$$y = \sum_r y_i \ .$$

y = resulting damage caused by the whole complex of human activities due to unreproductive utilization of ecological resources;

$$u = 3 + y \ ,$$

u = resulting ecological expenses for the region.

7. Peculiarities in Assessing the Financial Aspects of the IPSR and Evaluating the Influence of Technological Progress in the Regional Production

7.1 In a great multitude of processes and relations of social productivity, several sub-populations joining the processes, attitudes and relations of the total population into one single entity can be singled out.

7.2 Subsystem of Financial Models. In order that, in making a forecast-planned decision, it would be possible to take into account the sources of economic growth (naturally having a substantial and financial character) and results of social production determining a complex interaction, the main financial relations of social productivity should also be taking into account in the forecast system.

It is necessary, together with substantial, scientific and technological, organization and other material and informational flows, to reflect also the noncommitant financial relations. Besides financial balances or incomes and expenses of the population, sectors (enterprise, collective farm and institutions), the State (in the form of the State budget and other financial and credit establishments in a republic) and balances of financial resources in a Union republic, accumulation fund and external relations, etc., the financial flows favoring the important regional programmes of development, technological progress, nature protection, etc., should also be reflected.

7.3 The integrity of economic turnover, the realization of a social product and national income as necessary conditions in order to realize the process of social productivity require that material and substantial, financial/value and material/financial balances exist. Hence, the construction principles and criteria for the realization of financial models are to be aimed at the search of long-run development variants which provide the fulfillment of these requirements in a necessary measure.

Detailed financial balances of incomes and the State reflect the main financial flows, hence, the main requirements for balanced social productivity are provided. Among the above-mentioned economic subjects, the main economic operations of production, distribution, exchange and consumption of social products are performed. The subjects can make relatively independent decisions and can exert influence on the process of social productivity. Financial participation of these subjects on one or another regional programme predetermines the financial resources of these programmes. Hence, detailed financial balances of the population, sectors and State, have a significant part of information for constructing the other balances listed in section *5.5.4*.

However, not all functional balances can be obtained by means of detailing the aforomentioned balances, since some regional programmes, partially or entirely, do not lie within the range of interests of the corresponding subjects.

7.4 Describing the balances of incomes and expenses for sectors of material production and the State budget and describing the differentiated balance of incomes and expenses of the population, the following methodological approach can be used: linking the income items of the balance with production results; constructing the function of expenses; detailing the expense items of the balance in accordance with the decision-making criteria and the existing limitations. After taking into account the income/expenses balances for the population, sectors and the State budget, we shall obtain a system of equations describing financial flows concomitant to substantial elements of the GNP (refer to equation in section *6.5.1*) and other sources of financial flows.

7.5 As a result of the numerical realization of the model system as a whole, the values of the GNP structural elements shown in the equation (in section *6.5.1*) and concomitant financial flows are determined. Hence, a direct result obtained after solving the system can be any indicator described by these parameters, as well as indicators of capital and turnover funds, number of workers in the economic sector, etc.

7.6 Peculiarities in assessing the influence of technological progress on forecasting social productivity in a region. A prototype for a category of technological progress is the complex of changes in the processes and conditions of social productivity due to human scientific and technological activities aimed at generating and spreading new knowledge about laws reflecting the evolution of natural and social phenomena, manifestation forms of these laws under concrete conditions and possibilities to use them in practice. Such an interpretation of technological progress, together with its obviously universal character, is sufficiently constructive for many problems of analyzing and forecasting scientific and technological progress.

7.7 Since, at the contemporary stage, the proportion and peculiarities of social productivity are considerably predetermined by the intensity of processes in technological progress and, on the contrary, since choosing the scientifically based strategy for real management of technological progress (potential possibilities of technological progress, e.g., in a State or the world, must be strictly distinguished from real possibilities of its manifestation in a region) is possible only in the process of social productivity, constructing the forecast system for regional productivity (as well as for scientific and technological progress) is impossible without dealing with the supersystem "social productivity - technological progress".

A fragment of the analysis scheme to assess the interrelationship between technological progress and other processes of social productivity is shown in Scheme 2 worked out by the Institute of Economics (of the Academy of Sciences of the Lithuanian SSR) to analyze and forecast processes of social productivity in a Union republic.

7.8 The incompatibility of most systems forecasting socio-economic development with the scientific and technological forecast systems is revealed in the absence of being able to single out general elements in macro-categories used to describe socio-economic processes and in the fact that categories of scientific and technological progress are more particular.

A fragment shown in Scheme 2 (in particular, the link "Carriers of Scientific-Technological Progress") and destined to study the relationship between the technological progress and other processes of social productivity deals with that part of the studied reality where socio-economic categories such as sectoral gross output, volume of capital funds and number of workers occupied in a sector, etc., and such categories of technological progress as the introduction of progressive technology, mechanisation and automation of production, etc., are "reduced to the same denominator". This favors the overcoming of the above-mentioned incompatibility of the system forecasting scientific and technological progress on the one hand, and socio-economic development on the other.

7.9 As mentioned earlier, a Union republic as a system of production units, settlements, manpower and nature conditions with material, financial and informational flows integrating into the process of social productivity has no single scientific or technological centre managing this process. In order for variants of scientific and technological measure worked out by separate centers to be coordinated in time, they should be coordinated with the basic scheme of regional productivity.

7.10 The share of inflow-outflow of fund-forming production in the produced volume considerably exceeds the analogous share of inflow-outflow, for instance of industrial products and shows a tendency to increase. This also applies to different projects. In short, the inflow-outflow problem awaits solution. This is a rather specific problem; however, its solution is closely related to the utilization of the system for forecasting social productivity in a region.

8. Practical Realization of the Forecasting System

The procedure of using the proposed system of models for forecasting calculations as decision support tools, is aimed at working out scenarios favoring the description of different versions of regional development by using the problems of forecasting the process of social productivity. The elements of balance equations (section *6.5.1*), together with other aforementioned indicators, present some elementary units by means of which the problems of forecasting the development of socio-economic processes are approximated by problems of forecasting the integrated process of productivity of population and manpower, GNP and capital funds and ecological resources.

The practical realization of the forecast calculations consists of two stages; in the first, the variation sphere of the parameters under study is singled out, with forecast indicators not contradicting the known regularities and limitations; when this is done, the search for purposeful information versions of long-run development proceeds.

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5.3 OVERALL STRUCTURE OF DECISION MAKING WITH THE HELP OF EXPERT SYSTEMS: A MODULAR APPROACH TO ECOLOGICAL SUSTAINABLE DEVELOPMENT

Jan Morovic
Institute of Management
Bratislava, CSSR

Our goal is to build a modular-integrated system which is defined generally and focused on that part of inputs and technologies which have impact (direct or indirect) on ecological sustainable regional development. The solution is based on concepts and artificial intelligence, applied systems analyses and operations research. The complex analysis of the ecological territorial problem can be treated as:

- geographically distributed
- functionally defined
- structurally described.

The idea of an integrated system is transformed to an integrated set of policies in all sectors and in environment over the natural resources (Figure 1). Actually, the ecological territorial problem can be solved with multifactor system analyses.

I am suggesting the construction of a system in generation languages (Prolog or Lisp ...) utilizing other available software products for data and knowledge bases for managing and coordinating such a regional development. The available data and knowledge background are synthesized for the whole integrated problem. To create an interactive tool for different decision-making bodies through a menu-driven system is at each moment presenting the overall integrated system and its expected details, scenarios – solutions from the analyzed point of view.

Users of the system are:

- policy makers
- decision makers
- planners
- managers, at the national, regional and enterprise (farm) level.

Such an integrated system is used for:

- decision support, by means of
  - interactive
    - multi-objective optimization

*In: Proceedings of the Workshop on *Ecological Sustainability of Regional Development*, Vilnius, Lithuania, USSR (22-26 June, 1987), L. Kairiukstis, A. Buracas and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

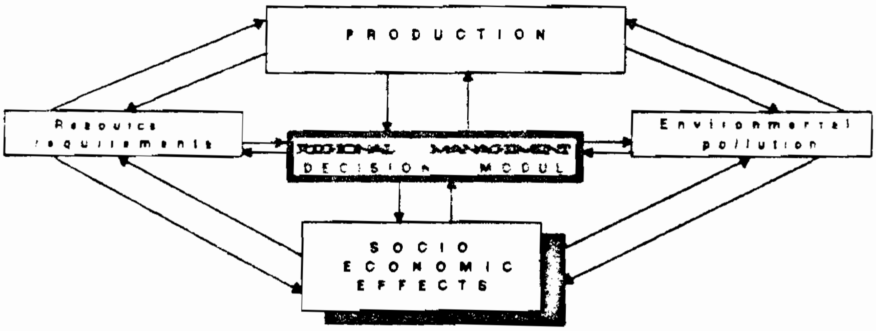

Figure 1: Modular structure

- multi-objective optimization
- graphics

- knowledge representation
- knowledge acquisition
- simulations.

Sectoral interconnection is one of the bases where we can deal from the managerial point of view with regional development. This interconnection is the place where there are opportunities for collective decision making. The whole process of collective decision making has its own practice and customs from the points of views of the different decision groups.

Generally the interaction problem of two sectors can be presented as:

interface

sector i | sector j

Labor
Investment
Capital
Prices
.
.
.

e.g.(agricultural authority) | (industrial authority)

To understand the whole regional decision problem, it is necessary to build up a modular system. One of the subsystems is maintaining the resource requirement for overall production within regions, another subsystem is gathering data about environmental pollution. The social-economic effects are maintained in a third subsystem (Figure 1).

The parts of the system, which exist only in principle are:

- decision module
- ecological module
- production module
  - industrial
  - agriculture

To my understanding, sustainability can function as some reference mirror (picture or tool) for continuous comparison with real and expected development

Our goal is to build up a system with wide knowledge bases for future dialogue (decision support or expert or both over a given management information system) capable of solving problems which arise. It is expected to begin with a so-called shell which can be implemented in different regional conditions satisfying a wide range of demands. For gathering of knowledge of environmental behavior, see Figure 2.

Gathering and classifying:

- questions
- decisions
- structures of control (management) decisions
- problems with which decision makers at different levels are tackling
- information about decision bodies and interfaces between decision makers and decision interpreters.

Our goals are as follows:

A. We would like to understand the system (knowledge maximization), e.g., mapping of the structure and dynamics of the interactions.

B. We would like to manage the problematic parts (minimizing and focusing on a particular problem).

C. We would like to control or manage globally:
   - on the several levels of decision makers
   - with some recommendations
   - with specialized ways of synthesizing all activities.

D. We would like to optimize the region's interests (what they are?).

E. We would like a continuing picture about the regional development.

F. We would like to estimate the limits of the regional development.

G. We would like to have a realistic overview of ecological limitations.

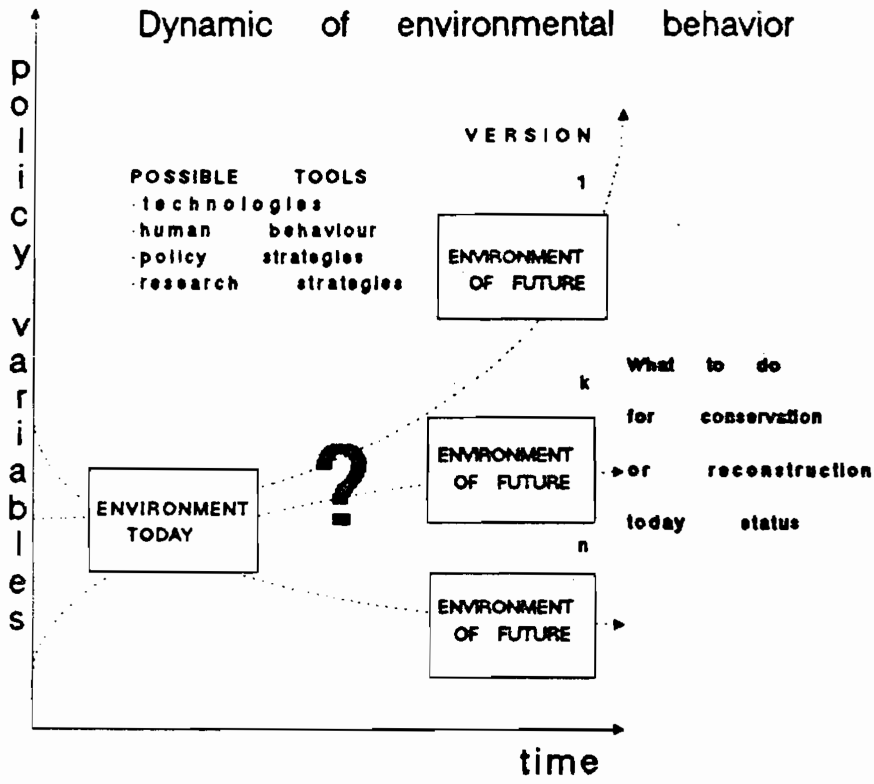

Figure 2: Dynamic of Environmental Behavior

The methods used are as follows:

1. *Analysis of the problem*

Goal-oriented analysis

- for comparison
- for management
- for overall control and decision making
- for ecological effects
- for economic consequences
- for comprehensive forecast
- for studying the behavior of the overall system.

Studying internal and external structures

internal – within region

external – interregional or national

Finding macro- and microrelations

macro – relations with other sectoral authorities

micro – relations within one sector

Hierarchies of relations

weighting of the different level of decision bodies and their decisions.

2. *Solution of the problem on different levels of interdependency* (Figure 3).

On the sublevel

- regional
- local
- enterprise (farm)

global level

- national
- multinational

We would like to find alternative scenarios within two (ecological–regional development) limitations.

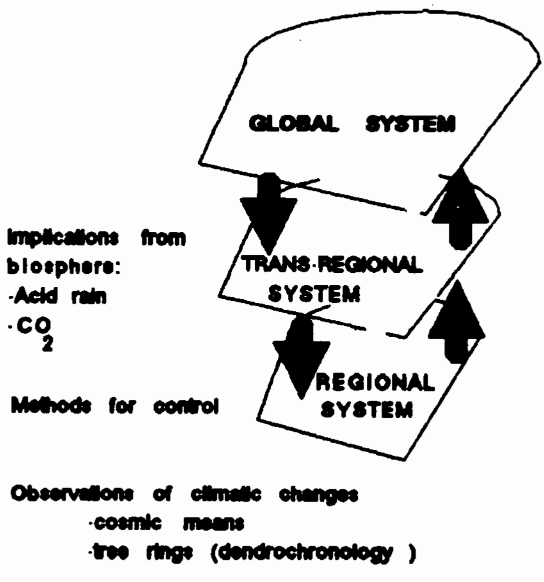

Figure 3: Structure of Independency

A schematic of the decision process is shown in Figure 4.
The models used are of the following types:

- national model
- global model
  - multisectoral
  - sectoral
- goal-oriented model
- detailed model

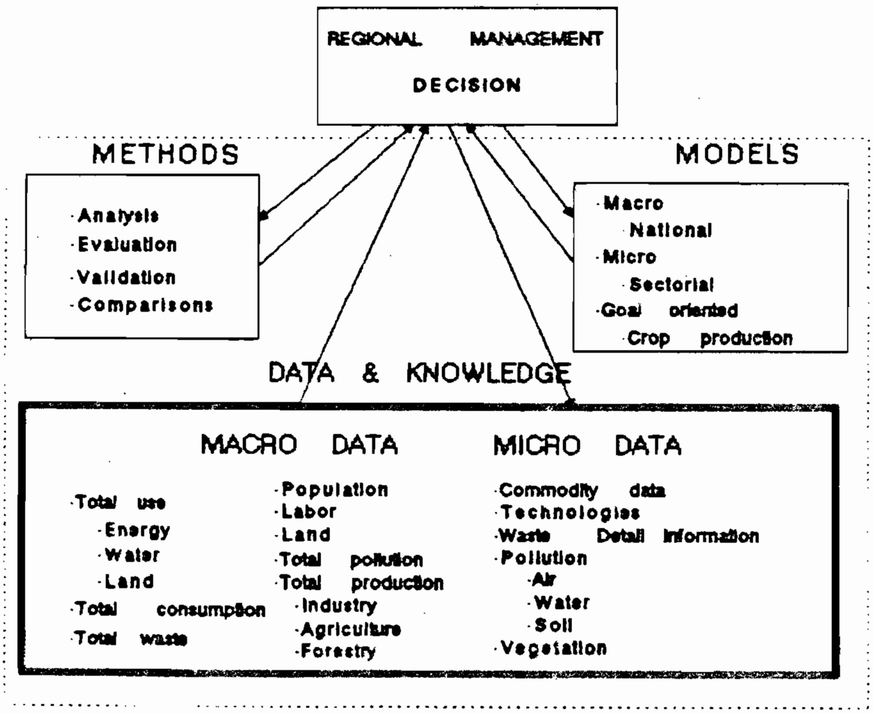

Figure 4: Decision process

These are applied to the following sectors:

- agriculture
- forestry

- industries
- socio-economic area

Let us focus on the interface between agriculture and the rest of the economy.

Methodologies (acceptable or not for the special goal)

- modeling methods
- methods of analysis and synthesis

Background data and knowledge bases.

Data bases, historical data, monitored data, newly defined observed data, ... (Figure 4).

Another important question is: Does a person or decision body exist to whom the result should be directly (correctly) addressed?

(a) Out of the region:

Government

(b) Within the region:

Regional authorities competence.

- Scientific body

As an example of interaction let's take agricultural development. If we are focusing on the interface of the whole economy and agriculture. Let's see what is the subject of our analyses. Generally it is an agroecological problem (neutrification of groundwatar, soil compaction,...).

Some of the questions to be raised are:

(1) Is it possible to find or define the optimal or sustainable level of interaction between the two studied subjects?

(2) With which tool or instruments is it possible to reach the appropriate level of interactions? Are there some optimal, suboptimal, better ... policy instruments?

(3) Are there some variants or boundaries for sets of scenarios which show us a realistic picture about interactions on the environmental and regional side at the same time? At what level must these policy instruments be set?

Searching and finding a precise answer to the first question is very difficult and usually it is sought in the context of setting standards for policy instruments and their levels.

Direct policy instruments act on a physical part of the system. Some of them are:

- per hectare restrictions of runoffs,
- restrictions on leaching of chemicals,
- water treatment,
- restrictions on chemical balance at:

- farm level
- regional level.

Indirect policy instruments rely on economic incentives to achieve a certain level of environmental quality. Among these instruments belong:

- excise taxes
- effluent charges
- market rights for chemicals
- vocational training.

From the overall system of criterion functions a cost damage function could be used for such an analyses. Costs are expressed as losses in benefits and/or as costs for removing pollutants.

Agricultural direct impacts on ecology are:

- livestock production (high concentration)
- ploughing
- fertilizer applications
- pesticides.

Expert systems should be constructed for diagnostics and also for planning purposes.

Special treatment should be offered to uncertainties.

I would like to suggest two ways of implementing expert systems:

A.1. Build up expert systems for regional development in different sectors: agriculture, forestry, separate exp. systems for different industrial sectors (electronic, heavy, light,...), social part, human part (system of weighting is not a simple question).

A.2. Build up expert system for ecology.

All these expert systems are part of the background for collective decision making, confrontation goal-oriented solution.

B. Create only one expert system which contains only aggregated data and knowledge for territorial management and has connections through networks to other databases from different subjects.

C. Design a flexible architecture of the overall system (See Figure 5).

Possible solutions are set of sub-scenarios for a given problem. Each sub-scenario from Es is described with the i-highest common (with other expert systems Es where $i \neq j$) j possible policy variables. Highest level of hierarchy (regional management) will have its own set of scenarios which support different long-term development in different shapes.

After some period of time each of the Es will contain i data and knowledge for a given problem area in a particular region.

The decision body for regional management will communicate through two interfaces. One interface i is created for interregional communication, the second interface N for national communication (regional – government).

Through interface N it would be possible to communicate in both directions:

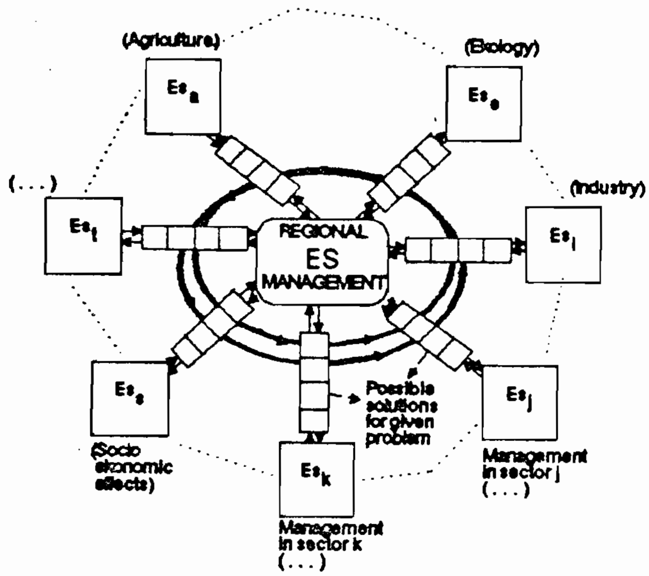

Figure 5. Dynamics of regional management for one problem.

- inward: (recommendations from national level)
- outward, to specify needs and wishes to the government.

Interface i is to serve as a solution of common problems, e.g., one factory has parts in different regions with labor for region i is migrating for job to region j.

PART VI

LONG-TERM ISSUES

6.1 STAGES AND TRENDS IN THE INTERACTIONS BETWEEN HUMAN SOCIETY AND THE ENVIRONMENT FROM NEOLITHIC TO PRESENT TIMES

Klaus-Dieter Jäger
Halle/Saale
German Democratic Republic

and

Arnd Bernhardt
Dresden, German Democratic Republic

The problem of ecological sustainability is closely connected with that of environmental change. At present the increasing impact of human society on the natural environment has placed the anthropogenic aspect of this change at the center of public attention. This fact is also reflected by the topics covered in this volume. However, from a geological point of view, environmental change is an essential feature of the Earth's history as a whole In early times, of course change was due to natural causes only.

This may be exemplified by the problem of climatic change. Scientists discuss the influence of CO_2 from fossil fuel on current and near-future climatic development, assuming that climate was more or less stable in earlier times, especially during the last millenia before the industrial revolution. However, this supposition is not true. In this context, we do not intend to trace back the geological evidence of climatic change to the very beginning of the Earth's history. However two examples may elucidate the character of the evidence.

The first is taken from a brickyard at Dolni Vestonice in Southern Moravia, Czechoslovakia, near the Austrian border where loess has been explored previously for the purpose of brickworks (Figure 1). The exposure is characterized by repeated alternating colors in the vertical sequence: The yellow beds are affected by aeolian deposition characterizing continental-type climate and locally open ground. The black layers represent buried humos horizons of previously superficial soils. They could arise only *in times when* loess deposition was interrupted. Therefore, they reflect climatic amelioration, an increase of moisture and a decrease of climatic continentality. Moreover, the position of the surface in the time of humus accumulation is shown. However, our main conclusion is that this climatic change was independent of any human activity or even impact to ecosystems, because the entire sequence is dated to the Upper Pleistocene when man still had produced only paleolithic stone implements. Our conclusion is confirmed by an ecological analysis of paleontological objects, i.e. fossil mollusc shells from the sequence investigated here

The next example is taken from a sequence of calcareous tufa deposits near the town of Jena in Thruingia, GDR: Again we see alternating white and black layers in the soil profile (Figure 2). The white ones represent freshwater lime deposits that must be due to subaquatic sedimentation, i.e. at the bottom of superficial waters. Morover, their deposition occurs only within a particular water

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*In: Proceedings of the Workshop on *Ecological Sustainability of Regional Development*, Vilnius, Lithuania, USSR (22-26 June, 1987), L. Kairiukstis, A. Buracas and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

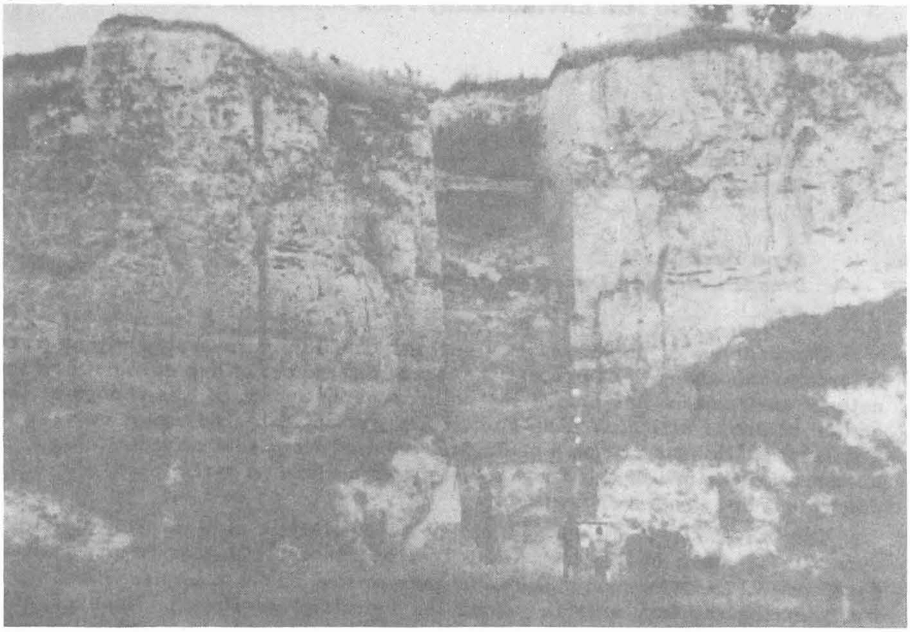


Figure 1. Dolni Vestonice (district of Breclav), Southern Moravia, CSSR. Brickyard exposure at the foot of Palava Mts.: The stratographic situation is characterized by alternating yellow loess layers and dark coloured soils.

temperature range during summer season. On the other hand, the black humos layers represent soil forming under terrestrial conditions, i.e. they reflect times when the site was dry and open to subaeric humus enrichment over a number of years, enough for visible humus accumulation. If there were any doubt of this conclusion, additional evidence is given by archeology, viz., sherds of prehistoric pottery (Figure 3) have been found in one the humous horizons (Figure 4).

They date this time-span to the younger Holecene, not more than about 3000 years ago. Similar observations are available from more than 60 sites with exposure of Holocene fresh-water lime deposits in different parts of Central Europe. Because the dry periods at such sites are practically the same in all parts of Central Europe, we have confirmation that climatic change took place without human intervention during the last millenia. Therefore, it cannot be excluded, and we must test rather carefully, whether recent climatic change is of natural origin or is due to human activities, technological processes, air pollution, so on. Otherwise, we may be faced with another case of mismatches in the sense described by U. Svedin (in the present volume).

Historical evidence of anthropogenic environmental impacts is given by stratigraphy. Again two examples may be sufficient to demonstrate and evaluate this type of field observations.

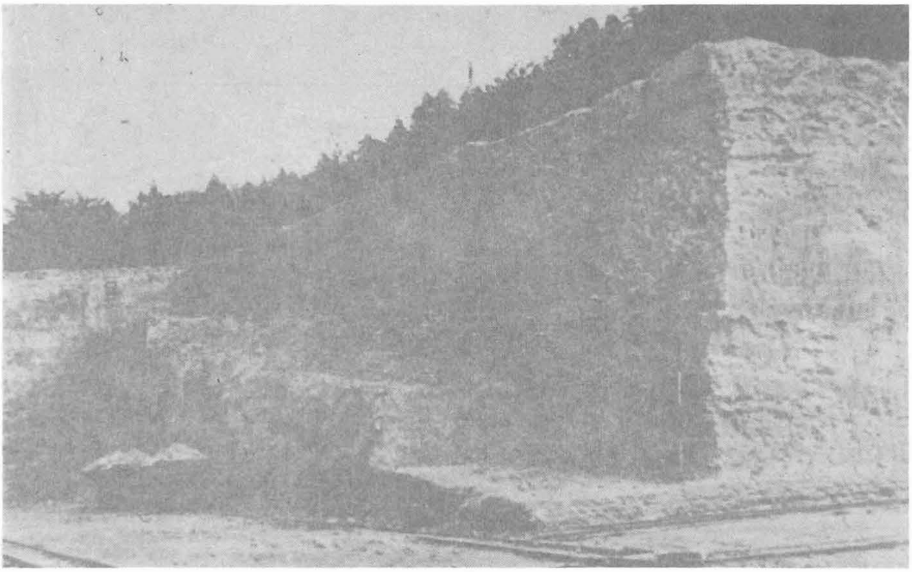


Figure 2. Jena-Wöllnitz (district of Jena), Thuringia, GDR. Exposure of a Holocene calcareous tufa sequence: White layers of fresh water lime deposits alternate with black ones indicating covered humos horizons of previous superficial rendizina soils.

The first one is a dune exposure near Fischbeck, district of Havelberg, GDR. Again we see alternating buried humus accumulation between sedimentary deposits (Figure 5). Moreover, archeological dating by prehistoric pottery is possible; one of the urns was found in a cemetery dated to the Pre-Roman Iron Age, about 2500 years ago.

The dating is similar to that of the freshwater lime deposits discussed earlier, but several differences in detail may be mentioned.

- The layers underlying and covering the buried humus horizon consist of sand dune deposits.
- Many comparable exposures have been examined (a catalogue of available records from the lowlands of northern Poland and GDR has been prepared by a common working group. However, no period can be found in which blowing sand in dune areas occurs on a regional scale. The vents reflected bv stratigraphy are of local character in this case.
- There is a high degree of correlation between archeological evidence and the appearance of buried soils in dune areas. Thus, it is obvious, Holocene blowing sand is closely connected with the local presence of prehistoric man. Forest clearing for the purpose of settlement, field-work, or cemeteries have opened the sites for sand redeposition. In this case, stratigraphy may reveal cases of human impact to the local environment in prehistoric times

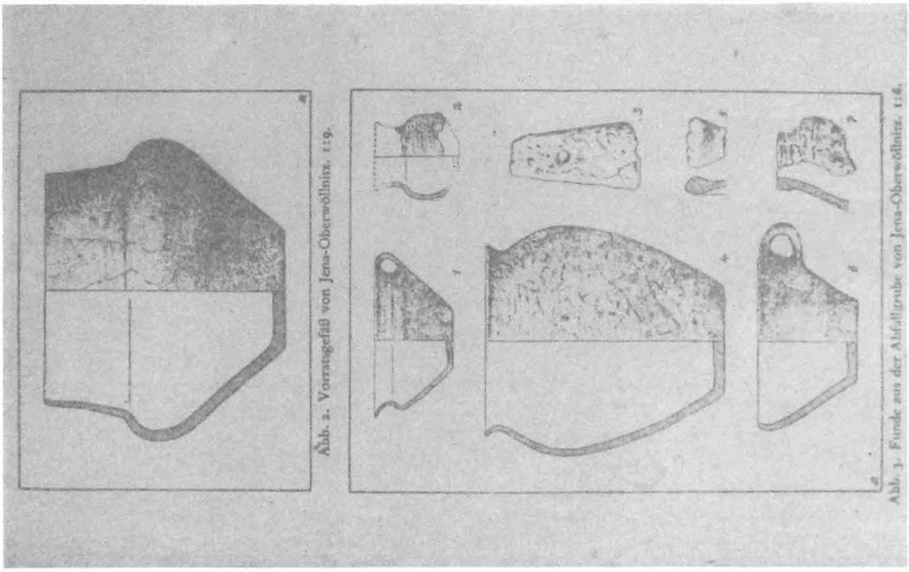


Figure 3. Jena-Wollnitz (district of Jena), Thuringia, GDR. Prehistoric pottery dating the uppermost of the covert humos horizons in the sequence of Holocene fresh-water lime deposits (Figure 2) to the late Bronze Age.

Another view is provided by floam loam deposits of inundated riverbanks as in the next case showing an exposure north to Erfurt in Thuringia, GDR (Figure 6).

The buried humus horizon below the fine-grained floam loam permits dating of these deposits to the young Holocene period. The accumulation may be illustrated by two pictures of the riverside meadows of the Elbe stream near Lutherstadt Wittenberg, GDR (Figure 7).

One is taken at the time of loam, the other two weeks later (Figure 8).

In riverside-stratigraphies we again find alternating buried humus horizons and sedimentary deposits. In this case of fluviol origin (Figure 8). Older and younger floam loam are separated by buried soils and thus distinguishable. Occasionally they are dated by archeology or radiocarbon techniques, Thomas Litt from Halle demonstrated recently that:

- There is no floam loam accumulation older than the time of the neolithic introduction of agriculture into Central Europe, and
- The distribution of the earliest floam loams covers exactly the same area as the early neolithic settlements that introduced agriculture to this area (Figure 9).

Thus, the conclusion is justified that the earliest far-reaching human impact on the environment was connected with early agricultural land use causing soil erosion.

The methodical details supporting this conclusion are interesting:

1) Evidence of human impact to past environments even before the appearance of any written record is possible through correlation of geological and archeological field-observations.

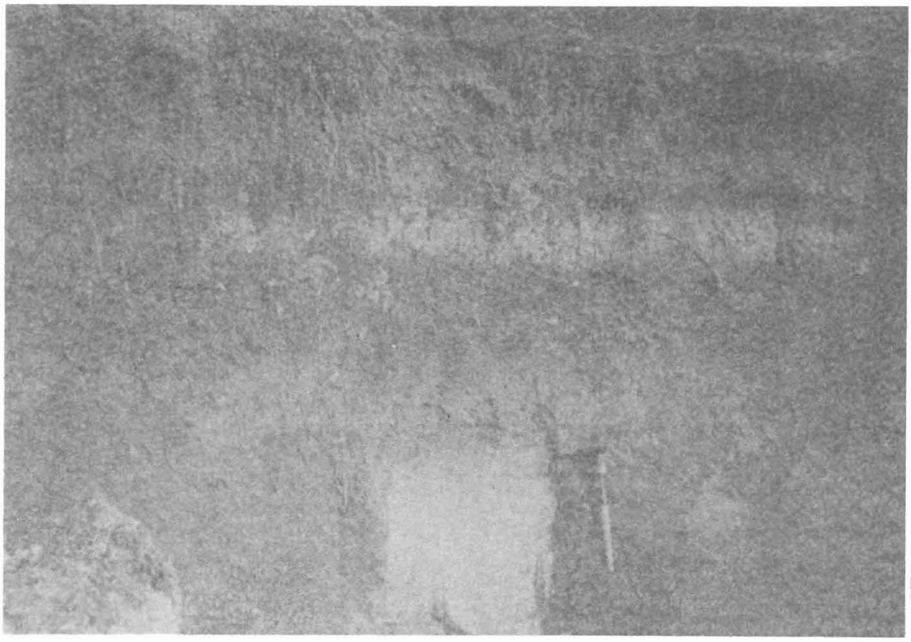


Figure 4. Jena-Wöllnitz (district of Jena), Thuringia, GDR. The uppermost humos horizon of rendzina soils alternating with marl-like layers of fresh-water lime deposits and buried by slope debris of the Upper Holocene (Medieval) age.

2) The main tool that binds these two disciplines is stratigraphy.

3) The temporal distribution of datings concerning buried soils on a regional scale indicates the existence of climatic changes independently from human presence (as in freshwater lime deposits).

Human impact to the environment began seriously with the introduction of agricultural landuse during early neolithic time. Furthermore, careful case studies merit a differentiated analysis of the available record considering:

- different kinds of anthropogenic impacts to environment;
- different types of geomorphological conditions, soils and vegetation, at least of distinguishable types of landscape units, and (last not least)
- different periods covering different stages of technical and social development of human society.

An example will illustrate our remarks (Figure 10). This case concerns an area of intensive fruit-culture near Dresden in Saxony, GDR, where herbicide application has cleared the weeds from under the trees whereas the strips between the trees-are covered by grass. The colour of the grassland strips is a dark green, that of the surface under the trees is a light one, due to a moss cover that has replaced the weeds. In the foreground, the grassland strips are interrupted, and we see the same light green colour as under the trees in the

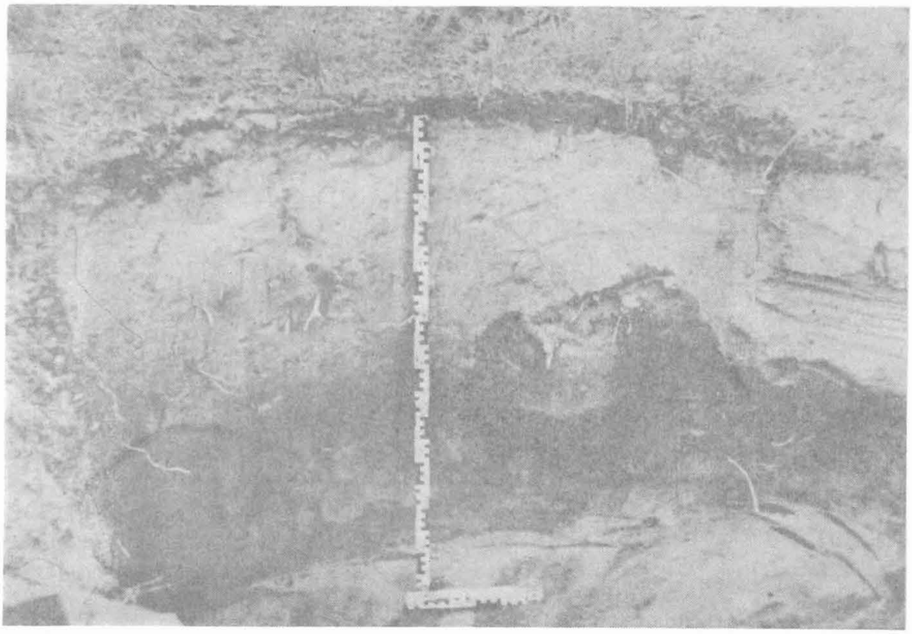


Figure 5 Fischbeck (district of Havelberg), GDR. Dune stratigraphy including the humus horizon (bah) of a buried ranker profile in a sequence of Holocene wind-blown sands. The humus horizon is dated by prehistoric pottery to the so-called Early Iron Age (Pre-Roman period).

background. This is why in the background the trees are standing on a gentle slope. Superficial run-off follows the slope gradient, but in the foreground it reaches a depression crossing the tree border. There, superficial run-off from neighbouring slopes is collected, concentrated, and directed into a new course crossing tree and grassland strips. In the case of herbicide contamination, their dispersion is not restricted to the surface under the trees but covers the strips between them, too. The result is a bio-indication of the contamination pattern in the fruit-culture area. It may be noticed that this pattern can easily be seen on air photographs.

Compiling all the evidence discussed here, four main stages of human impact to environment can be distinguished.

1) Stage of agricultural land occupation and land use (table 1);
2) Stage of complex land use (table 2);
3) Stage of industrial production (table 3);

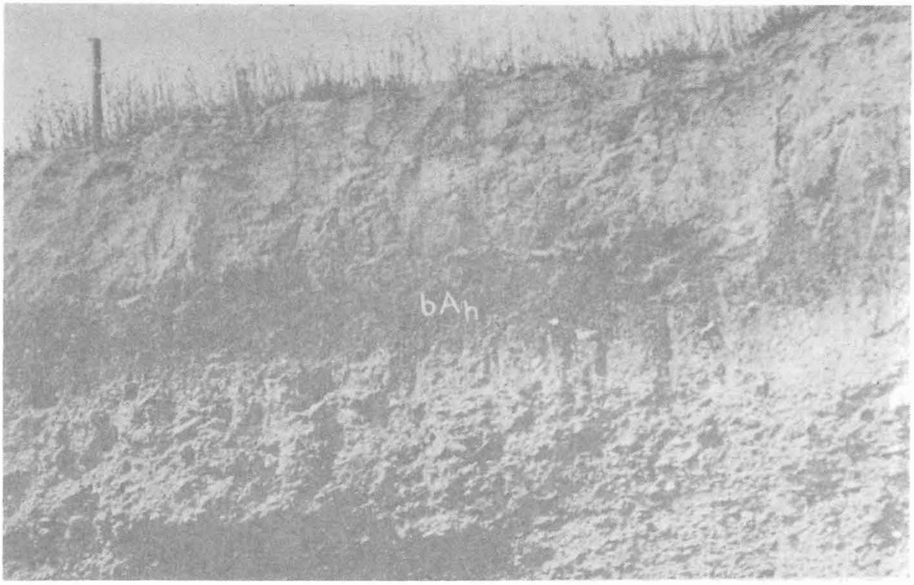


Figure 6. Stotternheim (district of Erfurt), Thuringia, GDR. Gravel-pit exposure at a riverside location. A humus horizon resting on gravel is covered by young Holocene floam-loam deposits of fluvial origin.

4) Stage of scientific technical revolution (table 4);

Human impact to the environment has reached a high and ever increasing intensity, reaching out to the global scale. This situation is the result of more or less continuous development of the interrelations between human society and nature. Extrapolation of current trends in the course of this historical process are given in Table 5.

Figure 7. Lutherstadt Wittenberg, GDR. Floamed banks of the Elbe stream.

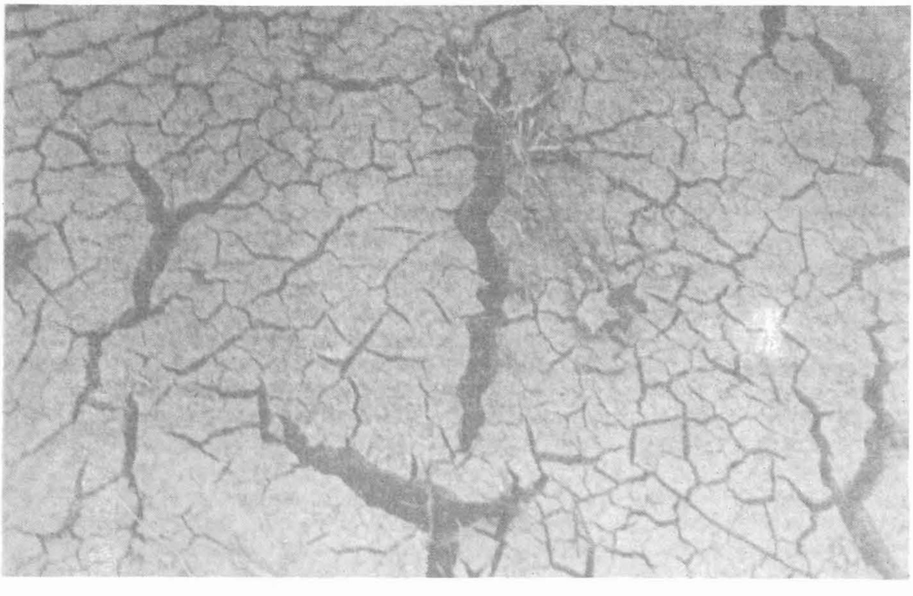


Figure 8. Lutherstadt Wittenberg, GDR. Surface at a riverside site covered by recent floam-loam deposits from the inundation visible in Figure 7.

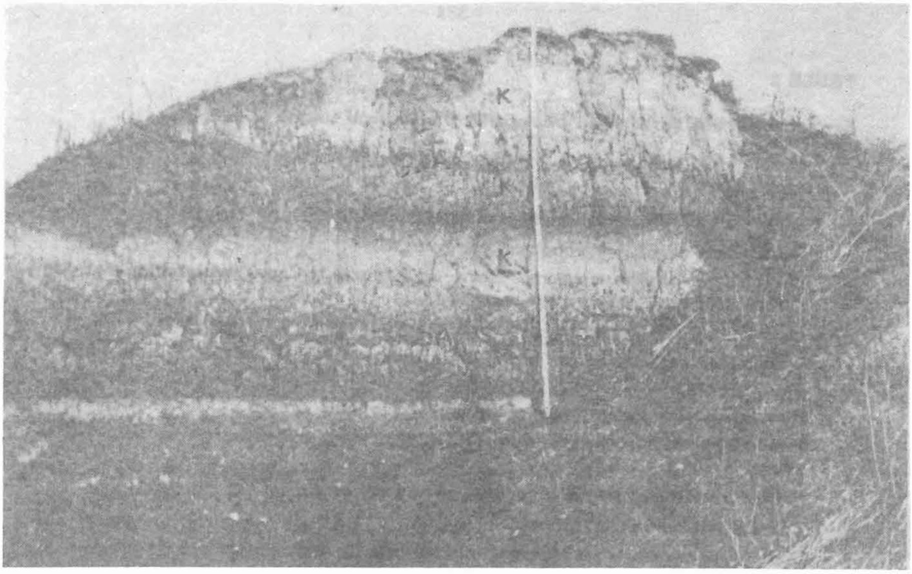


Figure 9. Wallendorf (district of Merseburg), GDR. Exposure of vierside stratigraphy comprising alternating layers of fluvial laom and humus horizons. A repeated change between fluvial deposition and superficial pedogenesis at the same site is recorded.

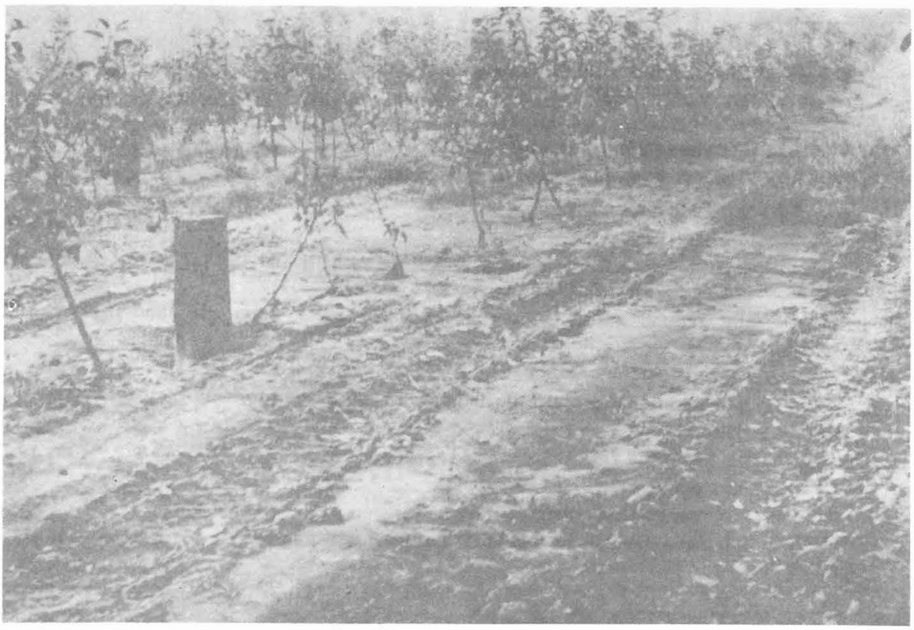


Figure 10 Röhrsdorf (district of Pirna) near Dresden, Saxony, GDR. Biopindication of recent herbicide contamination in the area of intensive fruit-culture (detailed explanation in the text).

TABLE 1

Stage of agricultural land occupation and land use

- Large-scale deforestation by woodland clearing
- Decreasing density of woodland due to pasture
- Enrichment of the regional flora and fauna by new immigrants, i.e. an increase of biotic diversity
- Increase of soil erosion of deforested areas
- Increasing sedimentation along lower slope as well as at the bottom of depressions and valleys
- Reactivation of aeolian sand redeposition in dune areas
- Increasing variability of run-off, intensifying soil erosion in deforested areas
- Transformation of soil and vegetation to simpler forms
- Local modifications of climate
- Local appearance of anthropogenic surface transformations especially as a consequence of prehistoric mining
- Appearance of anthropogenic types of landscape units, as a consequence of sedimentary redeposition from arable land to inundated valley bottoms
- First irreversible side-effects as a consequence of land use.

TABLE 2

Stage of complex land use arrangement

- Spatial enlargement of utilized land
- Increasing multiplicity and intensity of land use
- Diverging land-use aims
- Considerable impact on
  - superficial waters (number and state of still and flowing water density and composition of the discharge system);
  - the ground water table (due to water mills, dams and land improvements);
  - regional water balance
  - Increasing anthropogenic impacts on other components of the environment such as
    - surface relief;
    - soil;
    - vegetation cover
  - Spatial enlargement and local intensification of forest devastation

- Increasing biotic and landscape diversity (to its maximum at the end of this stage) due to the growing multiplicity of land uses
- Increasing irreversible effects on the changing landscape caused by land use

TABLE 3

Stage of industrial production

- Increasing intensification, multiplicity, and diversity of land use
- Transformation of the earth's surface by buildings, traffic systems and mining
- Greater dissection of landscape by systems of (linear) communication
- Increasing exploitation of natural resources (raw materials, fossil fuel, water)
- Growing chemical industrialization producing increasing environmental pollution
- Advancing homogeneity of woodland and areas open to agrarian land use due to fertilizing, land improvement, and monocultures
- Reduction of landscape heterogenity (lost habitats) and biotic diversity (endangering and extinction of sensitive taxa)

TABLE 4

Stage of scientific technical revolution

- Increasing and intensified application of technical tools (including automation in land use
- Increasing application of chemicals in land use
- Increasing emissions of wastes causing pollution of air, water, soil, and vegetation
- Increasing turnover of matter and energy with growing anthropogenic share
- Increasing complexity of landscape metabolism
- Increasing multiplicity and differentiation of land use causing growing interference and local impacts
- Increasing share of landscape units dominated by man-made developments
- Increasing degree of artificial water storage, and multiple use of water resources
- Decreasing landscape heterogeneity and biotic diversity
- Increasing frequency of anthropogenic innovations causing a progressive decrease of the time intervals between them
- Increasing lability of natural balances and process cycles

- Growing damage to the landscape requiring increasing expensive corrective actions

TABLE 5

General trends

- Increasing range and intensity of anthropogenic landscape impacts
- Increasing amount and complexity of anthropogenic landscape effects
- Increasing appearance a d spreading of new (anthropogenic) types of landscape units, in areas of sedimentary deposition
- Advancing erosion due to agricultural land use
- Increasing anthropogenic impacts on natural process balances in landscape
- Increasing anthropogenic influences on landscape heterogeneity and biotic diversity causing
  - an increase from neolithic times to the 19th century
  - a decrease since the last century
- Increasing anthropogenic transformation of the biogeochemical systems
- Increasing acceleration of anthropogenic impacts
- Advancing labilization of landscape dynamics

6.2 THE IMPACT OF INDUSTRY ON LANDSCAPE AND ENVIRONMENT IN AUSTRIA FROM THE SECOND PART OF THE 19TH CENTURY TO 1914

Elisabeth Johann
Institute für Bodenkultur
Vienna, Austria

1. Introduction

Today, more than ever before the forest landscape is badly affected by a multitude of factors caused mainly by the impact of industry, agriculture, human settlements and tourism. As far as these damages are caused by human activities, i.e. large clear cuts and deforestations they can be eliminated by foresters and forest owners themselves. As far as damages are caused by the impact of industry and traffic they can only be limited by the collective economic and sociopolitical change of public opinion.

These problems are by no means new but have been present throughout history. The forest landscape was greatly endangered in periods of large mining and industrial development, since fuelwood was the only source of energy, or in periods with a local increase in population combined with a lesser increase in productivity of agriculture and forest land. In some places overcutting and devastation led to permanent damage of the landscape, in some places nature was able to recover, when human pressure decreased. Generally one can assume, that the destruction of the environment increased steadily when charcoal was replaced by hard coal in the production engineering practice, which had taken place since the middle of the 19th century. Foreign and domestic affairs stopped this development temporarily, but the trend was increasing. The first and second world wars as well as the worldwide economic crisis in between made the environmental problems apparently less important. But simultaneously with the economic growth of the fifties the disadvantages of an unlimited industrial expansion became visible.

2. Retrospective View at the Ecological Consequences of the Early Industrial Time

The increasing industrialization at the beginning of the 19th century had direct and indirect effects on the environment. On the one hand the expansion of production and with it the increased use of charcoal caused excess cutting and extended unstocked areas in many parts of the country. Especially in the mountain regions these logged off areas were the releasing factor for avalanches and flood disasters. The local situation could be improved by legal corrective

*In: Proceedings of the Workshop on *Ecological Sustainability of Regional Development*, Vilnius, Lithuania, USSR (22-26 June, 1987), L. Kairiukstis, A. Buracas and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

measures relating to the improved use of energy afforestation programmes, and limitation of production. But these activities stood in the way of the ideas of liberalization of trade and industry. In all parts of the country, where iron ore was smelted and worked up, eyewitness reports confirmed clear cutting areas to an extent, where natural regeneration seemed to be impossible. The line up of numerous annual cutting areas led to the complete clearing of mountainous slopes. In the opinion of foresters the vast gaps especially in the Alps could become reafforestated only by artificial regeneration. There was a lack of suitable arable and pastural land at the densely populated bottom of the valleys, as a rule the deforestated areas were used for grazing. Thus natural regeneration became impossible. All these factors together with new settlement activities in the mountain forests led to a further decrease of the forest limit. On the other hand the development of trade and industry as a whole was accompanied by some serious problems for the population of these narrow valleys.

Several eyewitness reports mentioned the loud, heavy, and dull beat of forgehammers as well as soot flakes and fumes emitted by the chimneys of blast furnaces. Nevertheless the pernicous consequences of air could be observed in many regions of Bohemia and Moravia for instance in Joachimthal (Erzgebirge), Eger, and Ostrau. Here trees dried up from the top to the roots. The poisoned dew was considered as one of the possible factors endangering the forests. In 1699 a local observer pointed out the decease of vegetation and bees caused by air pollution around the zinc-, iron-, and cobalt-industry in the region of Erzgebirge in Bohemia. In any case the problems caused by air pollution were not generally discussed in Austria until about the middle of the 19th century, as long as charcoal was the only source of energy.

3. Heyday of Industrialization and its Impact on Landscape and Environment

3.1 Preconditions

At the beginning of the 19th century the diminution of forest stands caused a noticeable shortage of fuelwood and charcoal and as a consequence an increase in price of these materials in all mining regions of Austria. Therefore the substitution of fuelwood and charcoal by other types of fuel gained in importance. A switch from charcoal to hard coal or lignite in the iron and steel producing industry as well as in other industrial enterprises took place everywhere. The first steps to this end had already been made in the 16th century, and especially in the 18th century in some parts of Austria, for instance in Styria and Carinthia, but it took another hundred years for the use of hard coal and lignite to become a success.

Also the government promoted the consumption of hard coal by tax reductions, sales promotions, recommendations, and announcements of successful tests. Since the beginning of the 19th century only the iron foundries and forgehammers using hard coal instead of charcoal were allowed to be put into operation.

When charcoal was substituted by hard coal, lignite, and coke as well as water power by steam power, an extended railway network made the transfer of furnaces and forgehammers to those regions possible, where the supply base of hard coal was considered to be sufficient, for instance to Vitkovitz in Moravia. Progress in production engineering made mass production possible but at the same time signified the falling off and at last put an end to former ironworks away from modern traffic facilities.

Statistical figures from the year 1865 show that whereas the consumption of charcoal in Vienna between 1848 to 1865 decreased by one third, that of hardcoal and lignite showed a nineteenfold increase for the same period. Although there was a general switch from charcoal to hardcoal heating in urban dwellings this rapid development was mainly caused by industry. In Austria the total output of pig iron increased eleven times, the estimated hard coal consumption about 44 times from 1851 to 1913.

3.2 The impact of the industrial development to landscape and environment

3.2.1 The impact on human beings

In the industrial centres mentioned above medical checkups from the end of the 19th century proved a higher mortality rate than the Austrian average. This observation was made in Moravia for the overcroweded low lands in the centre and for the district of Mistek, in Bohemia for the mountainous regions of the Erzgebirge, Isargebirge and Riesengebirge. In Bohemia the mining districts of Falkenau and Brux had the highest rate of mortality. In these regions the output of lignite mining had increased 24 times from 1860 to 1890 and was considered to cause severe injuries to health. Already in 1866 the press reported injuries to the health of people living in large cities due to the bad housing conditions as well as smoke, soot flakes, and fumes emitted by chimneys, factories, chemical and industrial enterprises. Based on the results of a considerable number of studies the important beneficial role of vegetation especially forests with regard to the improvement of air quality was realized. Therefore the injuries to vegetation caused by air pollution were regarded as particularly harmful.

The impact of soot flakes, fumes, smoke, and coal gas, and the detremental effects from dust and vermin were an increasing menace to the existence of trees in the public parks and avenues. Toxic substances such as ammonia and hydrogene sulphide produced by coal gas leaking from pipelines used for lighting and laid under pavements caused fatal damage to the roots of trees and led to the die off especially of lime and oak trees as well as poplars.

In cities the devastation of monuments of art made of marble or bronze was ascribed to the wet deposit, especially snow, of sulphur emitted by hard coal heating. In wintertime monuments had to be covered to be protected against these considerable injuries. Analysis of snow showed a high concentration of sulphur in the centre of cities and a marked reduction in suburbs. In cities with a continuous cover of snow specific injuries were noticed to the coniferous and deciduous trees caused by a lasting deposit of sulphur.

3.2.2 The impact of vegetation and landscape

By and by the extension of hard coal heating in densely populated areas led to a growing impact of air pollution on vegetation, gardens, parks, forests, and fields. In Austria the first damages caused by fumes and smoke were noticed in 1852. Also at this time, big industrial enterprises with a high consumption of hard coal were considered to be the main source for the damages caused. Already the dependence of the scale of injury of plants from different factors was detected as sulphur concentration of the fumes, the distance from the source, the height of the chimney, geological and climatic conditions, the wind, and the specific resistance of plants. Damages caused by fumes, mainly emitted by roasting furnaces for zinc and copper, had been known for a long time.

At the turn of the century the emission of smoke and fumes became a serious menace to the survival of the forest cover in some regions of Austria. Especially in the district of Mährisch Ostrau and the industrial site of Vitkovitz nearby, where furnaces, coke firing and machine plants had grown rapidly, eyewitness reports told about the air pollution caused by fumes and soot flakes intoxicating the environment and also by the deafening noise of forgehammers.

But they also gave an account of the loss of the former beauty of this landscape as a consequence of the industrial development. Similar observations were made for the district of Karvina, where the atmosphere was filled with smoke. In the Austrian-Silesian coal basin the damages caused by fumes had reached an extension of about 2000 hectares. In some of these forest areas, wood production had already become impossible. General inquiries made in Bohemia related about injuries to forest stands in 15 political districts. In the district of Karlsbad, 62 percent of forest stands were damaged by fumes, of which 18 percent had to be eliminated for the coniferous wood production. In the district of Falkenau 88 per cent of the forest cover had to be eliminated for coniferous wood production.

According to the national economic importance of forests the Austrian Forest Congress put a resolution to the government in Vienna in 1899 requiring precautions by law. Therewith industrial enterprises should be forced to reduce and to filter their emissions. Under the preconditions of continuous emission of toxicological fumes the die back of forests was feared in industrial sites as well as in the narrow valleys of the mountainous regions of Austria. Also increasing problems in regeneration were to be expected up to the limit whereupon regeneration was supposed to become impossible. Only the shut down of these factories, which were considered to be the main sources of damages could ensure the conservation of forests situated on steep slopes in mountainous sites.

Nevertheless within the following years increasing damages caused by fumes were noticed. The area of damaged forest stands increased in equal proportion to the annual increase in industrial enterprises. Considerable reductions in growth and yield, a falloff in quality of coniferous stand, premature forest cropping, and a deterioration in soil conditions were the most important effects caused by air pollution. As a result the drying up of the trees and insect pest multiplied. Eyewitnesses reported the gradual withering of trees proceeding from the top to the roots at 1200 m above sealevel on the main crest of the Desenke in Moravia. At the turn of the century dried skeletons of trees or corpses, as people used to call them, were observed also in the mountain forests of the Altvatergebirge in Silesia.

A number of technical and forest actions were considered to reduce the damages caused by air pollution for instance cultivation of resistant plants or trees, afforestating of leaf wood, separation of industrial sites, installation of filters, and claim for damages.

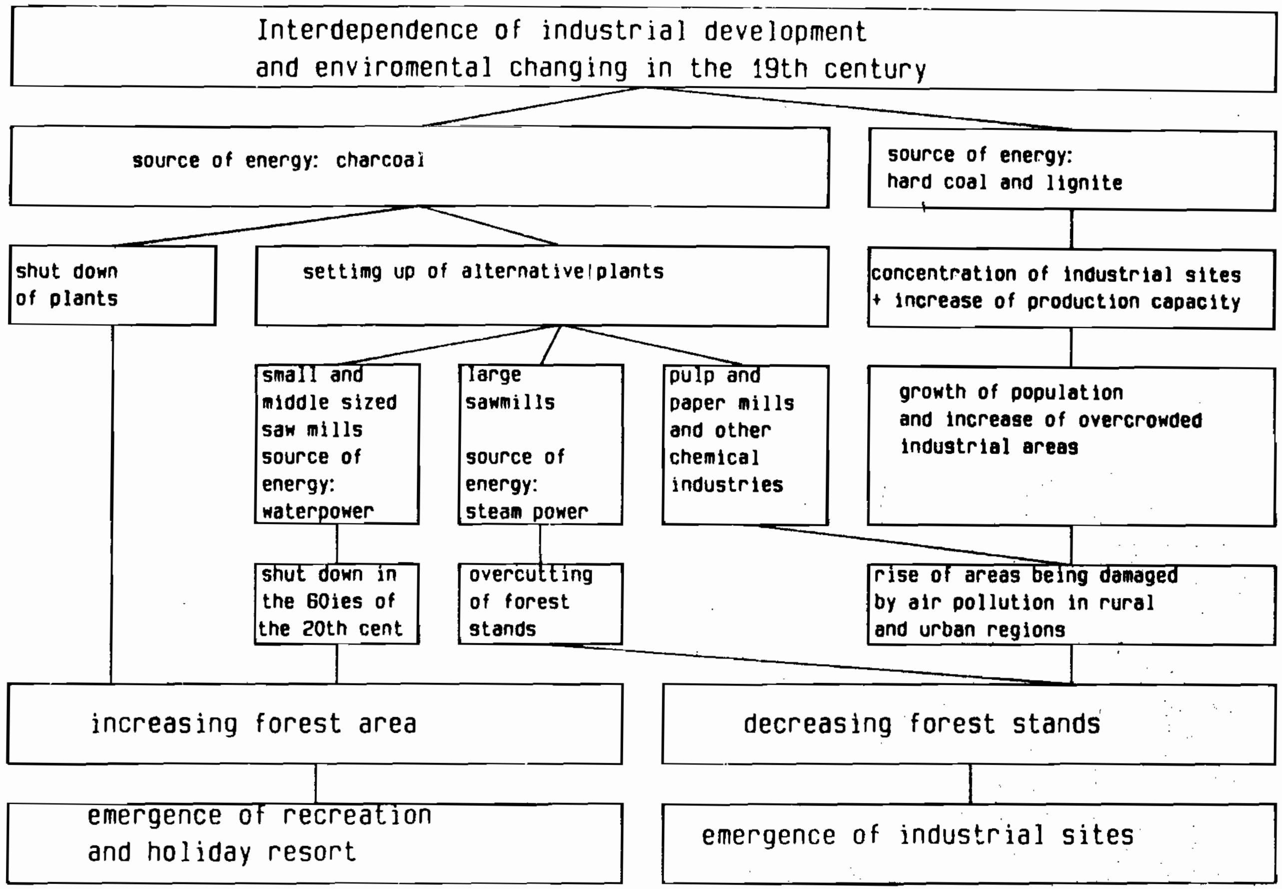
In the first decade of the 20th century the scale of emitted sulphur increased still further in spite the fact it was considered to be the main reason for the extended die back of forest stands. Thereby the burning of mineral coal contributed the major part for the air to become polluted by sulphur. In 1913 the consumption of hard coal and lignite in Austria-Hungary was estimated at about 48 millions tons a year representing a yearly blow off about 480 000 tons of sulphur. Wind and a number of other factors reduced the concentration in the open areas. Thus for instance the damages were less in the countryside than in the densely build-up city area. In Prague an emission of about 120000 hundred-weights yearly caused not only the total die off of spruce, fir, and pine but also inhibited regeneration.

Air pollution by sulphur was considerably increased by the addition of 619 mines (126 hard coal-, 185 lignite-, 30 iron ore-, 321 mineral oil-, 20 graphite-, 11 copper-, 12 zinc-, and 14 lead-mines) and 28 furnaces, of which 16 produced pig iron. In addition brick works and factories producing fertilizer and other chemicals emitted flour, chlorine, nitrogen thereby causing serious injury to vegetation.

Also in the surroundings of big railway stations these kinds of damages on cultures of plants especially on coniferous trees were observed. Apart from the gaseous pollutants soot flakes and dust also damaged the vegetation as a whole as well as the health of animals living in the forests and fields.

Furthermore the impact of fumes delimed the forest soil to such an extent, that regeneration as well as arboriculture became impossible. In the surrounding of furnaces emitting high rates of sulphur an extreme lack of lime caused the disappearance of all kinds of trees. In 1913 the annual financial loss caused by air pollution was estimated at least at 24 million crowns in Bohemia, and at 100 million or more for the the whole of Austria.

Until the beginning of the first world war in 1914 no measures were taken to reduce the impact of air pollution on the environment for the purpose of forest conservation even when damages were clearly visible. Foresters were unsuccessful in their demands for regulations enforced by law for the reduction of emissions and the right to claim for damages against the industry. Considering the forest die off and the deforestated and waste areas, having increased to more than hundred thousands of hectares, the question of air pollution can not be regarded to have been solved to the present day, especially not in the densely populated industrial areas of the former Austria-Hungarian Empire.


Interdependence of industrial development
and enviromental changing in the 19th century
source of energy: charcoal
source of energy:
hard coal and lignite
shut down
of plants
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+ increase of production capacity
small and
middle sized
saw mills
source of
energy:
waterpower
large
sawmills
source of
energy:
steam power
pulp and
paper mills
and other
chemical
industries
growth of population
and increase of overcrowded
industrial areas
shut down in
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the 20th cent
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increasing forest area
decreasing forest stands
emergence of recreation
and holiday resort
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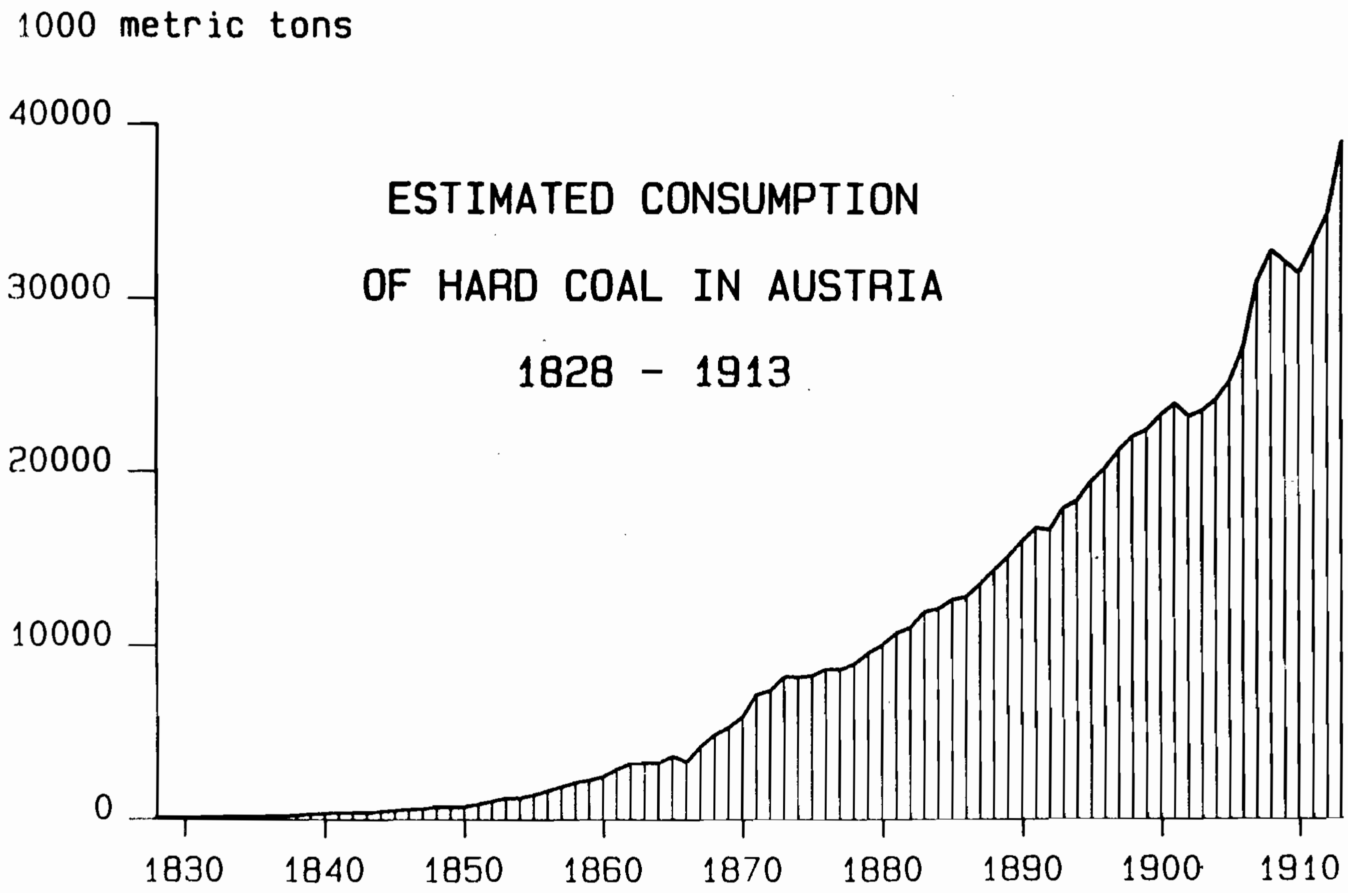
1000 metric tons
40000
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ESTIMATED CONSUMPTION
OF HARD COAL IN AUSTRIA
1828 - 1913
1830
1840
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1870
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1900
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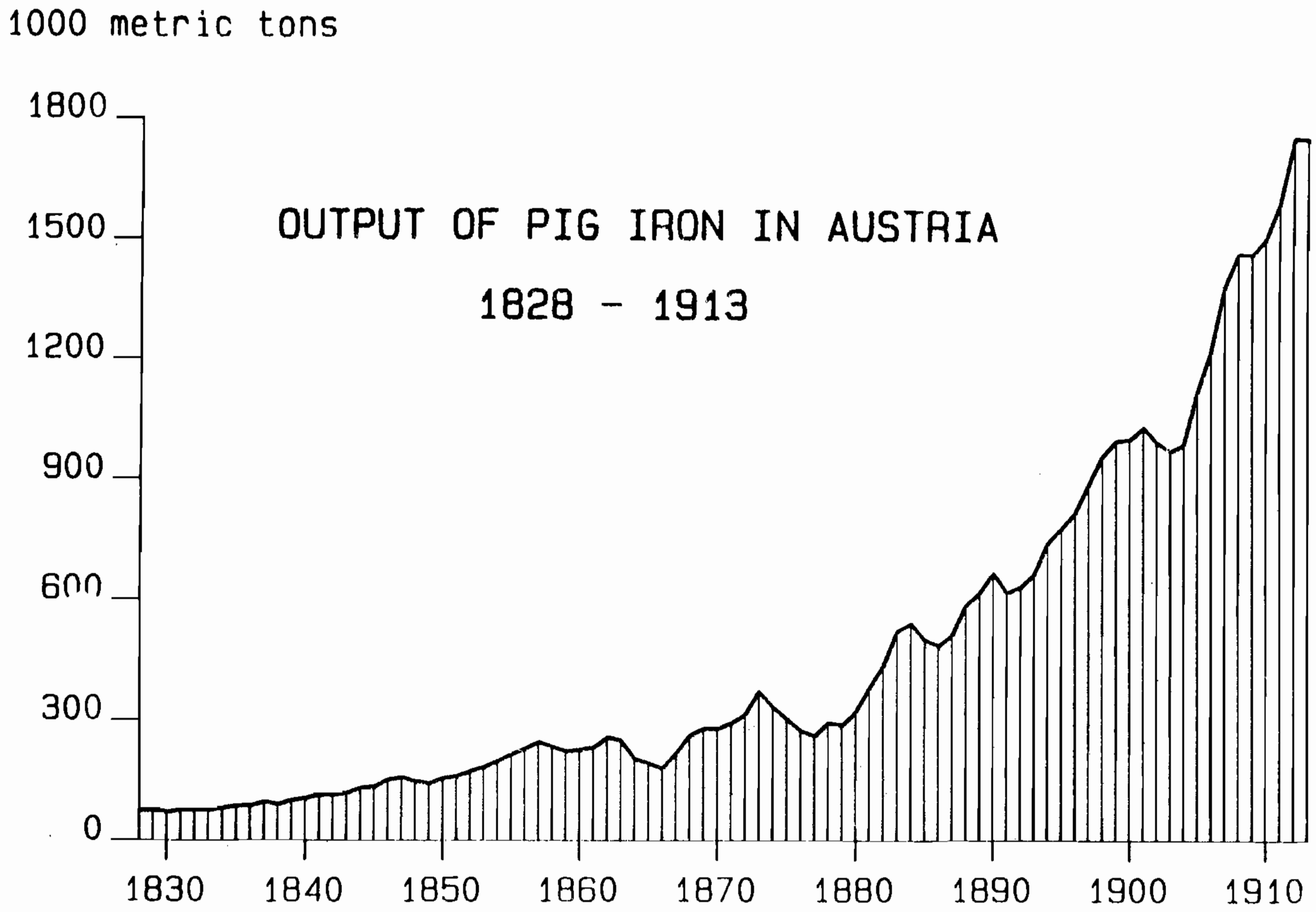
1000 metric tons
OUTPUT OF PIG IRON IN AUSTRIA
1828 - 1913
1800
1500
1200
900
600
300
0
1830
1840
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1880
1890
1900
1910

6.3 ENVIRONMENTAL PROSPECTS FOR THE 21ST CENTURY: IMPLICATIONS FOR LONG-TERM POLICY AND RESEARCH STRATEGIES*

Robert E. Munn
Environment Program
International Institute for Applied Systems Analysis
A-2361, Laxenburg, Austria

1. Introduction

This paper first examines environmental prospects for the 21st century, and then suggests some long-term management strategies and research priorities. Answers are sought to the question, "*How* should a manager, policy analyst or politician include long-term (20–50 years) perspectives within the planning process?". Because many managers will first need to be convinced of the need for considering such a long time horizon, the following question will also be discussed, "*Why* should long-term perspectives be included in the planning process?".

It should be emphasized that efforts to forecast environmental conditions in the next century would be presumptuous, even when averaged globally. In fact, all that can be usefully stated concerning environmental prospects for the 21st century may be summarized in a few sentences:

> Some environmental trends are practically irreversible over the next couple of decades, due to inertias in the systems involved.
>
> Mass and energy budget principles place long-term bounds on the sustainable use of renewable resources.
>
> There will be non-linearities, discontinuities and surprises in the behaviour of many environmentally-related systems over the next several decades.
>
> Knowledge in the environmental sciences is exploding, and this is leading to specialization, fragmentation and irrelevance with respect to comprehensive environmental policy. The problem will become more serious in the years ahead, even with the development of complex data storage and retrieval systems.

It is clear that society needs better methods for managing the environment. These methods should include monitoring systems that provide early warning of impending change, and institutional mechanisms for responding to these changes even when their outline is perceived only dimly.

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*In: Proceedings of the Workshop on *Ecological Sustainability of Regional Development*, Vilnius, Lithuania, USSR (22-26 June, 1987), L. Kairiukstis, A. Buracas and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

2. Current Trends

(a) *Global increases of greenhouse-type gases and resulting climate changes*

Atmospheric concentrations of the greenhouse gases (CO_2, methane, nitrous oxide, chlorofluorocarbons and tropospheric ozone) are increasing steadily. Even if society decided to stop increasing anthropogenic emissions of these gases, atmospheric concentrations would not level off in less than 25 years, due to socioeconomic inertias.

Although the extent of climate warming that would result is still controversial, a general consensus has emerged that some warming is imminent, or may already have arrived. A common feature of numerical simulations models is that warming is greatest in the polar regions in winter and least in the tropics.

(b) *Trends in Population, Agricultural Production and Energy Consumption*

Population is one of the driving variables not only with respect to agricultural production and energy use but also with respect to *environmental quality*. As part of the IIASA summer program, a group of young scientists studied several recent forecasts of global population, agricultural production and energy consumption in the 21st century. An attempt was also made to produce an internally consistent scenario that fell within the range of other projections. The results indicate a doubling of the world's population by year 2025. The associated relative increases in total agricultural production and energy consumption are much larger but the per capita increases are smaller. In this connection, the participants of a recent Dahlem Conference (McLaren and Skinner, 1987) believed that "for the world as a whole, enough land and water resources exist to meet any plausible needs of the human population over the next 50 years." Nevertheless, hunger and contaminated water will continue to be endemic in some parts of the globe.

(c) *Environmental Quality*

(1) In the Developed Countries

Over the last 3 decades, environmental quality has improved steadily in most urban areas. However, there has been a general deterioration in the surrounding countryside where

- Concentrations of atmospheric ozone, sulphates and oxides of nitrogen have increased;
- Agricultural wastes have been accumulating;
- Lake acidification has taken place in sensitive areas in both Scandinavia and North America;
- Forest decline has recently been observed in central Europe and eastern North America;
- Water quality has generally been declining slowly although there have been some success stories.

There is also concern that human activities are depleting tropospheric concentrations of OH-radicals, which help remove methane, ozone and other greenhouse gases from the atmosphere (Khalil and Rasmussen, 1985).

Mention should also be made of the feedback effects of climate warming on environmental quality. For example, warmer and drier summers could result in an increase in the production of photochemical ozone. The effects have hardly yet been studied.

(2) In the Developing Countries

With certain exceptions, environmental quality has deteriorated over the last 3 decades in both urban and rural areas (Holdgate et al., 1982). For example,

Air quality in urban areas is worsening, frequently exceeding WHO health criteria;

In semi-arid regions, fuelwood gathering, overgrazing, desertification and salinization are major concerns;

In the humid tropics, deforestation continues (Gwynne et al., 1983).

Water quantity and quality continue to be serious issues.

The problem of meeting the basic needs of millions of people in developing countries will not easily be solved.

3. Ecologically Sustainable Development of the Biosphere

In the mid-1970's UNEP introduced the term *outer limits*, which was intended to suggest that overexploitation of Planet Earth would lead to ecological disaster over the long term. A phrase with a rather similar but subtly different connotation – *maximum sustainable yield (MSY)* – has been used for many years with respect to a single resource such as a fishery or forest. In this case, there is the implication that a renewable resource may be safely harvested up to a certain level. As has been emphasized by Walters (1986), however, this is a dangerous strategy because "the exploitation rate that produces MSY is likely to be near a cliff edge, with slightly higher rates driving the stocks toward extinction". MSY varies with externalities, and can decrease appreciably following the occurrence of a rare event, such as an El Nino in the case of fisheries or prolonged drought in the case of productive rangeland.

Two related terms are:

- *assimilative capacity*, e.g., of a watershed with respect to sources of pollution;
- *carrying capacity*, e.g., of an area with respect to the population (usually human) that it can sustain.

IIASA has made a series of important contributions to the science of renewable resource management, e.g., Holling (1978), Walters (1986), Clark and Munn (1986), and a current IIASA Project within the Environment Program entitled *Ecologically Sustainable Development of the Biosphere*. These words are used at IIASA in the following ways:

Development is intended to convey the idea that the biosphere can be made more productive, or "better" in some sense; the word therefore involves a value judgement. *Development* often implies *structural change* as opposed to *growth*. The rate of development is not constant but depends on ecological, political, cultural and technological factors.

Sustainable refers to the maintenance or enhancement of a process or activity over the long term (WCED, 1986), and it is necessary to answer the question "Sustainable for what purpose?" The words *sustainable* and *development* may seem to be contradictory (O'Riordan, 1985). However, one need not be overoptimistic to believe that development can be sustained through technological innovations and improved management strategies.

Ecologically sustainable development implies that biosphere development can be sustained through the wise use of sound ecological principles that maintain or improve biosphere resilience; possible examples of policies with the opposite effect include the promotion of monocultures or massive applications of fertilizers, herbicides, pesticides, lime or energy. The modifier *ecologically* has been added for emphasis. *Development* is *sustainable* over the long term only if it is *ecologically sustainable*.

Biosphere development could not, of course, be sustained in a Malthusian world. In fact, mass and energy budget principles seem to place long-term bounds on the number of people that could be supported on Earth or in a region. In principle, it ought to be possible to estimate the increases in agricultural production and energy consumption required to sustain any given number of people. However, there are important environment–resources–population–technology interactions. Thus for sufficiently large increases in population, environmental quality and the stock of renewable resources would both decline. The extent and rapidity of these declines are difficult to estimate, particularly because new technology unforeseen today could provide a counterbalancing influence.

4. Non-Linearities, Discontinuities and Surprises

Computer outputs from large simulation models are often smooth curves as functions of time. In the case of complex biogeochemical and social systems, these curves are not likely to represent real behaviour except as approximations over small segments of time. Complex systems usually contain positive feedbacks and non-linearities, some of which may ultimately produce discontinuities. There are of course many negative feedbacks which keep system behaviour within tight limits for long periods of time. For example, the average temperature of the Earth has remained within narrow bounds over several centuries. This, however, does not ensure that such a condition will continue over a time period even as short as the next century. Here it should be emphasized that it is very difficult to predict a runaway excursion, although in retrospect it is usually easy to explain.

An associated idea is that of *resilience* and *vulnerability*. Motivated by the ecosystem studies of C.S. Holling (1973) at the University of British Columbia and at IIASA, ecologists have become very interested in discontinuities. One of the central themes of resilience is that although an ecological or social system may seem to be in a steady state, it may shift to a new steady state if perturbed sufficiently by a large shock. Resilience is difficult to quantify, although qualitatively,

- Patchiness is characteristic of a resilient forest (Holling, 1986).
- Societies in the process of losing their traditional skills have little resilience (Burton et al., 1977).
- An increase in the reliability of a managed system often leads to a decrease in resilience (Hashimoto et al., 1982; Timmerman, 1981, 1986).

In the case of social systems, resilience may be affected by changing values, norms and aspirations. It could in fact be argued that before beginning a consideration of possible environmental futures, it is necessary to reflect upon the changing attitudes and goals of society over the coming decades.

5. Usable Knowledge

The knowledge base in the environmental sciences is very large and growing rapidly. When applying this knowledge to an emerging poorly-focused issue, however, the available information is often largely irrelevant. Not only are there important knowledge and data gaps but also the existing information is compartmentalized within a traditional framework that cannot easily be mobilized to meet the new paradigm. The problem arises partly because of the separations that exist amongst scientific disciplines, both in the universities and in government research institutes.

The experience in IIASA is that scientists in the same discipline coming from different countries and speaking different languages understand each other. Scientists from different disciplines often have great communication problems, even when working in the same university.

Another important point is that the knowledge needed for policy analyses is usually quite different from that provided by scientists. Within the IIASA Environment Program, special efforts are being made to overcome this difficulty: most of the Projects are *policy-driven*. In the case of the Acid Rain and the Large International Rivers Projects, this knowledge is in the form of user-friendly decision support systems, in which the outputs of some very complex environmental models are displayed in meaningful ways.

6. Environmental Management

A central theme of this paper is that surprises are certain to occur, and that long-term environmental management ought to concentrate on the development of strategies to cope with the unexpected. The challenge to policy-makers is to recognize that a seemingly steady-state condition may hide instabilities that could become important if the system were subjected to a sudden shock.

The following check-list summarizes the several strategies that have been applied to cope with surprises for which there are historical precedents, e.g., floods, cancer due to exposure to asbestos (Munn, 1986). Some practical examples are given in brackets.

- Removal (banning of hazardous substances)
- Avoidance (siting towns on high ground to avoid floods)
- Risk protection (strengthening the foundations of buildings in earthquake zones)
- Mitigation (crop insurance; the International Red Cross)
- Learning by experience (information retrieval systems)
- Diversification (multiple crops; staggered planting)
- Small is beautiful (construction of several small dams rather than one large one)
- Saving for a rainy day (world food banks; conservation)
- Self-sufficiency (recycling; ecodevelopment)
- Development of an ability to react rapidly to surprise (adaptive impact assessment; resilience; keeping options open)
- Development of early warning indicators (World Weather Watch; tidal wave forecasting systems)

With respect to surprises and discontinuities for which there are historical precedents, governmental bodies are unlikely to take anticipatory actions. In addition, the people most affected sometimes lack viable options; Glantz (1981), for example, suggests that the Peruvian fishery fleet was so over-capitalized at the time of the "El Nino" 1972-73 decline of the anchovy population that operators had no option but to continue harvesting.

In some of his current reflections at IIASA, Clark (1985, 1986) has used the climate-warming issue to illustrate his belief that many of the current environmental issues should be re-examined within a risk assessment framework. The idea of a 2° C global warming predicted by numerical models is not very surprising anymore. However, the 2° rise is a maximum likelihood estimate, and as pointed out by Dickinson (1986), the models also suggest a 1% probability of a 9° C warming by the year 2100, and a 0.1 to 0.01% probability of 15° C warming. In either case, the Earth's climate would be as warm as that of the Cretaceous era 100 million years ago. Such an occurrence would indeed be a surprise! In this connection, a large hydroelectric dam has about the same probability of failure by the year 2100 as that of an atmospheric warming of 9° C, and its impact is less. Clark's conclusion is that "this assessment jars common sense, which is exactly why careful risk assessments of the CO_2 question and the possible social responses to it should become a priority task".

7. The IIASA Case Study of the Future Environments for the European Continent

One of the current activities at IIASA, and one of its most important undertakings to date is the *Study of Future Environments for the European Continent* carried out within the Biosphere Project by William Clark, William Stigliani and colleagues. Europe is defined as extending from the Atlantic to the Ural mountains; the time span is 200 years into the past and 100 years into the future. The study has three related objectives:

(1) To characterize the large-scale environmental transformations that could be associated with plausible scenarios of Europe's socioeconomic development over the next century.

(2) To identify the research and monitoring priorities for improving the scientific community's policy-relevant assessments of the environmental transformations characterized in (1).

(3) To assess the implications, feasibility, and limitations of alternative technological and institutional initiatives that might be undertaken in an effort to manage long-term, large-scale interactions of Europe's future development with its natural environment.

A unique feature of the study is the inclusion of "surprise-rich" futures and of associated early-warning monitoring systems. The objective of the study is not to predict the future but to design robust management strategies, e.g., ones that keep as many options open as possible.

Because the Case Study is still at an early stage, it would be inappropriate to discuss results. However, it should come as no surprise that the usual issue-by-issue sectoral approach has been replaced by an integrated regional assessment in which the impacts of concurrent changes in several environmental and socioeconomic factors are examined, e.g., climate, acidity, oxidants, toxic materials, major nutrients, ionizing radiation, primary productivity, species diversity, land use patterns (and interconversions) and water use and availability. The surprises to be incorporated into the scenarios are still being developed. Workshops on surprises were held in Sweden in 1986 (Hägerstrand, 1987) and at IIASA in June 1987.

8. Conclusions

An implicit conclusion to be drawn from this paper is, "Stop trying to predict the problem-of-next-year." That is futile! Instead, try to develop scientific and institutional frameworks within which a suite of issues, some unexpected, can be managed. Here it should be emphasized that we need not only an integrating environmental framework but also an integrating institutional framework. As emphasized by Brooks (1986), we must avoid "partial solutions" which may be optimal for a particular sector or decade but which are far from optimal for the biosphere as a whole over the long term.

Additional scientific questions that should be given priority in the next decade are:

1. What are the criteria for sustainable development of the biosphere – for both natural and managed (e.g., agriculture, fisheries) systems? This question provides a central focus for the IIASA Biosphere Project.
2. Even before establishing sustainability criteria, what management actions can be taken to improve the resilience of the biosphere?
3. What are the possibilities for more efficient use of natural resources?

There remains, of course, the problem of persuading managers, policy analysts and politicians that they should plan not just for the next 2–4 years but also for the next century. Several arguments can be given for taking this long-term perspective:

1. The next century is only 13 years away!
2. The life cycle of some natural resources is of the order of decades.
3. Large engineering works typically have life expectancies of 30–75 years.
4. Because the past, the present and the future are tightly coupled, environmental "surprises" often have their roots in cumulative mismanagement over many decades. Some future crises may already be in the incubation stage (Stigliani, 1987).
5. Long-term perspectives therefore help in developing appropriate management strategies, keeping options open, and helping in the assignment of priorities for research and monitoring programs.

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6.4 DEVELOPMENT OF A REGIONAL SYSTEM OF INDUSTRIAL WASTE DECONTAMINATION AND ITS REALIZATION IN THE LITHUANIAN SSR*

J.Ya. Budilovskij
Head, Industrial Ecology Division
Scientific-Industrial Company "Litstankoprojekt"
Vilnius, Lithuanian SSR, USSR

1. Introduction

Nowadays the problem of environment control is mainly concerned with strict regulation of toxic industrial wastes, such as ions of heavy metals (IHM), resulting from electroplating, etching, processing of printed circuit boards, tanning, as well as lubricant-cooling liquids (LCL), oil products, organic wastes, surface active materials (SAM), etc.

On entering the human body with water and food, IHM accumulate, provoking diseases of the heart, brain, liver and other organs. They block the entrance of calcium into human cells, thus disturbing the functioning of calmodulin and other calcium-absorbing molecules which control the most important systems of cells in the human organism [10, 14].

According to the scale of generally accepted stress factors [4, 5] influencing human beings, IHM are in first place (135 points), far ahead of other harmful factors – noise (15 points), pesticides (30 points), CO (15 points) and acid rain (72 points).

It must be emphasized that on entering a municipal sewage treatment system, the above-mentioned wastes not only ruin the biological purification system but also prevent processing of active sludge into a compost of adequate condition. This happens mainly because of the great amount of IHM in it.

All these problems must be solved as soon as possible. However, the solution must cover not only individual shops or industrial plants but the entire region (district, republic or province) with regard to adjacent regions making a certain contribution to sewage. The project must be universally available, cheap and realizable in short terms.

2. Traditional Methods

2.1 Burying. The most popular traditional method provides: a) construction of sewage purification systems in all the plants for separation of toxic substances from water; b) burying of toxic substances in places devoted specially to these purposes.

*In: *Ecological Sustainability of Regional Development*, Proceedings of a Workshop held in Vilnius, Lithuania, USSR, 22-26 June 1987. L. Kairiukstis, A. Buračas, and A. Straszak (Eds.), 1988, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.

This method is always accompanied by high expenditures due to great amounts of treated wastewater. Certain difficulties arise because of inadequate technologies. Realization of this method only in machine-tool enterprises of the Lithuanian SSR would require 350 million rubles of capital investments.

2.2 The second way is through integration of the so-called closed-loop systems [11] (ion exchange, reverse osmosis, electrodialysis, evaporation, electrolysis), both in individual plants and in regional centers of waste regeneration. This method also requires high capital investments, multiplex equipment, great quantities of chemical reagents, well-trained personnel and long term realization.

3. The Utilization Program

The main point in our regional program of waste decontamination is utilization. The most effective, economical and, consequently, practical way is the creation of centralized systems of utilization. It allows us to process a great part of toxic wastes into valuable products. Moreover, it leads to the development of wastefree technologies (WT) on a regional scale. Each individual plant introduces low-waste technologies (LWT) and automatic equipment, promoting in turn reduction and conditioning of wastes.

In contrast to traditional methods, the problem of waste decontamination is tightly connected with the reduction of toxic substance consumption.

In the 1970s, specialists of the scientific-industrial company "Litstankoprojekt" took active part in the development of nontraditional measures for improvement of basic processes of production, introducing LWT and unified technologies, as well as equipment for industrial waste decontamination.

Namely the improvement of basic processes of production and purification of industrial wastes allowed one to solve the most complicated part of the waste utilization problem very effectively.

In the beginning of the 1980s, the development of the Republican regional complex program 82.22 "Decontamination of Industrial Wastes" was started. The customer of the program is the State Planning Committee of the Lithuanian SSR. The leading organization responsible for the development and realization of the program is the scientific-industrial company "Litstankoprojekt" (Vilnius) [1].

The program covers the main interconnected principles of realization of WT – systematics, constraints from the ecological point of view, complex consumption of resources and energy, effective processes of production and uniform supply of materials.

The new approach suggests the following:

- all plants in the region must keep to rigorous but economically justified norms of toxic resource consumption;
- each plant in the region must adopt the outlined norms according to the schedule;
- each plant, in order to fulfill the program of production under rigid reclamation of materials, must introduce LWT and WT;
- an information center must provide a computerized account of resource consumption and wastes for each individual plant and for the entire region;
- a set of measures for production modernization by introducing robots, flexible automatic processes (FAP), resource-saving technologies and equipment are to be developed for realization of LWT and WT in the plants of the region

(under the guidance of the scientific-industrial company "Litstankoprojekt").

As far as usage of toxic materials and wastes is concerned, the region becomes a unified organization-economic system step by step. All equipment and technological processes in individual plants become the components of a unified technological process with resource consumption and wastes control on the regional scale.

Realization of the complex program provides:

- protection of human health and the environment from toxic industrial pollutants;
- reduction of specific consumption of toxic materials;
- manufacturing of valuable products from wastes and sludge;
- economy of investments, necessary for building sewage systems and areas for burying.

A complete realization of the utilization program will provide the recycling of:

- galvanic sludge;
- sludge of tanning and the fur industry;
- lubricant-cooling liquids;
- nonregenerable oil products;
- dissolved detergents;
- copper-containing wastes of printed circuit boards production;
- sludge of ferrous metal etching;
- sludge of nonferrous metal etching;
- lubricated grind-dust;
- lubricated sawdust;
- wastes of paper production;
- hydrolytic lignite;
- used tyres;
- used molding sand;
- lubricated ballast water;
- wastes of the chemical coating processes.

Now, according to the program, three centralized systems for conditioned sludge and waste utilization operate in the Lithuanian SSR. The first one provides utilization of electroplating sludge for tile production [3], the second – processing of SAM, nonrefinable oil products, hydrolytic lignite and MC sludge with subsequent use for lightweight aggregate concrete (LAC) production [6]. The third centralized system is designed for molding sand and lubricated sawdust utilization in brick production.

A Plant of Structural Clay Products using the slip method ("wet" technology) is reconstructed and fitted for processing of the above-mentioned wastes. A special laboratory for sludge condition control is founded. Conditioned sludge from the on-line decontamination system is processed. Many valuable products, e.g., several sorts of ceramics, glazes, etc., are produced.

The experiments proved that, after adding from 2,5 to 5% of sludge into ceramics, absorption is reduced, the burning temperature is lowered ~ 40–70° C, providing at the same time adequate strength and durability of the ceramics. Sludge leaching experiments based on tests proposed by American and Japanese standards, showed the possibility of bringing sludge into the dumping sites devoted to neutral wastes (in the case of the absence of the centralized systems). The total amount of IHM did not exceed 5 mg/l (MPC is ~ 20–50 mg/l). During the last two years, sanitary control has been carried out in the territory of the plant and adjacent areas. The measured concentrations of heavy metals did not exceed background values. Tests for products (tile, LAC, etc.) toxicity showed that even in very acid media, no leaching was observed.

Experimental work has been carried out in order to clear up the possibilities of galvanic sludge usage for dye production.

A centralized system for ferrite production by using conditioned electroplating sludge has been designed. One of the most important requirements for sludge is the necessity to use only distilled or deionized water in electroplating. A centralized system for copper-containing etching wastes of printed circuit board production as microelements in fertilizers is being designed.

4. Purification of Industrial Wastes

Proceeding from general principles of WT and LWT, the obtained sludge must be used as a raw material for manufacturing products in the same or other plants of the region [3, 4]. The sludge must meet the following requirements:

- maximum degree of dewatering with regard to transportation and subsequent recycling;
- low-toxicity, since transportation and utilization involve a great number of personnel, not ready to work in harmful conditions, as well as the equipment;
- usage of sludge in the processes of production, the final products of which do not activate toxic substances;
- usage of sludge for manufacturing products for which water-receptive properties do not require additional consumption of energy for evaporation.

The requirements for sludge with regard to subsequent utilization are better fulfilled provided adequate components of the technological process and method of purification are chosen.

Traditional methods of purification, based on the use of reagents, do not allow one, as a rule, to clean wastewater up to MPC, therefore sludge cannot be used (it contains great amounts of calcium, sulphates, etc.).

4.1 Purification by using electrically generated coagulants obtained from waste metal

The scientific-industrial company "Litstankoprojekt" has developed a simple and cheap technology and a set of equipment. The main point of this technology is that effluents are treated with a coagulant produced from metal chip by electrolysis. Electrolysis takes place in a special working solution of increased conductivity. Steel chips, wastes of stamping, etc., are used as metal waste.

The set of equipment, employed for realization of this technology, side by side with standard units, has special electrolyzers for obtaining a coagulant from metal waste and reagents for conducting the sewage neutralization reaction. The method is worked out with regard to specific properties of the electrically generated coagulant.

The technology differs from traditional methods of reagent cleaning, which foresee the use of quicklime, sodium bisulphite or ferrous salts, by the fact that:

- an electrically generated coagulant is a practically pure reagent, owing to the small amount of anions and cations introduced into sewage to be purified;
- no more than 3–5 kWh of energy are consumed for obtaining 1 kg of coagulant (in terms of iron);
- the sludge, formed during sewage treatment, can be utilized for obtaining high-quality ceramics, glaze, ferrites, dyes, etc.

Table 1. Main indices characterizing the technology using the example of a sewage water treatment plant with a sewage flow rate of 10 m^3/h.

Residual content of IHM (mg/l)	
hexavalent chromium	0.005–0.02
trivalent chromium	0.02–0.1
nickel	0.01–0.25
zinc	0.02–0.1
copper	0.01–0.1
Consumption of energy for obtaining a coagulant necessary for treatment of 1 m^3 of sewage, kWh	1
Required production areas (for treatment equipment)	
area, m^2	72
height, m	7.2
Employment of personnel, h/shift	1.5

After treatment, the water meets the requirements of circulating water supply (12, 13] and can be used again in electroplating as well as other contiguous processes.

4.2 On-line system purification

Our company has designed on-line equipment for automatic lines. The on-line equipment does not exceed the dimensions of electroplating baths and does not require scarce reagents since metal chip is used as the source material for obtaining a working material-sorbent. The fundamental unit of equipment is the eletrolyzer.

The adopted principal scheme of sewage purification for on-line equipment allows one to clean not only "his" automaton but several adjacent ones (with the same sort of electroplating) also.

This provides uniformity of precipitation and simplifies utilization.

Insufficient attention (both in our country and abroad) devoted to design of continuous complex automatic technological processes can be explained by a conservative approach to effluent purification. It is treated following electroplating and carried out by one of the familiar methods in individual systems of purification.

The experience of many years and experimentation have shown that the process of industrial waste decontamination is closely related to technology. First of all, the amount of wastes in the basic processes of production must be reduced

For this, a new type of robot is designed [7, 8]. It integrates the traditional lift-transportation functions with several new ones, meeting at the same time scientific-methodologic requirements:

- optimal distribution of details drag-out and exposition time;
- reduction of solution drag-out by mechanical impact;
- the equipment for maintenance of the automatic line must attend the on-line system as well. The design of on-line purification must suit the type of the baths of automatic line.

The application of on-line cleaning places additional requirements on the purification method and equipment:

- reagents, used for purification together with those used in the technological process, and consequently becoming components of the sludge, must provide sludge fit for utilization. With regard to the small volumes of the purification system, the method of purification must provide high sedimentation of heavy metals and complex-forming agents.

5. Modernization of Basic Processes of Production

The complex of measures undertaken for basic production modernization includes 18 items. The most important are:

- introduction of a wide range of abilities of robots for reduction of sewage amount and concentration of toxic substances in industrial wastewater;
- organization of a unified system of galvanic automatons to meet the requirements of WT. The system has been tested in many industrial plants of the Republic and the USSR;
- design of a device for primary regeneration of technological solutions reducing the escape of toxic substances during the process of production;
- introduction of a water supply control system providing economic consumption of water and a decrease of investments for building sewage treatment systems;
- regeneration of LCL and oil products, including the development of processes for primary regeneration. This will allow one to save lubricant-cooling and oil products, as well as investments for waste decontamination and utilization.

6. Organizational Matters

The program includes toxicological tests, personnel training, information and material-technical supply.

Transition to WT on a regional level is accompanied by a certain discrepancy between the existing norms for material consumption and realization of resource-saving measures.

Let us consider electroplating processes [2, 9] first of all, since these are the most toxic and nonferrous metals-consuming processes. Drag-out of electrolyte from basic baths is the main process where metal salts are lost. It may be divided into two parts:

$$q = q_1 + q_2 \,, \qquad \text{where}$$

q_1 – the amount of the removable electrolyte due to introduction of resource-saving measures;

q_2 – the amount of unremoved electrolyte, determined by physical-chemical properties of the electrolyte and the material under treatment.

Rigid norms for toxic materials are ratified for ministries and the results of introduction of norms are reflected in the entire region. An interdepartmental commission consisting of experts of sanitary-epidemiologic and water inspectorates, the State Supply Committee, the State Standard Committee and chief organizations for design and technology has been organized.

7. Realization of the Regional Program

The measures, planned for the first stage of the regional program, have been introduced in 75 of 120 regional industrial plants. The amount of utilized wastes has become one of economic plan indicators in the plants. The remaining enterprises are carrying out preparatory work according to an outlined plan: reconstruction of basic processes of production and sewage treatment systems, introduction of new technologies for waste utilization. Realization of the program effects a substantial saving of capital investments. The introduction of nature-protecting measures provides an annual economic effect of 45 million rubles.

The Lithuanian SSR plays a role as a test region. In the near future, a complex of scientific-technical and organizational-economic measures will be developed in order to establish universal solutions of the problem, applicable in other regions of the USSR.

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6.5 THE PROFITABLE COMBINATION OF WASTE INCINERATION AND WET FLUE GAS CLEANING*

A. Wahlström
Svenska von Roll AB
Box 45162, S-104 30 Stockholm, Sweden

1. Introduction

The subject of this Workshop – Ecological Sustainability – indicates an interest in how to preserve today's environmental quality, or even better, how to improve it in the future. There are lots of possibilities for Regional Planning, which could make a contribution to this improvement.

In this paper, one simple example from Sweden will be given. After several years of trial and error on how to solve the problem of getting rid of refuse, the Swedish authorities and communities finally realized that incineration with heat recovery was the best solution. There are 25 plants for this purpose in Sweden today; see Figure 1.

This enviro-economic system is not only profitable for the total economy, but also contributes to a better environment. The energy needed in the district heating systems can be provided by burning the refuse in specially designed incinerators and by recovering the heat in a boiler.

As an example, Sweden can reduce the consumption of imported oil for district heating purposes by approximately 350,000 tons/year corresponding to 3 TWh. See Table 1.

The environmental consequences of this system consist of a chain of interrelated improvements. First of all, we can reduce the volumes necessary for landfill and thus the quantity of contaminated leakage-water from present landfill areas.

Secondly, we can reduce the emissions of, for instance, acid substances due to the lower consumption of oil and coal. And why is that? Primarily, the reason is that the environmental requirements for waste incineration in Sweden today are very great, especially regarding emission levels for noxious compounds in flue gases as, for example, dust, mercury and hydrochloric acid. See Table 2.

This means that by today's standards the total flue gas emission of acid equivalents is reduced – perhaps to a small extent – but even so this is an improvement.

This reduction naturally has a direct impact on the concentration of acid in rain and consequently on the ratio of forest and lake die-off.

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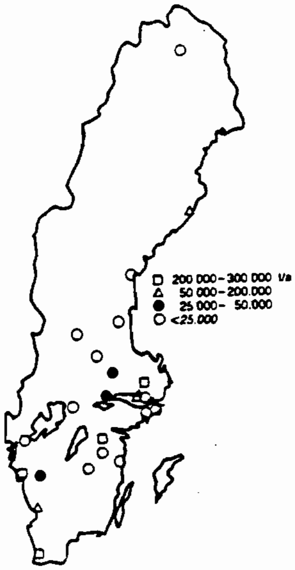


FIGURE 1

Table 1.

	1980	1985	1995
Total district heating, TWh	25,8	33,9	32–40
Refuse heat, TWh	1,0	2,6	2,3–3,8
Percentage of total (%)	3,9	7,2	7–9,5

Table 2.

Pollutant	Requirement
Dust	20 mg/Nm^3
Mercury	0,04–0,08 mg/Nm^3
Hydrochloric acid	20–100 mg/Nm^3

2. System Configuration

2.1 Incineration

Figure 2 shows a typical longitudinal section of a modern waste-incineration plant.

The refuse is fed into the system through a chute and via a feeding pusher. The burning itself takes place on a grate and the incineration gases are burned in the burning chamber. The cooling of the gases and the heat recovery are secured in the boiler. The flue gases still contain several harmful substances and gas cleaning is necessary.

2.2 Flue gas cleaning

Due to the Swedish emission regulations, the flue gas cleaning system has to be very efficient regarding the total precipitation. The technical development in this field has been tremendous during the last 5 years.

Today the most sophisticated solution is the wet flue gas cleaning system. The system layout is shown in Figure 3.

In the quench, partial absorption of the gaseous acid substances HCl and HF takes place. The flue gases are cooled here and charged with steam. After the quench, the flue gases flow into the scrubbing tower, filled with a "hedgehog" packing bed.

The large specific surface of the bed gives excellent absorption of HCl and HF. Moreover, the aerosols are conditioned by the high gas moisture and an ample duration time for the following process stage, the so-called Ring Jet stage, which separates fine dust and aerosol. At the same time, the SO_2 can be efficiently extracted by adding caustic soda.

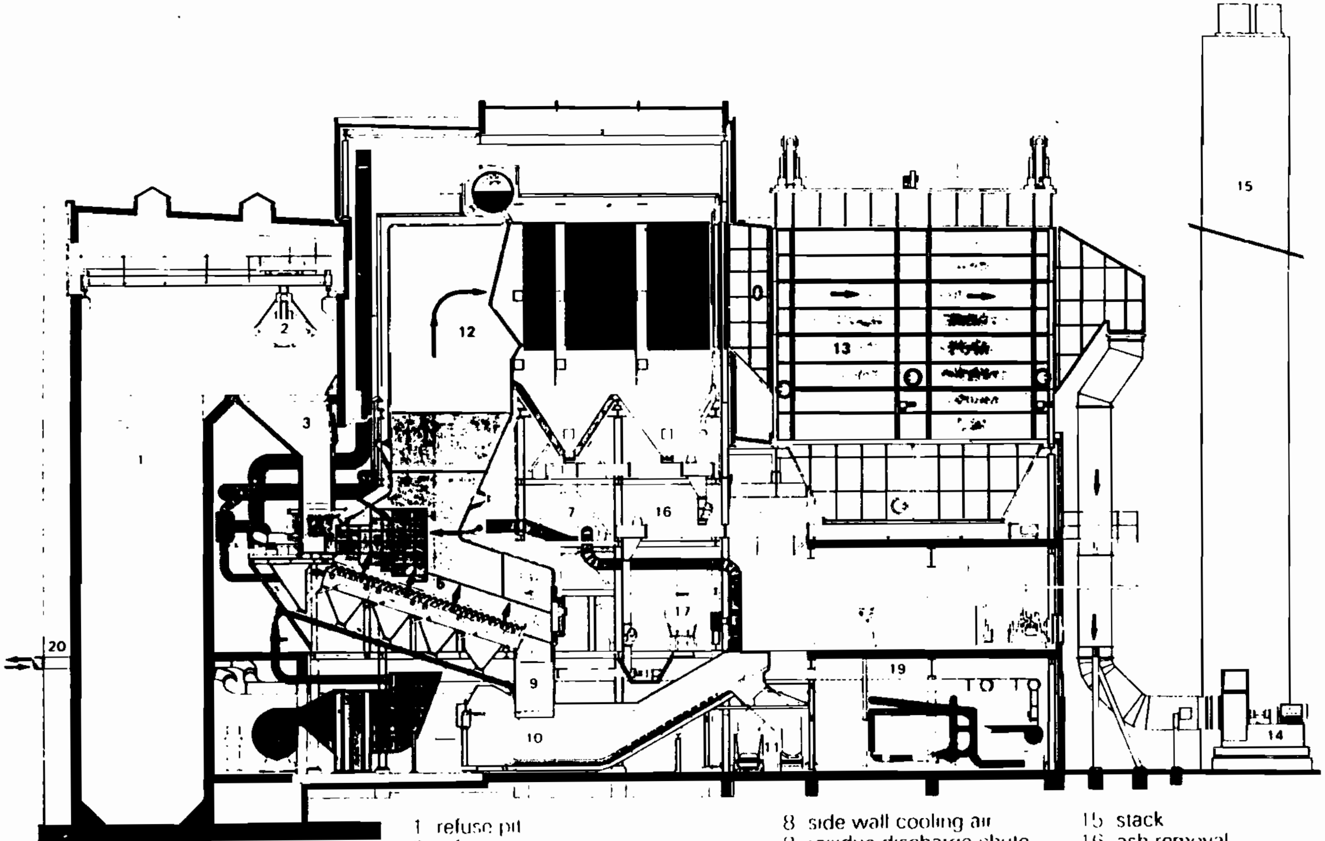
The washing water passes in counterflow through the scrubber, i.e., in the first washing stage (quench); steam is added to the system in the last stage (Ring Jet stage). From there, it is washed through the middle stage into the quench

2.3 Additional energy recovery

With the wet flue gas scrubbing system, the energy contained in the flue gases upon leaving the boiler is transformed into latent heat through water injection, which turns into steam.

By cooling the flue gases after this transformation of heat, the steam condenses again. With this process, part of the energy can be recovered, although at a lower temperature. This process is carried out as shown in Figure 4.

Saturation temperature of the flue gas after incineration is approximately 60° C; therefore, the washing water has the same temperature. This water is pumped through a heating pump and fed into a pipe system for district heating. As shown in the figure, an additional heat-carrying circulation system is necessary between the washing water circulation and the heating pump circulation because the washing water, which is very aggressive, would destroy the heat exchanger of the heat pump, which is driven by the steam turbine. The steam gives its latent heat via a condenser to a district heating system.



1 refuse pit
2 refuse crane
3 feeding hopper
4 ram feeding device
5 combustion grate
6 primary combustion air system
7 secondary combustion air system
8 side wall cooling air
9 residue discharge chute
10 wet type residual expeller
11 transverse residual expeller
12 hot water boiler
13 electro static precipitator
14 induced draft fan
15 stack
16 ash removal
17 feed water tank
18 heat exchanger
19 pump station
20 district heating

FIGURE 2

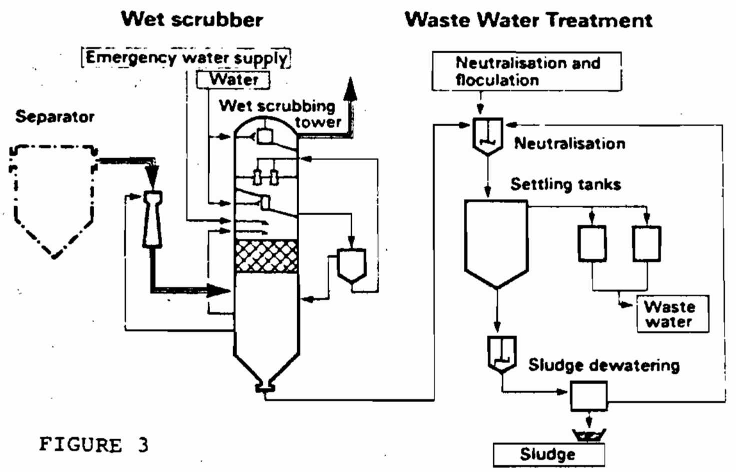


FIGURE 3

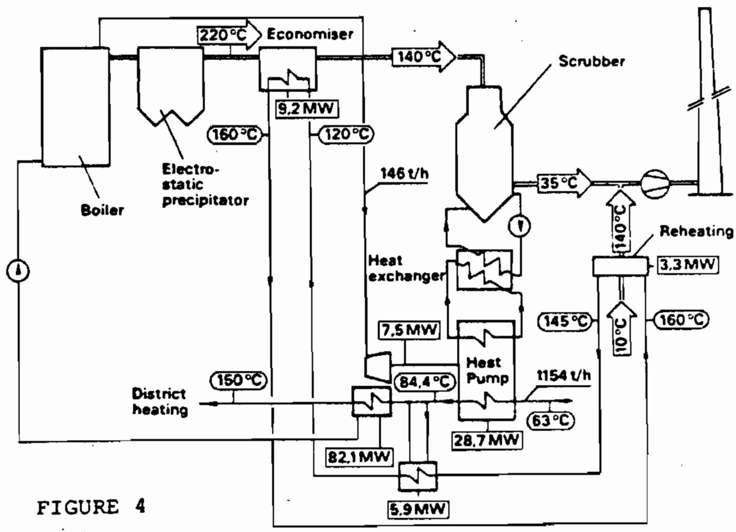


FIGURE 4

In case it is necessary to reheat the flue gas after wet flue gas scrubbing, e.g., when the flue gas stack is not suitable for damp flue gas, then this process can be carried out as shown in the figure. A heat carrier is heated in an economizer through which flue gases flow between the boiler and the flue gas treatment system. Part of this heat goes to a secondary air system which mixes it with wet flue gas after the wet washer. The flue gas temperature rises and the steam content is reduced (heating and dilution of the mixture). The rest of the heat from the economizer goes to the district heating system via a heat exchanger.

3. Conclusion

This example stresses the importance of a total analysis in Regional Planning for one specific field. The often forgotten and "simple" problem of waste disposal can be solved in the most efficient enviro-economic way with a perfect interaction between different authorities within the Region.

A profitable combination of modern technologies can secure waste disposal in a proper way and, at the same time, produce heat for different purposes. Additionally, the reduction of emissions will increase with increasing heat efficiency due to the wet condensing cleaning process.

6.6 AN APPROACH TO THE EVALUATION OF REGIONAL ENVIRONMENTAL PROGRAMS*

R. Rayatskas and L. Tchekanavitchyus
Vilnius State University
Sauletekio 11, Vilnius
Lithuanian SSR, USSR

The scarcity of resources, which are available to regional authorities at any given period of time, inevitably leads to the search for an optimal way of their allocation to meet various goals, i.e., making the best compromise among all possible alternatives of regional socioeconomic and ecological development.

Regional Environmental Programs (REP) should be regarded as a constituent part of those alternatives. Therefore, they ought to be evaluated in terms of achievement of general regional policy objectives as well. The existence of different allocation targets makes it necessary: 1) to compare alternative REPs among themselves; 2) to compare the consequences of an REP realization with respect to alternative ways of resource utilization from the societal point of view; 3) to ascertain the extent that REP benefits justify (exceed) the required expenditures. In order to be able to make rational and consistent judgments, the decisionmaker must assess the possible repercussions of any choice. The duty of environmental scientists is to provide him with: 1) information concerning the range of all feasible alternative projects of REP; 2) comprehensive assessments of impacts which may emerge from their realization; and 3) appropriate evaluation criteria.

If regional resources are to be used in an optimal way, the effects of any environmental improvement or conservation program should be weighed against the costs of its implementation. Thus the problem of any social, economic or environmental project evaluation can be split into two relatively independent tasks: the evaluation of the effects – both positive and negative ones – resulting from the project's realization, and the estimation of the corresponding costs.

Most scholars are inclined to consider the problem of estimation of project realization costs as a relatively simple one. It is almost automatically assumed that an appropriate measure for environmental quality (EQ) improvement costs is the amount of the monetarily evaluated inputs of the production factors necessary for project realization. Therefore, major attention is focused on description and evaluation of the benefits and losses, which emerge from REP realization.

A great variety of theoretical concepts concerning this matter can be found. However, according to the basic principle on which an approach has been based, they might be classified into two major groups, i.e.: a) social indicators approach, and b) the economic (monetary) evaluation approach. The assumptions on which both approaches towards environmental impact assessment are based, and the merits and shortcomings of methods proposed within each of them, are

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briefly examined below.

The social indicator approach has emerged as a sort of reaction to the alleged incapability of monetary measures to give an appropriate and comprehensive evaluation of the different kinds of impacts resulting from the social project's realization.

It has been argued that no reliable monetary estimate could be obtained for some environmental impacts due to the lack of information concerning the relation of impact in question to social-cultural changes (e.g., the loss of aesthetic value of nature or the damage to historical monuments). Moreover, there are also biological changes which could not be measured in monetary terms (e.g., genetic dangers of pollution). In order to obtain a comprehensive picture both of the benefits and losses, a wide set of indicators measured in physical units has to be used. The system of indicators might be presented as a vector or with the help of an hierarchical structure. Different sets of indicators have been proposed, including, inter alia, the characteristics of population (mobility, density, health, life expectancy, community growth and cohesion), environment (climate and weather changes, pollution level, wildlife population, aesthetic values), economic effects (economic growth rate, employment, price-level stability), and so on.

The unquestionable merit of the multiple dimensions approach lies in the possibility of giving a complex image of all the effects concerned in a relatively simple way. On the other hand, the approach has some explicit shortcomings, for instance:

a) only a relatively small number of indicators should be presented to the policymaker to be manageable. So, the danger of overlooking some important effects arises;

b) environmental impacts measured in physical units often fail to characterize properly the real losses or gains of society. For example, damage emerging from lake pollution strongly depends upon water use, e.g., industrial, drinking water, recreational, etc.;

c) the coverage of indicators is liable to overlap, i.e., some indicators would be interrelated and, in fact, would duplicate the same effect of the REP implementation (for instance, health, life expectancy). This would cause difficulties for the decisionmaker;

d) the expected effects of two or more alternatives, when presented in the form of indicators, may sometimes not show any superior alternatives. It is then extremely difficult for the policymaker to make a rational choice;

e) any decision of the policymaker either explicitly or implicitly implies some weighting procedure of the particular components of an indicators set. Thus, the aggregation problem is simply passed on to the decisionmaker, although there is no evidence that he is capable of coping with it any better than the researcher;

f) if the effects of the REP realization are measured in various physical units and the implementation costs are expressed in monetary terms, it is difficult to judge whether the benefits outweigh the sacrifices which society must make in shifting the necessary resources from another social project.

The economic (monetary) valuation approach leads to a monetary yardstick for all benefits and costs of REP realization. It is based on the assumption that there exists some trade-off between immediate social or environmental goals and economic effects. As for the merits of using monetary measures in environmental impact assessments, it is usually emphasized that:

1) monetary evaluation is indispensable in comparing the environmental consequences of alternative projects with the costs of their implementation. In this way, one can learn not only *if* the project is beneficial (i.e., if the benefits exceed the costs), but also *how much* net benefit it provides (i.e., benefits minus costs);

2) monetary estimates of environmental policy benefits and costs can be used in establishing environmental standards in such a way that the total sacrifices of society due to environmental deterioration are minimized. Consequently, pollution charges can be appropriately determined;

3) even in cases when it is impossible in general or due to the lack of information to achieve monetary evaluations of all components of REP effects, a partial impact aggregation reduces the number of factors to be taken into account in the decision-making process.

The economic evaluation concept, nevertheless, has its own problems, viz., should we seek maximization of output of the economic system or the satisfaction of the desires (wants) of individuals. Respectively, the "macroeconomic" and "microeconomic (hedonic)" concepts can be identified.

The basic point of the "macroeconomic" approach is that monetary evaluation of changes in EQ has to be obtained by measuring the corresponding changes in the resource expenditures necessary to prevent or to compensate for the negative environmental effects. For example, the destructive effect of pollution on human health is usually equated with the monetary value of the productivity losses due to the accelerated mortality rate and pollution-induced morbidity, plus the overhead costs of medicare which are necessary to compensate for the ill-effects of pollution. The damage to materials (i.e., buildings, machines, historical monuments, etc.) is evaluated by expenditures necessary to carry out cleaning, washing, painting, repairing, and other measures. The value of the harm to natural resources is obtained by estimation of the decrease in their usefulness to the production process.

Such an approach often pays lip service to the needs and well-being of man – it is usually based on the requirements of the economic subsystem. Even the life and health of man are not considered as a value by itself, but are determined by the advantage brought by the individual in the production process. Such a phenomenon is an inevitable result of the principle underlying the approach: the social welfare of the population is either explicitly or implicitly assumed to be indicated by the magnitudes of the macroeconomic variables (such as GNP or national income, total expenditures, etc.). In reality, however, GNP or national income had never been intended to serve as a welfare measure and may only be considered as the suitable (although imperfect) characteristic of an economic activity scale. Apparently the realization of this paradox in some cases has led to attempts to modify the GNP or similar indicators in order to yield a more adequate welfare indicator. In some cases, attempts have been made to add the consumer's additional pollution-induced expenses to the macroeconomic evaluations of environmental damage. Of course, such kinds of modifications *did not* and *could not* remove the fact that the "macroeconomic" approach ultimately comes down to relating everything to GNP-type variables and, in reality, provides *producer-oriented* evaluations of environmental effects. Many socially undesirable externalities, such as suffering of members of society from the limitations imposed upon them by noise or odors, leisure-time and other opportunity losses, are not included in the analysis.

The following theoretical scheme may be proposed in an attempt to disclose the grounds on which the observed discrepancies could arise. The essential idea is the following. Due to the relatively independent economic goals of particular socioeconomic bodies (consumers, firms, national or regional economy), three EQ optimum levels can be distinguished. It is assumed that consumers wish to maximize their welfare, firms strive to maximize their profits, and the regional (national) economy, or in other words, society as a whole wants to maximize the national income (or GNP).[1] Accordingly, one can speak about a consumer's optimum, a firm's optimum and society's optimum of environmental quality.

The *consumer's optimum* of EQ is reached when the curve of marginal benefits of the changes in the environment (consumer's gains from environmental improvement) intersects the curve of the marginal disadvantages arising from society's activity on behalf of the environment (consumer costs of environmental protection). Another definition of the consumer's optimum which is, in fact, precisely identical to the first one, can be formulated: it is the level of EQ where the consumer's environmentally generated benefits exceed as much as possible his corresponding costs. Consumer gains are, for example, time and/or money saving due to reduced damage to household articles, decreased danger to health, increased recreational amenities, etc.; while consumer costs include the higher prices paid for goods, spending more time and/or money to get to work, enjoying fewer social benefits (different from environmental ones), etc.

The *firm's optimum* of EQ corresponds to the level where its marginal profits arising from the use of environmental services (e.g., expenditures on pollution-control equipment and due to the advantages of higher quality natural resource utilization) become equal to the firm's marginal costs associated with the use of those services (pollution charges, natural resources exploitation expenses, etc.).

Society's optimum of EQ at the regional (national) level is determined by the minimum of so-called "environmental costs" which include pollution-control costs and monetary damage of environmental deterioration (the latter evaluated in the "producer-oriented" manner indicated above). The equivalent definition of society's optimum is the point of maximum difference between benefits, i.e., reduced monetary damage, and costs of environmental improvement.

Some preliminary conclusions concerning the levels determined by various sorts of optimality criteria can be formulated. For instance, it is very likely that the lowest level of EQ corresponds to a firm's optimum, since many types of environmental dangers manifest themselves outside the range of the immediate interests of the firm and, thus, have not been taken into account. Effluent charges are an instrument for bringing a firm's optimum point closer to that of society's. However, regardless of the efficiency of such an interest-coordinated mechanism, it is obvious that it completely ignores the consumer's judgments on an acceptable EQ level. At the same time, we face the paradox that most of the economic doctrines related to the "macroeconomic" approach proclaim that the needs of man are a "measure for all purposes." Meanwhile, there is no evidence that an adequate relationship exists between what society *is* prepared to pay (i.e., to sacrifice in terms of GNP loss) and what society *should be* prepared to pay for environmental benefits. It should be realized that a gap exists between a consumer's perception of environmental effects, expressed by the marginal rate of substitution between environmental and nonenvironmental goods and society's

[1]The authors realize that those assumptions are somewhat simplified. Nevertheless, they are rather common in economic theory.

costs of *providing* those effects, reflected in the marginal rates of transformation between those goods. Such a gap has to be equal to the total sum of the positive and negative externalities conveyed to the consumers utilizing the commodities mentioned above. For example, the wage loss due to pollution-induced illness is a direct consumer's loss. Only under certain, rather unreal, conditions will it represent the corresponding cost to society. The first condition is that the wage rate must be equal to the marginal labor productivity, the second – that no monetary transfers take place when an individual is on sick leave. If this viewpoint is accepted, valuation of the output lost or overhead resource expenditures would be merely regarded as the minimum that society ought to sacrifice for environmental improvement. In order to reach any decision on such an improvement, it must be compared with the *consumer-oriented* evaluations of the REP.[2]

The basic postulates of the so-called "microeconomic" approach are the following:

1) an ultimate criterion must be found satisfying the desires of the individuals;
2) the consumer is the best judge of the advantages which he obtains from a particular good or service.

Damage due to environmental deterioration may be conventionally classified into: a) financial losses (also known as direct, economic, tangible or physical costs) and b) losses of amenities (also called indirect, social, intangible or psychic costs). Those losses manifest themselves in the demand for marketable goods and services due to changes in EQ. They are measured by the amount of earnings foregone to prevent or compensate for the effects of those changes. Amenity losses are those effects of environmental changes which do not entail direct monetary costs, e.g., suffering and bereavement, leisure-time losses, reduced pleasure of fishing and hunting, enduring soiled or damaged materials, decreased aesthetic values of nature, etc.

The main difficulties arising in the consumer's loss estimation process are, for rather clear reasons, associated with the monetary evaluation of amenity losses. The essential point in the methodology of all methods used is the notion that there exists some kind of trade-off between financial and amenity losses. Monetary evaluations of amenity losses are obtained by studying consumer decisions – both expressed explicitly or implicitly in his behavior pattern.

The most frequent valuation methods used are the following:

1) Property price approach: EQ estimates are derived from observed differences in property (land, dwelling units) prices in nonpolluted and polluted areas, provided that pollution-caused price differences can be disentangled from the influence of many other factors.
2) Demand curves approach: the value of environmental services is determined by the alterations in consumer expenditures on other commodities as a result of environmental changes. The relationship between the specific amenity and the demand for the marketable good has to be identified.

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[2]Samuelson's well-known requirement for the consumer-oriented economy optimal functioning is that the marginal rates of transformation between a pure private good and a pure public good should be equal to the sum of the consumers' marginal rates of substitution between that private good and the public one. The public good may be defined as a commodity which can be used by several individuals at the same time and from which one's use no-one can or should be excluded (e.g., environmental goods).

3) Exclusion facilities approach: estimation of monetary expenditure, which a person chooses to bear in order to evade amenity losses, is assumed to be given by the latter. However, it ought to be remembered that the use of this method will understate the real value of amenity losses: the costs borne by the consumer will represent the minimum price he is willing to pay for maintaining the amenity in question.

4) Social survey (questionnaire) approach: the information on the consumer's willingness to pay for environmental benefits is elicited by applying various interview or questionnaire techniques.

Most researchers emphasize that the enumerated evaluation methods suffer from a number of severe shortcomings. The major ones are the following:

- The consumer's explicitly expressed willingness to pay for environmental goods and, to some extent, his behavior depend on quite a number of factors, e.g., his attitudes with regard to health; his aesthetic, cultural and moral views; the level of information on environmental matters available; the ability to perceive environmental quality change; the incentive to distort responses; and so on.
- The subjective perceptions of environmental pollution hazards are liable to differ from the objective risk. In other words, some of the environmental effects can be "invisible" to the senses of a person, but nevertheless convey an externality, for example, they may be destructive to his health.
- The evaluation methods discussed above are concerned not with *needs*, but with *wants* (desires). It must be pointed out that the concept of happiness does not coincide with that of *welfare*. Man's desires (e.g., tobacco smoking) often do not reflect accurately the true survival values of human life. Thus, doubt should be given to the principles of a "hedonic" approach to environmental changes evaluation.

It is easy to notice that the two preceding approaches – "macroeconomic" and "microeconomic (hedonic)" – represent somewhat extreme views of the problem discussed. The former completely relies on imposed values associated with productivity losses or "unproductive" resource expenditures and does not immediately reflect consumer preferences. The other one emphasizes consumer sovereignty on estimating his own welfare. In spite of this fact, the two approaches are not mutually exclusive, but merely provide different perspectives for valuation of REP. Indeed, a well-known truism is that consumption is the *source* (although not the only one) of welfare and production is merely the *means* to this purpose. Despite the triviality of this statement, it seems to us that it suggests a way of reconciling the two potential approaches.

Since there are always different alternatives for utilizing limited resources, choice of a single one implies that the possible results of all others are excluded. Accordingly, REP realization expenditures can be treated as resources diverted from the direct production process. Therefore, by directing part of its resources to secure REP fulfillment, society is deprived of those economic benefits which could be gained if the resources had been used in output augmentation. These wastes, evaluated in terms of potential GNP (or national income) loss, should be considered as a basis for estimation of *social costs of environmental programs realization*. More accurate estimation is obtained by taking into account (subtracting from the losses mentioned above) the magnitude of so-called feedback economic effects of environmental improvement, i.e., increases in productivity of production factors due to the benevolence of the environmental condition.

Although there remain a number of unsolved problems in regard to the proposed social costs estimation approach (for more detailed analysis. We shall subsequently devote our attention to the extremely complicated problem of the determination of *environmental quality's social price*.

As was discussed above, due to its serious shortcomings, the "hedonic" approach cannot be considered as an appropriate tool for evaluation of the social price of the environment. However, it is clear that such an evaluation ought to be consumer-oriented, since undoubtedly the REP realization goals are the satisfaction of a region's population needs. Seeking some sort of compromise it is necessary to determine to what extent consumer preferences can be reflected in the valuation of the merit goods.

Let us assume that the socially justified goal of consumption is the maximization of a consumer's welfare in order to ensure the full development of his personality. Then the consumer's resources, which can be assigned to this purpose, ought to be investigated. In our opinion, two main kinds of consumer resources could be separated:

1) financial resources (wealth), which may be further divided into a) monetary savings ("cash resources") and b) the resources "capitalized" in personal, movable and/or real property form;
2) time resources of the consumer, excluding the time spent on money-earning work, of course (in fact, income can be interpreted as "materialized" working time).

Further on, if we are concerned with the development of a person, resource expenditures for *ordinary* productivity of an individual should not be considered. That is, the time spent on sleeping, maintaining the household and looking after personal needs should be excluded from further analysis. Therefore, speaking about the time resources of the consumer we shall use the "leisure-time" term, which includes the time spent on cultural, educational, sports and entertainment activities.

Suppose that EQ has deteriorated. The possible effect of those changes on the consumer's potential opportunity to achieve the higher level of welfare could be evaluated in terms of his "welfare-augmenting" resources diminution. For instance, health effects could be evaluated by the amount of wages lost minus any sum paid for social insurance, increased costs of health care, leisure-time loss due to illness and health restoration.[3] Furthermore, the pollution-induced soiling of laundry and fabrics causes the consumer additional expenses in the form of money and time losses for the cleaning required and so on. In short, every kind of negative effect of environmental deterioration is reflected as a consumer's financial losses, or his leisure-time losses, or simultaneously both. It is important to point out that the magnitudes of both kinds of losses are in every case determined by the consumer's behavior. For example, in the case of health damage, the options could be, say, medical treatment or reduced productivity at work. The latter behavior pattern would inflict greater harm on the individual's health and, therefore, would require more time to achieve a cure. If all other conditions are kept constant, this would mean a diminution of the "welfare-augmenting" time resources.

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[3] It is obvious that description of the enumerated losses in more detail is possible.

In the light of the above-outlined approach, one can speak about "pure" leisure time and "gross" leisure time. The former is used for *direct* augmenting of consumer welfare and the latter also includes the time spent on restoration to the initial welfare level. Apparently, the consumer's financial resources (wealth) can be divided into "welfare-augmenting" wealth and "compensating expenditures," the latter including household articles bought in order to prevent or compensate for the negative impacts of environmental deterioration.

The necessity to compare costs and benefits of REP imposes the requirement that the incommensurables amongst the consumer's losses should be reduced to a common scale. Since the social costs of EQ improvement are measured in monetary terms, monetary evaluation of leisure time is obviously preferable. A survey of the leisure-time economic evaluation methods enables one to conclude that, similarly to the approaches inspected above, they use the observed trade-offs between leisure-time lengthening opportunities and the increase in the consumption of other commodities. Obviously, the "macroeconomic" and "microeconomic" approaches might be separated. Naturally, the latter type of approach is interesting from our point of view. Two major methods could be mentioned. One is based on studies of the demand curves for timesaving household facilities or services. The other uses the questionnaire technique in order to build the consumer's substitution function between a potential wage increase and an increase in leisure time.

It is obvious that some of the previously mentioned drawbacks of similar "microeconomic" approaches to environmental problems apply also to the methods discussed. Nevertheless, it seems to us that those limitations to a considerable extent might be softened due to the specific features of the evaluation problem. Anyway, it must be pointed out that the "welfare-augmenting" resources approach considerably reduces the number of incommensurable consumer perceived tangible and intangible environmental effects which ought to be taken into account in the decision-making process.

APPENDICES

APPENDIX I: FINAL STATEMENT

INTERNATIONAL WORKSHOP ON

ECOLOGICAL SUSTAINABILITY OF REGIONAL DEVELOPMENT

Vilnius, Lithuanian SSR, USSR

June 22 -26, 1987

FINAL STATEMENT

The Workshop considered the basic notions related to sustainability, viz., conditions for sustainability, measures to achieve it, and crucial research to be undertaken in the domains of monitoring, modelling, technology and policy with respect to sustainable regional development. Sustainability is that feature of a system which makes it possible to maintain itself, over an infinite time horizon.

With regard to ecological systems including human ones, it is necessary to distinguish three levels of sustainability: global, regional and local. In view of the capacities of solving the sustainability problem, i.e., of planning and managing development to secure sustainability, the regional level is of crucial importance.

One of the major distinctions among the levels appears to be the nature of appropriate variables for sustainability assessment with regard to ecological systems. Thus, for global systems – oxygen and food production; for regional systems – food production, adequately clean water and availability of crucial raw materials; for local systems – habitat (environment) and system element availability, seem to be the variables ensuring sustainability.

Sustainability allows for important structural changes, as witnessed by Earth's history, but kept within defined limits. These limits may be transgressed locally where destruction of habitats occurs quite frequently, thus posing a threat to regional and thereby to global systems. This threat originates from mismatches between the economic, social and ecological spheres, ranging from those regarding value and conceptual systems, through those concerning methods and techniques, as well as experience, to those relating to policy, institutional mechanisms and public responses.

Sustainability can only be ensured through resolution of these mismatches. One must, by necessity, start with the value mismatch. Means must be provided for giving equal weight to the economic, social and ecological values of particular assets or system elements. In the sustainability perspective, a value assessment must take long-term use and consequences into account. Within the value domain, tools must be elaborated for easy real-time multi-actor evaluations of dilemmas, problems, scenarios, etc. Such readily available tools, if computerized, would also help in resolving conceptual mismatches.

With regard to knowledge, methods and techniques, and their development and application, it seems necessary to establish through further resource dynamics studies, the general conditions for sustainability for particular levels and types of ecological systems. This should lead to provision of sustainable development rules, in particular those oriented at the regional level. Such rules would include an indication of minimum levels or maximum depletion rates, etc., of particular resources. The rules have to distinguish regional conditions in terms of various climates, natural resource compositions, etc. The rules must be developed in a step-wise manner, as knowledge increases.

The rules would take into account dynamic balances of resources used, considering in appropriate cases their rates of recovery or renewal (water, biomass – distinguishing amongst products, soil and nutrients), upper limits of destruction, whether static or dynamic (air pollution, non-renewable resources) and requisite variety (maintenance of local species diversity, land use differentiation).

Coupled with this would be indicators revealing secular singularities in the on-going development process, where these indicators could be taken from e.g., climatology, dendrochronology, and other sources of information.

Over a shorter time horizon, the techniques should permit value-integrated assessments of plans and policies, in accordance with previously devised rules. Special attention should be paid to policy and institutional mechanisms, since it is within these mechanisms that values and concepts are to be reconciled and rules agreed upon. Thus, the creation of effective policy-oriented tools seems to be of great importance in bringing the message to those most capable of shaping decisions, including their participation in the entire analytical process, and in the specification of responses.

Within the technology domain, there is increasing demand for waste-free and waste-reducing technologies, that would stand the test of multiple-value assessment. In this respect, the importance of free information exchange, particularly in the elimination of pollutants as well as the utilization of wastes, cannot be overestimated.

As one example of methods to achieve the sustainability of regional systems, a complex scheme of development/redevelopment of the Lithuanian SSR (until and beyond year 2000) was discussed and given general approval.

The sustainability of local resources is already threatened, if not destroyed in many regions. This has an important bearing on the sustainability of regional systems. On the other hand, regional systems influence each other through global level system interconnections. Thus, regional systems appear to be nodes of the sustainability question. The question requires, therefore, not only methodological and technological achievements, but also increased information exchange and active cooperation.

During the course of the Workshop, it was strongly suggested that a formulation of research directions should:

- find exact definitions of concepts (e.g., sustainability, etc.);
- study factors (and their relationships) on which sustainability and productivity of an ecosystem depend;
- examine the state of the biosphere at all three levels, local, regional and global, and their relationships;
- establish a set of indicators and elaborate efficient methods and instruments for measuring;

- eco-climate dynamics (for instance, through dendrochronologies),
- ozone and other pollutants;
- biomass dynamics;

– create regional ecological models for ecological assessment and forecasting based on:
  - experiences of the Club of Rome (their models);
  - control strategies which should be implemented before pollution occurs·
  - gathering, using and evaluating experiences from ecological and economic modelling.

– towards regional ecological sustainable development, conduct studies:
  - on more efficient energy use,
  - on conservation of raw materials (including water, etc.), minimizing waster production (which cannot be utilized by the ecosystem);

– from a managerial point of view, check the reliability of present information relating to:
  - environmental data (monitoring, level of pollution, etc.),
  - predictability of models based on these data.

– from the point of view of historical analogies:
  - integrate spatial (national, international) experiences,
  - store past experience (data, knowledge),

– from an evaluation point of view, draw and search for causality. Study these in terms of:
  - time, duration
  - range (physical, monetary, etc.),
  - inadvertency.

Finally, the participants of the Workshop agreed that the main goal of ecological sustainability of regional development is the sustainable survival of the human micro-population or ethnic groups, within each defined geographical space for an undefined length of time. Therefore, consistent regional and national policies as well as international cooperation relating to sustainability of regional systems are required. It was also recognized that IIASA is an appropriate institution as a catalyst for such cooperation, both in scientific and policy terms.

APPENDIX II: LIST OF PARTICIPANTS

INTERNATIONAL WORKSHOP

on

"ECOLOGICAL SUSTAINABILITY OF REGIONAL DEVELOPMENT"

Vilnius, Lithuanian SSR, USSR • June 22-26, 1987

Organized by the

Lithuanian Academy of Sciences & *Committee for Systems Analysis, Academy*
Vilnius, Lithuanian SSR, USSR *of Sciences of the USSR, Moscou*

and co-sponsored by the

International Institute for Applied Systems Analysis (IIASA)
A-2361 Laxenburg, Austria

LIST OF PARTICIPANTS

(by country)

AUSTRIA

Dr. Elisabeth Johann
Center for Environment and
Nature Protection
Institute für Bodenkultur
George-Mendel Strasse 33
1180 Vienna
AUSTRIA

Dr. Klaus Johann
Forest Experimental Station
Schönbrunner Tirolergarten
A-1130 Vienna
AUSTRIA

CZECHOSLOVAKIA

Dr. Jan Morović
Institute of Management
P.O. Box 89815
Dubravska cesta 3
Bratislava
C.S.S.R.

GERMAN DEMOCRATIC REPUBLIC

Dr. Klaus-Dieter Jäger
Sektion Orient- und Altertums-
wissenschaften
Martin-Luther Universität
Richard-Wagner-Strasse 9-10
DDR-4020 Halle/Saale
GERMAN DEMOCRATIC REPUBLIC

GERMAN FEDERAL REPUBLIC

Prof.Dr. Dieter Eckstein
Institut für Holzbiologie
Universität Hamburg
Leuschnerstrasse 91d
D-2050 Hamburg 80
FEDERAL REPUBLIC OF GERMANY

THE NETHERLANDS

Dr. Frits Soeteman
Dept. of Spatial Economics
Free University
Postbus 7161
1007 MC Amsterdam
THE NETHERLANDS

POLAND

Dr. Jan Owsinski
Systems Research Institute
Polish Academy of Sciences
Newelska 6
PL-01 447 Warsaw
POLAND

Prof. Andrzej Straszak
Systems Research Institute
Polish Academy of Sciences
Newelska 6
PL-01 447 Warsaw
POLAND

Prof. K. Rykowski
Forest Research Institute
Wery Kostrzewy 3
PL-00973 Warsaw
POLAND

SWEDEN

Prof. Lennart Schotte
Director General
Royal Swedish Academy of
Engineering Sciences
Laensstyrelsen
S-79184 Falun
SWEDEN

Dr. Uno Svedin
Swedish Council for Planning
and Coordination of Research
FRN
Box 6710
S-113 85 Stockholm
SWEDEN

Prof. Anders Wahlström
Svenska von Roll AB
Tecknologgatan 5
Box 45162
S-104 30 Stockholm
SWEDEN

U. S. A.

Prof. John A. Eddy
Director
Office for Interdisciplinary
Earth Studies
National Center for Atmospheric
Research
University Corporation for
Atmospheric Research
P.O. Box 3000
Boulder, Colorado 80307
U. S. A.

Prof. William R. Moomaw
Director, Center for Environmental
Studies, Williams College
Williamstown, Mass.
U. S. A.

U. S. S. R.

Prof. N.A. Agadjenian
Corresponding Member
Medical Academy of Sciences
Chairman, "Ecology of Man"
Section of the Scientific Council
for Biospheric Problems of the
USSR Academy of Sciences
Leninski Prosp. 14, corp.
5 Moscow B-71
U. S. S. R.

Prof. Antanaitis
Lithuanian Academy of Agriculture
Kaunas, Girionys
Lithuanian SSR
U. S. S. R.

Dr. Balcevic
Lithuanian Institute of Forestry
234312 Kaunas, Girionys
Lithuanian SSR
U. S. S. R.

Dr. T. Bitvinskas
Chairman, Dendrochronological
Data Bank of the USSR
Institute of Botany
Lithuanian Academy of Sciences
Kanuas, Laisves allee 53
Lithuanian SSR
U. S. S. R.

Prof. E.P. Borisenkov
Main Geophysical Observatory
Karbinsheva Street 15
194021 Leningrad
U. S. S. R.

Dr. J.Ya. Budilovskij
c/o Dr. Liandzbergas
State Planning Committee of the
Lithuanian SSR
Lenino 3
Vilnius, Lithuanian SSR
U. S. S. R.

Prof. A. Budvytis
Corresponding Member, Academy of
Agricultural Sciences
Director, Agricultural Institute
of the Lithuanian SSR
Dotnuva
U. S. S. R.

Prof. M. I. Budyko
Corresponding Member of the Academy
of Sciences of the USSR
Head of Laboratory
Central Institute of Hydrology
State Committee for Hydrometeorology
and Environmental Control
Prospect Marksa 75-63
Leningrad 194100
U. S. S. R.

Prof. Antanas Buracas
Academician, Institute of Economy
of the Lithuanian Academy of
Sciences
Vice-President of Lithuanian
National Committee MAB
Pozelos 52-315
232600 Vilnius, Lithuanian SSR
U. S. S. R.

Dr. R. Gajauskaite
c/o Acad. L. Kairiukstis
Director
Lithuanian Scientific Research
Institute of Forestry
Girionys, Kaunas
Lithuanian SSR
U. S. S. R.

Dr. K. Giniunas
Chairman of the Lithuanian
State Committe for
Environmental Protection
Pozelos 26
232600 Vilnius, Lithuanian SSR
U. S. S. R.

Prof. M.B. Jegorov
Deputy Head, Laboratory of
Systems Science
Leningrad Institute of
Information
USSR Academy of Sciences
Mendeleevskaja Liniya 1
Leningrad
U. S. S. R.

Dr. S. Karazija
Lithuanian Forest Research
Institute
State Committee of Forestry
of the USSR
234312 Kaunas, Lithuanian SSR
U. S. S. R.

Dr. P. Kavaliauskas
V. Kapsukas State University
Vilnius
Lithuanian SSR
U. S. S. R.

Dr. G.E. Kocharov
Leningrad Physical Technical
Institute of the Academy of
Sciences of the USSR
Leningrad
U. S. S. R.

Dr. Komarov
c/o Acad. L. Kairiukstis
Director
Lithuanian Scientific Research
Institute of Forestry
Girionys, Kaunas
Lithuanian SSR
U. S. S. R.

Acad. K.Ja. Kondratiev
President of the Scientific Committee
on Problems of Regional Ecological
Development
Committee on Systems Analysis,
Academy of Sciences of the USSR
Sevastjarova 9
196199 Leningrad
U. S. S. R.

Acad. V. Kontrimavicius
Scientific Secretary
Department of Chemical, Biolo-
gical and Technical Sciences
Lithuanian Academy of Sciences
President, Lithuanian National
Committee, MAB
U. S. S. R.

Dr. Kretchetov
Central Economic-Mathematical
Institute
Krasikova 32
117418 Moscow
U. S. S. R.

Prof. E. Kudaba
University of Vilnius
Vilnius, Lithuanian SSR
U. S. S. R.

Dr. V. Kulikov
Scientific Secretary of the Leningrad
Section of the Committee on Problems
of Regional Ecological Development
Novrosijskeja 44-11
194018 Leningrad
U. S. S. R.

Dr. L. Liandzbergas
Head of Department
State Planning Committee of the
Lithuanian SSR
Lenino 3
Vilnius, Lithuanian SSR
U. S. S. R.

Dr. Heino Luik
Chairman
Dept. of Ecological Protection
Ministry of Forest Economy and Nature
200101 Tallinn
Estonian SSR
U. S. S. R.

Prof. V. Malisauskas
Head of Department of Evaluation
of Natural Resources
Academician, Institute of Economy
of the Lithuanian Academy of Sciences
Pozelos 52
232600 Vilnius, Lithuanian SSR
U. S. S. R.

Dr. K. Mikalajunas
Chairman, Committee for
Hydrometeorology
Vilnius, Lithuanian SSR
U. S. S. R.

Dr. S. Mizaras
Head of Laboratory
Lithuanian Institute of Forestry
234312 Kaunas, Girionys
Lithuanian SSR
U. S. S. R.

Dr. R. Pakalnis
Botanical Institute
Lithuanian Academy of Sciences
Lenino 3
232600 Vilnius, Lithuanian SSR
U. S. S. R.

Dr. G. Pauliukevicius
Institute of Zoology & Parazitology
Academy of Sciences
Vilnius, Lithuanian SSR
U. S. S. R.

Dr. R.A. Perelet
Committee for Systems Analysis
Presidium of the Academy of
Sciences of the USSR
Prospect 60 Let Octyabria, 9
117312 Moscow
U. S. S. R.

Prof. B. Poškus
Director, Lithuanian Research
Institute of Agricultural Economy
Academy of Vask'hnil
Vilnius, Lithuanian SSR
U. S. S. R.

Dr. A.I. Potapov
c/o Acad. L. Kairiukstis
Director
Lithuanian Scientific Research
Institute of Forestry
Girionys, Kaunas
Lithuanian SSR
U. S. S. R.

Acad. Juras Pozela
Presidium of the Academy of
Sciences of the Lithuanian SSR
Lenino 3
Vilnius 232 600, Lithuanian SSR
U. S. S. R.

Prof. V.S. Priobrazenski
Institute of Geography
Academy of Sciences of the USSR
Staromonietni per 29
109017 Moscow G-17
U. S. S. R.

Dr. V. Protasov
Senior Researcher
Institute of Biology of the
Southern Sea
Ukranian Academy of Sciences
Gargarina 34-15
335028 Sevastopol
U. S. S. R.

Prof. Ju.G. Pusachenko
Head of Department
Institute of Evolutional Mor-
phology and Animal Ecology
Lenina 33
Moscow
U. S. S. R.

Dr. A. Racinskas
Institute of Agricultural
Economy
Committee of Agroindustry of
the Lithuanian SSR
Kaunas, Lithuanian SSR
U. S. S. R.

Prof. R. Rayatskas
Corresponding Member of the
Lithuanian Academy of Sciences
Head of Department of Economic
Cybernetics
Vilnius State University
Sauletekio 11
Vilnius, Lithuanian SSR
U. S. S. R.

Dr. A.V. Rutkauskas
Head of Dept. for Complex
Programming of Scientific
and Technological Progress
Institute of Economics
Managing Director, Regional
Resource Development Project
Lithuanian Academy of Sciences
Lenino 3, Vilnius
Lithuanian SSR
U. S. S. R.

Prof. S.S. Shatalin
Corresponding Member of the
USSR Academy of Sciences
Deputy Director, Institute
for Systems Studies of the
State Committee for Science
and Technology
Academy of Sciences of the USSR
11 Gorky Street
Moscow
U. S. S. R.

Dr. Igor V. Shwitov
Prospect Severni 77-1-20
Lenningrad
U. S. S. R.

Prof. V. Statulevichius
Vice President
Lithuanian Academy of Sciences
Director, Institute of Mathematics and Cybernetics
Vilnius, Lithuanian SSR
U. S. S. R.

Dr. V. Stepanov
Head of Laboratory of Economic Evaluation of Sea Resources
Ukranian Academy of Sciences
Kiev, Ukranian SSR
U. S. S. R.

Dr. J. Tamosaitis
Department of Geography
Academy of Sciences of the Lithuanian SSR
Vilnius, Lithuanian SSR
U. S. S. R.

Dr. R. Tamosiumiene
Institute of Philosophy, Sociology and Law
Lithuanian Academy of Sciences
Kaunas, Lithuanian SSR
U. S. S. R.

Dr. Yuri A. Tomilin
Committee for Systems Analysis
Presidium of the Academy of Sciences of the USSR
Prospect 60 Let Octyabria, 9
117312 Moscow
U. S. S. R.

Dr. E. Ushakov
Senior Researcher
Central Economic-Mathematical Institute
USSR Academy of Sciences
Krasikova 32
117418 Moscow
U. S. S. R.

Prof. M. Vaichys
Director, Lithuanian Forest Research Institute
State Committee of Forestry of the USSR
234312 Kaunas, Lithuanian SSR
U. S. S. R.

Acad. Alexander L. Yanshin
Vice President
Academy of Sciences of the USSR
Leninski Prosp. 14
117071 Moscow
U. S. S. R.

Mr. B. Zaikauskas
Chairman, Lithuanian State Planning Committee
Deputy Chairman, Council of Ministers
Lenino 3
Vilnius, Lithuanian SSR
U. S. S. R.

IIASA PARTICIPANTS

Dr. Jean-Paul Hettelingh
Acid Rain Project
Environment Program
International Institute for Applied Systems Analysis (IIASA)
A-2361 Laxenburg
AUSTRIA

Prof. Robert E. Munn
Leader, Environment Program
International Institute for Applied Systems Analysis (IIASA)
A-2361 Laxenburg
AUSTRIA

Acad. Leonardas Kairiukstis
Deputy Leader, Environment Program
International Institute for Applied Systems Analysis (IIASA)
A-2361 Laxenburg
AUSTRIA

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APPENDIX III: AGENDA

INTERNATIONAL WORKSHOP

on

"ECOLOGICAL SUSTAINABILITY OF REGIONAL DEVELOPMENT"

Vilnius, Lithuanian SSR, USSR • June 22-26, 1987

Organized by the

Lithuanian Academy of Sciences **&** *Committee for Systems Analysis, Academy*
Vilnius, Lithuanian SSR, USSR *of Sciences of the USSR, Moscow*

and co-sponsored by the

International Institute for Applied Systems Analysis (IIASA)
A-2361 Laxenburg, Austria

FINAL AGENDA

<u>SUNDAY 21st JUNE, 1987</u>

09:00 - 11:00	**MEETING OF ORGANIZING COMMITTEE**
15:00 - 18:00	**REGISTRATION of PARTICIPANTS — Draugyste Hotel, Ciurlionio Street 84 (phone: 662711 or 661603)**
18:30 - 20:00	**Meeting of Organizing Committee, Session Chairmen & Rapporteurs - Conference Secretariat**

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MONDAY 22nd JUNE, 1987

08:30 - 09:00 REGISTRATION

09:00 - 10:20 OPENING SESSION

09:00 - 09:20 WELCOME FROM THE ACADEMY OF SCIENCES OF THE USSR
Acad. A. YANSHIN *(Vice President of the Academy of Sciences of the USSR)*

09:20 - 09:35 WELCOME FROM THE COUNCIL OF MINISTERS OF THE LITHUANIAN SSR
Dr. B. ZAIKAUSKAS *(First Deputy President of Council, Chairman of the State Planning Committee)*

09:35 - 09:50 WELCOME FROM THE ACADEMY OF SCIENCES OF THE LITHUANIAN SSR
Acad. V. STATULEVICIUS *(Vice President of the Academy of Sciences of the Lithuanian SSR)*

09:50 - 10:10 WELCOME FROM THE INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS (IIASA) and INTRODUCTION to the WORKSHOP
Acad. L. KAIRIUKSTIS *(Deputy Leader, Environment Program, IIASA)*

10:10 - 11:10 SELF-INTRODUCTION OF PARTICIPANTS *(about 30 seconds each)*
[Giving name, affiliation, and scientific interests]

11:10 - 11:30 B R E A K

SESSION I: PERCEPTION OF REGIONAL SOCIO-ECONOMIC AND ENVIRONMENTAL SYSTEMS

11:30 - 13:10 CHAIRMAN: Acad. L. KAIRIUKSTIS (IIASA/USSR)

Rapporteur: Dr. Jan OWSINSKI (POLAND)

11:30 - 11:55 **Acad. K. KONDRATIEV (USSR):** *Ecological Management and Climate Change: Role of Cosmic Means of Observation*

11:55 - 12:20 **U. SVEDIN (Sweden):** *The Challenge of Sustainability: The Search for a Dynamical Relationship Between Ecosystemic, Social and Economic Factors*

12:20 - 12:45 **A. BURACAS (USSR):** *Social Criteria and Preferences within Ecologically Sustainable Regional Development*

12:45 - 13:10 **L. KRECHETOV and G. GOFMAN (USSR):** *Economic Criteria and Tools in Regional Environmental Management*

12:45 - 13:10 **V.M. KULIKOV (USSR):** *A Complex Assessment of the Ecological Regional Situation*

13:10 - 15:00 L U N C H

Monday 22nd June, 1987 (Continued)

SESSION II: INTERDEPENDENCY OF REGIONAL, TRANSREGIONAL AND GLOBAL SYSTEMS

15:00 - 16:15 **CHAIRMAN:** **Acad. K. KONDRATIEV (USSR)**

Rapporteur: **J. TOMILIN (USSR)**

15:00 - 15:25 **J. EDDY (USA):** *U.S. Initiatives in the International Geosphere-Biosphere Program (IGBP)*

15:25 - 15:50 **R. PERELET (USSR):** *Global and Regional Approaches to Management of Environmental Problems*

15:50 - 16:15 **A. WAHLSTROM (Sweden):** *The Profitable Combination of Waste Incineration and Wet Flue Gas Cleaning*

16:15 - 16:35 **B R E A K**

SESSION II: (Continued)

15:00 - 18:15 **CHAIRMAN:** **Prof. John A. EDDY (USA)**

Rapporteur: **Dr. Ju. ROSTOPSHIN (USSR)**

16:35 - 17:05 **J.P. HETTELINGH (IIASA/Netherlands):** *Acid Rain in Europe: Regional and National Implications*

17:05 - 17:30 **D. ECKSTEIN (FRG):** *Tree Rings as Recorders of Environmental Changes*

17:30 - 18:15 **DISCUSSION**

18:15 - 19:00 **COFFEE BREAK**

19:30 **Sightseeing excursion of Vilnius - Departure from Palace of Art Workers**

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TUESDAY 23rd JUNE, 1987

SESSION III: MANAGEMENT OF REGIONAL RESOURCES

09:30 - 13:00	**CHAIRMAN:**	**Dr. Uno SVEDIN (Sweden)**
	Rapporteur:	**Dr. Juri TOMILIN (USSR)**
	09:30 - 10:00	**B. POSKUS, A. TIKNUIS, A. RACINSKAS (USSR):** *Principles of Organization of Agriculture and Landscape Reclamation in Regional Development*
	10:00 - 10:25	**W. MOOMAW (USA):** *Integrating Ecological Data Into Local and National Management of Wetland Ecosystems in the Williamstown, Massachusetts Area*
10:25 - 10:50	**B R E A K**	
	10:50 - 11:10	**V. MALISAUSKAS (USSR):** *Evaluation and Methods of Rational Use of Natural Resources*
	11:10 - 11:35	**Jan. MOROVIC (CSSR):** *Overall Structure of Decision-Making with the Help of Expert Systems*
	11:35 - 12:00	**Ju. ROSTOPSHIN (USSR):** *Methodological Aspects of Model Studies of Regional Development Consequences*
12:20 - 13:00	**DISCUSSION**	
13:00 - 14:30	**L U N C H**	
14:30 - 16:15	**Session III (Continued)**	
	CHAIRMAN:	**Prof. W.R. MOOMAW (USA)**
	Rapporteur:	**Dr. Jan MOROVIC (CSSR)**
	14:30 - 14:55	**Prof. BUDYKO (USSR):** *Regional and Global Problems of Biospheric Evolution*
	14:55 - 15:20	**D. SCHVITRA and R. GRIKIENIS (USSR):** *Mathematical Modeling of Population Dynamics of Insect Host and it's Main Parasytes*
	15:20 - 15:45	**K. JOHANN (Austria):** *Forest Resources and Conditions of Austrian Forests*
15:45 - 16:10	**DISCUSSION**	
16:10 - 16:30	**B R E A K**	
16:30 - 19:00	**Excursion to Trakai, Medieval Castle and Old Capital of Lithuania, XIVth Century** - *Departure from Palace of Art Workers, guided by* **Dr. R. Pakalnis, Dr. G. Pauliukevicius and Dr. A. Koncius**	
19:00	EVENING FREE	

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WEDNESDAY 24th JUNE, 1987

SESSION IV: ECONOMIC AND ECOLOGICAL MODELING OF REGIONAL SYSTEMS

09:30 - 10:45 CHAIRMAN: **Dr. Jan MOROVIC (CSSR)**

Rapporteur: **Dr. Jan OWSINSKI (Poland)**

09:30 - 09:55 **R. SOETEMAN (Netherlands):** *Economic Development and Ecological Sustainability: Methodological Framework for Conflicts and Compromises*

09:55 - 10:20 **J. OWSINSKI and A. STRASZAK (Poland):** *The Polish Case Study: Regional Impact of Large-Scale Mining and Energy Development*

10:20 - 10:45 **A.V. RUTKAUSKAS (USSR):** *System for Analyzing and Forecasting Regional Reproduction with regard to Technological Progress and Environmental Management*

10:45 - 11:05 B R E A K

SESSION IV (Continued)

11:05 - 13:00 CHAIRMAN: **Prof. A. BURACAS (USSR)**

Rapporteur: **Dr. Jan OWSINSKI (Poland)**

11:05 - 11:30 **K.D. JAEGGER (GDR):** *Stages and Trends in the Mutual Relations Between Human Society and the Environment from Neolithic to Present Times as a Basis for Prognistic Implications*

11:30 - 11:55 **M. EGOROV (USSR):** *Ecological and Economic Modeling in Terms of Flows*

11:55 - 12:20 **E. JOHANN (Austria):** *The Impact on Industry on the Landscape and Environment in Austria: 1850–1914 (A Case Study)*

12:20 - 12:45 **H. LUIK (USSR):** *Hierarchy of Planning Levels as a Basis of Optimizated Regional Ecological Management*

12:45 - 13:00 DISCUSSION

13:00 - 14:30 L U N C H

Wednesday 24th June, 1987 (Continued)

15:00 - 18:30 MEETING IN STATE PLANNING COMMITTEE OF THE LITHUANIAN SSR: LONG-TERM NATURE PROTECTION & MANAGEMENT

15:00 - 16:30 *Films on Lithuanian Nature Protection Programs*

16:30 - 18:30 **ROUND-TABLE DISCUSSION:** *Environmental Problems and Management in the Lithuanian SSR*

Panel Members:

- **Acad. A. YANSHIN:** Vice President of the Academy of Sciences of the USSR
- **Acad. L. KAIRIUKSTIS:** International Institute for Applied Systems Anlaysis, Laxenburg, Austria
- **Dr. L. LIANDZBERGAS:** Head of Department, State Planning Committee
- **Mr. K. GINIUNAS:** Chairman, State Committee for Environmental Protection of the Lithuanian SSR
- **Dr. M. MIKALAJUNAS:** Chairman, Committee for Hydrometeorology of the Lithuanian SSR
- **Acad. KONTRIMAVICIUS:** Department Chairman, Academy of Sciences of the Lithuanian SSR
- **Dr. R. PAKALNIS:** Scientific Secretary, Lithuanian National Committee for the UNESCO Programme "MAB"

18:30 **EVENING FREE**

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THURSDAY 25th JUNE, 1987

STUDY TOUR AND EXCURSION

09:00 - 18:30 A **study tour** to Kaunas and Girionys

Presentation of:

1. Lithuanian Landscape Management: conducted by
   Prof. N. Kudaba (Vilinus State University),
   Dr. R. Pakalnis (Institute of Botany), and
   Dr. A. Koncius (Institute of Economics).

10:00 - 10:30 Welcoming Address from the Chairman of Kaunas City Council
P. STASHKUNAS (USSR)

10:30 - 13:30 Sightseeing Tour around Kannas - Visit to the Ciurlionis Art Museum

13:30 - 15:00 L U N C H

2. Lithuanian Research Institute of Forestry in Girionys:

ROUND-TABLE DISCUSSION: *The Forest Sector in Regional Economic-Environmental Development*

Panel Members:

- **Acad. A. YANSHIN** (Vice President of the Academy of Sciences of the USSR)
- **Acad. L. KAIRIUKSTIS** (USSR/IIASA)
- **Prof. M. VAICYS** (Director, Lithuanian Research Institute of Forestry)
- **Dr. S. MIZARAS** (Head of Laboratory, Lithuanian Research Institute of Forestry)
- **Prof. V. ANTANAITIS** (Lithuanian Agricultural Academy)
- **Dr. R. DELTUVAS** (Lithuanian Agricultural Academy)
- **Dr. J. KENSTAVICIUS** (Head of Laboratory, Lithuanian Research Institute of Forestry)
- **Dr. S. KARASIJA** (Head of Laboratory, Lithuanian Research Institute of Forestry)
- **Prof. M. JANKAUSKAS** (Head of Laboratory, Lithuanian Research Institute of Forestry)

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FRIDAY 26th JUNE, 1987

SESSION V: **OPTIMIZATION METHODS IN REGIONAL DEVELOPMENT AND REDEVELOPMENT STRATEGIES**

09:30 - 11:00	CHAIRMAN:	**Prof. Lennart** SCHOTTE **(SWEDEN)**
	Rapporteur:	**Dr. Jan MOROVIC (CSSR)**
	09:30 - 09:55	**Prof. N.A. AGADJANIAN (USSR):** *Problems of Human Ecololgy*
	09:55 - 10:20	**Dr. J.Ya. BUDILOVSKIJ (USSR):** *Development of a Regional System of Industrial Waste Decontamination and its Realization in the Lithuanian SSR*
	10:20 - 10:45	**G. BURACAS (USSR):** *Ecological Assessment of Physical Fields on Living Organisms*
10:45 - 11:00	**B R E A K**	

SESSION VI: **THE ENVIRONMENT OF THE FUTURE**

11:00 - 13:00	CHAIRMAN:	**Acad. Leonardas KAIRIUKSTIS (IIASA/USSR)**
	Rapporteur:	**Dr. Renat PERELET (USSR)**
	11:00 - 11:25	**R.E. MUNN (IIASA/Canada):** *Environmental Prospects for the 21st Century: Implications for Long-Term Policy and Research Strategies*
	11:25 - 11:50	**J. CEKANAVICIUS (USSR):** *An Approach to the Evaluation of Regional Socio-Economic and Environmental Prognoses*
11:50 - 13:00	**DISCUSSION**	
13:00 - 14:30	**L U N C H**	

Friday 26th June, 1987 (Continued)

SESSION VII: FINAL DISCUSSION AND ADOPTION OF RESOLUTIONS

14:30 - 15:30 **CHAIRMAN:** **Prof. R.E. MUNN (IIASA/Canada)**

CO-CHAIRMAN: Acad. K. KONDRATIEV (USSR)

Rapporteur: Dr. Renat PERELET

14:30 - 14:40 **L. SHVYTOV (USSR):** *Mathematical Modeling Using Methodology for Forecasting and Assessment of the Regional Ecological Impact in Crop Production*

14:40 - 15:00 **K. KONDRATIEV (USSR):** *Closing Statements*

15:00 - 15:35 **L. SCHOTTE (Sweden):** *Future Policies and International Cooperation in Reducing Forest Damage*

15:35 - 16:00 **B R E A K**

16:00 - 16:45 **DISCUSSION**

16:45 - 17:15 **Meeting of Session Chairmen and Rapporteurs**
Preparation of Concluding Statements

19:30 - 22:00 **Ballet performance of "Copelia" (L. Delibes), at the State Academic Opera and Ballet Theatre (A. Vienulis Str. 1)**

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