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On the Future Role of Environmental Systems Analysis

Leen Hordijk
Director, International Institute for Applied Systems Analysis

Thank you, Mr. Chairman. It is a pleasure to be here. I have been at this Congress for about two days and have enjoyed many presentations and discussions. I would now like to draw from my experience in environmental systems analysis, in particular from the multidisciplinary collaboration and from the interaction with policy making. I will be using my experience in IIASA, my participation in the negotiations in Geneva about air quality in Europe and other systems analysis projects that I did in the Netherlands. I am trying to draw some lessons from the history of 30 years in applied systems analysis.

I would like to start with an anecdote. I am a professor of Environmental Systems Analysis at the Agriculture University of the Netherlands in Wageningen. But that field description came quite by coincidence, because when I was asked to apply for the job in Wageningen, the chair could not be called "Environmental Science", which was my preferred terminology. This impossibility was not because of the English words, but because of the Dutch word used: "Milieukunde". That word was not appreciated very much by the disciplinary people, because it suggested a well defined field that, according to these colleagues, was not the case. So at Wageningen, in 1991 we did not want to upset the atmospheric scientists, the aquatic people, et cetera, and "Milieukunde" was more or less forbidden. I had to invent another title for the chair: Environmental Systems Analysis (ESA). Of course I had to write the definition of this field and develop the teaching program. It was a learning process, implementing ESA in classes for Dutch and foreign students of environmental systems analysis.

The outline of my lecture is as follows. I'll first introduce IIASA as it is at the moment. Many people have heard of it. Quite a few in this conference are connected with IIASA, are alumni, or were visitors. They came from science, industry and governmental offices. Then I will present a few examples of environmental systems analysis as done at IIASA in the last 20 years. I will then turn to the goals and tools, of ESA. Thereafter I will address barriers and solutions to remove barriers in applying systems analysis in the field of the environment. Finally, I will draw conclusions and discuss priority topics as I see them.

The International Institute for Applied Systems Analysis (IIASA)

IIASA started about 33 years ago at the initiative of the Soviet Union and the United States who wanted a scientific institute in which they would collaborate rather than be involved in cold war issues. Through intensive discussion at very high political levels these countries had come to an agreement about the focus and the name of the institute. Systems analysis was found to be a neutral enough term to satisfy both camps. The name has not been changed until today.

IIASA was meant to be a research center to bridge the East and West, and it stayed that way for about 20 years. The Institute has fulfilled its role because scientists from the Soviet Union but also from countries such as Poland, Czechoslovakia, Hungary and the German Democratic Republic joined with their colleagues from Canada, the United Kingdom, Japan, The Federal Republic of Germany, the Netherlands, Sweden, and other Western European nations.

Of course the geopolitical situation changed drastically at the end of the 1980s, and thus the institute had to change. IIASA is still doing systems analysis but the Institute is much more focused on North-South issues and generally dedicated to research on global change; not just global environment change but also technology, economics and social systems.

Membership has also changed. We have added members from China and Egypt, and hopefully very soon also India and South Africa.

IIASA is independent, a characteristic that I will use later on when I explain why certain topics have been successfully addressed at IIASA which might not have been successful if carried out in another institute.

IIASA is non-governmental, and that means that our members are non-governmental organizations like academies or national research councils. In some countries there is a special committee for IIASA. Of course indirectly all the funding comes from governments because most science funding comes from governments.

IIASA is inter- or at least multi-disciplinary. It is not organized in faculties but in research areas, where natural scientists and social scientists work together on an issue, e.g. in environment, in agriculture, in energy, in technology or in forestry. We attempt to cross the disciplinary boundaries by putting people together in one research program.

We employ about 160 scientists annually, but many people come to IIASA for short periods or only part-time. The 160 people represent only 80 person years, and they come from over 25 different nations. About 40% of the scientists have a background in the social sciences, others come from natural sciences, mathematics and engineering.

IIASA has many collaborators across the globe. More than 3,000 scientists have worked at IIASA including many in Japan. Many of them continue to work with us after their return to their home countries or moving on to other institutes outside their nations. I am one example. My first visit to IIASA was at a conference in 1979, and then I worked as project leader from 1984 till 1987. I returned as Director of IIASA in 2002. There are many people like me who want to stay involved with IIASA for the rest of their lives.

The Institute's official goal is "to conduct international and interdisciplinary scientific studies to provide timely and relevant information and options, addressing critical issues of global environmental, economic and social change, for the benefit of the public, the scientific community, and national and international institutions". This is a long sentence and I would like to stress a few words. One is "international and interdisciplinary," which I already mentioned, but the other one is "issues of global environmental, economic and social change." We work for the benefit of the public, the scientific community, and national and international institutions. And the emphasis is on the word "applied," applied meaning to solve a problem and that is also what I will expand on in the next half hour.

IIASA's Governing Council approved our research program for the next five years just this June.

In the "Energy and Technology" theme we have three programs: one on energy, one on technology and one on dynamic systems. The latter is more mathematically oriented with a focus on optimal control and game theory.

In the energy program we are quite known and experienced in developing global energy scenarios which have played and are playing an important role in the international climate negotiations.

The technology program tries to look into the "black box" of technologies and investigates diffusion through space and time. What are the most important factors for diffusion? Why do some technologies get used and others not?

Our theme "Environment and Natural Resources" includes four programs: evolutionary ecology, land use and agriculture, air pollution, and forestry. We do not have a separate program on water, although all of these four programs pay attention to water issues. I will come back to the atmospheric program because I use that program's model as an example of successful systems analysis.

The ecological program is on the one hand more theoretical. They publish at least once or sometimes twice in a year an article in the journals Science and Nature. On the other hand this program applies its knowledge in practical issues, such as fisheries.

The forestry program has a focus on the role of forests in the carbon cycle and a focus on forest governance issues.

The land use program's strategic goal is to support policy makers in developing rational, science based and realistic national, regional and global strategies that achieve long-term sustainability and environmental stewardship of land and water resource management for the production and distribution of food, fiber and bio-energy, while promoting rural development.

The third theme is "Population and Society". The programs in this theme have an orientation on the social sciences, although natural sciences are also present.

The "Population and Climate Change" program is funded by the European Young Investigators (EURYI) awards. We were very proud that last year a young brilliant scientist, of IIASA won that award and is now leading this program. His focus is on the behavior of consumer and households and their impact on climate change. This is very important because most research programs world wide focus on governments and industry.

The "World Population" program is known for its global population projections and has improved the methodology in this field, including probabilistic estimates.

The program "Processes of International Negotiations" is a network of collaborators across the globe that publishes books and gives courses in a variety of places including Cairo and Teheran.

Finally, this theme includes the "Risk and Vulnerability" program. Risk has been a research area at IIASA since its beginning. We will focus in the near future on risk and vulnerability rather than on risk as a single cost and consequence calculations.

Since the beginning of this year we have two special projects and a crosscutting activity. The last one, the greenhouse gas initiative, is a combination of work done in six of the other programs which all deal with an aspect of climate change. We try to bring the people who work on climate together in one across-the-institute effort to be more effective and more helpful in climate change. Principal research activities include the development of long-term, global scenarios that meet the UN Framework Convention on Climate Change objective.

The special project "Integrated Modeling Environment" will start as of January 1, it will be led by Marek Makowski, chair of this afternoon, and it will also have a focus across the institute. The strategic goal of this project is to build capacity to meet IIASA's growing needs for integrated modeling support where commonly known methodology and/or general-purpose modeling tools are inadequate.

"Health and Global Change" is a new project that will look at the emerging issues of global influenza epidemics especially the socio-economic aspects of it.

Environmental Systems Analysis (ESA)

Environmental systems analysis is a quantitative and multidisciplinary research field aiming at combining, interpreting and communicating knowledge from the natural and social sciences and technology. It is a multidisciplinary effort trying to bring together in a quantitative way as many aspects of a real life problem as possible, including the communication of results of the systems analysis.

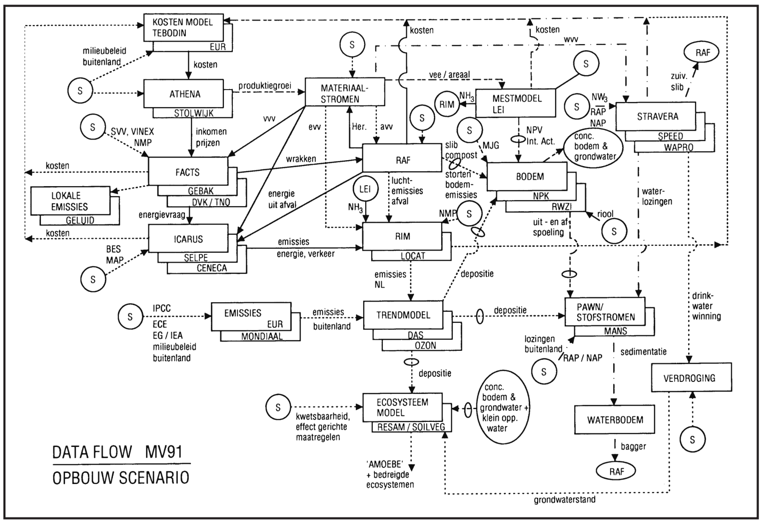


Figure 1. Graph of an Environmental Systems Analysis for the development of the national environmental outlook of the Netherlands in 1991.

The mission of ESA is to develop methodologies and tools and to apply these tools in strategic research topics which are mainly society-driven. ESA is thus not just for the sake of science, to improve our understanding, but it also tries to address topics of benefit for society. The applications of ESA describe and analyze the causes, mechanisms, effects and potential solutions for specific environmental problems. My own research has been focused air pollution as one of the fields of environmental problems with some links to water, soil and waste management.

Figure 1 is my standard scary picture for the students in Wageningen when I teach environmental systems analysis. I am not inviting you to understand it or even have a close look at it because it is in Dutch. It is a diagram from1991, when the Netherlands National Institute of Public Health and Environment (RIVM) were preparing for the first time a national assessment of the environment. That was a full-blown environmental assessment, not just the quality of water and air, but also what one might call the social drivers of it, the economics, the energy use, the transportation, et cetera, et cetera.

This picture is an environmental systems instrument in which the causes of all environmental problems in the Netherlands have been brought together with the environmental consequences and options for alleviating these consequences. In the boxes you see the abbreviations (in Dutch) of models, data bases, and indicators that come from various research institutes and ministerial offices.

What we hoped to achieve with this picture is to get a handle on the very complicated issue of environmental quality in the Netherlands. It is important to note that this is not meant for forecasting, but just for projections.

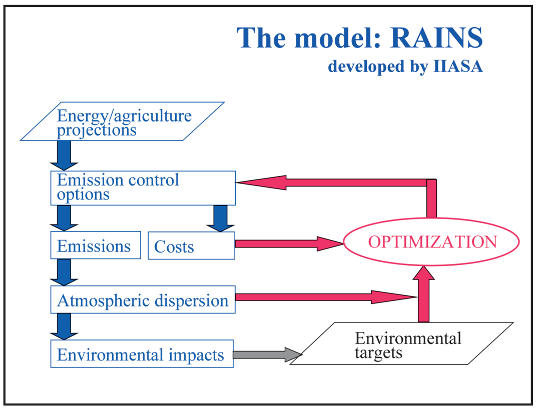


Figure 2. The RAINS model of IIASA (around 1995)

Now I show a much simpler ESA picture that was also described by Marek Makowski in the first session of Symposium 6 in this conference. IIASA has developed a model called RAINS which stands for Regional Air Pollution Information and Simulation model. It consists of varying modules, and includes the socio-economic drivers of the air pollution problem in Europe. The work started in the 1980s with a focus on the major air pollution issue of those years, acid rain. Figure 2 shows the structure of RAINS in which you will note modules for socio-economic aspects (energy and agriculture), for technology and economics (the emission control options), for atmospheric dispersion, and for environmental impacts. The RAINS model has been and is still being used in two ways. The first type of use is to generate environmental impacts of energy and agricultural scenarios.

The second way of using RAINS is to find minimum cost solutions for emission controls given environmental targets. In the 1980s RAINS was used for finding least cost solutions for reducing the levels of acid rain to a given threshold. European negotiators had agreed on those thresholds and used the IIASA model as a basis for their discussions about sharing the cost of improving the environment. Today, RAINS includes many more air pollutants, such as nitrogen oxides, ammonia, hydrocarbons, and particles.

The use of RAINS in real life negotiations has been studied by many social scientists, because it is a rare example of practical use of environmental science in negotiations. Why was RAINS used? Which factors played an important role?

Getting RAINS used by practitioners has been a long process. Model development started in 1983, and is still continuing, but the first real success took place in 1994, ten years after the start of work, when the Second Sulfur Protocol was signed in Oslo (Norway). The model was not used as a recipe for the negotiators but as a menu to choose from. A menu with numerous options for alternative clean air policies in Europe based on the latest state of science and on an agreed international data base.

As I have said in another session, one of the lessons I learned in this process, in the early life of the RAINS model, came from a very experienced Dutch negotiator in environmental issues who said to me, "Leen, I don't want a recipe from you; I need a menu to choose from." And I think that has guided the attitude of IIASA group over the years, that they will not be the scientists telling the negotiator what to do, the normative approach, but they gave them a set of options: if you decide to do this, then that will happen.

In 1994, at the signing of the Oslo Second Sulfur Protocol, there was a late hiccup because one of the countries, and I'm not at the liberty to say which one, one of the central European countries, all of a sudden came up with disagreement. Of course all of the European leaders were present in Oslo and wanted to sign the Protocol; thus they had to find a solution very quickly. We were asked to meet the negotiators in a room with doors closed and to do a quick calculation: what would the impact on neighboring countries be if that particular country would not sign the agreement and if they would sign a lower percentage of emission reduction. We could do that in a few minutes to satisfy the ministers and the ceremony could continue.

The Convention on Long-range Transboundary Air Pollution (LRTAP) celebrated its 25th anniversary last December; and we dug up a few of the old pictures. Figure 3 shows a European soil acidification map as output of the RAINS model in 1984, Figure 4 shows RAINS output 20 years later, again for impacts of air pollution. This map is being used in the Clean Air For Europe (CAFE) program of the European Union.

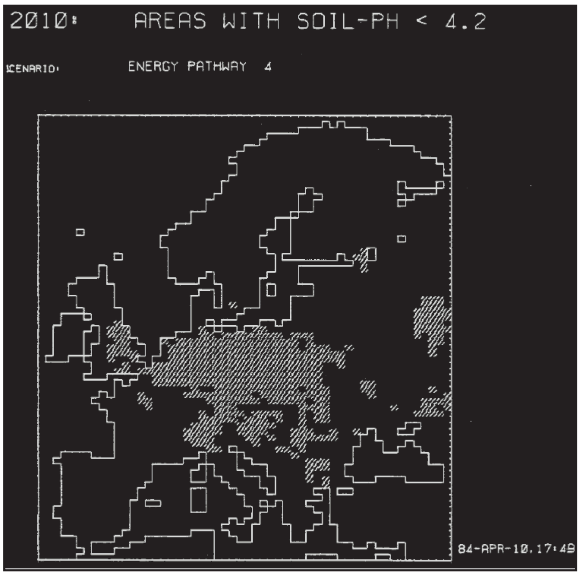


Figure 3. A map from RAINS 1.1.; soil acidification assessment for 2010 (April 1984)

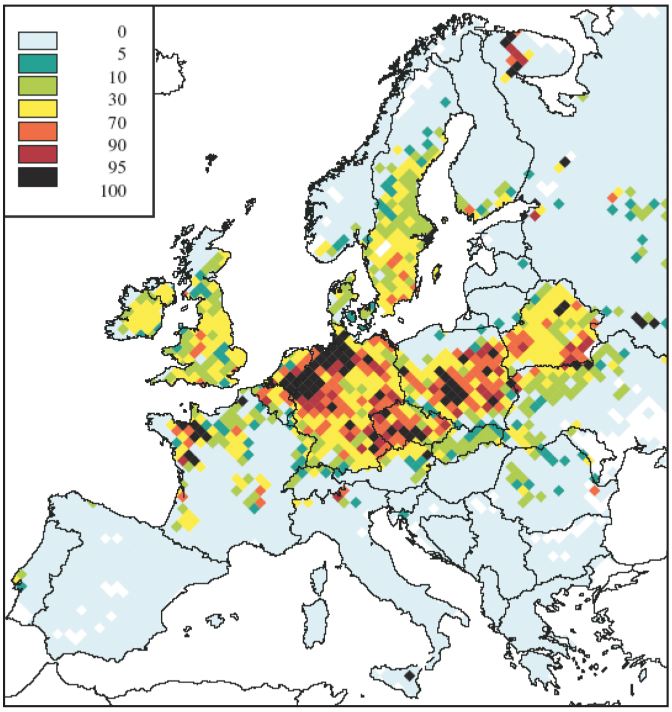
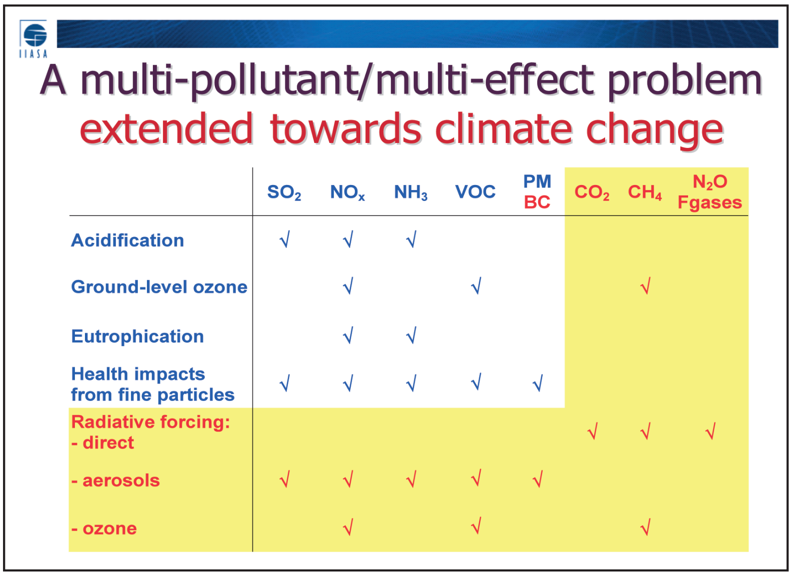


Figure 4. RAINS output in 2004 used in EU policy making

Today the RAINS model has been extended with many other air pollutants and most recently it has been coupled with greenhouse gases. The resulting GAINS model can be used to jointly analyze air pollution and climate change. This new model will have different versions for different parts of the world: Europe, Asia, Latin America and Africa



IIASA

A multi-pollutant/multi-effect problem extended towards climate change

	SO_2	NO_x	NH_3	VOC	PM BC	CO_2	CH_4	N_2O Fgases
Acidification	√	√	√					
Ground-level ozone		√		√			√	
Eutrophication		√	√					
Health impacts from fine particles	√	√	√	√	√			
Radiative forcing: - direct						√	√	√
- aerosols	√	√	√	√	√			
- ozone		√		√			√	

Figure 5. The RAINS model extended with greenhouse gases can now be used for the joint analysis of air pollution and climate change

The land use and agriculture program of IIASA has a set of models that has been used to analyze the expected impact of climate change on agricultural vulnerability (See Figure 6). The IIASA team has combined emission scenarios (SRES), with results of four climate models (Global Circulation Models), an agro-ecological data base (AEZ), and an international trade model (BLS). The analysis has shown that already vulnerable countries in Africa, Asia and Latin America will become even more vulnerable due to long term effects of climate change. These results have been discussed at the World Summit on Sustainable Development in Johannesburg, 2002.

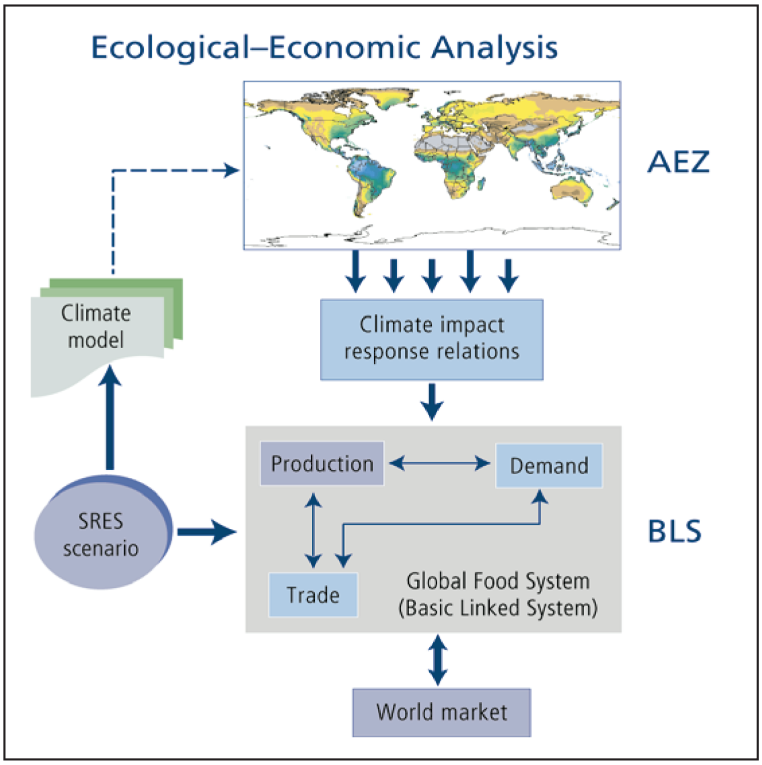


Figure 6. Set of coupled models for analyzing climate impact on agriculture

It is more and more important to involve stakeholders in environmental systems analysis. The RAINS example that I presented before is an example of successful stakeholder involvement. Another example comes from the IIASA program on Risk and Vulnerability. They have used their systems models about economic consequences of flooding in a poor region of Hungary. In a series workshops with local population, local and regional authorities and representatives from an insurance company and the World Bank they developed a new insurance scheme for potential victims of the next floods.

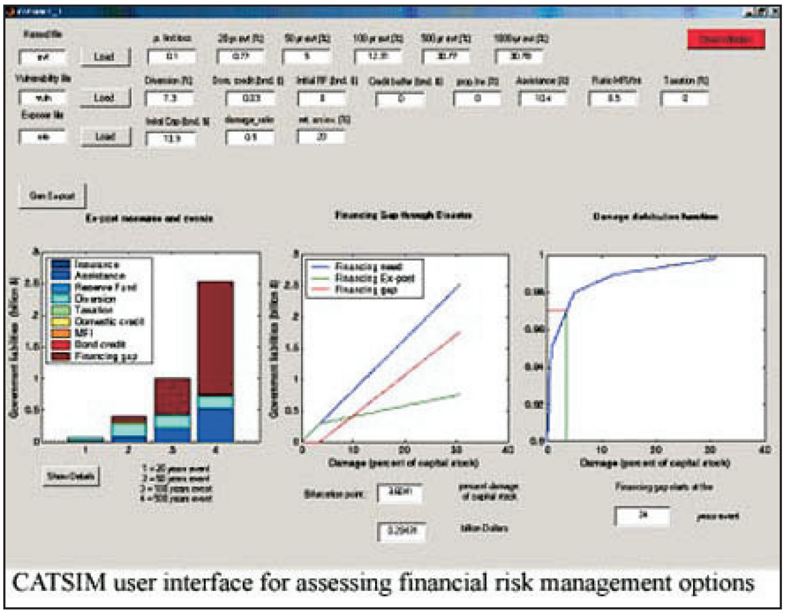


Figure 7. The CATSIM model is used for stakeholder meetings about catastrophes

The Forestry Program is about to start a new project for a solid analysis of development trends of the Chinese forest sector and the implications to other countries of this development. There is contradicting data and lack of relevant consistent official statistics and independent reviews. Therefore, there is a lack of consistent information for understanding and assessment of the implications of the development of the Chinese forest sector.

Tools of Environmental Systems Analysis

The goals of environmental science analysis are to build integrated models and to use these models for generating what I call "futures": scenarios, images, story lines, visions. It is also the intent to have others use those futures to obtain insight in the problems they are addressing. An example of this is the RAINS model and how it was used in Europe.

The tools of ESA are related to your fields of expertise: modeling, estimation (from my own background in econometrics), optimization (which is more in your field), multi-criteria analysis, scenario construction, uncertainty analyses, indicators, example, and communicating to the policy-making area. The latter belongs to the field of the social sciences.

A large part of ESA is devoted to the use of models. Models connect disciplines. And that role constitutes a large part of my own experience. I remember most vividly discussions in the RAINS project in the 1980s about the ways in which we connect models from different disciplines with each other. For example, the atmospheric model calculates the deposition of air pollutants and the forest soil model uses that as input for its calculation of air pollution impact on forest health. We had discussions about the "forest filtering factor", the degree to which trees, in particular the edges of a forest, catch air pollutants effectively form the air that passes the forest. The forestry colleagues thought that this would be part of their model and the atmospheric colleagues deemed it their turf. This led to discussions which were sometimes very emotional.

ESA also provides tools for Integrated Environmental Assessments or IEA. IEA is used to bring together all we know about a certain problem such as waste, climate, acid rain and so on. These assessments are aimed at being used in policy preparation to generate alternative options for policy, but also to educate policy makers. Again the RAINS work is a nice example of this.

An interesting study on Global Environmental Assessment which is about to be published by researchers in a project of the Kennedy School of Government (Harvard University) analyzes global environment assessments of air quality in Europe, global climate change, El Nino, and so forth. The authors found three factors that are important for the success of Integrated Environmental Assessment: credibility, legitimacy and relevance. Credibility refers to the scientific and technical believability of the assessment to a defined user of that assessment. The assessment has to satisfy users that it is scientifically and technically sound. Users accept assessments as credible when the information is consistent with other information already available, when they trust the source as authoritative or when the assessment process has been according to scientific standards. Legitimacy refers to the political acceptability or perceived fairness to a user of that assessment. The assessment has to satisfy users that the assessment process has been fair and that the users' interests and concerns have been taken into account. Salience (or, in more common terms: relevance) refers to the extent to which an assessment and its results address the particular concerns of the user. In the first place the user has to be aware of the assessment and the assessment must be relevant to current policy and behavioural decisions. The assessment has to address questions that are relevant for the user.

Stumbling blocks for interdisciplinary collaboration in ESA

What are the problems when building and using models, when carrying out environmental systems analysis?

In my experience a major stumbling block for collaboration across disciplines is that the research questions are formulated by one side, in most cases by the colleagues from the natural sciences. And this is particularly so in areas like climate change, where research proposal initiatives are taken by physicists, meteorologists, and biogeochemists. It happens frequently that natural scientists formulate the research questions and then very late in the process realize themselves that they need social science involvement. They call a colleague from another faculty or another university and ask "Can you join in this proposal?" Thus the social science aspects of, for example, climate change will not be very well integrated in the research proposal and later on in the research project itself. This most frequently leads to problems in the collaboration after a year or so. Also the output of such research is frequently judged to be not policy relevant.

A second stumbling block is that concepts in scientific disciplines differ. Sustainability, the buzz word in environmental research since the Brundtland report in 1989 is an example. I am pretty sure that if you put a biologist and an economist together they have different explanations of the word "sustainability", because economists of all sorts have some notion of efficiency or effectiveness in relation to sustainability, whereas for an ecologist it is probably not related to economic notions.

Thirdly, interdisciplinary collaboration is threatened by semantics. Earlier in this conference I attended sessions where a heated debate took place between hard and soft systems science. Various colleagues heavily discussed the boundaries of these two approaches and fought about their turf and the perceived underdog role of 'soft systems science'. First of all I don't like the word "soft" in relation to systems, because it has a connotation of 'not reliable', 'not good enough'. I know it was developed in the history of systems science, and it served its role to discuss different approaches in systems science. However, it has not served to provide a bridge between the natural sciences and the social sciences. Semantics, language is very important in interdisciplinary collaborations.

Lack of commitment is the fourth stumbling block. Interdisciplinary work requires teamwork and teams are not easily built. It also takes time to understand each other and to devote enough attention to it. In my experience in air pollution and climate change work I realized myself that these topics are closer to the heart of the natural scientists than to the social scientists. I noticed much more commitment by the first and less by the latter. It could be that social scientists have so many other policy related topics to address like transportation, forest management and globalization that the environment is just another issue among many.

In the fifth place, I see the stumbling block 'misconception of roles and place'. I could again refer to "hard and soft science", but this stumbling block has also to do with the attitudes that I sometimes have noticed with natural scientists with regard to social scientists. They see themselves as the leaders of the projects and the social scientists as those who make their, the natural scientists', work policy relevant. They have a misconception of their role and down play the value of the social sciences.

It is difficult to attract good scientists to interdisciplinary collaboration in environmental systems analysis. Young and very good scientists are under constant pressure to 'publish or perish', to publish in disciplinary peer reviewed journals with a high impact factor. There are not many good and high impact journals that publish ESA results. Thus the very good scientists might be in doubt, and they might fear for their careers if they join these projects. They might not be interested in joining these groups, and thus we have to create opportunities for publication and exchange.

Another and final important stumbling block is poor communication and what I call physical separation. The RAINS project was carried out by a group at IIASA with offices in one corridor, which facilitated easy and daily communication between the scientists working on different parts of the model.

After I left IIASA in 1987 and went back to the Netherlands, I was in charge of a project to build an acid rain model for the Netherlands, but that failed in the first year. A major cause was that some scientists were located in Utrecht and others were in Amsterdam and Wageningen. It was not until I had brought everybody to one building at RIVM (the Netherlands Institute Public Health and Environment) that the model was really being built as a joint interdisciplinary effort.

Solutions

What helps; how to get rid of the stumbling blocks? Of course one line of attack is to realize the importance and presence of all the above stumbling blocks and to avoid or counteract these. That means invest time and effort in drafting proposals, research questions and work plans together. Project leaders should search for the top scientists in the respective disciplines and avoid the situation that environmental systems analysis is being seen as the dumping ground for not-so-good soil scientists or not-so-good mathematicians, or, in general, not-so-good people in their field. In order to be able to communicate well with others about their fields and subjects, you should be good in your own subject. To attract excellent young researchers, environmental systems analysis projects and integrated assessments should include some sub-projects that are well defined and limited in scope. That will present these young scholars with opportunities to publish in the disciplines that they were trained in.

Proposals for research should be judged by multidisciplinary panels of review to be valid. In my time as chairman of the Social Science Council of the Netherlands, we established those panels because it had become clear that many funding proposals failed to pass the review. Disciplinary review of an ESA project led to rejections because these did not live up to the standards of, for instance, the chemists, economists and meteorologists. Reviewers did not appreciate renewal in these proposals and they found them not to be at the edge of their disciplines. Of course they were not, they were not meant to be. The panels worked well in providing a fair chance in competing for scarce research money.

Intellectual respect and respectability are difficult to achieve because they are related to the long held view that social science is not really a science. Building mutual respect will be hard and requires experienced project leadership.

Long-term commitment is needed for a successful ESA project. It is, however, difficult to achieve because most funders of research want to see results quickly. They run out of money and patience when results take time. In an institute like IIASA long term commitment can be built. In my case it was the IIASA director, Thomas Lee, who in 1986 said "I haven't seen any success of the acid rain project yet, but I think it has potential to become a flagship of IIASA." And thus he continued to fund it, and it became a flagship indeed.

Conclusions

1) Applications in environmental systems analysis are manifold. There is not a single method or recipe for success and thus I do not support the sometimes heard call for standardization in the field. Different applications of ESA require different sets of combinations of tools of ESA. That is why transferability of methods is limited. The method used to make a successful ESA model for integrated assessment of acid rain in Europe is not necessarily a successful method for the global impacts of climate change. Of course, one can learn from each other's successes and failures, but that does not need standardization.

2) Social science plays a very important role in policy advice, but is underrepresented in environmental systems analysis. I still see limited involvement of these colleagues. That is partly due to the way in which the projects are actually formulated, but it is also because of the unwillingness of some of the disciplines in social science. My example is from the Netherlands where the national climate research program has a large number of social science questions related to climate issues. But the interest in the country was rather limited. One really had to go out and find economists and sociologists and political scientists to reach significant involvement. It is a two-way street: natural scientists should be more willing to involve social scientists in the early stages of development of research plans and social scientists should be more willing to educate themselves about the basics of the relevant natural sciences.

3) The documentation of ESA and integrated assessment is rather limited. We see descriptions of models, but seldom an analysis of the processes of collaboration, of building a team, of communication with stakeholders and of applications in the policy formation process. The exception is the application of RAINS in the European context of air quality policy. I have seen at least four doctoral theses in social sciences that used the RAINS case to illustrate useful interaction between science and policy based on environmental systems analysis.

4) For the future, I see the following priorities (based on my IIASA experience and earlier work in the Netherlands). Firstly, uncertainty analysis, or as the other side of the coin, robustness of models is very important. Environmental systems analysis, with its focus on policy relevance and its use of large scale models is in need of establishing the credibility of its models. Therefore uncertainty analysis is important, not only in a quantitative way but also as part of quality assurance processes. I see that as a challenge for future systems research and thus as a challenge for this audience.

Spatial specificity is another problem that needs more attention. We build our global models but of course policy actions are taken much more on a local or at least a national scale. And thus down scaling of global models to regional, national and sub-national levels is important. However, we generally do not have data to perform the downscaling. Modelers have a tendency to refine their models more and more. I would like to warn for this tendency for two reasons: a) In down scaling one has to make many assumptions about (non)-proportionality; and b) Down scaling might increase uncertainty.

Stakeholder involvement is a third area of priorities for ESA. If the RAINS model work had not been done together with the policy makers, industry and NGOs in Geneva and in Brussels, it would never have been used, nor would we have had that success and influence. Thus the challenge for everybody in this audience is to think about how to better arrange stakeholder involvement and to improve the methods for a successful involvement. In a broader context, the challenge for the field is to establish means to bridge the science-policy divide and to make systems science, in particular environmental systems analysis more policy relevant.

Mr. Chairman, ladies and gentlemen, colleagues, I thank you for your attention.