Integrated Environmental Modelling: a Tool in Science and Planning

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Introduction

This paper concentrates on integrated environmental modelling as a tool in science and planning. Environment covers a wide range of interests and includes all aspects of the natural and the social environment. Modelling describes ways to present real world situations in a simplified form. A final aim of modelling is to cope better with the increasing level of complexity of today's planning tasks.

This paper is directed to students, to colleagues and to applied users of our research in the field of planning and administration. The paper should explain my way of problem understanding and the underlying philosophy how to contribute to problem solutions.

Individual modelling efforts have to be linked to a larger program. The practical applicability of science in planning is a leading principle. The integration of results is at least as important as results themselves. The ever-increasing load of information has to be condensed to serve problem management by decision makers.

The first theoretical part of the paper describes the framework of integrated environmental modelling, the second practical part describes the possible achievements of integrated environmental modelling taking global climate change and land use planning as example.

Theory of Integrated Environmental Modelling

Integration and science complement each other. Integration is arranging elaborated facts in a new way and thereby gaining new insights. Science is focusing on a particular field of interest and generating new facts by observations and measurements. The trend of developing away from each other became stronger than the trend to meet.

Meeting other disciplines is a time consuming process and one cannot be sure if this meeting will lead to results. For this reason scientists have not only to consider the content of their research, but also the method to share their results. Thereby individual scientific efforts can be combined within a common framework.

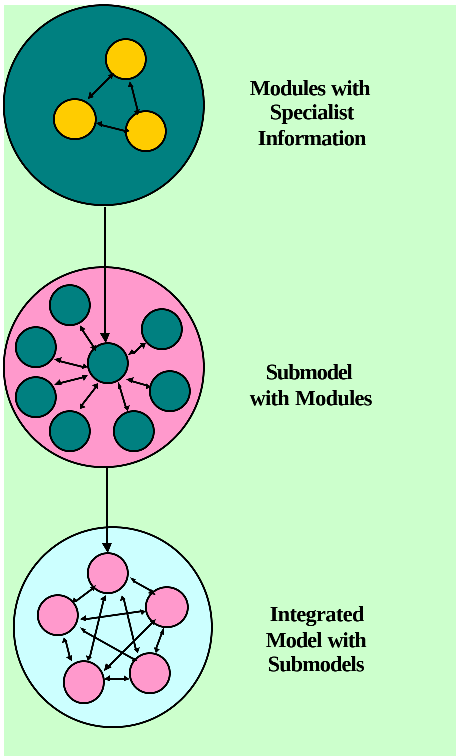
Integration of topics

At the beginning of the integrated environmental modelling exercise one will prepare a concept and determine all contributing subjects. This will be done on a subjective base, if a scientist can decide alone or according to the requirements of co-ordinated research programs. In most cases it will be a mixture of a predefined research concept and individual ideas.

The second step is to collect data according to concept as modelling depends on qualitative information and quantitative data. Social science data can be economic and population data. Natural science data are time series of climate, soil, vegetation or hydrology. Not all the topics of relevance are explicitly covered by data. Many qualitative concepts, like structural functionality of environment or human perceptions of nature are not yet considered adequately. There is a huge potential for improvement.

The third step is transfer basic ideas to formal mathematical modules. A large number of modeling techniques can be used for this purpose. But the more complicated single modules are constructed, the more likely are failures to integrate the module. It is not necessary to use all available data. There does not exist a straightforward approach but a long lasting process, which will hardly ever be complete.

Figure 1. Integration of various topics of interests



The figure shows the way of interaction. Let us assume an integrated environmental model to assess the economic importance of snow for Nagano district. The upper module can describe how snow is related to temperature and precipitation. The module is part of the submodel, which assesses the economic importance of snow, as a resource for skiing or as a problem for transportation and others. In the integrated model, the total economic impact of snow will be treated in an overall picture to economy of Nagano district, relative to four other factors of influence.

The fourth step is to integrate various modules to a larger topic within a submodel. There the information of various modules is used and combined together to a submodel output. The module can be used in many submodels and concern various topics. The submodel may produce a different kind of information (economic value of snow) than the module (amount of snow). Various submodels can thereafter be combined to the final integrated model (relative importance of snow as compared to other topics influencing the economy), which again provides a different output.

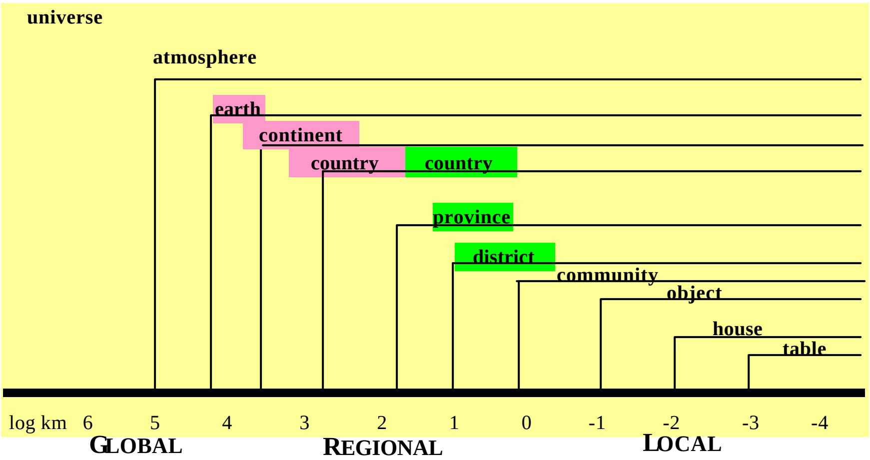
In a final fifth step, the output of the integrated model has to be related to the problem context. Consequences of the output have to be interpreted by the modellers. This is a retransformation of the formal output to the conceptual level. From there the results can be given to decision makers and influence various kinds of planning.

A theoretical field of science like mathematics with a sophisticated methodology has to level down its formal standards in order to meet the standard of other more applied disciplines like economists, engineers, architects or landscape planners. In general applied professionals have to gain more theoretical skills to transfer their experience into mathematical formulas as a mean of integration.

Space and time considerations

The integrated model has a reference space and a reference period to be valid. Outside the borders of space and time the model will have other parameters of influence. It is not possible to transfer know how from one place to another without a local adaptation. The dynamics of processes may be different in various spatial units. Spatial models interpolate missing spatial data for a particular region. Commonly such a model is called a GIS or geographical information system. Process models refer only to one location and interpolate data in time. Usually those models are covered by operation research methods. A key question to integrated environmental modeling is how to combine the combined output of the integrated model with GIS methods and operation research methods.

Figure 2. Integration of spatial scales

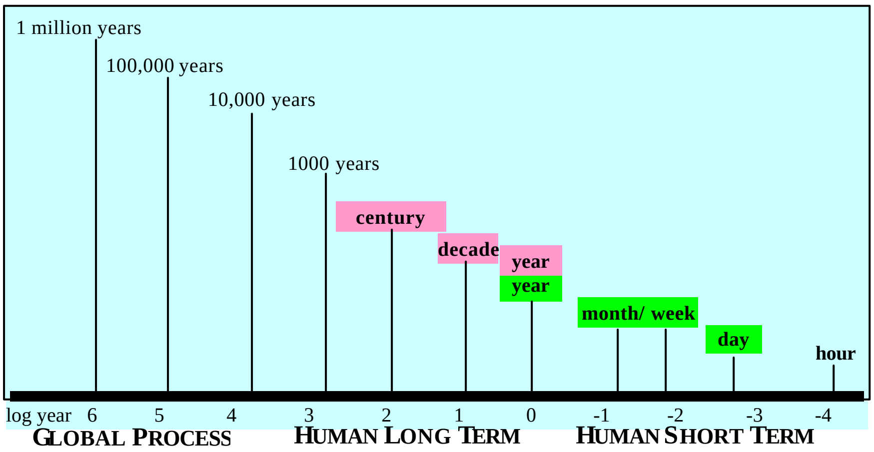


Every integrated environmental model follows a spatial standard. Within the global scales we find sub scales of atmosphere and earth. Within regional scales we find continents, countries province and district scales. Within local scales we find community, object, house and table scale.

A model should explain spatial and process relations with a minimum of data. The amount of observed data should be high as compared to the modeled data. Combinations of integrated models with GIS models and process models impair a higher risk of model mistakes than a specific GIS or operation research model in isolation. The number of modeled values relative to observed values increases over proportionate.

According to the model purpose, I will choose the "appropriate scales". Three spatial scales are considered to be appropriate for data handling. The largest scale will provide the overview, the medium scale will give rough variations and the smallest scale will yield fine variations of selected indicators.

Figure 3. Integration of time horizons



Every integrated environmental model covers many processes in time periods of 1 million years, 100,000 years, 10,000 years, 1000 years, centuries, decades, years, month, days or hours.

A distinction between process, period and dynamics is useful. Process is going on over time , a period terminates a process and dynamics indicate the degree of change in a period of the process. The period consists of subunits of the period, simply called steps. At each step we will find a data record for our analysis. The dynamics of long-term processes is not observable if their steps are larger than the observation period of our problem situation. In this case, we assume a structure that does not change.

Integrating topics, scales and process is not trivial with regard to the methodology. If we would like to combine spatial and process modelling, we have to limit our interests to key factors. Further, we should restrict ourselves to a rough space-time resolution to reduce the amount of data and increase the reliability of the integrated model.

In conclusion: integrated environmental modelling is a rather young field and that developed together with computer technology. At current, we find methodological obstacles to integrated environmental modelling. We need to define of what to integrate and how to integrate. We need spatial and time references. Progress was made in the applied science field and in practical problem management. The trials in improving the methodology are accompanied by improvements of conceptual thinking.

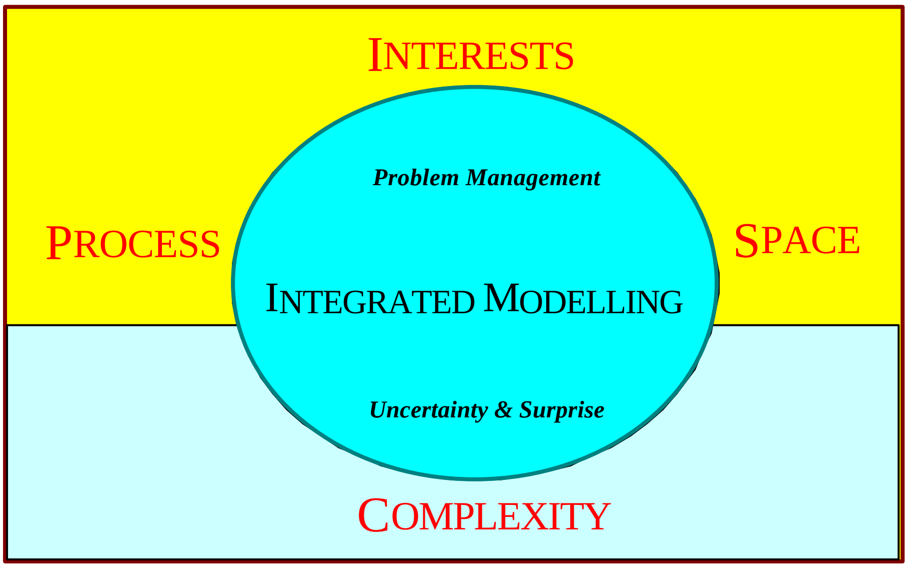
Example of integration: climate change and land use planning

Many interests drive land use planning, which covers landscape planning, rural planning, regional planning, urban planning and other kinds of physical planning. Integrated environmental modelling is - similar to planning - an open ended process. Important issues have to be added to the integrated model over time. The interests of the society determine what should be modelled and managed.

For practical applicability, it might be a good idea to work with administrative borders. Using a grid pattern is also useful, if I relate the grid points to administrative units. The planning aim is not explanation (which can be a scientific aim), but management. Within the chosen administrative borders I can locate responsible persons to change the current situation to a more desired future situation.

The expected users behind integrated environmental models are administrators, politicians and a concerned public, all together, so called decision makers. Figure 4 explains on how far we can come with integrated modelling. On top we find our interests that we want to integrate. The depth of analysis is dependent on our choice of process period and spatial coverage.

Figure 4. Problem Management by Integrated Environmental Modelling



The figure is divided into two rectangles and one oval. The oval maintains the problem to be solved with integrated environmental modelling. The upper rectangle covers interests, space and process, our known facts that we can define according to our task. In the green area of the oval, we can gain improvements in planning. The lower rectangle covers complexity. In the blue part oval, integrated modelling does not work.

When we manage a problem we have to improve shortcomings from interests, spatial resolution, and time. On the one – upper – side of Figure 4, the combination of known, but non related interests, spatial scales or time steps of processes will generate many new insights and improvements to planning. On the other – lower – side of the rectangle, we hardly cover all known interests, every important process or all spatial scales that we have at our disposal. The more we succeed to combine, the further down the baseline dividing the upper and lower rectangle will come. In addition we have unknown facts and relations which nobody can consider. Uncertainty and surprises will accompany the problem management, but we can do a lot to decrease them.

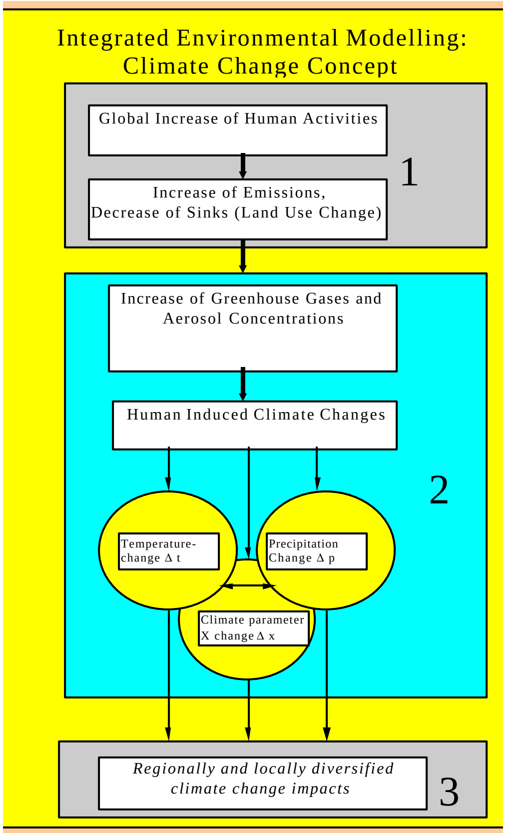
Possible human induced global climate change, perhaps one of the best-known fields of integrated environmental modelling, is used as an example. A large variety of scientists has contributed to this field and generated a common base of knowledge for the decision makers. They can be divided into three different groups.

Group 1 are those scientists, who explore the contribution of human actions to global climate change. They are concerned with increasing emission of greenhouse gases and the overuse of land in poorer world regions. The provide estimates of exhaust emissions connected with fossil fuel burning or losses of assimilative capacity of land. All models concerning the increase of CO_2 equivalents originate from this group.

Group 2 assesses the likely changes of single climate parameters due to changed concentrations of CO_2 . While today scientists agree that there will be a warming, they do not agree on the principal direction of other climate parameters like precipitation, frequency of extreme events and other more. They further disagree on the dynamics of likely global warming. All together these group of scientists use the models of CO_2 increase provided by their colleagues of group 1.

Group 3 translates changes of climate conditions into possible regional and local impacts. These impacts are highly relevant for local societies. The possibility of an increase in catastrophic events and a possible damage calls for counteraction. The threat is different from region to region. Flat regions and islands are threatened by sea level rise. Torrents and avalanches menace mountain regions. Agriculture and tourism are the most vulnerable economic activities with regard to climate. Figure 5 indicates on how the three groups relate to each other.

Figure 5. Three categories of global climate change research



Within each of those groups we will find different concepts and models. However, the concepts and models are continuously revised according to the results of other competing groups. In Group 1 major discussions concern the increase of fossil fuel consumption or the rate of land use changes. Group two has started to improve global circulation models with coupled ocean models. Most controversial are perhaps the climate impact models at the end of the chain. How should damage be quantified and how likely is damage? The costs to prevent disasters are high today while disasters may happen within decades.

On the other hand certain issues from before are considered as conventional wisdom: there is a warming of the atmosphere (in the 70s there was a competing cooling theory), fossil fuel emissions and land use changes do have an impact on the climate system. There will be drastic socio-economic impacts. The question is no longer "if", but "how much", "when" and "where". This silent agreement, the principle acceptance of the climate change theory, is considered more important for the foundations of planning than the open scientific questions.

An integrated environmental model is a tool to bring together scientists on the regional and global scale or concerned people on the local scale. The procedure of integrated environmental modelling counts most. The global climate change program and the international panel on climatic change, IPCC, including scientists and policy makers were indeed successful. Just 10 years after establishing a joint committee, a first agreement to reduce greenhouse gas emissions was signed in Kyoto in December 1997. Without integrated environmental modelling this would not have been possible.

Outlook

Integrated environmental modelling as a tool in science and planning. Current efforts in search for integration should continue and be enlarged.

We expect to contribute to this development. Our laboratory identifies in particular the practical implication of global climate change for land use planning in Japan. We started two projects during the last fiscal year. The first project investigates on how to reduce Japanese greenhouse gas emissions in relation to rice production. The second project assesses economic losses for the Japanese winter tourist industry in the case of global warming. Thereby global change research will become directly relevant for land use planning in local communities.

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WWW Links for further reading about integrated environmental models:

http://lee1.en.a.u-tokyo.ac.jp/meinhard/teaching/ruralplanning/rupla13.html
http://sedac.ciesin.org/mva/image-2.0/image-2.0-toc.html

http://crga.atmos.uiuc.edu/COSMIC/announce.html
http://sedac.ciesin.org/mva/iamcc.tg/TGHP.html

Links concerning methodology of integrated environmental modelling

http://www.lurpa.ens-cachan.fr/csap/publi/publi_93_3/hermes93_1.html
http://www.mcs.anl.gov/Projects/autodiff/AD_Tools/imas.html
http://lee1.en.a.u-tokyo.ac.jp/meinhard/teaching/ruralplanning/rupla06.html
http://lee1.en.a.u-tokyo.ac.jp/meinhard/teaching/ruralplanning/rupla07.html

Links to institutions promoting integrated environmental modelling

http://dis.start.org/news/int_assess_model.html
http://www.igbp.kva.se/secmenu2.html
http://www.wmo.ch/web/wcrp/wcrp-home.html
http://www.vu.nl/english/o_o/instituten/IVM/projects/research/efiea/links.htm
http://www.iiasa.ac.at/
http://www.cop3.or.jp/unfccc
http://sedac.ciesin.org/