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APPLICATIONS OF INFORMATICS IN ENVIRONMENT ENGINEERING AND MEDICINE

Editors:
Jan Studzinski
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This book consist of the papers describing the applications of informatics in environment and health engineering and protection. Problems presented in the papers concern quality management of the surface waters and the atmosphere, application of the mathematical modeling in environmental engineering, and development of computer systems in health and environmental protection. In several papers results of the research projects financed by the Polish Ministry of Science and Information Society Technologies are presented.

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CHAPTER 2

Mathematical Modeling in Environment Engineering

THE INTEGRATION OF KNOWLEDGE AND DECISIONS TO ANALYZE, SIMULATE AND ASSESS SPATIAL LAND USE DYNAMICS IN REGIONAL SCALE[1]

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An integrated approach on the research field "Land use – land cover change modelling" was developed. DPSIR models provide greater insight into the processes that are at work in complex environments. These frameworks aim at bridging between science and policy, promoting a better steering of complex terrestrial and aquatic ecosystems.

Keywords: DPSIR model, region, LUCC model, integrated model.

1. Introduction

The main purpose of this paper is to present an integrated approach on the field "Land use - land cover change modeling (LUCC models)" in the ongoing research project entitled "Meteorological and hydrological extreme events and their impact on the human environment". The framework that will be used in this paper is the DPSIR model (EEA 1999; Raju et al. 1999; Colijn et al. 2002).

Article 6 of the European Community Treaty states that "environmental protection requirements must be integrated into the definition and implementation of the Community policies and activities (...) in particular with a view to promoting sustainable development". There is a huge need to provide decision makers with tools to operationalize a sustainable development (SD), from the global, through regional, to the lower scales. While planning SD we must precisely define the subject of the development. Usually it refers to land assets, namely to the issues of change in land use and land cover (LUCC-*land use land cover change*). Tightly connected with the land are processes of erosion, of soil contamination, droughts, floods and other extreme events, problems of spatial planning, agriculture, forestry,

[1] Project of the State Committee for Scientific Research (KBN) No PBZ-KBN-086/P04/2003 and Inner University Grant of the Agricultural University in Szczecin "Land Use Land Cover Change (LUCC) Models". Author is contributing author in preparing IPCC report 2007, The IPCC WG2 AR4, Chapter 7 "Industry, Settlement, and Society", "Climate Change 2007: Impacts, Adaptation and Vulnerability. II. Assessment of Future Impacts and Adaptation: Systems and Sectors".

industry, tourism, services, protected areas, infrastructure, rural areas, towns, peripheral area, and many of other important aspects related to development and economic growth. Planning LUCC under SD we must take into account water assets (precipitations, cat-chments, basins, rivers, lakes, ground waters and others), their quality and impact on the human life. Land and water become more and more scarce resources.

Global changes are studied under supervising of The Intergovernmental Panel on Climate Change (IPCC Fig.1). The Intergovernmental Panel on Climate Change (IPCC) has been established by WMO (World Meteorological Organization) and UNEP (United Nations Environment Programme) to assess scientific, technical and socio- economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.

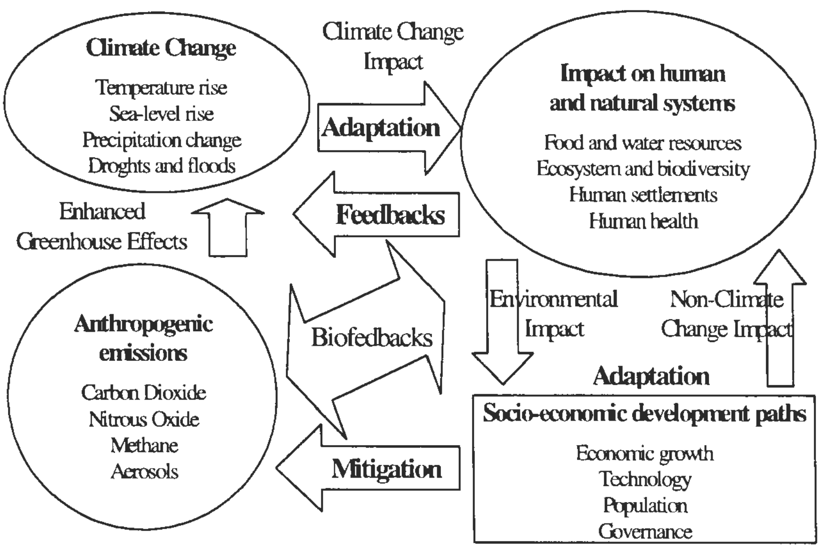

Figure 1. Main global processes on the basis of IPCC (Adaptation from IPCC 2001)

Real, visible for people problems of SD planning, however exist in the regional level. As never before, the integration of knowledge and decisions to analyze, simulate and assess spatial land use dynamics in regional scale, is needed.

While region?

„The most effective scale at which to create competitive advantage „... is at the level of regional clusters„". Paul Krugman, *Trade, Jobs and Wages* (1993).

„In a "learning economy" the competitive advantage of firms and regions is based on innovation, and innovation processes are seen as socially and territorially embedded, interactive learning processes." B.T. Asheim, *Learning Regions in a Globalized World Economy* (1996)."To be meaningful, the vision and actions must be set within a coherent framework, which requires setting priorities, encouraging partnership, and taking into account the global and regional environment....At the same time, many countries' strategies must be set within the context of developments within their region." J.E. Stiglitz, *Towards a New paradigm for Development: Strategies, Policies, and Processes* (1998).

2. DPSIR approach

The framework that will be used in this paper is the DPSIR model (Driving Forces–Pressure–State–Impact–Response, Fig. 2).

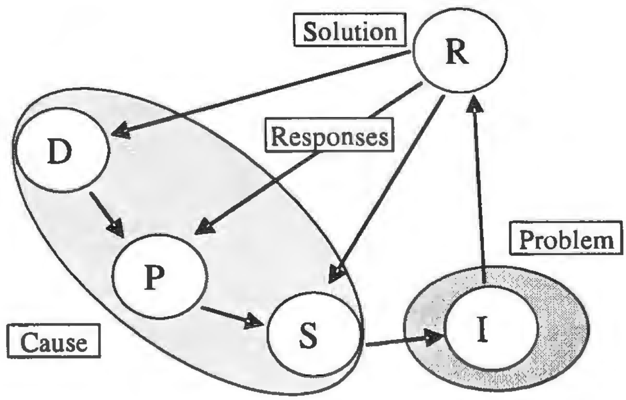

Figure 2. DPSIR model

It is a causal framework that is an extension of the PSR model (Pressure–State–Response) developed by the OECD (Organization for Economic Co-operation and Development). DPSIR models provide greater insight into the processes that are at work in complex environments (EEA 1999; Miklewski 2001, 2003; Miklewska 2004). These frameworks aim at bridging between science and policy, promoting a better steering of complex terrestrial and aquatic ecosystems. The DPSIR framework is viewed as providing a systems analysis view of the relations between the environmental system and the human system (Fig. 3).

According to this view, social and economic developments (driving forces) exert pressure on the environment and, as a consequence, the state of the environment changes (e.g. provision of adequate conditions for health, resources availability and biodiversity). This leads to impacts on human health, ecosystems and materials that may elicit societal responses that feed back on all the other elements. Although the DPSIR framework was developed as an extended cause-effect-response model, the framework is most useful in describing the origins and consequences of environmental problems. In developing linkages between the various categories, the dynamic relationships within a system can be analyzed (Fig. 4).

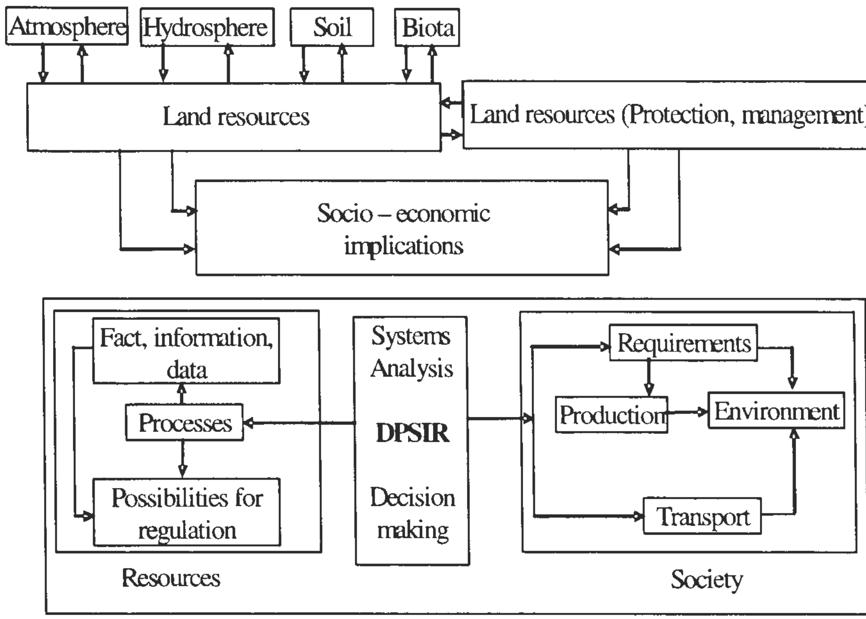

Figure 3. Interrelations Resources-Society

Ecological-economic systems are extremely complex. "Complex" means a lot more than complicated. Complex systems are characterized by positive and negative feedback loops, highly non-linear behavior, emergent phenomena, surprises and hazardous behavior. For example: extremely floods on research areas, arbitrary German decision concerning up-building of Hohensaaten-Fridrichsthaler Wasserstrase channel (HFW) which will disturb natural ecological equilibrium around trans-boundary protected areas along the Lower Oder protected areas (Ministerstwo Środowiska, 2003). The basic point in such systems is that the whole is greater than the sum of the parts. When dramatic change will occur, neither the direction of change, nor the state into which a system will evolve can be predicted. Evolution is a complex behavior, and ecological-economic systems co-evolve. In such systems, cause and effect is neither deterministic nor linear (Kay et al., 2000). Typical pure science is then thought to take place under conditions more or less described by Thomas Kuhn (1970) that is, doing puzzle-solving normal science within a paradigm that ensures the steady accumulation of relatively stable and certain facts, employing recognized methods. The paradigm in itself and the methods it includes will of course be theory-and value-laden – it is a world-view, if we believe Kuhn – but that is rarely a troublesome concern for the scientist in a period of normal science. In fact, he may never think about it at all, except in the occasional period of crisis. On the other hand, when doing science for policy, the researcher may face uncertainty and value issues on an everyday-basis. The standard phrase, often found in the papers referring to post-normal science, is that in some policy processes, facts are uncertain; values are in dispute, stakes are high and decisions are urgent (Funtowicz et al., 1999). So, for decision making process author proposes to take DPSIR chain (Fig. 4).

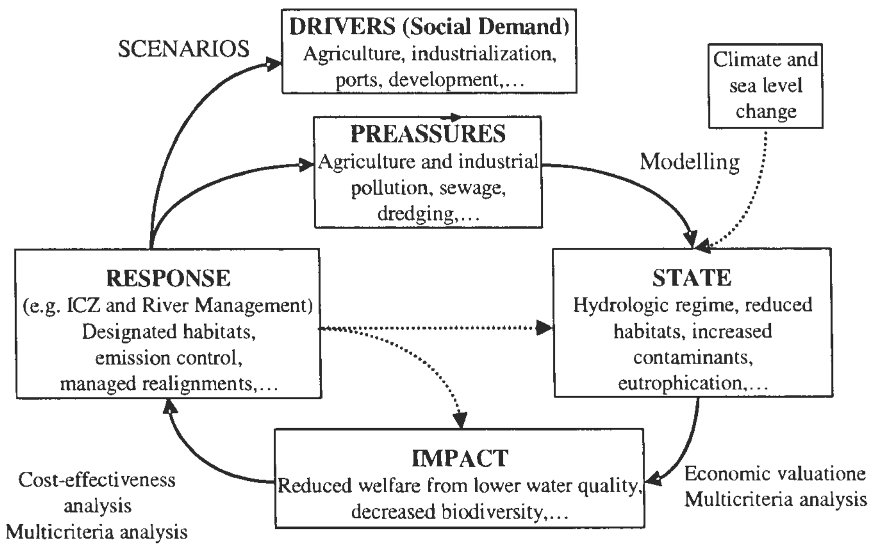

Figure 4. The DPSIR framework is a system for scoping of complicated management issues and problems. It can make tractable the complexity of causes of water resources, habitat/species, degradation or losses and the links to socio-economic activities across the relevant spatial and temporal scales. It also provides the important conceptual connection between ecosystem change and effects of that change (Impacts) on people's economic and social wellbeing.

3. LUCC modelling

Multifunctional land use – land cover change modelling (included water management) has recently received increasing attention, both as a planning concept and as a tool for integrated modeling (Fig. 5, Fig. 6, Fig. 7). When a multifunctional spatial planning design is used, socio-economic synergy benefits may be obtained, if several (complementary or mutually strengthening) functions are exercised at the same place and time (Rodenburg, Nijkamp 2002; Miklewski 2003). Sustainable use of soil and land is a complex issue, which must be based on scientific knowledge. But complex issues are difficult to understand, specifically for those at grass root level, e.g. stakeholders, as well as for those who provide solutions such a politicians and decision makers. The question is therefore how to bridge between the available scientific knowledge on one side and those who need it for defining policies and operational procedures.

There is a lack of linking element balances to possible ecological and economical risks. Element balances should link the relevant fraction of an element in soil (e.g. soluble or bioavailable fraction) to crop quality, to the effect of this element on the soil ecosystem, and to element losses through run off, erosion, leaching and gaseous emissions which in turn affect air and water ecosystems quality. Finally, links should be established between element balances and the economical aspects of various production systems so as to be able to evaluate different management options in view of a sustainable land use.

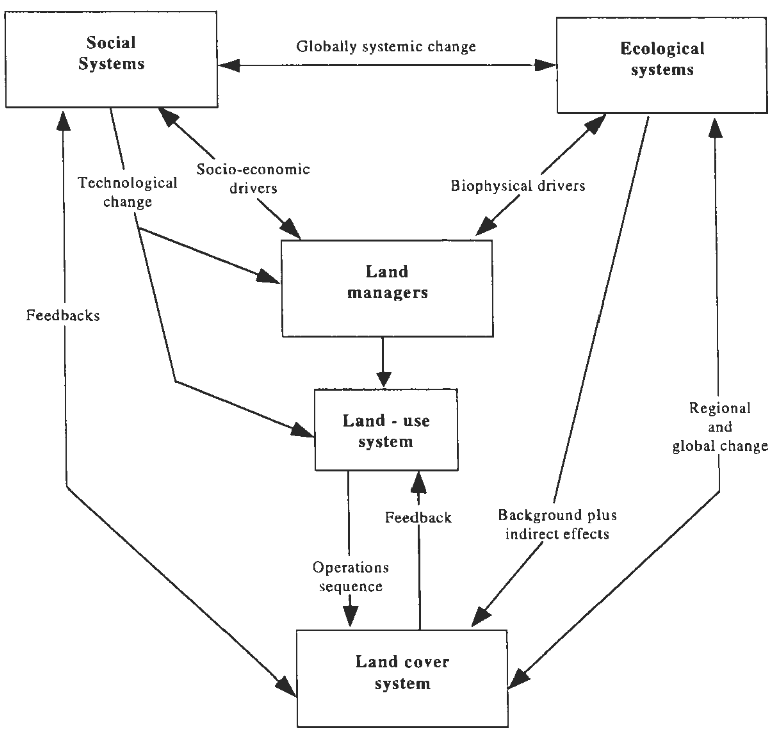

Figure 5. Framework for Understanding Land Use/Cover Situations

EC Directive 2000/60/EC establishing a framework for Community action in the field of water policy, commonly known as the Water Framework Directive (WFD), requires development and implementation of a range of technical tasks that relate inter alia to characterization of catchments, monitoring procedures, establishing relationships between catchment pressures and impacts on aquatic systems, and remediation measures where water bodies are considered to be at risk of failure to achieve their environmental objectives. The technical requirements of the WFD that necessitate scientific support are outlined mainly in Article 5 (Characteristics of the River Basin District) and its associated Annex II, Article 8 (Monitoring of water status) and its associated Annex V, Article 11 (Programmes of Measures), Article 16 (strategies against pollution of water) that addresses listed substances, and Article 17 (strategies to prevent and control pollution of groundwater). Detailed analysis of catchment characteristics, assessment of risk to surface and groundwaters, further analysis of existing information and collection of new data are all needed to support the implementation of the WFD. However, there is still much to understand about the relationships between the catchment and the movement of pollutants, and the response of the aquatic ecosystem to anthropogenic impacts.

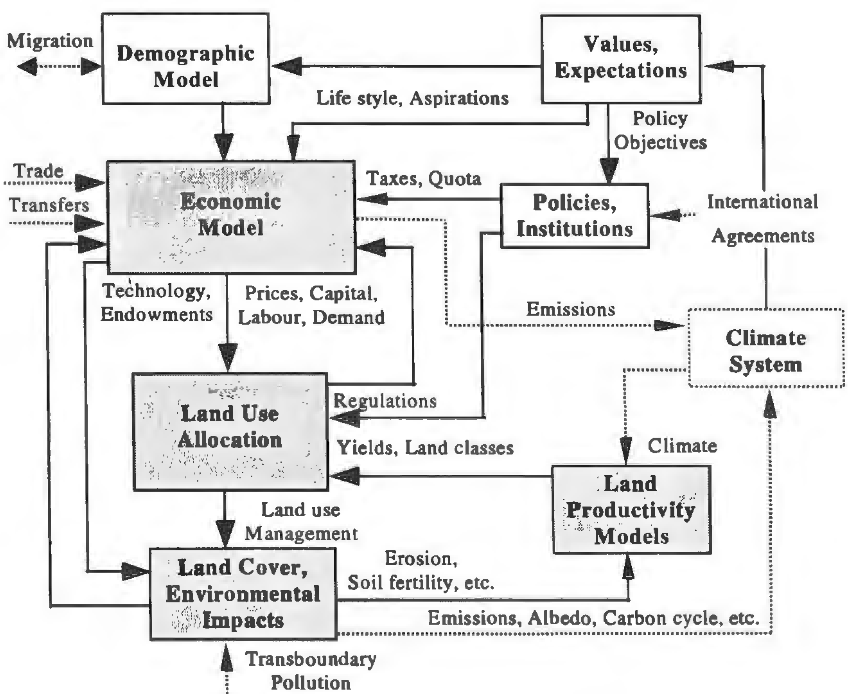

Figure 6. Integrated Land Use/Land Cover Modelling

Internal catchment processes, dominant pathways of pollutant load and hydromorphology are all important for the response of aquatic biological communities to pressures that arise within the catchment. Understanding these relationships is, further, restricted by the inherent complexity of natural systems. The simplification of that complexity through the identification of key variables and prediction of responses is a valuable tool as in DPSIR model. Such modelling is a likely feature of implementation of all of the technical Articles that support the overall objectives of the WFD.

The complex economic aspects of risk management aspects are presented in Fig. 7.

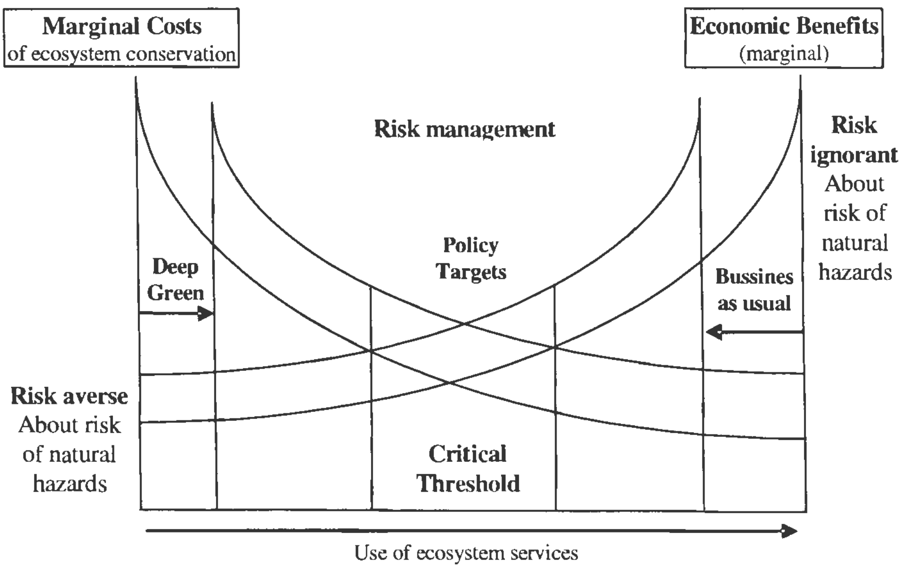

Figure 7. Economic aspects of risk management

4. Conclusions

The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill (Einstein, 1938).

From the above, the potentials of the DPSIR approach for decision making process and policy analysis in the field of natural resource management should result clear. Nevertheless the methodology for an effective implementation of a decisional process in the DPSIR framework is far from being clear, nor unique, as demonstrated by the substantial lack of implementations outside the field of environmental reporting. The adoption of the DPSIR scheme has been developed in a operational DSS tool by the ongoing research project within the development of innovative theory and methodologies aimed at transforming a static reporting scheme in a framework for dynamic integrated assessment modelling (IAM) and evaluation procedures.

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The purpose of the present publication is to popularize applications of informatics in environment and health engineering and protection. Runned papers are thematically chosen from the works presented during the conference *Multiaccessible Computer Systems* (*Komputerowe Systemy Wielodostępne*) that has been organized by the Systems Research Institute and University of Technology and Agriculture of Bydgoszcz for several years in Ciechocinek. Problems described in the papers concern quality management of the surface waters and the atmosphere, application of the mathematical modelling in environmental engineering, and development of computer systems in health and environmental protection. In several papers results of the research projects financed by the Polish Ministry of Science and Information Society Technologies are presented.

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