Observatorio Medioambiental ISSN: 1132-1660
2001, número 4, 19-47

Decision making and decision support systems for balancing Socio-Economic and Natural Capital Development

Angheluta VADINEANU*

ABSTRACT

The paper discusses briefly a hierarchical spatio-temporal framework to study globalization, economics and ecology for better understanding and conceptualization of the balance between biodiversity and Natural Capital (NC) on one side, and the Socio-Economic Systems (SES), on the other side, which was designed based on the recent achievements in the field of Systems Ecology.

Based on the conceptual clarification of the dynamic condictions for sustainability and on an extensive review of the most recent literature, there are proposed and discussed the decision support system and decision making model as the operational interface between Natural Capital components and Socio-Economic Systems, which might enable to establish and maintain the balance among them.

The identified weaknesses and gaps in the structure and function of the Decision Support System (DSS) show the need for extensive and long term research and integrated monitoring and for development and improvement of the methodology and tools.

KEY WORDS: Globalization economics, Globalization ecology, Natural capital.

CONTENTS

1. Introduction.
2. Basic conceptual and methodological elements for the co-development NC ⇔ SES.

Aceptado: 27/III/2001.

* Department of Systems ecology/University of Bucharest/Romania.

3. How to design the dynamic attractor for Sustainable Development?
4. Overview of decision support system structure.
5. Gaps, shortages and challenges in some basic components of the DSS.
6. Decision making for balancing Socio-Economic and Natural Capital Development.
7. Conclusions.
8. References.

1. INTRODUCCIÓN

The overall topic «Globalization, Ecology, Economy: Bridging worlds» is the most comprehensive and challenging one for all countries and regions in the world and in particular for both EU and CEE countries.

The European Conference which is designed to be focused on this topic is expected to make one step further in the very difficult process of operationalization of the general definition of sustainability as it was stated in the Brundtland Report (1987 WCED) in order to implement the sustainability vision in practical policy decisions. In this respect, I made an attempt to assess and integrate a wide range of operational definitions which were developed and checked in almost one decade (DALY, 1987; PEARCE et al, 1990; CONSTANZA et al, 1992, 1995, 1996; RENNING et al, 1997; HINTERBERGER et al, 1997; PROOPS et al, 1996, 1999; WALPOLE et al, 1997; RING IRENE, 1997; MUSTERS et al, 1998; RUIJGRAK et al, 1999; BERKES et al, 1994; CAIRNS, 1997; ARROW et al, 1995; DE GROU, 1995, 1998; WACKERNAGEL et al, 1999; AYRES et al, 1994; OGLETHORPE et al, 1999; VADINEANU, 1998) and I found the following basic requirements which have to be met in order to put in practice the concept of sustainability:

i. the assessment of the conceptual and methodological approach of development, establishment of state of the art in the field as well as the main gaps and shortages and the needs for further development and improvement;
ii. formulation of at least some of the basic elements of the dynamic model for «Co-development» of socio-economic systems and Natural Capital/«Sustainable Socio-Economic development» to be used as the «attractor» in the local, regional and global transition;
iii. identification of the premises or advantages (opportunities) and the limits or constraints each country and region may relay on or be faced in the designing and implementation of long term «co-development» strategies and action plans;

iv. identification of the existing shortages and gaps in the policy and decision making process dealing with sustainability and formulation of a comprehensive and dynamic model for the «decision support systems» as the interface or the operational infrastructure, the only one enabling us to balance the spatio-temporal relationships and the mass and energy exchanges between the Natural Capital Structure, serving as foot print and the Socio-Economic Systems. Taking the above statements into consideration, one can easily understand the reasons to have one background paper dealing with this specific topic.

2. BASIC CONCEPTUAL AND METHODOLOGICAL ELEMENTS OF SUSTAINABILITY

Following the above introductory remarks, I am proposing a brief chapter dealing with the basic conceptual and methodological elements on which I am relying when I am taking the «co-development» of SES ⇔ NC as the practical target of the «vision of sustainability» as well as for formulation of the structure of the dynamic «Decision Support Systems» which I believe it can bring sustainability into practice.

- The concepts and methods dealing with the «environment» have been changed and improved as the ecological theory has developed from the early stage, usually described as «biological ecology», towards the current stage, which is more often and more appropriate defined as «systems ecology» (Fig. 1). The identification and description of the natural, seminatural and human-dominated and created environment has changed as well from a former conceptual model which defined the environment as an assemblage of factors; air, water, soil, biota and human settlements, to the most recent one, which considers that the environment has a «hierarchical spatio-temporal organization» (ODUM, 1993, 1997; CLAUDIA PAHL-WOSTL, 1995; VADINEANU, 1980) (Fig. 2 & 3).

The ecological systems, as organized units and components of the hierarchy, are described as self-organizing and self-maintaining systems or as life supporting systems.

More recently, they have been described as non-linear dynamic systems with evolving productive and carrying capacity.

The ecological hierarchy contains two main hierarchical chains of ecological systems which show a marked and evolving dichotomy in their spatio-

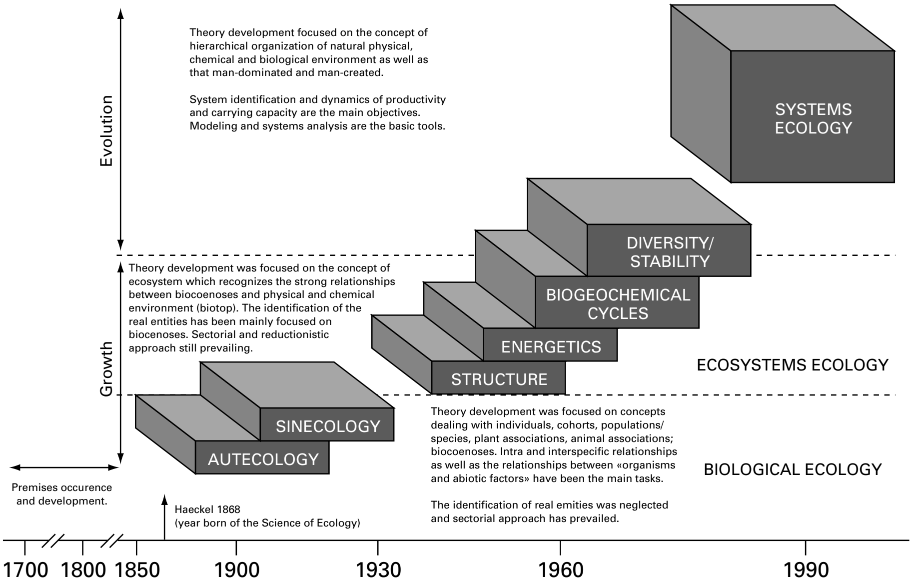


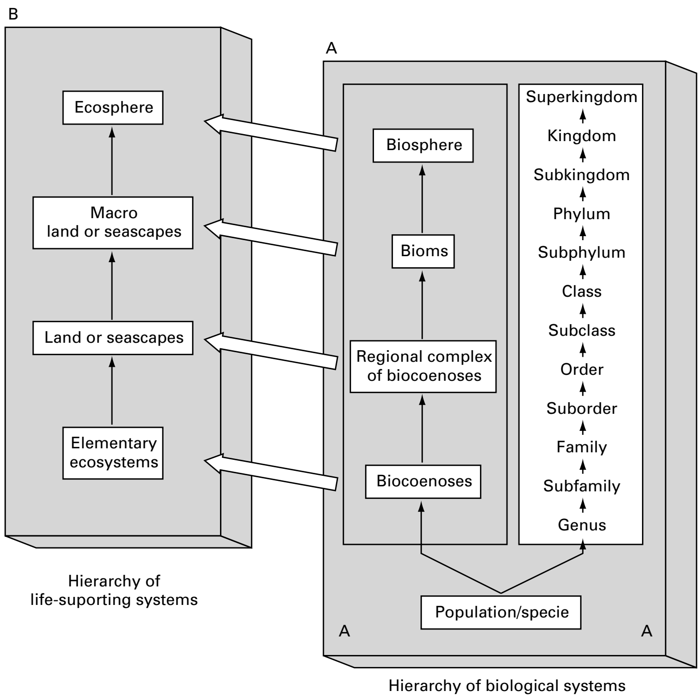
Fig. 1. Growth and evvolution of the Science of Ecology.

temporal development, which in fact is the core of the so called «ecological crisis»:

i. natural and seminatural ecological systems that are self maintained and provide a wide range of natural resources and services;
ii. human-dominated ecological systems which depend in different degrees on comercial auxiliary energy and material inflow (e.g. agrosystems, intensive fish ponds) and human-made systems (e.g. urban ecosystems, industrial complexes), which are totally dependent on commercial energy and material inflow.

- The ecological hierarchy integrate both the components of the Natural Capital and those of the Socio-Economic Systems.

NC — Natural
NC — Seminatural
NC / SES — Human-dominated
SES — Human-created



A1 - covers the diversity of living organisms and it hierarchical order of the taxons established based on the similarity between ordered entities.
A2 - hierarchical organization of living organisms in large and complex biological systems.
B - reflects the hierarchy of spatio-temporal organization of the upper layer of lithosphere, of hydrosphere, troposohere and biosphere.

Fig. 2. Relationships between taxonomic and organizational hierarchies of the living systems (A) and their integration within the hierarchy of life supporting systems or ecological systems (B).
(Adapted after Botnariuc N. 1995 and Barnes K. R. 1998).

According to the above statements, I use for the term «biodiversity» the broader meaning which covers on one hand the components of Natural Capital together with their taxonomic and genetic diversity and on the other hand, human social organization, ethnic, linguistic and cultural diversity.

In other words, I can say that the biodiversity consists in Natural Capital, Social and Cultural Capital and provides, on one side, the foot print which supports and feeds with resources and services the Socio-Economic Systems and, on the other side, provides the interface between Natural Capital and the Structure and metabolism of the «economic subsystem» (see Fig. 4).

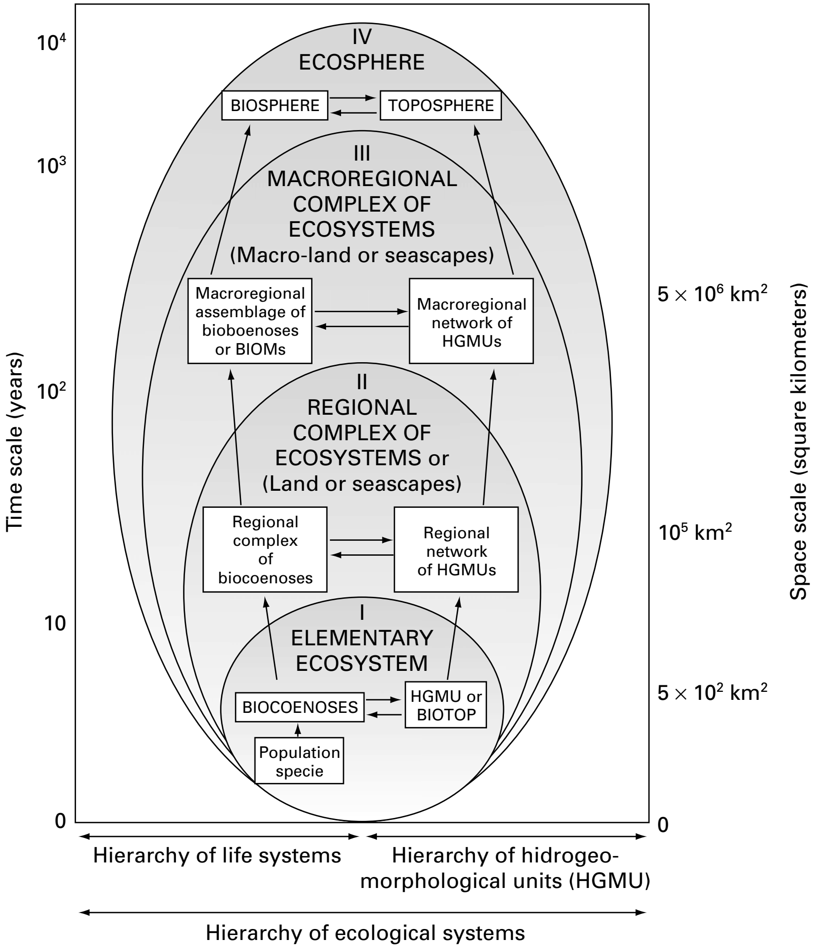


Fig. 3. Hierarchical organization of natural, man-transformed and man-created physical, chemical and biological environment.

According with the sxisting knowledge concerning the organization of life one can discriminate among five hierarchical levels on top of biological individuals and four spatio-temporal levels within the ecological hierarchy.

It has to be noticed that 3-dimensional space of the hierarchical organization integrates upper lithosphere, ocean basins and traposphere and the time constants of the ecological systems are of years, decades, centuries or millennia.

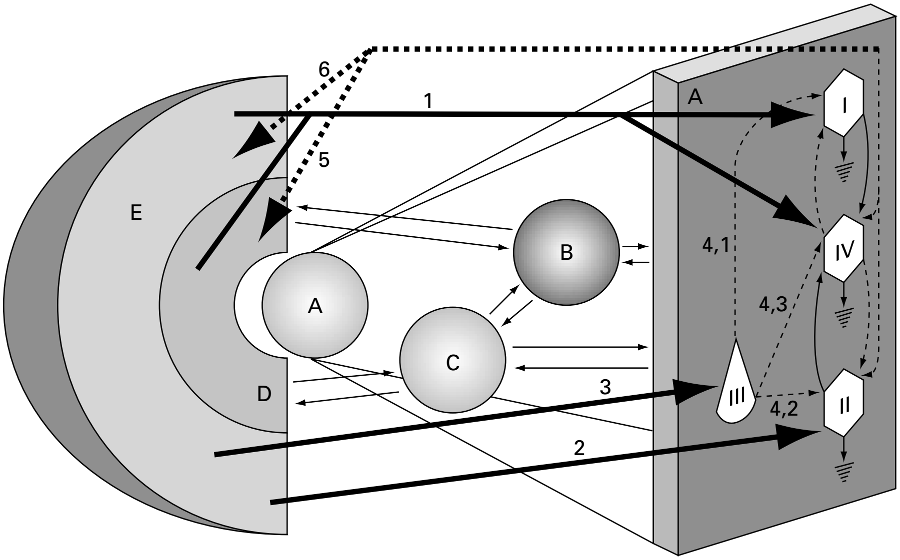


Fig. 4. The general physical model of the socio-economic system and its relationships with Natural Capital.
A - The man-made physical capital: I - the infrastructure of the economic subsystem dependent on the renewable resources provided by the components of the Natural Capital; II - the industrial infrastructure of the economic subsystem dependent on «non-renewable» resources; III - Systems* for commercial energy production using as primary resources: fossil and nuclear fuels and hydro-power potential; IV - the human settlements infrastructure. B - Social capital; C - Cultural capital; D - Man-dominated components of the Natural Capital; E - natural and semi-natural components of thr Natural Capital: 1 - flow of renewable resources; 2 - flow of raw materials; 3 - flow of fossil and nuclear fuels; 4 - flows of electrical energy; 5 - material and energy inputs (fertilisation, pesticides, agrotechnical works, irrigation, selection etc.) to support tje management of man-dominated systems; 6 - dispersion of heat of secondary products (wastes) in the troposphere and in the HGMU components.

It has also to be noticed that «in order to make the transition» from the current status of strong dichotomy between SSE ⇔ NC to that of co-development there is a need to establish an internal balance between economic subsystem, on one side, and social and cultural capital, on the other side.

As far as the methodological approach is concerned, we notice very clearly in the last decade a rapid shift from the sectoral, reductionistic and inappropriate temporal (months and years) and spatial scale approach towards a holistic and long term approach (decades and centuries). Systems analysis and modeling are used more extensively for the identification and description of the ecological systems (including SES^{s}) as large, complex, dissipative and dynamic systems.

The relationships between «humans and nature» more recently referred to as «development and environmental» relationships or between «economy and ecology» should be further reformulated and recast as the mediated and dynamic relationships at local, regional and global scale between the structure and metabolism of Socio-Economic Systems, on one side, and the structure, productivity and carrying capacity of the natural, seminatural and human-dominated systems (NC), on the other side.

3. HOW TO DESIGN THE DYNAMIC ATTRACTOR FOR SUSTAINABLE DEVELOPMENT?

In this chapter, I have the intention to make a very brief presentation of few of the most critical elemtns which I believe that should establish the core of the dynamic «attractor» for local, regional and global transition towards co-development.

Especially I am stressing the need for replacing «free market», which increasingly indebted to Natural Capital our Socio-Economic Systems, by «sustainable market», which, in fact, requires proper identification of the overall dynamic frame for «co-development», according with the structure, productivity and carrying capacities of the local, regional and global NC as well as with the ethical and moral criteria for sharing its resources and services within and among generations or among states and regions.

It will be also stressed the need to establish thresholds for the regulation of the structure and spatial relationships within NC and between NC and SES[s] (e.g. natural ans seminatural ecological systems should represent more than 50% of the total NC of a country or region; the structure and metabolism of a particular SES should have at least 70% complementarity with the structure, productivity and carrying capacity of the domestic NC).

4. OVERVIEW OF THE DECISION SUPPORT SYSTEM STRUCTURE

The structure of the Decision Support System (DSS) which is proposed in this paper was designed as to integrate valuable elements already existing in the structure of social and cultural capital and also to show clearly what is further needed for being developed.

As shown in Fig. 5, we have considered as key components for any coherent and powerful DSS the knowledge and data generation subsystems and the complementary information subsystem dealing with structural and func-

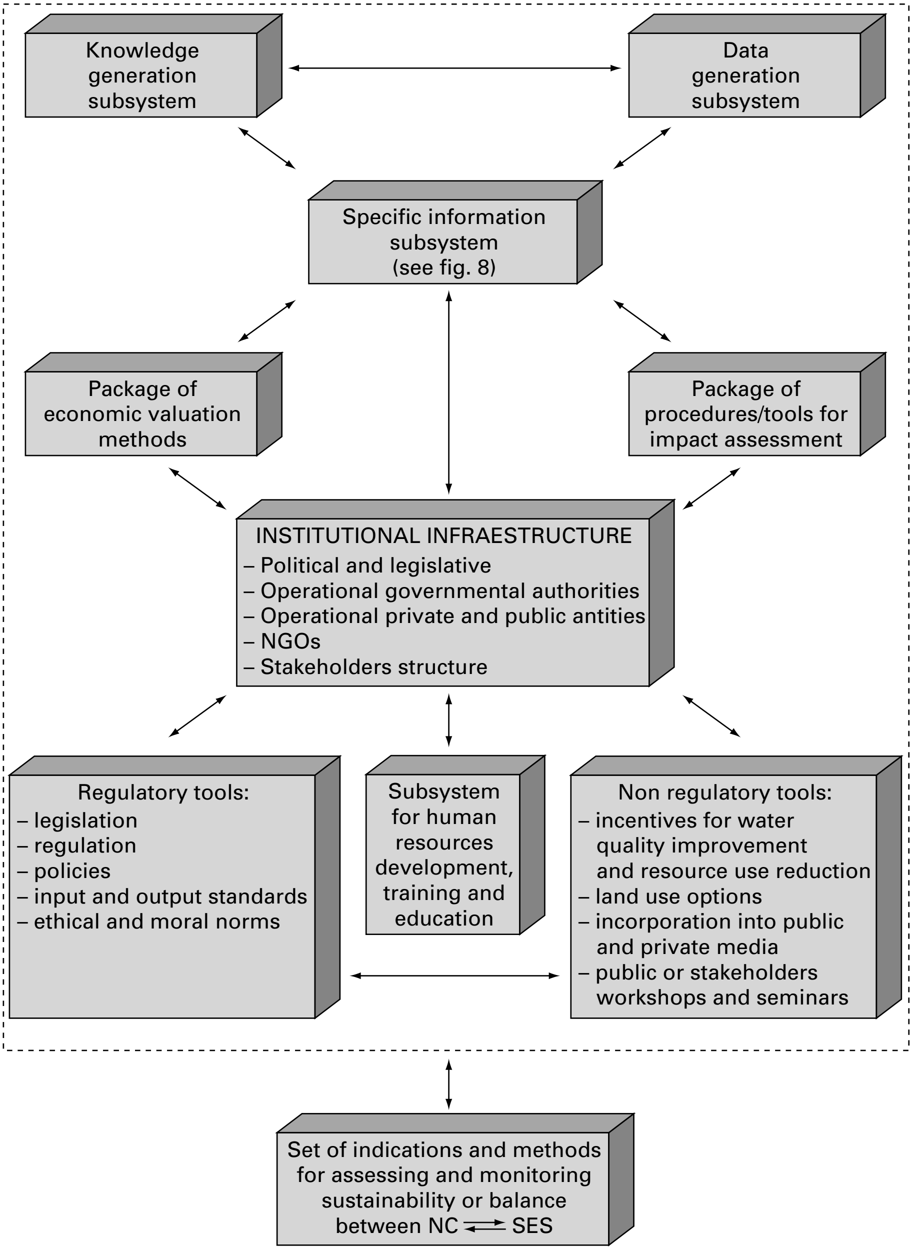


Fig. 5. The Structure of the Decision Support System for balancing the development of SES and NC or in other terms for «integration ecology and economy» at different spatio-temporal scales.

tional dynamics of different categories of Natural Capital components and Socio-Economic Systems as organized units at different spatio-temporal scales, which have always almost been neglected or less developed.

In order to ovoid any missinterpretation we are stressing once more that we are not speaking here about huge bulk of existing data concerning different «environmental factors» or some components of the ecological systems which are produced very often by implementing sectoral research and monitoring programmes, designed and carried out at inadequent spatio-temporal scales.

Very often less than 30% of the existing data and information, when they are properly structured and available, can effectively support the decision making process.

In the recent years it has been manifested an increasing effort focused on the identification and establishment of the structure of the knowledge and data generation subsystems (GOSZ, 1999; WIENS, 1997; LIENS, 1989).

They are designed to be progressively developed as interconnected national networks of representative ecological systems for both Natural Capital and Socio-Economic System and corresponding networks of institutions which are expected to function as long term integrated research and monitoring platforms.

In other words, they are expected to provide the needed scientific basis for policy decisions and integrated management dealing with the components of the Natural Capital, structure and metabolism of the Socio-Economic Systems and the dynamic relationships among them.

The knowledge concerning mechanisms and processes of structural and functional dynamics of the systems together with the data showing the variability of their key state variables and driving forces, feed the specific information subsystems.

In the end, the information subsystems have to contain the required knowledge and data or the «scientific basis» and the methods and modeling techniques in order to integrate ecological, social and economic information for policy and decision making dealing with balancing the development of NC components and SES[s].

From this perspective it is obvious that the information subsystems should be considered as the core of DSS.

The other two components of the DSS consisting in a package of complementary methods for economic valuation of non-marketable goods and services provided by the components of NC and the package of procedures for Ecological Impact Assessment (EcIA) of comprehensive or sectoral economic development plans and individual development project can be considered as being in an advanced stage of development.

The questionable role and efficiency of these two components of the DSS for the decision and policy making, so often revealed in recent times, may be explained in a less extend by intrinsec shortages of the methods and procedures themself and more by the lack or underdeveloped information subsystems.

In spite of the existing shortages which directly or indirectly relate to these components of the DSS, they are the only effective tools for integrating ecological, social and economic information into the process of solution formulation.

Once a set of solutions are formulated for any particular problem and their potential ecological impact (long term, cumulative and long distance) is estimated, choosing the best solution which fits to overall goal of sustainability as well as the development of the management plan are the next crucial steps.

For these stages of decision making and implementation process, any decision support system has to integrate other specialized compartments like the flexible subsystem for communication, education and training and the coherent and effective subsystems of regulatory and non-regulatory tools. It is obvious that all the above listed components of the DSS are or have to be grounded in a complex, flexible and free of overlapping and parallelism institutional infrastructure which unfortunately is not the case at our time being.

However, the institutional infrastructure of the DSS tends to integrate governmental and non-governmental as well as public and private institutions in order to establish the needed flexible and effective system of checks and balances throughout the decision making and sustainable management plan process (RUIJGRAK et al, 1999; MUSTURES et al, 1998; DE GROOT, 1998; WEINS, 1998; BOON, 1998; MEPPEM et al, 1998).

It is also a wide acceptance of the fact that the governmental institutions have to play the major role of developing the operational subsystems of the DSS and policies while the NGO^{S} and private interests have to provide for the implementation link into the community structure.

As far as both processes of decision making and implementing the management plans, which are targeted for achieving and maintaining the balance among Natural Capital components and Socio-Economic Systems development, are dealing with complex and dynamic systems at large spatio-temporal scale, it was strongly perceived the need for integration within the DSS structure of a specific subsystems containing the evaluation and monitoring methods and indicators of the overall co-development process.

In other words, it might be said that by integrating the evaluation and monitoring subsystem within the structure of DSS it was established the loop for specific feedback on the status of progress to the goal of sustainability.

5. GAPS, SHORTAGES AND CHALLENGES IN SOME BASIC COMPONENTS OF THE DSS

Although it is not the aim of this paper to discuss into details each component subsystem of the DSS, I am still considering that it might be very useful to integrate in this section a brief presentation of some of the most critical shortages and needs related to those components of the DSS, which in fact support or assist the preparatory steps of policies and decisions (see Fig. 9).

They might be also considered as priorities in a specific research programme targeted for further development and improvement of the specific DCC as the operational infrastructure for achieving and maintaining a balanced development among NC components and SES[S] or, in other words, to «integrate ecology and economy at different spatio-temporal scales-from local to global scale».

5.1. KNOWLEDGE AND DATA GENERATION AND THE INFORMATION SUBSYSTEMS

After Jorgensen (1999) more than 4000 ecological models have already been developed and used in the last three decades as tool in research of complex and dynamic ecological systems or in «environmental management».

Few years ago, Jorgensen et al (1995 b) published an excellent book that integrated fhe best available experience in the field of ecological modeling, which emerged after reviewign more than 400 models.

However, the power of the existing models to describe the complexity and dynamic behavior of different categories of ecological systems or to explain and give reliable prognoses for specific environmental problems is still very limited due to the following constraints:

- Poor or very poor identification of the particular ecological systems at spatial and temporal scale before developing the models, which keep both scientists and managers far from the real world;
- The models have been developed based on the unrealistic assumption that the ecological systems maintain rigid structures and on a fixed and incomplete set of parameters;
- Usually, for the model development and especially for the parameter estimation only incomplete and weak quality of data sets have been available;
- In most cases, the structural and functional diversity of ecological systems have been neglected and the human society only recently has started to be identified and modeled as human dominated and created ecological systems.

In order to overcome the above constraints, different research initiatives have been launched in the last decade for further development and improvement of both concepts and techniques in the field of ecological modeling.

i. Identification of ecological systems, both components of Natural Capital and Socio-Economic Systems by specific and dynamic structural and functional models (dynamic homomorph models) which preserve their specific dynamic properties at the most appropriate spatio-temporal dimensions.

   Such structural dynamic models integrate: the network of major components in the structure of hydrogeomorphologic units (HGMU^{S}) and troposphere; the network of tropodynamic modules describing the spatio-temporal organization of biocoenoses or the network of modules in the economic subsystem; the patterns for inner mass, energy and information transfer and the boundary conditions or the pathways of the so called «metabolism» of Socio-Economic Systems (Fig. 4). To each structural dynamic model used for the identification of a particular category of ecological system it always has to be associated a set of external driving forces, a set of structural and functional parameters and the corresponding sets of state variables.

   Many significant contributions to the development of a coherent set of methods and techniques which, after my opinion, can help reasonable well, to implement since now, first critical step in ecological modeling, have been brought in the last decade (JORGENSEN, 1990, 1992 a, b, 1999; CLAUDIA PAHL WOSTL, 1995; MUSTERS et al, 1998; PIZZOCARE SILVIA, 1998; BACCINI and BRUNNER, 1991; ANDERBERG, 1998; VADINEANU, 1998; MALTBY et al, 1996; ODUM H. T., 1996) and they have completed and improved those developed in 70s and 80s (PATTEN, 1971, 1979; HALFON, 1979; ZIEGLER, 1979; ODUM, T. H., 1983; ODUM, E., 1971; BOTNAURIC and VADINEANU, 1982).

ii. In order to improve the knowledge and data quality concerning the structural and functional dynamics of ecological systems, part of the Natural Capital of that concerning the structure and metabolism of Socio-Economic Systems, in the last years have started to be developed both conceptual frame and methodology, to establish according with the diversity of ecological structure at the national and macroregional scale the networks of different types of ecological systems (especially belonging to the hierarchical level of microlandscapes or seascapes), including components of socio-economic systems where «long term ecological research and integrated monitoring programmes» to be carried out.

In this respect, I would like to mention the E.U. initiatives to identify and maintain or improve EECONET which in turn requires the accession countries from CEE to identify their own National Ecological Network and to design and develop the European Integrated Monitoring System (NoLimits project/Coordinator-Institute of Terrestrial Ecology/UK) as well as the initiative of most East-European countries to develop their networks of sites for «Long Term Ecological Research and Integrated Monitoring» as part of ILTER]* network.

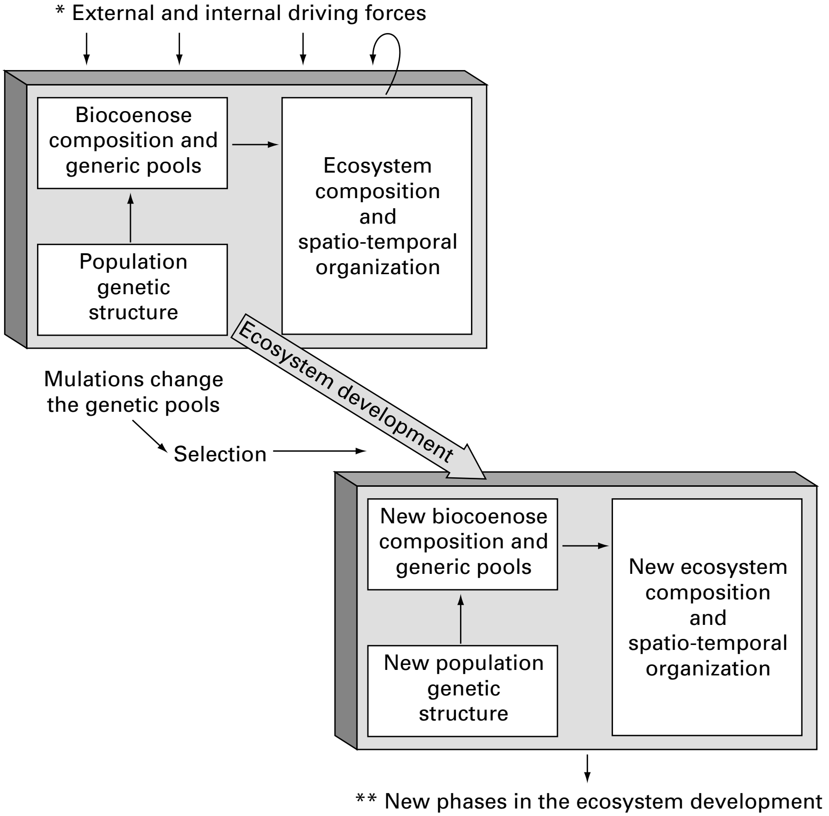
iii. Development and improvement of the mathematical modeling techniques in order to cope with: a) poor data base, with b) specific decision making and management issues and, that is more important, c) to take the complexity, adaptability and structural and functional dynamics of the ecological systems into account (Fig. 6).

a) To manage the constraints linked to poor data base in the case of many particular ecological systems or very specific environmental issues, they have been developed and used on one hand «fuzzy models» (JORGENSEN, 1994 a) and on the other hand modeling techniques based on chaos and fractal theory in order to improve the parameter estimation (JORGENSEN, 1995, 1997, 1999).

b) Artificial neural networks (ANNs) methods and especially the «multi-layer feed-forward neural network» (BPN) and the «Kohonen self-organizing mapping» (SOM) have been extensively used for ecological modelling (LEK and GUEGAN, 1999) and in particular for performing specific tasks in different fields of applied ecology like: soil hydrology (VILA et al, 1999); modeling the green house effect (SEIGNER et al, 1994); modeling water and carbon fluxes above European coniferous forests (VAN WIJK and BOUTEN, 1999); modeling phytoplankton primary production (SCARDI and HARDING, 1999; SCARDI, 1996; RECKNAGEL et al, 1997); applying ANNs tool to ocean color remote sensing (GROSS et al, 1999); predicting P/B ration of animal populations (BREY et al, 1996); predicting collembolan diversity and abundance in riparian habitats (LEK et al, 1999) and predicting the response of zooplankton biomass to climatic and oceanic changes (AOKI et al, 1999).

The technique of stochastic dynamic programming, previously used in agricultural economics (KENNEDY, 1986) and in commercial fisheries (GILLIS et al, 1995) has been improved and used in

* International Long Term Ecological Research.



* At a time scale of years, decades and centuries occurs changes in their number and nature or in their range of fluctuations, intensity and frequency. Their impact on populationes and biocoenose composition lead to time delayed and long term effects.
** The ecosystem development is a long term process which involves a long serie of succesive phases of growth and evolution.

Fig. 6. Concepts for development of ecologiacal mathematical models.
(Adapted after Jorgensen E. S., Mejer P.H., 1983).

order to get solution for maintaining minimum viable population size with minimum economic loss and has suggested that this approach can have a «universal applicability in conservation biology» (DOHERTY et al, 1999).

The numerical method of analysis and input-output models have been also used recently for the assessment of «ecological sustainability» of a regional economy (EDER and NARODOSLAWSKY, 1999) or the national economy Australia (LAWN and SANDERS, 1999).

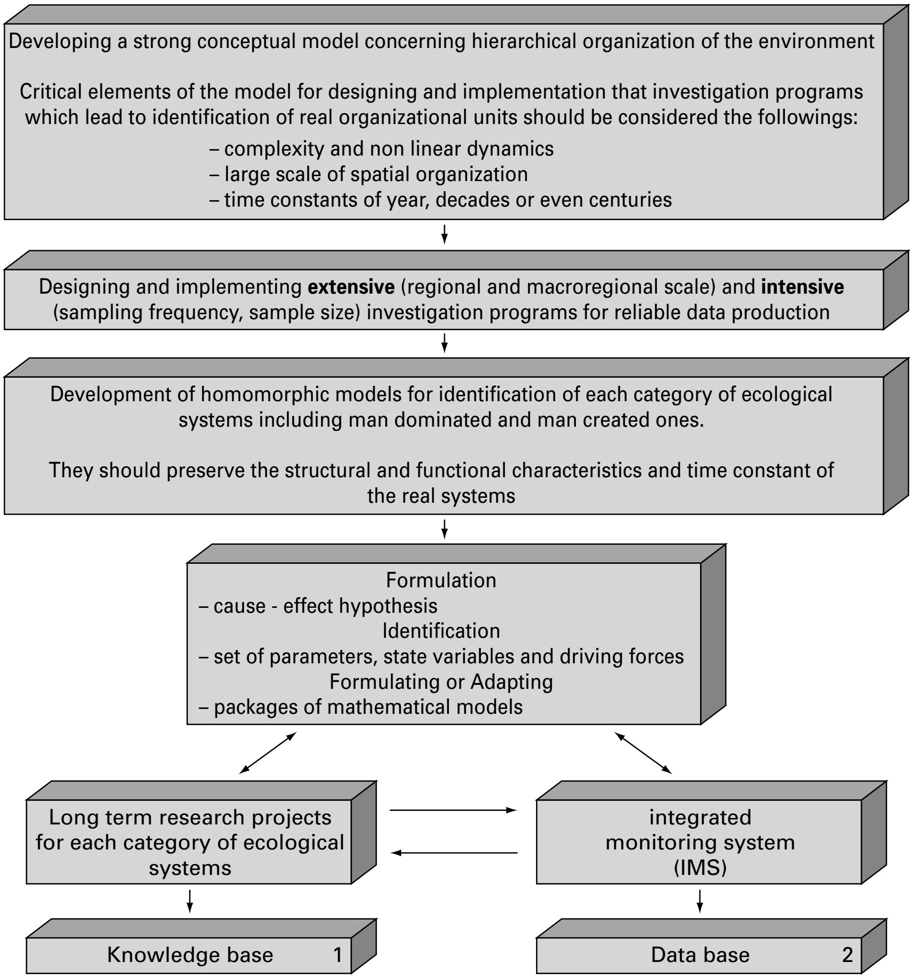
c) In spite of persisting many constraints, I have mentioned above that a great effort was done in recent years in order to develop and apply techniques for modeling structural changes in ecological systems, based on the catastrophe theory (JORGENSEN, 1997, 1999) and for mathematical modeling of the structural dynamic homomorph models describing the ecological systems. Very promising are the models consisting in linear differential equations with time varying parameters (PATTEN, 1997) and especially the dynamic mathematical models developed by using as goal function the exergy (JORGENSEN, 1999).

According to the above brief presentation of the main outputs of a much wider critical analysis of the recent approaches and developments in the field of ecological modeling, there are available now on one side enough and strong concepts enabling the systemic approach of the environment and human society and on the other side almost a complete range of methods, modeling tools and logistics for:

- designing and launching large scale study programmes for spatio-temporal identification of Natural Capital and Socio-Economic Systems as well as quality assessment of historical data and knowledge (Fig. 7);
- designing and developing initial structure of the information system for each category of identified ecological systems consisting in the knowledge and data base (Fig. 8);
- developing or adapting the most appropriate package of mathematical models in order to describe specific phenomena, processes or structural changes and dynamic of the whole system by using the existing knowledge and data as well as the set of hypotheses dealing with the uncertainties and gaps in knowledge and data;
- building the interface and guidelines for information system management;
- establishing the network of microlandscapes or seascapes according with the diversity of identified ecological network and launching long term ecological research and Integrated Monitoring programmes in order to feed and improve knowledge and data bases.

5.2. ECONOMIC VALUATION METHODOLOGY

Each component of the Natural Capital provides to SES marketable goods and services (e.g. food, timber, drinking water or transportation,



1. In the first instance it is supplied with information produced by rhe implementation of extensive and intensive research projects for systems identification and that gainer during critical analysis and integration of the historial data. Each phase in a long term reseatch project provide new information as long as the hypothesis are validated. The information concerns the structural and funcional mechanisms, phenomena and processes in a given category of ecological systems. They help to describe the dynamics, productivity and carrying capacity of that systems.
2. Data base is developed according with the structure of the integrated Monitoring System. The data concerning the dynamics of key state variables make possible the assessment of system Status at any particular time.

Fig. 7. Main steps in the developement of information Systems concerning the organization, dynamics, productivity and carrying capacity of ecological systems.

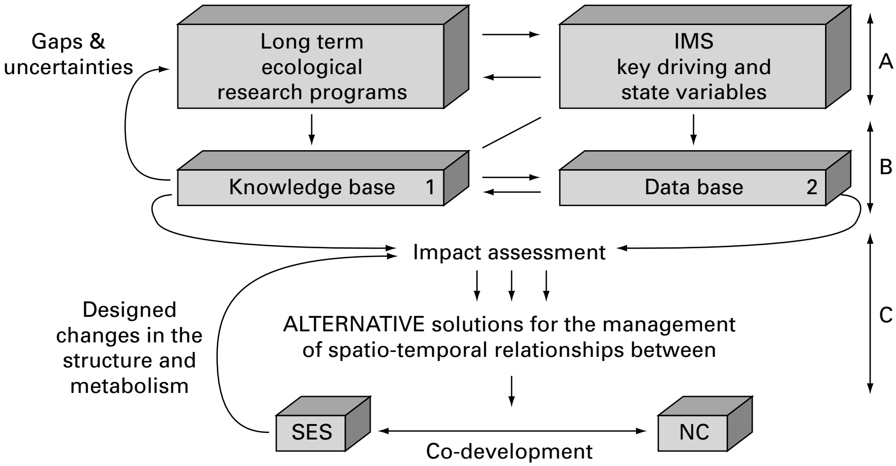


Fig. 8. A general diagram showing the complementary relationships between research and integrates monitoring programs (A) the structure and use of the Information System (B) and the significance for balancing the relationshios between Socio-Economic System (SES) and Nature Capital (NC) or their co-development (C). Strategic and project impact assessment requires the cost benefit analysis in a large socio-economic context and at a large time scale and provides alternatives solucions either for rehabilitation and reconstruction of the damaged system or for maintenance of the dynamics of healthy ecological systems within the limits of their productive and carrying capacities.

electricity generation s.o.) and many non-marketable goods and services (e.g. biological diversity, soils, water cycling, biogeochemical cycles, air and water quality, aesthetic and cultural benefits) (COSTANZA et al, 1997; WILSON et al, 1999; DE GROOT, 1994 a).

Many attempts have been registered in the last two decades for economic valuation of the non traded goods and services produced by the natural and seminatural ecological systems in order to avoid or at least to minimize the overestimation of the role of use values or underestimation of the role of non-use values during policy and decision making process and in turn to minimize deterioration of Natural Capital (Freeman 1993, Diamond et al. 1994, Pate et al. 1997, van der Straaten J., 1998, Wilson et al. 1999).

Thus, it was made a great effort for the development and applying alternative methods of assigning economic values as direct and indirect use values to the marketable goods and services as well as non-use values to the non-marketable goods and services among which one can identify the option, quasi option, bequest and existence values.

In most of the cases dealing with economic valuation of the non-marketable goods and services provided by the Natural Capital components, three primary methods: travel cost methods (TCM); hedonic pricing (HP) and contingent valuation (CV) have been extensively used. Wilson and Carpenter (1999) have published very recently the results of a critical analysis carried out on 30 research papers and study reports dealing with economic valuation of surface freshwater ecosystem goods and services.

In all the reviewed papers, the methods applied for economic valuation were developed according with the theory of neoclassical economics which, in fact, recognizes the only human centered values for the non-marketable resources and services. Based on the main conclusions of Wilson and Carpenter (1999) and many other authors working in the field of «total economic valuation» of the Natural Capital (Pimentel et al. 1997, Costanza et al. 1997), the following gaps and research needs should be considered in the near future:

i. Each valuation method targets a different aspect of total economic value (use and non-use values together) or in other terms its estimation potential tends to be limited to some specific goods and services of the total package associated with a given component of the Natural Capital.

ii. Economic valuation of the non-market goods and services tends to be specific to a particular method, ecological system and socio-economic circumstances.

iii. The human centered systems of economic valuation grounded in the theory of neoclassical economics preserves a significant human bias, which in turn induces serious limitations in the dynamic process of balancing SES with Natural Capital as long as we are missing powerful Information Systems and effective decision support systems.

iv. A valuation system free of human bias is also developing fast as an alternative to that supported by the neoclassical economics. This system of valuation is based on the principle that «value is derived from what goes into something rather than on what one gets out of it» (Brown et al. 1999). The value of solar Emergy is proposed to be used in order to evaluate the flows of energy and resources that sustain both the development of socio-economic systems and the components of Natural Capital. It is obvious that this methodology is also highly dependent by the level and quality of knowledge and data concerning the structural and functional dynamics of natural, seminatural, human dominated and human made ecological systems.

v. Further comparative studies of the efficiency of existing methods in the human biased system of economic valuation for the estimation in monetary terms of non-market resources and services provided by similar ecological systems should be promoted by any research programme developed and applied in the coming years.

They have to take into account the fact that ecological systems of one particular type could be at one particular time in different phases of their development which, in fact, means that they may differ in a large extent in terms of type and level of non-market resources and services provided. It also has to be taken into account the differences concerning the knowledge development related to each ecological systems as well as those among knowledge availability or among ways of perception of the non-market resources and services by the population involved.

Such comparative studies have to establish complementarity among the available methods of economic valuation and to integrate them into effective package of tools or to identify the needs for new methods.

vi. Comparative valuation studies of Natural Capital components and its relationships with Socio-Economic Systems by using both the human-centered and free of human bias valuation systems should be promoted in order to improve and strengthen the decision making and management dealing with the balancing or co-development between Natural Capital components and SES[s].

We believe that this should be the practical way of integrating the ecological knowledge and data into an «economically meaningful framework before a meaningful assessment of value can be made «as Wilson and Carpenter (1999) have requested recently.

Although the methodology of NC components valuation has significant limits and gaps which have to be eliminated or at least reduced we still believe that the most important limitation of the process is related to poor and unstructured «ecological knowledge and data».

5.3. Impact Assessment procedures

As it was outlined in chapter 4, among the components of the decision support system for balancing Socio-Economic and Natural Capital development, the package of complementary and effective procedures for earlier identification and valuation of the potential impacts associated to the strategic planning and policy making or to the particular projects designed for policy implementation is playing, together with the package for economic valuation of NC, the major role in the decision making process.

Since 1969, when US National Environmental Policy Act (NEPA) established for the first time a legislative requirement for the assessment of potential environmental impacts of the development actions, the Environmental Impact Assessment (EIA) procedure has been adopted by many countries as a prerequisite for effective management of the complex relationship between economic development actions and the state of the environment.

The Environmental Impact Assessment was defined since the beginning as a process of identification, estimation and evaluation of the environmental consequences of current or proposed actions (TREWEEK, 1999).

Most commonly, the procedure has been applied to individual project proposals or actions which were expected to have a significant negative impact on the environment.

At early 90s, it was carried out an International study on the effectiveness of the EIA practice which investigated both EIA principles and procedures as they developed, applied and legislated for throughout the world (SCADLER, 1996, DEVUYST, 1998). Many shortages of the traditional EIA procedure have been identified like those concerning the inadequate time and space scaling, missing the cumulative and social effects as well as the direct or indirect and long distance ecological effects.

In order to limit the consequences of some identified shortages, they have been developed specific procedures like: Cumulative Impact Assessment (CIA) and Socio-Economic Impact Assessment or it has been proposed to establish links between EIA and Life Cycle Analysis (LCA) procedures in order to enable a holistic product oriented analysis.

However, the maintenance of some of the most severe constraints in the project EIA procedure has pushed the governments to extend the principles of EIA to cover development policies, plans and programmes (TREWEEK, 1999).

By doing this, the traditional project-EIA procedure has been significantly changed in terms of its scope and scale of application. The new version of EIA well known as Strategic Environmental Assessment (SEA) has been legislated for separately and has been developed its own approaches and techniques. Whereas the Project EIA is more detailed, quantitative and essentially reactive, SEA is mostly proactive, qualitative and indicative.

The Government of Netherlands has developed provisions for SEA application to national development policies and plans in early 90s (VERHEEM, 1992, RUIJGRAK et al. 1999) and, recently, other EU countries have established their own provision for SEA application.

TREWEEK (1999) has published an excellent book dealing with an extensive critical analysis of the existing procedures for Impact Assessment.

He also stressed the need for systemic approach in order to cover the complexity of ecological systems and to meet the provision for Biodiversity Conservation.

In order to achieve the above objectives which are strongly related to the carrying capacity and productivity of natural, seminatural and human dominated systems, he has proposed and described a more comprehensive procedure, labeled as Ecological Impact Assessment (EcIA).

It seems that this new procedure for the Impact Assessment integrates all viable elements of the former EIA procedures and, in addition, can be further developed by integrating other existing methods like: Material Flow Analysis (MFA), Life Cycle Analysis (LCA) and Cost Benefit Analysis (CBA).

In this respect, extensive and intensive research and integrated monitoring have to be carried out at different type of ecological systems, including the structure and metabolism of the socioeconomic systems.

The Project EcIA and SEcIA are considered in the context of this analysis as the major procedures which can assist efficiently the decision making.

6. DECISION MAKING FOR BALANCING SOCIO-ECONOMIC AND NATURAL CAPITAL DEVELOPMENT

Very often in our days, it is stated by politicians, decision makers and ordinary people that the needed holistic or systemic approach of all our economic, social and engineering activities is just written down in strategic papers but not really practiced in an extent which would allow to speak of sustainable development.

In other words, it might be easier to use terms like: ecological crisis, integrated or interdisciplinary approach of the environment or carrying capacity, but very hard to conceptualize that the ecological crisis has to be linked to the dichotomy in the development of Natural Capital components and Socio-Economic Systems, that the integrated or systemic approach requires the understanding that physical, chemical and biological environment has a hierarchical organization which integrates the Socio-Economic Systems as human dominated and created ecological systems dependent on the mass and energy transfer with the other components of the hierarchy, and that the carrying capacity of Natural Capital is linked to the stability in a broad sense as well as to the dynamic capacity of the ecological systems to provide goods and services and to assimilate the wastes of Socio-Economic Systems (RING IRENE, 1997; COSTANZA, 1996; MUSTERS et al. 1998, VADINEANU, 1998).

Under these unfavorable circumstances which basically are linked to the severe shortages in the human resources development and training system and those dealing with the lack or underdeveloped Decision Support Systems it is even more difficult for the decision makers to put in practice dynamic strategies and policies targeted to adapt economic patterns of development to ecological patterns of development.

Taking into account the above gaps or shortage and the corresponding urgent needs as well as the proposed structure of the Decision Support System (Fig. 5) and the brief comments on the role of each compartment, we made an attempt to build up a decision making model which integrates the basic steps of a comprehensive and cycling process (Fig. 9) targeted to establish and maintain the balance between Socio-Economic Systems and Natural Capital at different spatio-temporal scale.

The model implementation in the decision making process and its efficiency improvement requires long term and multidisciplinary research focused on each of the components of the DSS as we already stressed in the previous chapters.

We have to be aware that as long as the reliable ecological information will remain poor and the gaps will be further filled up with data derived from more or less unrealistic assumptions, the risk associated to solutions and respectively to the decisions remains also very high.

It also has to be stressed that choosing among alternative solutions emerged from EcIA and SEcIA is a complex and delicate process which requires: careful analysis of costs and benefits at different time and space scale; the involvement of all stakeholders, the public and private institutions with their particular interests and ways of perception of the values of NC; information transfer and conflict of interest negotiations and learning through dialogue.

7. CONCLUSIONS

The structure of DSS and the corresponding decision making model were designed as to integrate valuable elements already existing in the structure of social and cultural capital and also to show clearly what is further needed for being developed by promoting: large scale and long term integrated research and monitoring programmes of both components of NC and SES^s; specific research and technological development programmes in order to support the process of reshaping and adapting the structure and metabolism of SES to the productivity and carrying capacity of NC components; specific research programs for the development of effective economic, legal and social instruments, mechanisms and indicators required for bringing and maintaining the dynamics of SES^s along or among different potential trajectories within the «overall frame for co-development»; development and improvement of the appropriate institutional infrastructure in order to provide access and better information for general public and also support for learning and education, for changing perceptions and values and, in fact, to ensure a broader and effective participation through dialogue of the public to the policy and decision making

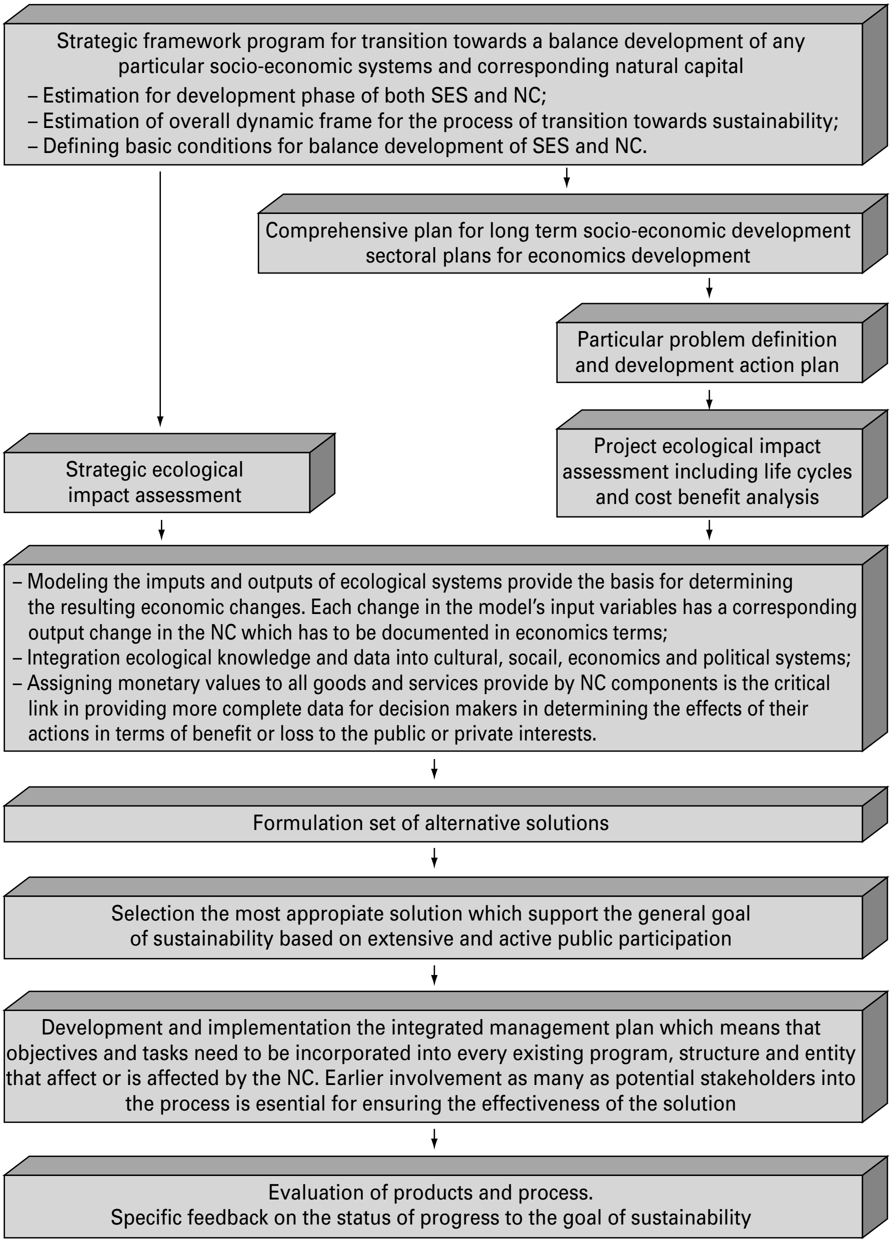


Fig. 9. Sepwise process as a decision making model with the goal to establish and maintain the balance between Socio-Economic Systems and Natural Capital.

process and not the last, development and continuous training of human resources.

In line with the major statements included in the paper, it was considered that the well-developed and maintained information systems are the core elements of the dynamic «decision support systems» and therefore they were properly discussed in the paper. In fact, for the time being, we miss exactly the core of the DSS[s] and this is the reason for proposing that development and improvement of the *information systems* for each category of ecological systems to be one of the major target of a specific and long term research program.

8. REFERENCES

ADENBERG, A. (1998): *Industrial metabolism and the linkages between economics, ethics and the environment*. Ecological Economics 24 (2,3), p. 311-321.

AOKI, I., KOMATSU, T. y Hwang, K. (1999): *Prediction of response of zooplankton biomass to climatic and the oceanic changes.* Ecol. Model, 120, p. 261-270.

ARROW, K., BOLIN, B., COSTANZA, R., DASCUPTA, P., FOLKE, C., HOLLING, S. C., JANSSON, O. J., LEVIN, S., MALER, G.K., PERRINGS, C. y PIMENTEL, D. (1995): «Economic growth, carrying capacity and the environment». *Ecological Economics*, 15(2): 91-97.

BACCINI, P. y BRUUNER, P. H. (1991): *Metabolism of Antroposphere*. Springer-Verlag, Berlín.

BERKS, R. y FOLKE, C. (1994): *Investing in Cultural Capital for Sustainable Use of Natural Capital* (Jansson A. M. Habber, Folke, C., Costanza, R., (Eds.), p. 128-151, Island Press.

BOON, K. E. (1998): *Environmental planning,* p. 69-88 in «Environmental Management in Practice», Nath B., Hens, L., Campton, P., Devuyst, D., Routled, G., London-New York.

BOTNARIUC, N. y VADINEANU, A. (1982): *Ecologie Generala,* Edig. Did. Pedag. Bucuresti.

BREY, T., TEICHMANN, J., BARLICK, O. (1996): *Artificial neural networks vs. multiple linear regression predicting P/B rations from empirical data,* Mar. Ecol. Prog. Ser., 140, p. 251-256.

BROWN, T. M. y ULGIATO, S. (1999): *Energy evaluation of the Biosphere and Natural Capital,* Ambio 28(6), p. 486-493.

CAIRNS, J. JR. (1997): *Sustainability, ecosystems services and health.* Int. J. Sustain. Dev. World. Ecol. 4(3), p. 153-166.

CLAUDIA PAHL VOSTL. (1995): *The dynamic nature of ecosystems,* John Wiley and sons, New York.

COSTANZA, R., D'ARGE, R., DE GROOT, R., FARBER, S., GROSSO, M., HANNON, B., LIMBURG, K., NAEEM, S., O'NEIL, R., PARNELO, J., RASKIN, R. G., SULTON, P. and VAN DEN BELT, M. (1997): *The value of the world's ecosystem services and natural capital.* Nature, 387, p. 253-260.

COSTANZA, R., SEGURA, O. y MARTÍNEZ-ALIER, J., (Eds.) (1996): *Getting down to Earth: Practical applications of ecological economics*. WashingtonDC., Island Press, 1996.

COSTANZA, R. (1995): *Economic growth, carrying capacity and the environment.* Ecological Economics, 15(2), p. 89-90.

COSTANZA, R. y DALY, H. (1992): *Natural Capital and Sustainable development.* Conserv. Biol. 6, p. 37-46.

DALY, H. E. (1987): *The economic growth debate: what some economists have learned, but many have not?* J. Environ. Ecol. Manag. 14, p. 323-336.

DE GROOT, R. S. (1994): *«Environmental functions and the economic value of Natural Ecosystems»* in: Jansson et al. «Inversting in Natural Capital: the Ecological economics approach to sustainability», Island Press, CA, USA, p. 151-168.

DE GROOT, U. (1998): *Problem in Context: a framework for the analysis, explanation and solution of environmental problems,* p. 22-43 in «Environmental Management in Practice-Vol. I), Nath, B., Hens, L., Campton, P., Devuyst, D., Routled, G., London-New York.

DEVUYST, D. (1998): *Environmental Impact Assessment*, p. 188-209, in «Environmental Management in Practice-Vol. I), Nath, B., Hens, L., Campton, P., Devuyst, D., Routled, G., London-New York.

DIAMOND, P. A. y HAUSMAN, A. J. (1994): *Contingent valuation: is some number better than no number?* Journal of Economic Perspectives, 8(4), p. 45-64.

DOHERTY, F. P. JR., MARSCHALL, A. E., GRUBB, C. T. JR. (1999): *Balancing Conservation and economic gain: a dynamic programing approach.* Ecological Economics, 29(3), p. 349-358.

EDER, P. y NARODOSLAWSKY, M. (1999): *What Environmental pressures are a region's industries responsible for? A method of analysis, with descriptive indices and input-output models.* Ecological Economics, 29(3), p. 359-374.

FREEMAN, M. (1993): *The measurement of Environmental and resource values: theory and methods,* RFF, Washington DC, USA.

GILLIS, D. M., PIKITCH, E. K. y PETERMAN, R. M. (1995): *Dynamic discarding decisions: Foraging theory for high-grading in a trawl fishery,* Behav. Ecol. 6, p. 146-154.

GOSZ, J. (1999): *International Long Term Ecological Resarch: collaboration among national networks of research sites for a global understanding,* p. 9-21 in «Long Term Ecological Research: Exemples, Methods, perspectives for Central Europe» Proceedings ILTER Regional workshop, 16-18 september 1998, Madralin, Poland, Kodruk.

GROSS, L., THIRIA, S. y FROVIN, R. (1999): *Applying artificial neural networks methodology to ocean color remote sensing.* Ecol. Model. 120, p. 237-247.

HALFON, E. (1979): *Theory in Ecosystem Analysis,* in «Halfon, E. (Ed.) Theoretical Systems Ecology, p. 1-12, Academic Press Inc., New York.

HINBERBERGER, L., LUKS, F. y BLEEK-SCHMIDT, F. (1997): *Material flows vs. «Natural Capital». What makes an economy sustainable?* Ecological Economics 23(1), p. 1-14.

JORGENSEN, E. S. y Mejer, P. H. (1983): *Trends in ecological modeling, in «Laurnroth, K.»* Skogerboier, V. G., Flug, M., (Eds.), «Analysis of Ecological Systems: State of the Art in Ecological Modeling», p. 21-27, Elsevier Sci. Publ., Amsterdam.

JORGENSEN, S. E. (1999): *State of the art of ecological modeling with emphasis on development of structural dynamic models.* Ecol. Model. 120, p. 75-96.

JORGENSEN, S. E. (1994): *Fundamentals of ecological modeling 2nd edition.* Elsevier, Amsterdam.

JORGENSEN, S. E. (1995): *The growth rate of zooplankton at the edge of chaos.* J. Theor. Bio. 175, p. 13-21.

JORGENSEN, S. E. (1997): *Integration of Ecosystem Theories: a pattern,* 2nd edition, K. Kluver, Dordrecht.

KENNEDY, J. O. S. (1986): *Dynamic Programming Applications to Agricultural and Natural Resources.* Elsevier, London.

LAWN, A. P. y SANDERS, D. R. (1999): *Has Australia surpassed its optimal macroeconomic scale? Finding out with the aid of benefit and cost account and a sustainable benefit index.* Ecological Economics, 28(2), p. 213.

LEG-ANG, S., DEHARVEMNG, I. y LEK, S. (1999): *Predictive models of collembolan diversity and abundance in a riparian habitat.* Ecol. Model. 120, p. 247-261.

LEK, S. y GUEGAN, F. J. (1999): *Artificial neural networks as a tool in ecological modeling, an introduction.* Ecol. Model. 120, p. 65-73.

LIKENS, G. E., (Ed.) (1989): *Long Term Studies in Ecology Springer-Verlag.* New York.

MALTBY, E., HOGAN, V. D. y MCINNES, J. R. (1996): *Functional Analysis of European wetlands ecosystems (FAEWE) Phase I.* Ecosystem Research Report No. 18, Brussels.

MEPPEM. T. y GILL, R. (1998): *Planning for Sustainability as a learning concept.* Ecological Economics, p. 121-138.

MUSTERS, M. J. C., DE GRAAF, J. H. y KEURS, J. W. (1998): *Defining socio-environmental systems for sustainable development.* Ecological Economics, 26(3), p. 243-259.

NICOLIS, G. y PRIGOGINE, I. (1997): *Self-Organization in non-Equilibrium Systems.* Wiley, New York.

ODUM, H. T. (1996): *Environmental accounting: energy and environmental decision making.* John Wiley and sons, New York.

ODUM, H. T. (1983): *Systems Ecology Wiley-Interscience.* New York.

ODUM, E. P. (1971): *Fundamentals of Ecology WB Sounders Company.* Philadelphia.

OGLETHORPE, R. D. y SANDERSON, A. R. (1999): *An ecological economic model for agri-environmental policy analysis.* Ecological Economics, 28(2), p. 245.

PATE, J. y LOOMIS, J. (1997): *The effect of distance on willingness to pay values: a case study of wetlands and Salmon in California.* Ecological Economics 20, p. 199-207.

PATTEN, C. B. (1971): *Systems Analysis and Simulation in Ecology.* Acad. Press Inc., New York.

PATTEN, C. B. (1997): *Bear Model for Airondack National Park.* Ecol. Model. 100, p. 11-42.

PEARCE, D. W. y TURNER, E. K. (1990): *Economics of natural resources and the environment.* John Hopkins, University Press, Baltimore.

PIMENTEL, D., WILSON, C., MCCULLUM, C., HUANG, R., DWEN, P., FLACK, J., TRAN, G., SALTMAN, T. and CLIFF, B. (1997): *Economic and Environmental benefits of biodiversitu.* Bio-Science 47, p. 747-757.

PIZZACARO SILVIA. (1998): *Steps to industrial ecology: reflections on theoretical aspects.* Int. J. Sustain. Dev. World Ecol. 5(4), p. 229-238.

PROOPS, R. C. J., FABER, M., MANSTETTEN, R. y JOST, F. (1996): *Achieving a Sustainable world.* Ecological Economics, 17(3), p. 133-136.

RECKNAGEL, F. (1997): *ANNA-Artificial neural networks model predicting blooms and succession of blue-green algae.* Hydrobiology, 349, p. 47-57, 1997.

RENNINGS, K. y WIGGERING, H. (1997): *Steps towards indicators of sustainable development: Linking economic and ecological aspects.* Ecological Economics 20(1), p. 25-37.

RING IRENE. (1997): *Evolutionary Strategies in Environmental policy,* Ecological Economics, 23(3), p. 237-250.

RUIJGROK, E., VELLINGA, P. y GOOSEN, H. (1999): *Dealing with nature.* Ecological Economics 28, p. 347.

SADLER, B. (1996): *Environmental impact assessment in a changing world: evaluating practice to improve performance.* Final Report of the International Study of the Effectiveness of EIA Canadian Environmental Assessment Agency and the International Association for Impact Assessment, Ottawa.

SCARDI, M. y HARDING, W. I. (1999): *Developing and empirical model of phytoplankton primary production: a neural network case study.* Ecol. Model., 120, p. 213-224.

SCARDI, M. (1996): *Artificial neural networks as empirical model of phytoplankton primary production.* Mar. Ecol. Prog. Ser., 139, p. 289-299.

SEGINER, I., BOULARD, T. y BAILEY, B. J. (1994): *Neural Network Models of the green house climate.* J. Agric. Eng. Res., 59, p. 203-216.

TREWEEK, J. (1999): *Ecological Impact Assessment.* Blackwell Science Ltd. Oxford.

VADINEANU, A. (1998): *Sustainable Development, Theory and practice.* Bucharest, University Press.

VAN DER STRAATEN, J. (1998): *The economic value of nature.* Katholike Univeristeit Braband.

VAN WIJK, T. M. y BOUTEN, W. (1999): *Water and carbon fluxes above European coniferous forest modeled with artificial neural networks.* Ecol. Model., 120, p. 181-198.

VERHEEM, R. (1992): *Environmental Impact Assessment at the strategic level in the Netherlands Project Appraisal 7(3),* p. 91-97.

VILA, P. J., WAGNER, V., NEVEN, P., VOLTZ, M. y LAGACHERIE, Ph. (1999): *Neural Network Architecture selection: New Bayesian perspectives in predictive modeling: application to a soil hydrology problem.* Ecol. Model. 120, p. 119-139.

WACKERNAGEL, M., ONISTO, L., BELLO, P., CALLEJAS LINARES, FALFAN LÓPEZ SUZANA, GARCÍA MÉNDEZ, J., SUÁREZ, I. y GUERRERO SUÁREZ, M. (1999): *National Natural Capital accounting with the ecological footprint concept.* Ecological Economics, 29(3), p. 375-391.

WALPOLE, C. S. y SINDEN, A. J., BCA & GIS. (1997): *Integration of Economic and environmental indicators to aid land management decisions.* Ecological Economics 23(1), p. 25-44.

WEYNS, W. (1998): *The cultural filter, p. 44-61,* in «Environmental Management in Practice-Vol. I), Nath, B., Hens, L., Campton, P., Devuyst, D., Routled, G. London-New York.

WIENS, J. (1997): *Lengthy ecological studies.* Trends in Ecology and Evolution, 12. p. 499.

WILSON, A. M. y CARPENTER, R. S. (1999): *Economic valuation of freshwater ecosystems services in the United States: 1971-1997.* Ecological Applications 9(3), p. 772-783.

ZIEGLER, P. B. (1979): *Multilevel Multiformalism Modeling: an ecosystem example*, in «Halfon, E. (Ed.) Theoretical Systems Ecology, p. 18-44, Academic Press Inc., New York.