Human Ecology: The Science of Sustainability for the Third Millennium?

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INTRODUCTION

Current trends in environmental degradation all over the planet and the general spreading of social unrest in many developing countries clearly indicate the need for an urgent paradigm shift in the way humankind is dealing with the issue of sustainability. In particular, the required paradigm change should be focused on improving the efficacy of two crucial activities of society:

(1) Scientific capability of providing useful representations, understanding and structuring of sustainability problems.
(2) Political capability of providing adequate mechanisms of governance for the sustainability predicament.

The fast process of globalization, in fact, implies dealing more and more with problems definable and workable only considering in parallel different levels. Integrated analyses of sustainability have to adopt scales much smaller – those related to individual values and life-styles - and much larger – those related to the analysis of global trends - than the typical domain of influence of national governments and national cultures. This requires the development of new methodologies of analysis and new mechanisms of control that should be able to detect, react to, and keep coordinated processes occurring in parallel on various spatial and temporal scales.

Actually, one evident sign of crisis is represented by the fact that the necessity of such a dramatic paradigm shift is much clearer for the general public than for the community of scientists or politicians giving them advice. That is, often the sustainability predicament currently experienced by humankind is ignored (or even denied) in many of the analyses provided by main academic disciplines and/or in the strategic planning of large national and international institutions. On the contrary, common people (those that should use these scientific analyses and that will be affected by these strategic plans) are feeling more and more uncomfortable with what they are receiving. In fact, common people are forced to watch every night in the news - or even worse when living in developing countries, by direct experience in their daily life - the growing and widespread crumbling of ecological and social fabrics all over the planet. In front of this emotional stress they are not receiving any convincing explanations that these should not be considered as a worrying signs of the existence of permanent and dangerous trends. This leads to the question of why existing academic and political institutions tend to ignore or - even worse - deny this obvious fact.

One obvious answer is that in order to deal with the issue of sustainability at a very large scale, scientists and decision makers should be able of understanding, representing and structuring the problems of governance in a completely new way. The process of globalization, however, is so quick that they are not having enough time to develop new analytical tools and to implement innovative yet adequate policies. As a result of this, they are left with no other choices but that of sticking with their obsolete repertoire of analytical tools and economic policies (e.g. the evergreen "more economic growth will fix it").

In this paper, I will elaborate on these points and discuss the role that Human Ecology could play in the supply of new analytical tools and procedures to be used to boost the usefulness of scientific analysis in the process of governance for sustainability. The text is divided in 3 parts:

Part 1 – A definition of Sustainable Development from the perspective of Human Ecology (the need of moving from the concept of "substantive" to that of "procedural" rationality).

Part 2 –The challenge for scientific analyses to go beyond commensurability and efficiency (the need of moving, when dealing with sustainability issues, from "monocriteria evaluation of experts" to "participatory multicriteria assessment").

Part 3 - Looking for a Post-Normal Science: can Human Ecology play the role of the new science for sustainability in the third millennium? (the reasons that make Human Ecology a good candidate for such a job).

Part 1

A Definition of Sustainable Development from the Perspective of Human Ecology

A new conceptualization of "sustainable development" is discussed in this section. Such a conceptualization is based on the distinction introduced by Herbert Simon (1976, 1983) between:

(1) "substantive rationality" (= based on the assumption that it is possible to define "the" optimal solution for the entire system, and that this definition will be accepted by all the stakeholders). In this paradigm the scientists are those in charge for individuating the optimal solutions and communicating them to the society. And,

(2) "procedural rationality" (= based on the assumption that it is possible to reach a consensus on a 'satisficing' solution negotiated among the stakeholders. 'Satisficing solution' is the term proposed by Simon as an alternative to "optimal solution";). In this paradigm "decision making" implies dealing with uncertainty, incomplete information, and unavoidable legitimate contrasting perspectives.

The idea that the process of decision making should be intended as a search for "satisficing solutions" implies that the new role of scientists should be that of helping the society to reach a consensus on how to deal with the sustainability predicament. To do that, they should be facilitating the negotiation among stakeholders (clarifying the nature and the consequences of sustainability trade-offs) rather than hampering such a process by taking sides (indicating the "best" solution among the considered options). The concept of "procedural rationality", therefore, implies a two-ways dialogue of science within the society (scientists teaching and learning at the same time). In contrast with the concept of "substantive rationality" entailing a one-way flow of information. Put in another way, the concept of "procedural rationality" put back the scientists within the social process, rather than something external and above it.

The movement to the paradigm of procedural sustainability is crucial for obtaining an operational definition of sustainable development. In fact, it is often stated, by those operating within the paradigm of substantive rationality, that "Sustainable Development" is something that can only be grasped as a "fuzzy concept" rather than expressed in terms of an exact definition. This claimed elusive nature of the concept led to a plurality of attempts to get the "true" definition of "sustainable development". For example, Goldman (1995) provides a list of fourteen academic definitions of sustainability. However, this "claimed fuzziness" is due to the fact that the concept of "Sustainable Development" is often imagined, within such a paradigm, as a formal, static concept that could be defined in general terms once and for all (out of space and time and without a specific context of reference needed to assign meaning to it).

To avoid the "fuzzy trap" implied by such a substantive interpretation of the concept of sustainability, I propose instead a definition which is based on (and implies the ability of performing) internal and external semantic "quality checks" on the correct use of adjectives and terms used in the definition. With "quality check" I mean the ability to verify the meaning assigned by various stakeholders operating within a specific context to the terms used in the definition.

This implies being aware of the specificity of the identity of a particular society operating at a given point in space and time (due to the strong dependency of these perceptions on the history of the local system - e.g. cultural identity of various social groups, existing institutions and power structure, existence of shared goals and patterns of trust among stakeholders).

The main point here is that a definition of Sustainable Development can be given (see below) but only after assuming that within a given society it is possible to obtain these semantic and quality checks (by assuming as valid the paradigm of procedural rationality). What I propose is: "**the ability of a given society to move, in an adequate time, among satisficing, adaptable, and viable states**"

Such a definition implies that sustainable development has to do with a process (procedural sustainability) rather than with a set of system-qualities, which can be defined without a specific knowledge of the context within which the issue of sustainability is dealt with (substantive sustainability). From this perspective sustainability implies the following tasks:

(1) **governance based on an adequate understanding of present predicaments and the ability of change** - as indicated by the expression: "the ability to move, in an adequate time,". This means that the system has to be able to provide a mechanism of control (= the decisional process and the implementation of an effective policy) able to operate with a lag time compatible with the dynamic of the mechanism generating the perceived problem.

(2) **recognition of legitimate contrasting perspective related to the existence of different identities for stakeholders** – as indicated by the expression "satisficing". The acknowledgment of the obvious fact that life is "the interaction of non-equivalent observers" (Rosen, 1985) implies the need of having available: (i) an adequate integrated scientific representation of reality. This requires the ability of using a set of non-equivalent scientific analyses, able to reflect various relevant aspects of the reality (various relevant qualities). The adjective relevant implies that they have to reflect the different legitimate views found among the stakeholders; and (ii)

adequate institutional organizations that can be used to generate a participatory process of decision making. Incommensurability between non-equivalent indicators of performance (e.g. "happiness of individuals" versus "ecological integrity" versus "economic growth") implies that "optimal solutions" cannot be detected applying algorithmic protocols. Different stakeholders can exhibit different "rational choices" when facing the same specific situation. Therefore, it is not possible to find a single mechanism, generating a single comparative term by which all different actions can be ranked in a way that will be accepted by all the stakeholders.

(3) **recognition of the unavoidable existence of uncertainty, indeterminacy and ignorance in our understanding, representation and forecasting of future events** - as indicated by the expression: "adaptable". When discussing of adaptability (= the usefulness of a larger option space in the future) we are forced to admit that: (i) reductionist analyses based on "ceteris paribus" hypothesis have little to say, when dealing with evolutionary trajectories and future scenarios. In fact, when dealing with them, even validated models can fail, since: (a) the structure of causal relations in the natural system (simulated by the model) can change (or may have changed), and/or (b) our selection of the set of relevant qualities to be used to describe the problem can become no longer valid (Giampietro, 2001).

(4) **availability of sound reductionist analyses** able to verify within different scientific disciplines the "viability" of possible solutions in terms of existing technical, economic, ecological and social constraints - as indicated by the expression: "viable". I stress here the term "reductionist analyses" and the claim that they are essential, even when adopting a holistic approach. In fact, even though, when dealing with the issue of sustainability, they are not useful when used one at the time (as discussed in the second part), they remain crucial to detect the feasibility of proposed change in relation to specific constraints (e.g. to check the economic viability, ecological compatibility, technical feasibility of a proposed solution).

I personally believe that reaching a societal agreement on a procedural definition of sustainable development (sharing the meaning of the terms used in this definition in relation to a specific situation and adopt participatory processes to reach negotiated solutions) is a possible task. After all this is what social organization is all about (and what Human Ecology should deal with). However, as noted in the introduction, the new set of problems faced by humankind in the last decades requires a paradigm shift in the way scientific information is generated and organized when providing inputs to the process of decision making. The challenge implied by such a paradigm shift, is the subject of the second section of this paper.

Before closing this section I would like to quote Faucheux et al. (1997; pag. 57) commenting Simon's analysis: 'When indeterminacy or complexity prevail, decision making embodies deliberation and search, and is sensitive to the forms of representation the decision makers know about or prefer. A solution is then constructed through a heuristic process in which it is reasonable to retain "an alternative that meets and exceeds specified criteria, but that is not guaranteed to be either unique or in any sense the best". This defines as "satisficing" solution adequate to some aspiration level, which is the essence of the procedural rationality. It is no longer possible to get rid of deliberation when there is indeterminacy or complexity. The formation of human perceptions and preferences should be considered as part of the problem of decision. Decision making is influenced by the decision-maker's mind: " A body of theory for procedural rationality is consistent with a world in which human beings continue to think and continue to invent: a theory of substantive rationality is not" (Simon, 1976)'.

Part 2

The Challenge for Scientific Analyses to go Beyond Commensurability and Efficiency

The growing concern for the sustainability of human development is making more and more clear that when dealing with the issue of sustainability one is dealing with complexity (Giampietro, 2001). This entails that the sustainability of human development means forgetting about the search for optimal solutions, but rather focusing on a "value loaded" integrated assessment of trade-offs. Examples of "value loaded" integrated assessment of these trade-offs are: "how to weight ecological impact versus economic growth", or "how to weight the goal of changing as quick as possible unsatisfactory situations versus the goal of preserving cultural heritage, especially when operating in marginal social groups". As noted these sustainability trade-offs can be defined in general terms. However, at the moment of deciding on a particular policy at a particular point in space and time, the integrated assessment of the relative incommensurable "costs" and "benefits" can only be obtained in relation to a specific context and a specific social entity (after defining the particular problem at that particular point in space and time). This fact is generating a new challenge for science for two reasons:

1. The need of considering in parallel different dimensions of sustainability requires the use of non-equivalent descriptive domains. (= the parallel use of scientific models which are not reducible, since they are based on non-equivalent representation of the reality – for more see Giampietro, 2001). For example, the representation of economic benefits is non reducible with the representation of ecological benefits. An accurate assessment of economic costs and benefits requires the adoption of a descriptive domain (measuring changes in dollar value and on a time scale of no more than 5/10 year). This descriptive domain is not appropriate to get an accurate representation of ecological costs and benefits (e.g. measured in changes in biodiversity). Let alone the representation and assessment of social costs. In this situation, if we want to assess the overall effect of a given policy in terms of several trade-offs (e.g. social justice, economic stability, demand of fresh water) we face an epistemological impasse. The use of a single system of mapping (e.g. using a single indicator of performance based on monetary units, as done in Cost/Benefit Analysis) will induce a bias in the consequent evaluation. In fact, those relevant qualities, which are better detected by the economic system of representation (e.g. the ability of generating added value in market-driven activities) will have to be weighted against other incommensurable qualities that can only be represented using different and non-equivalent indicators (e.g. happiness of people, dependence on non-renewable resources). Obviously, if we want to express non-equivalent and incommensurable costs and benefits in a common unit (money), we should expect a huge arbitrariness in the resulting numbers (who knows for sure how to measure happiness in 1994 US$?) – O'Connor and Spash, 1998.
2. There are always different hierarchical levels at which the effects of a particular change, linked to a given policy should be assessed (Giampietro, 1994; 2001). For example, the effect of increasing the taxes is, in general, perceived in a negative way by households – in terms of less net disposable cash. However, the very same change is perceived in a positive way by local administrations – in terms of more money available for social investments. The nested hierarchical nature of socio-economic systems implies that this is a standard feature of these systems (Giampietro, 1994; 2001). This peculiar behavior of hierarchical systems implies that as a consequence of this fact, the very choice of the level at which we describe changes, will imply a bias in the description of the consequences. Therefore, even remaining within a given academic discipline (e.g. economics, ecology, sociology), when dealing with the issue of sustainability, the proposed analyses should be able to provide a parallel representation of changes as seen at different hierarchical levels (from that of the individual household to that of the world economy). This multilevel representation should apply also to: (a) technical performance achieved in various activities; (b) relevant societal indicators of development or well-being; (c) ecological impact induced by societal activities; (d) other aspects which are considered as relevant by individual citizen in relation to their quality of life.

The goal for the scientists at this point is that of providing a problem structuring, a coherent handling of a heterogeneous information space (Giampietro and Mayumi, 2000a; 2000b), which has to reflect: (1) different, relevant, but incommensurable, dimensions (e.g. ecological, economic, social): and (2) different perceptions referring to different relevant levels (e.g. individual, household, community, national) in relation to a given socioeconomic system (specific context). As noted earlier, this assumes that it is possible to know with enough efficacy the relevant dimensions and criteria to be considered and the relevant levels to be considered for better describing the behaviors of interest.

In order to do that, scientists have to package their analyses in a way that makes possible an integrated representation across scales of the various trade-offs over all relevant dimensions (examples of this approach in Giampietro and Mayumi, 2000c; 2001). This implies, however, that the traditional reductionist paradigm can no longer be used to organize scientific information in the process of decision making. In the rest of this section, I focus, using specific examples, on three points that justify the call for an urgent paradigm shift:

(1) the deep implications of incommensurability for scientific representations of sustainability (the impossibility of using a single indicator of performance, or using a monocriteria analysis of development as proposed by many neo-classical economists);
(2) the multiple causality implied by nested hierarchical systems (the impossibility of defining a single direction of causality in complex systems, such as human societies); and finally
(3) the impossible formalization of the dilemma "efficiency" versus "adaptability" when dealing

with analyses of sustainability (the need of participatory processes when dealing with integrated assessment of sustainability).

2.1. The challenge Implied by Incommensurability

An example of integrated assessment based on the consideration of various indicators, reflecting incommensurable criteria of performance, is given in figure 1. Very little explanations are needed to present this example, since the structuring of the problem of how to chose a car to buy is a quite familiar one. The radar-type graph shown in figure 1 (called also "spider-web" or "AMOEBA" – ten Brink, 1992) consists of various axes coming out of a common origin in the center. Each axis represents an indicator of performance (reflecting a previous selection of relevant criteria) which indicates "improvements" (= a given performance getting closer to the expectation) in relation to perceived changes in the quality of the system encoded by it. For example, a position more distant from the center for the indicator "Price" - e.g. that indicated by Profile 1 - implies a car which is much cheaper than that characterized by Profile 2. At this point, if we introduce a target value over an indicator, the distance between the actual score from the given target becomes an attribute to be used in a multicriteria analysis (Munda and Giampietro, 2001).

Three observations about the two profiles shown in figure 1:

(1) the shape of various profiles linking the numerical values taken by the set of indicators of performance on the graph (the shapes of different "amoebas" so to speak) indicates **overall "satisficing solutions"** for the buyer in relation to the various trade-offs considered in the multicriteria analysis of performance. How to select the most satisficing "trade-offs profile" obviously depends on a "value call" (required to weight the various performances related to incommensurable criteria). Clearly, the pre-analytical step of selection of the set of indicators used to assess trade-offs (e.g. why considering the safety devices and not the number of tires) will affect such a final decision. This means that, after including a new (or different) criteria in the set (e.g. the risk that the car gets stolen, when the buyer is living in a place where such a risk is very high), we should expect a different combination of satisficing values for the same set of indicators (e.g. different shapes of "amoebas") even for the same buyer. That is, a change in the set of selected criteria (by the addition of a new one) could imply changes over the old profile of satisficing values related to the old set of 12 indicators.

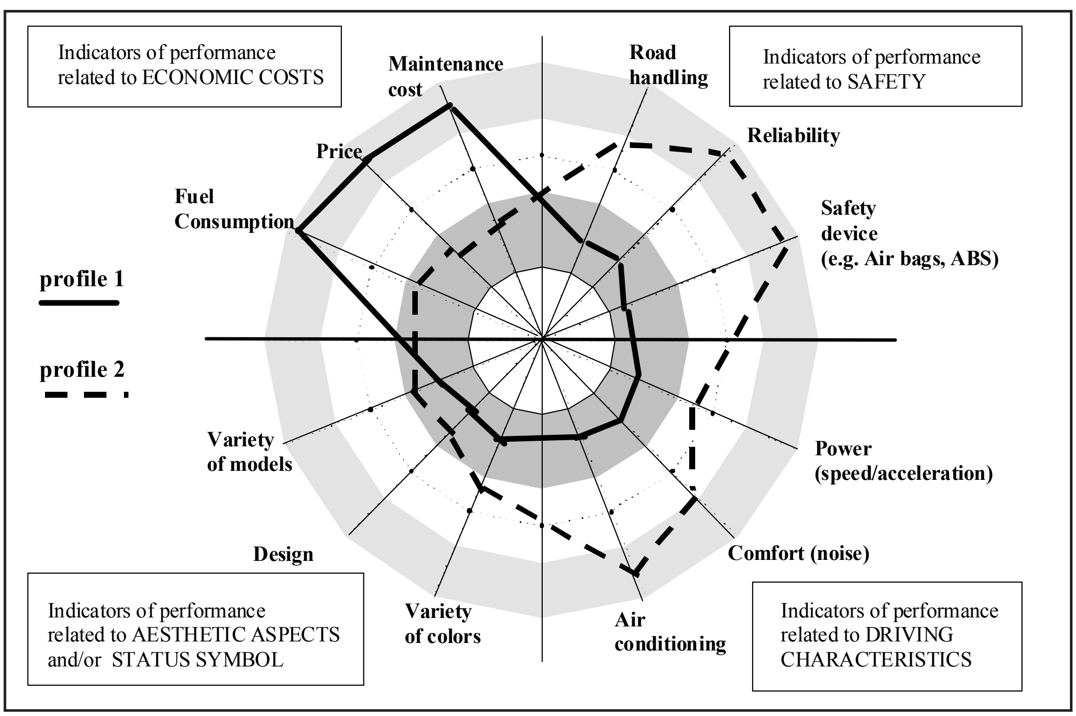

Fig. 1. A Multi-Objective Integrated Representation of the performance of a car

(2) the 4 different classes (reflecting **non-equivalent criteria**) in which the various performance indicators have been clustered (Safety, Economic costs, Driving Characteristics, Aesthetic Aspects/Status Symbol) imply the existence of non-linear "threshold values" on the final decision of the buyer. That is, if the performance of the considered car - in the buyer's perception - fails completely on only one of these 4 aspects, the car will not be purchased, no matter how well performing in the others. This implies that - after agreeing on the selection of crucial non-reducible aspects of the performance of a system - an integrated assessment of this type can be used to explore buyers' perception of sustainability trade-offs.

In fact, the integrated assessment of the performance of a car (illustrated in Fig. 1) can be used as a metaphor for sustainability. A given model of a car (or an implemented policy in the analogy) will be "sustainable" on the market only if: (A) its trade-offs profile over the various crucial and incommensurable aspects of its performance remains above minimum acceptable values over all the relevant criteria considered as relevant (e.g. in terms of economic performance, social justice, respect of local cultural identity, ecological compatibility, etc.). (B) the given trade-offs profile is judged as satisficing by a consistent number of buyers (there is a correspondence between buyers expectations of performance and the perceived performance of a given model of car). Several examples of analyses of this type for discussing the sustainability of farming systems in specific case studies are available (Giampietro and Pastore, 1999; Pastore and Giampietro, 1999; Giampietro and Pastore, 2001; Gomiero and Giampietro, 2001). More in general, this approach is based on the concept of Multicriteria Analysis, which seems to be much more promising than conventional Cost/Benefit Analysis in the field of integrated assessment (good overviews are available – e.g. Nijkamp et al., 1990; Munda, 1995; Beinat and Nijkamp, 1998).

Using this analogy we can see that trade-offs profiles of performance of the "car types" reported in figure 1 are mapping the weighting profiles given by various "types" of buyer to the set of criteria considered in the integrated assessment. That is, by using multi-objective performance space of the type illustrated in figure 1 we can put in relation different "satisficing trade-offs profiles" to different "buyer types" (this is what is called in marketing identification of the "consumer targets" for various products). When dealing with ecological systems this would be the "niche identification" of the particular species described on a multi-dimensional state space . When dealing with sustainability this would make it possible to study the knowledge system of a given social group about their perception of sustainability trade-offs.

(3) the same buyer can change her/his perception of "satisficing trade-offs profile" in time. For example, Profile 1 can represent a satisficing solution for a student without a strong financial support (the basic concern is to have a car moving her/him around at a low economic cost). Whereas Profile 2 can represent a satisficing solution for the same student after getting a well paid job and after becoming a father of 3. In this case, a top priority given to Safety and Comfort could imply accepting a higher economic cost for the car.

(4) the same multi-objective performance space (the radar frame illustrated in Fig. 1) can generate a lot of different satisficing "trade-offs profiles" (different amoeba shapes) in relation to different typologies of buyers operating in the same context, or for the same typology of buyer operating in different contexts. Obviously, this is what explains the existence of different models of cars on the market. If the universe of car-buyers were not made of non-equivalent observers (people having different perceptions of their own utility and therefore expressing different "rational choices" when buying a car) we would have only one model of car on the market (that providing the maximum utility for such a homogeneous universe of buyers) in each given context. From this simple consideration it is obvious that an interdisciplinary team of scientists (no matter how smart and how interdisciplinary) cannot, even in principle, determine from the desk of their office the profile of an "optimal car", even when knowing enough about the existing boundary conditions. Actually, they can not even decide how to "improve" the performance of a specific car already used by a specific individual in a particular point in space and time. In order to be able to do so, they have to receive first an input from that specific individual about what would be perceived as an improvement, by her/him, right now. In spite of the obviousness of these considerations, it is not clear then why the literature is full of studies in which well educated scientists calculate the optimal solution for farming systems or the optimal use of resources for a given community (Optimal for whom? Regarding which selection of criteria? Optimal for how long?).

(5) as a consequence of the previous point, the co-existence of different "buyer types" in the real world (reflecting the existence of different trajectories in the evolution of expectations and perceptions of car performance of possible buyers operating in different "context specific" situations) implies that

a "substantive" definition of a "sustainable model" of car on the market (even if obtained by considering a very large database) does not make much sense. Clearly, the combined knowledge of buyers' preferences and technical aspects of the performance of cars can make possible the definition of general principles. For example, we can use our knowledge of general trends to guess satisficing profiles for "categories" of buyers (e.g. the higher the income of the buyer the more we can expect her/his concern for the criteria safety – or in the analogy, the higher the income in a country the higher the consumption of fossil energy). We can also use our knowledge of technical aspects to explore the existence of internal links among trade-offs (e.g. more safety implies higher prices – higher income implies higher CO_2 emissions per capita).

However, we cannot expect that this better structuring of the information space related to "trade-offs analysis" when buying a car, can make possible to get away completely from the need of receiving direct information related to "context specific" characteristics. As noted earlier, the addition of only one "special" criteria can alter the validity of "standard trade-offs analyses. For example, in a place with very cold winters diesel cars are not recommended, no matter how they are performing in the standards indicators of performance. In the same way, in particular cultures, a particular car color may not be accepted for social rules.

Relating this discussion of a multicriteria analysis of the performance of a car to the issue of a multicriteria analysis of sustainable development, we can further use the analogy. The existence of an heterogeneous population of car buyers can be translated into the obvious fact that different social systems operating in different areas, with different histories and cultural identities, will have different legitimate, but contrasting views of how sustainable development should be defined and implemented within their context. The most relevant part for our discussion is that these social systems have access to "location specific information" (e.g. which indicators should be used for assessing the performance within their context in relation to a given set of criteria) which nobody else can know.

2.2. Dealing with Multiple Causality in Nested Hierarchical Systems

The example given in figure 2 addresses explicitly the importance of considering the hierarchical nature of the system under investigation. The example mentioned below has been suggested to me by David Waltner-Toews (personal communication – details on the study at the IDRC website). The goal of this example is to illustrate that when reading the same event on different levels (on different space-time horizons) we will see different solutions for the very same problem.

Briefly, the case study deals with the occurrence of a plague in a rural village of Tanzania. The plague was generated by the presence of rats in the houses of villagers. The rats moved into the houses following the stored corn, which previously was stored outside. The move of the corn inside the houses resulted necessary due to the local collapse of the social fabric (it was no longer safe to store corn outside). Such a collapse was due to the very fast process of change of this rural society (triggered by the construction of a big road). Other details of the story are not relevant here, since this example does not deal with the implications of this case study, but just points at a methodological impasse.

The term Holarchy used in Fig. 2 indicates a nested hierarchy of element (a hierarchical system made of holons) and is following the terminology proposed by Koestler (1968 p. 102). A 'holon' is a component of a nested hierarchical system which has a double nature of "whole" and "part" (for a discussion of the concept see also Koestler, 1969; and Allen and Starr, 1982, pp. 8-16, and Giampietro, 2001). That is, a holon is a whole made of smaller parts (e.g. a human being made of organs, tissues, cells, atoms), and at the same time it forms a part of a larger whole (an individual human being is a part of a household, a community, a country, the global economy).

A simple procedure that can be used to explore the implication of the fact that human societies are organized in hierarchical levels is indicated in figure 2. After stating the original problem defined at a given level, it is possible to explore the causal relations in the holarchy by climbing the various levels through a series of "why and because" (upper part of Fig. 2). When arriving to an explanation which has no implications for action we can stop. Then we can descend the various levels by answering new types of questions related to the "how and when" dimension (lower part of Fig. 2).

Looking at possible ways of structuring the problem experienced by the villagers in this way (Fig. 2) we are left with a set of questions and decisions that lead us directly into a typical "Science for Governance" domain:

• *What is the "best" level that should be considered when making a decision about eliminating the plague? Who is entitled to decide that?* The higher

Phase 1: climbing the Holarchy through resonating WHY and BECAUSE

WHY there is the plague in the village?

BECAUSE rats and humans interact too much - **WHY?**
BECAUSE the structure of local Society and Ecosystem were disturbed - **WHY?**
BECAUSE an exogenous model of development was imposed on them - **WHY?**
BECAUSE of lack of empowerment of local communities (changes too much influenced by western models) - **WHY?**
BECAUSE two socio-economic systems with a big difference in their level of development are interacting too much (North/South). This is generating a strong friction on lower level holons (= changes are so fast, that marginal social groups operating on a very small scale have no power of negotiation) -**WHY?**
BECAUSE of historical accidents and different boundary conditions
—> answer indicating that there is nothing we can do about it

Phase 2: re-descending the Holarchy through resonating HOW and WHEN

HOW/WHEN can we eliminate the problem?

HOW/WHEN - existing difference between North and South can be eliminated? Which one of the two models of development we like most ? Which model is feasible for the entire world? (= compatible with biophysical constraints, compatible with different cultures)? What is the lag time needed for expected changes ?
HOW/WHEN - can we re-establish a fair negotiation among the elements of the holarchy in spite of the large differences between North and South ? (it is possible to empower local communities ? how ? what is the expected lag time to get relevant changes ?)
HOW/WHEN - can we generate room for expressing local aspirations within the constraints given by the evolutionary trajectory of the larger system to which the community belongs ?
HOW/WHEN - the disturbance to the local ecosystem and the local social system can be reduced to acceptable levels? what are the possible options? what are the expected lag time to get results? what is the level of uncertainty on the options?
HOW/WHEN - can we eliminate the rats ? what is the expected lag time? What are the costs? What are possible negative side effects? If rats are symptoms rather than the real cause, then, there is any negative feed-back in curing symptoms?

Fig. 2. Multiple causality for a given problem: plague in the village

we move in the holarchy the better is the overview of parallel causal relations and the richer (more complex) is the explanation. On the other hand, this implies a stronger uncertainty about predicting the outcome of possible policies as well as a longer lag-time to get a fix (= prolongation of sufferance of lower level holons = those affected by the plague in the village - in this specific case, mainly women). The smaller is the scale, the easier the identification of direct causal relations (= the easier the handling of specific projects looking for quick-fixes). However, faster and more reliable causal relations (leading to rapid solutions) carry the risk of curing symptoms rather than causes. That is, the adoption of a very small scale of analysis can imply the risk of "locking in" the system in the same dynamic that generated the problem in the first place. Since this main dynamics operating on a larger scale has not been addressed in the "location specific" analysis.

• *How to assess the trade-offs linked to the choice of a level rather than another?*

When using a very short time horizon to fix the problem (e.g. kill the rats while keeping the society and the ecosystem totally unbalanced) it is likely to get, sooner or later, into another problem. If rats were just a symptom of some bigger problem, the cause is still there. On the other hand, when using a too large time horizon (e.g. trying to fix the injustice in the world) implies a different risk. That of attempting to solve the perceived problem very far in the future or distant in space, basing our policies on present knowledge and boundary conditions (perceptions referring to a very small space-time scale). The very same problems we want to save today with major structural changes in social institutions could have a different and easy solution in 20/50 years (e.g. new sources of energy and/or climatic changes that make impossible life in that area). If this is the case, policies aiming only at a quick relief to the suffering of the poor (e.g. killing the rats) could have been implemented without negative side-effects (e.g. generation of a lock-in of a larger scale problem). Unfortunately we can never know this type of information ahead.

• *It is our integrated assessment of changes reflecting existing multiple goals found in the system?* Any integrated assessment of the performance of a system depends on:

(1) expectations and related priorities (relevant criteria to be considered and weighting factors among them); and (2) perception of effects of changes (the level of satisfaction given by a certain profile of values taken by indicators of performance). In turn, these expectation and perceptions both heavily depend on: (i) the level of the holarchy at which the system is described (e.g. if we ask the opinion of the president of Tanzania or of a farmer living in that village); and

(ii) the identity of the various social groups operating within the socio-economic system at any given level in the holarchy. For example, farmers of a different village in Tanzania can have different perspectives on the effects of the same new road. In the same way, women or men of the same village can judge in different way the very same change.

• *What is the risk that cultural mode-locking - which is clearly "space and time specific" - is preventing the feasibility of alternative solutions?* It is well known that the past – in the form of cultural identity in social systems - is always constraining the possibility of finding new models of development. This is why, changes imply always tragedy (Funtowicz and Ravetz, 1994). As noted earlier, when solving a sustainability problem socio-economic systems have to be prepared to lose something to get something else. This introduces one of the most clear dimension of incommensurability in the analysis of trade-offs. Decisions about sustainability have to be based on a continuous negotiation. The various stakeholders should be able to reach, in an adequate period of time a consensus on the nature of the problem and, an agreement on how to deal with it. In particular this implies deciding on:

(i) what do they want to keep of present situation [e.g. how important is to keep what they are getting now?].
(ii) what do they want to change in present situation [e.g. how important is to get away as fast as possible from current state?].
(iii) how reliable is the information which is used to translate into practical action the agreement reached about points: (i) and (ii)?

These questions can be reformulated as: when forced to re-define their identity as a social system, what do they want to become?

Clearly, a total agreement over a common "satisficing trade-offs profile" is certainly not easy to reach (if not impossible) in any social system. The unavoidable existence of different perceptions about how to answer these questions can only be worked out through negotiation. Negotiation is crucial to keep diversity in the social entity. The alternative solution - imposing a particular view-point (= a given best "satisficing trade-offs profile") with the force (hegemonization) - beside the very high cost in terms of human suffering, carries the risk of an excessive reduction in the cultural diversity, and therefore a dramatic reduction of adaptability, in the resulting social systems. The expression "Ancien Regime Syndrome" proposed by Funtowicz and Ravetz (personal communcation) exactly indicates that boosting short-term efficiency through hegemonization in a society is often paid for in terms of lack of adaptability in the long term. Such a typical pattern leading to the collapse of complex social organization has been discussed in detail by Tainter, (1988). More on this dilemma in the next section.

2.2. An additional problem: the impossible formalization of the dilemma "efficiency" versus "adaptability"- the need of participatory integrated assessment

Adaptability and flexibility are crucial qualities for the sustainability of adaptive systems (Conrad, 1983; Ulanowicz, 1986; Holling, 1995). They both depend on the ability of preserving diversity (actually this is also the theoretical foundation of democracy). However, the goal of preserving diversity *per se* collides with that of augmenting efficiency at a particular point in space and time (this is the problem with total anarchy). Efficiency, in fact requires elimination of those activities that are less performing according to a given set of goals, functions and boundary conditions and an amplification of those activities which are perceived as the most performing at a given point in space and time. Clearly this general rule applies also to technological progress . For example, in agricultural production, "improving" world agriculture according to a given set of goals expressed now by a given social group in power and according to present perception of boundary conditions (e.g. plenty of oil) is implying a dramatic reduction of the diversity of systems of production (e.g. the disappearance of traditional farming systems). More and more (driven by technological innovations such as the green revolution) agricultural production all over our planet is converging on a very small set of standard solutions (e.g. monocultures of high yielding varieties supported by "energy intensive" technical inputs, such as synthetic fertilizers, pesticides and irrigation - Pimentel and Pimentel, 1996). On the other hand, the "obsolete" agricultural systems of production, being abandoned all over the planet can show a very high performance when assessing them under a different set of goals and criteria (Altieri, 1987) .

When reading the process of evolution in terms of complex systems theory (Giampietro, 1997; Giampietro et al, 1997; Giampietro and Mayumi, forthcoming), we can observe that, in last analysis, the drive toward instability is generated by the reciprocal influence between efficiency and adaptability, which are operating on different time scales. The continuous transformation of "efficiency" into "adaptability" and that of "adaptability" into "efficiency" is the responsible for the continuous push of the system toward non-sustainable evolutionary trajectories. The steps of this circular cycle (with an arbitrary choice of a starting step) are: (i) accumulation of experience in the system leads to more efficiency (by amplification of the most performing activities and elimination of the less performing); (ii) more efficiency makes available more surplus to fuel societal activities; (iii) the consequent increase in the intensity and the scale of interaction of the socio-economic system with its environment, implies an increased stress on the stability of boundary conditions (more stress on the environment and a higher pressure on resources). This calls for increased investments in adaptability; (iv) in order to be able to invest more in adaptability (= expand the diversity of activities, which implies developing new activities that, at the moment, can result not particularly performing) the system needs to be more efficient - i.e. has to better use it experience on how to produce more. This can only be obtained by an amplification of the most performing activities and an elimination of the less performing. At this point the system gets back into the step (i)

An overview of the co-existence of different causal paths between efficiency and adaptability, described on different time scales, is illustrated in figure 3. When considered on a short time scale, efficiency would imply a negative effect on adaptability and vice-versa. When a long-term perspective is adopted, they both thrive on each other. However, the only way to obtain this result (based on a sound Yin-Yang tension) is by continuously expanding the size of the domain of activity of human societies. That is, increases in efficiency are obtained by amplifying the most performing activities, without eliminating completely the obsolete ones. These activities will be preserved in the repertoire of possible activities of the societal system (as a memory of "different meanings" of efficiency when adopting a different set of boundary conditions and a different set of goals). When the insurgence of new boundary conditions or new goals will require a different definition of efficiency, the activities amplified until now, will become obsolete, and the system will scan for new (or old) ones in the available repertoire. In this way, at each cycle, societal systems will enlarge their repertoire of knowledge of possible activities and accessible states (boost their adaptability). This expansion in the computational capability of the society, however, requires an expansion of its domain of

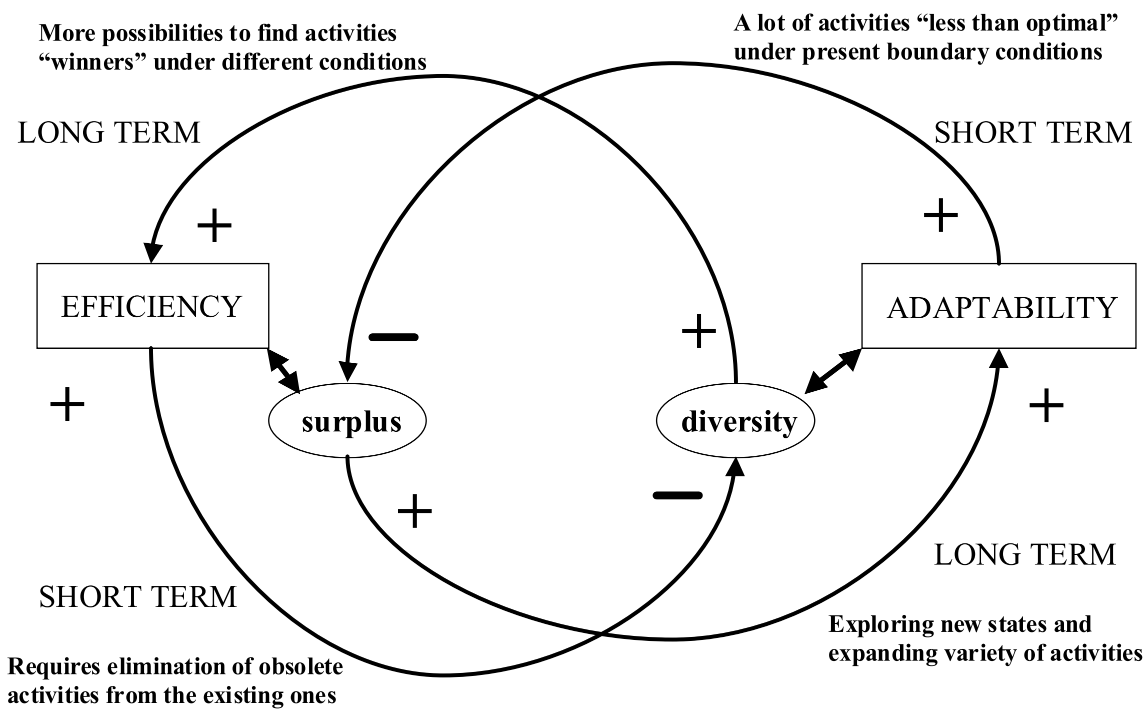

Fig. 3. The self-entailment between "Efficiency" and "Adaptability" across time scales

activity, that is an increase in its size (no matter how we decide to measure its size – total amount of energy controlled, of information processed, of kg of human mass, of GNP) – Giampietro et al. 1997.

Sustainability of societal systems can therefore only be imagined as a dynamic balance between the rate of development of their "efficiency" and "adaptability". This can be obtained by a continuous change of structures to maintain existing functions and a continuous change of functions to maintain existing structures. Put it in another way, neither a particular societal structure or a particular societal function can be expected to be "sustainable" indefinitely in the future.

Practical solutions to this challenge means deciding on how to deal with the tragedy of change. That is, any social system in its process of evolutions has to decide how to become a different system, but maintaining in this process its own identity(!). The "feasibility" of this process (which is like changing the structure of an airplane while flying on it) depends on the nature of internal and external constraints faced by society. The "advisability" of the final changes (what the plane will look like at the end of the process, if still flying) will depend on the legitimate contrasting perceptions of those flying on it, their social relation and the ability expressed by such a society to make changes to the plane.

This adds an additional complication to the practical operationalization of the process of decision making. In fact, not only, it is difficult to find an agreement on what are the most important features to preserve or to enhance when attempting to build a different airplane. But this decision has to be taken without having a solid information about the feasibility of the various possible projects to be followed. As noted earlier, the definition and forecasting of viability constraints is unavoidably affected by a large dose of uncertainty and ignorance about possible unexpected future situations. Put in another way, when facing the sustainability predicament, humans must continuously gamble trying to find a balance between their efficiency and adaptability. In cultural terms, this means finding an equilibrium in focus between the consideration that has to be given to the past and the future of their civilization (Giampietro, 1994).

Part 3

Looking for a Post-Normal Science: can Human Ecology Play the Role of the New Science for Sustainability in the Third Millennium?

3.1. The Call for a Post-Normal Science

The way humans represent and structure the problem of sustainability, in scientific terms, necessarily reflects the values and interests of those that generate the analysis. This is perfectly OK as long as this obvious fact is acknowledged and its related implications are taken into account. The same applies to the mechanism used to compare and rank possible alternative actions. From a philosophical perspective, it is possible to distinguish between two key concepts (Martinez-Alier et al., 1998; O'Neill, 1993). (1) *strong comparability* (= it is possible to find a single comparative term by which all different actions can be ranked). This implies strong commensurability (= it is possible to obtain a common measure of the different consequences of an action based on a cardinal scale). Which, in turn, translates into the assumption that the "value" of "everything" (including your mother) can be compared to the value of "everything else" (including someone else mother) in an objective way, by using a single numerical variable (e.g. monetary units). (2) *weak comparability* (= there is an irreducible value conflict when deciding what term should be used to rank alternative actions). This translates into the assumption that different stakeholders can exhibit different "rational choices" when facing the same specific situation. Weak comparability, however, does not imply that it is not possible to use "rationality" when deciding. Rather, it implies that we have to move from the concept of "substantive rationality" (based on strong comparability) – an objective rationality that applies to all - to that of "procedural rationality" (based on weak comparability). As discussed earlier, procedural rationality is based on the acknowledgement of ignorance, uncertainty and the existence of legitimate non-equivalent views of different stakeholders.

In any case, every time we rank options we have to chose an operational definition of "value" applied at the societal level, in spite of the fact that stakeholders with different interests, cultural identities and goals have different definitions of "value". That is, when ranking options, we are making a decision about **what is important** for the stakeholder as well as **what is relevant** for the stability of the process described in the model. As a consequence of this fact, the validity of a given approach used to evaluate and rank possible options depends on its ability to include **several legitimate perspectives** (acknowledging the reflexive properties of the system) and check the viability of the system in relation **to different dimensions of viability** (technical, economic, ecological, social). As discussed in the previous section, this, in turn, requires "transparency" in relation to two main points:

(1) the need of performing a quality check on the

representative tools used in the process. When dealing with mathematical and descriptive properties, which make the models used conform to given requirements. e.g. what are the assumptions, what are the implications of these assumptions?. (2) the need of performing a quality check on the process of decision making. How the models are used in an integrated way within the decision process. e.g. How fair and open was the discussion about the selection of a given problem structuring? Who did chose the models used to characterize scenarios? Who selected the set of alternatives to be considered in the option space? How fair was the mechanism used for the final decision?

In general, these concerns have not be considered as relevant by "hard scientists" in the past. So that, the goal of "improving the quality of a decision process" was not considered to belong to the realm of scientific investigation. On the other hand, the new nature of the problems faced in this third millennium, implies that very often when deciding on facts that can have long term consequences we are confronting issues: "*where facts are uncertain, values in dispute, stakes high and decisions urgent*" Funtowicz and Ravetz (1991). In this case, scientists cannot provide any useful input without interacting with the rest of the society, as well as, the rest of the society cannot perform any sound decision making without interacting with the scientists. That is, the question on "how to improve the quality of a decision process", must be put, quite quickly, on the agenda of both "scientists" and "decision makers". Moreover, when science is used in policy, lay-persons (e.g. judges, journalists, scientists from another field, or just citizens of mothers) can often master enough of the subject to become effective participants in the dialogue. This obliged step, will be easier to take if scientists make an effort to package in a more "user friendly" way their scientific input. This extension of the "peer community" is essential for maintaining the quality of the process of decision making when dealing with reflexive complex systems. In relation to this goal Funtowicz and Ravetz (1991) have developed a new epistemological framework called "post-normal science", where it is possible to better deal with two crucial aspects of science in the policy domain: uncertainty and value conflict. The name "post-normal" wants to indicate a difference from the puzzle-solving exercises of normal science, in the Kuhnian sense (Kuhn, 1962). Normal science, which was so successfully extended from the laboratory of core science to the conquest of nature through applied science, is no longer appropriate for the solution of sustainability problems. In sustainability problems social, technical and ecological dimensions are so deeply mixed that it is simply impossible to consider them as separated, one at the time, within conventional disciplinary fields (Special Issue of Future on PNS, 1999).

Post-Normal Science can be characterized in relation to other, complementary scientific strategies, according to the diagram given in figure 4, which is based on two axes: "systems uncertainties" and "decision stakes". When both uncertainty and stakes are small, we are in the realm of "normal" science, where it is safe to rely on "codified expertise". When either uncertainty or stakes are in the medium range, then the application of routine techniques and standardized and generalized knowledge is no longer enough. In these cases, skill, judgement, sometimes even courage are required to adjust the "general knowledge" available to the "special situation". Funtowicz and Ravetz call this "professional consultancy", with the examples of the surgeon or the senior engineer facing a critical situation. Finally we arrive to cases, in which conclusions are not completely determined by scientific facts, inferences will (naturally and legitimately) be conditioned by the values held by the various agents. When the stakes are very high (as when an institution is seriously threatened by a policy –e.g. a law restricting the use of GMOs) then a defensive tactic will involve challenging every step of a scientific argument (this applies even to those cases in which systems uncertainties are actually small –e.g. a chemical company questioning the toxicity of a given pesticide). Such a tactic should be considered wrong only when is conducted covertly, as by scientists who present

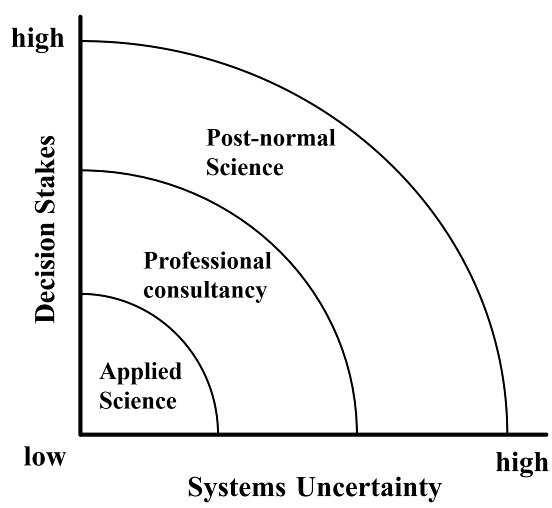

Fig. 4. Diagram of Post-Normal Science after Funtowicz and Ravetz, 1991

themselves as impartial judges when, in reality, they are actually committed advocates of one view. Otherwise, when legitimate contrasting views are openly used to challenge scientific arguments, we are in the realm of Post-Normal Science. For example, when debating in scientific terms the pros and cons of two possible policies of development in relation to discordant integrated assessments of expected scenarios. According to what discussed in section 2, my point is that when dealing with the issue of sustainability (when one has to provide an integrated assessment of changes in relation to dimensions that include the social, the ecological, the economic one) we are always in a field where we need Post-Normal Science.

By the way, the call for a Post-Normal Science is nothing else but a call for an "ideological" revolution of the type "the King is naked". This is the type of revolution needed to better use science when discussing of sustainability. This paradigm shift, in fact, simply requires that humans should just stop pretending that their processes of decision making are based on the ability to detect the "best" of the possible courses of action (after applying standard protocols based on reductionist analyses). As a matter of fact, this has never been in the past and it will never be in the future. The confusion has been generated by the fact that, in the last decades, in Western countries, the "elite" in power, for various reasons, decided to pretend that they were taking decision based on "substantive rationality". Clearly, this was simply not true. But pretending so was very useful for justifying and boosting the process of rapid expansion of Western economic organization over the whole planet. Now that the planet has been won to market economy, the priority for determining policies (and the selection of analytical tools used to represent changes in societal performance) should change. The priority has to move from the goal of "expanding a given model of social organization, as fast as possible, over the whole planet to boost efficiency (→ looking for rapid economic growth)" to the goal of "diversify viable models of social organization, as much as possible, over the whole planet to boost adaptability (→ looking for a form of development more compatible with social and ecological perspectives)". This means avoiding to repeat the mistake made in food production. After the excessive spreading of "monoculture agriculture" humans should avoid the excessive spreading of "monoculture of the mind" (Shiva, 1993).

3.2. Is Human Ecology a Good Candidate for Such a Job?

In my view, the most naive attempt to deal with the issue of sustainability, in scientific terms and on large scale, has been that of the application of Cost/Benefit Analysis based on the use of monetary units. Those using this tool seem to believe that they can in this way provide at the same time: (1) an adequate representations of the sustainability trade-offs over different dimensions and different scales; (2) a mechanism for weighting the non-equivalent costs and benefits referring to non-equivalent criteria of performance. That is, the very idea of CBA assumes that it is possible to collapse the complexity typical of sustainability trade-offs into a single indicator of performance, by adopting a very simplistic analytical tool. This idea means going against everything discussed up to now (that the representation of changes referring to different dimensions and described on different scales can be reducible, that incommensurable costs and benefits can be compared, that the paradigm of substantive rationality is a valid one). Actually, the idea of comparing the relative performance of different scenarios (including the value of human lives, of the whole planet, of cultural diversity, including personal feelings and the aesthetic dimension of landscapes) using money units is criticized even from the very same field of economics (O' Connor and Spash, 1998).

The following attempt to deal with the issue of sustainability, in scientific terms, seems to be, at the moment, that of integrated assessment (e.g. developed in many scientific networks and academic societies dealing with sustainability). The very concept of Integrated Assessment has the goal of establishing a bridge between:

(A) the "economic reading" referred to the economic process (to verify economic viability). This reading is needed to detect changes in social qualities linked to the ability of producing and consuming goods and services, as well as to elaborate policies based on economic variables. and

(B) the "biophysical reading" of the economic process, referred to the biophysical interaction of societal metabolism with its environment (to verify its technical feasibility and ecological compatibility).

This approach explicitly addresses the obvious fact that when dealing with sustainability we can no longer only deal with the perceptions (of welfare, utility and or risk) and preferences of humans, based on existing human values (culture and institutions). Sustainability implies also considering a set of biophysical constraints coming from the unavoidable interaction that the metabolism of human society implies with ecological processes. Ecological processes are operating independently of human perceptions and wants.

However, in order to fully address the issue of sustainability we have to expand the bridge proposed by the approach of integrated assessment (the integrated use of economic and biophysical analyses). The integrated analysis should, then, be extended into the realm of anthropological, social and political analyses. In fact, only in this way, it becomes possible to perform additional checks on the compatibility and feasibility of proposed scenarios and/or policies with existing human relations (e.g. political feasibility, institutional compatibility, compatibility with cultural identity and aspirations of various stakeholders).

As already noted, if we want to add to the issue of representation and assessment of sustainability trade-offs also the issue of governance, we get an additional challenge for scientific analyses. The concept of Post-Normal Science requires also the scientific ability of interacting (involving) the rest of the society in the discussion over sustainability. Since nobody can know "a priori" the "best possible way" of being sustainable, the only possible approach to deal with this challenge is that of establishing a process of social learning on how to better perceive, describe, evaluate and deliberate about the various trade-offs of sustainability. Scientists have a crucial role to play in this process. But to do that, they have to learn how to help rather than hamper this process. They have to learn how to mix the know-how developed in two different scientific areas that until now have been kept separated - natural and social science – when discussing with the rest of the society.

In retrospect, one can see how the division between the natural and the social sciences prevented the development of a more vigorous current of quantified studies of Human Ecology. But in spite of that, Human Ecology has always been one of the scientific fields in which, for natural vocation, the scientists have been trying to get into holistic analyses of the interaction of humans and their environment. The very nature of this field requires, in fact, addressing the reciprocal feed-backs implied by such an interaction. Human ecologists have been – so to speak – "all over the place" in this regard. Working on ecological anthropology, social ecology, urban ecology, industrial ecology, food ecology, ethno-ecology, social forestry just to name a few of the official branches. There has been much discussion of agricultural energetics since the 1970s (e.g. David Pimentel, Vaclav Smil) or energetics applied to anthropological analysis (e.g. the pioneer work of Rappaport), as well as more systemic approach of energy based analysis of the interaction of ecological and social systems (e.g. H.T. Odum school of Emergy analysis). Lately, we assisted at a flourishing of theoretical efforts to describe the interaction of humans and natural process using a plurality of perspectives and analytical approaches (e.g. see for example the last volumes of Advances in Human Ecology – Freese, 1992-1998). In this sea of heterogeneous efforts, those working in these different branches of human Ecology have developed not only the ability of handling different analytical tools (belonging to the traditional domain of both social and natural sciences), but also the ability of developing tools for participatory techniques in specific field research (e.g. participatory rural appraisal).

If we agree on the fact that when dealing with the issue of sustainability: (1) the division between the natural and the social sciences can no longer be held. (2) we need a new scientific paradigm based on the ability of involving the rest of the society in the analytical process. Then, it is obvious that the field of Human Ecology is where we should start to build a new science for sustainability in the new millennium. It is my opinion, in fact, that Human Ecology is one of the best candidate for this job for its proved ability of handling various analytical tools developed in various analytical disciplines (either social and natural) and the flexibility already manifested by its scientists that are used to consider themselves, in the majority of the cases, as a part of the society. On the other hand, developing a new science of sustainability in the third millennium will require getting away from dangerous academic lock-in. These academic lock-in are those keeping the separation "among traditional scientific disciplines" and "between scientists and the rest of the society".

The answer to the question posed by the title of this paper, therefore, can only be given by those working in human ecologists that will determine whether or not such a challenge will be met, and by whom.

ACKNOWLEDGMENT

I would like to thank Giuseppe Munda, Kozo Mayumi and Tiziano Gomiero for their comments on previous versions of this paper.

KEY WORDS Sustainability. Human Ecology. Post-Normal Science. Multi-criteria Decision Aid. Integrated Assessment-Science for Governance.

ABSTRACT The fast process of globalization and fast economic transformation all over the world, are generating a crisis in the process of governance within human societies (both in the developed and developing world). This crisis is especially evident when the issue of sustainability is addressed. This phenomenon can be linked to a growing inability of conventional science to handle in

a satisfactory way the representation, communication and policy analysis when dealing with the sustainability predicament. The text starts providing a definition of Sustainable Development from the perspective of Human Ecology. Such a definition is based on the concept of "Procedural" rationality, rather than the concept of the "Substantive" rationality, typical of "reductionist science. Then the paper illustrates the new challenges that the issue of sustainability implies for scientific analyses, forced to go beyond the concept of commensurability and efficiency (the need of moving from "monocriteria analyses of experts" to "multicriteria participatory assessment"). Finally, it concludes saying that the paradigm shift needed for developing a new science for sustainability (looking for a Post-Normal Science) implies a set of characteristics which indicate the field of Human Ecology as a good candidate for this job.

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