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SUSTAINABILITY, COMPLEXITY AND WATER MANAGEMENT

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Abstract:
Considering the complexity and the uncertainties of social and natural systems and the present sustainable vision, it seems that the contemporary planning are no longer pertinent. We need adopting ecosystem approaches that converge to adaptive and collaborative approaches which emphasise active public participation and social learning. For its realization it is necessary to build collaborative and adaptive capacity.
Adaptive management corresponds to a permanent and continuous, prospective, interactive system and of a constant reformulation process, which needs coordination of the activities, of the people and resources, besides dealing with innovation and change.

1. Addressing sustainability

Water is essential to all life. The present perception that fresh water is a finite and vulnerable natural resource, that it is a social and an economic good and that it is inextricably linked with the global environment (its movement by gravity, and through evaporation and condensation, contributes to driving the Earth's biogeochemical cycles and to controlling its climate) are demanding increasing attention.
The complexity of the theme increases with the diversity of the characteristics of water, in terms of its quantity and quality, that vary in time and space.
Globally, humanity now uses more than half of the runoff water that is fresh and reasonably accessible, with about 70% of this use in agriculture (Postel *et al*., 1996).
Projections for the year 2050 show that 66 countries with about two thirds of the world population will face moderate to severe water scarcity (World Water Council, 1999).
The pressures facing the hydrological infrastructures system and water resources are the rapid growth of population and urban communities; changing land-use (as siting of industrial plants; agricultural activities; deforestation; loss of catchment areas); changing land-management practices (pollution from human activities as the use of agrochemicals, discharges of industrial waste water); increasing demands of available resources (in general); and climate change (there are some uncertainties about this) will have impacts on groundwater recharge, water quality or flooding patterns. These changes in the cycling of water could have very significant impacts across many sectors of the economy, society and the environment.
There are increasing conflicts of use of water between different stakeholders' interests.
In dry climate areas the needs of water are increasingly become an objective of military action or an instrument of war. There exist upstream and downstream conflicts over (scarce) water resources within watersheds (within states and between neighbour states); conflicts over abundance; conflicts of interests in water use: from irrigation communities, industrial enterprises, domestic use, all these actors have different objectives and resources; water without quality causes problems of public health risks; the scarcity or over abundance of water threatened ecosystems (in all space scales); and finally there exist conflicting visions for water management.
The exploration of water resource needs to be sustainable. In attendance to the environmental dimension of sustainability and according with Daly (1990) that means:

- its rates of use of renewable resources do not exceed their rates of regeneration;
- its rates of use of non-renewable resources (as fossil fresh water) do not exceed the rate at which substitutes are developed;
- its rates of pollution (inherent to irrigation, Industrial and power station cooling, Navigation) do not exceed the assimilative capacity of the environment.

Thinking on the dimension of social sustainability we must attend that, the human right to water is fundamental to meet basic needs as United Nations Committee on Economic, Social and Cultural Rights determines in November of 2002. Communities must attend systematically to the principle of equitable use based on an upstream-downstream hydro-solidarity.
Effectively, one of the principal aims of strong sustainability is equity: equity between men (considering social and economic aspects) and equity between society and nature. To attend to this last one it is important to promote changes on patterns of consumption and production, to promote values of self-sufficiency and efficiency and to consider a more equitable access and distribution of natural resources (such as freshwater) but in a sustainable way. Consequently it needs the attendance of ecological integrity of ecosystems. If a system is capable of keeping its organization before environmental changes, then it is said to have integrity (Kay, 1989).

2. Attending to complexity

From the 1970s onwards, authors such as Edgar Morin who introduced the "epistemology of complexity", Joël de Rosnay with the "symbionomy", Prigogine and Stengers with the "new alliance", Fritjof Capra who presented a holistic, systemic and ecological approach and Maturana and Varela with the concept of "self-poietic systems", are advocating the emergence of a new production of knowledge. This "Complexity Paradigm" is characterised by complexity, non-linearity, uncertain, chaos, self-organization, recursivity and reflexivity (Rosnay, 1995).
This new paradigm needs the opening of barriers of the subjects, of the connectivity of different fields of knowledge, it needs a dialogical and recursive thought, it considers systems of multiple levels of reality and aims, and it finally needs a unified linguistic domain.
Complexity is linked with the variety of elements and interactions of a system, the nonlinear aspect of interactions and organized totality and characterized by the emergence of unprecedented events and therefore comports a special behavior that is difficult to predict (Rosnay, 1975).
It requires the understanding of the concept of "self-organization": it refers to the ability of a system to be able to construct and change its own behaviour or internal organization; in a recursive way, the order in the system forms spontaneously from chaos and a process of adaptiveness happens so that the system adjusts to new situations (Prigogine and Stengers, 1986). Some of its features (necessary to the process by which a new order is created) are: the absence of centralized control, an inherent global order emerging from local interactions, fluctuation, change and dissipation, multiple equilibria, the ability to adapt and complexity usually associated with structural variety, functional variety and connectivity.
All these characteristics promote adaptaviness and flexibility (Morin,1994) the more complex a system, the more complex its control system must be in order to provide a "response" to the multiple disturbances produced by the environment.
Considering the global environmental system, we have the perception of the coevolution of ecological and societal systems and the complexity that emerge from these constant interdependences of physical, biological, economic, cultural and political phenomena. We realize that nowadays there are relevant environmental and social problems that have a great complexity and a high degree of uncertainty.
Funtowicz and Ravetz (1990) consider that new issues like risk and environment have common features: uncertain facts, values in dispute, high stakes, pressing need for decision-making. If so, they propose the necessity to develop "a new scientific method, neither value-free nor ethically neutral" which is defined as Post-normal science, a new science for new times, a science with values (Figure 1). They assume that the essential function of quality assurance and critical assessment can no longer be performed only by a restricted corps of insiders (such as scientists and experts), the dialogue must be extended to all those who have a stake in the issue, that is, to the extended peer community. Therefore cultural issues are determinant to this new science.
Effectively, culture embodies the basic principles of society and its way of living. Cultural sustainability promotes cultural diversity, the respect of human rights, the respect of different values and practices which attend the specificity of each ecosystem or territory, so it emphasises, too, local and traditional knowledge, that are so important to the new production of knowledge.

Figure 1 – Problem-solving strategies

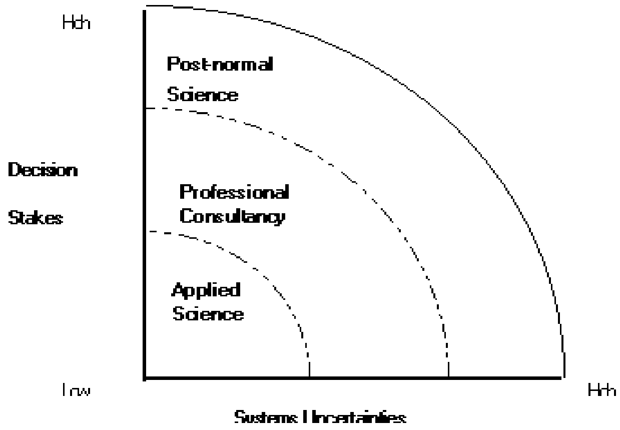

Figure 1

Source: Funtowicz and Ravetz (1994)

Considering these above mentioned issues it is necessary to promote, create and maintain the active participation of local cultures to build a sustainable community; the citizens (including minorities and vulnerable people) have to be considered as key actors influencing the decision making. People must strengthen their intellectual and social capabilities to enable solve problems, to behave autonomously and to secure their existence. A lot of heritage and culture actions (which consider a plurality of solutions) can contribute to the sustainable process.
In all this process it is necessary to have empowerment, participation, association activity and common purpose, supporting networks and reciprocity, collective norms and values, trust, safety and belonging.

3. Toward adaptive water management

Considering water policies, in "developed" and developing countries the attending of the "Hydraulic paradigm" (Moral and Saurí, 1999) has dominated supply-side adaptive options (water supply management), approach that has been to develop new supplies and to construct structures to utilise available supplies to meet water needs as we can see on Table1. It is in general associated with technocratic perspectives of development.
Nowadays the attention to other ways of water management which lead to demand-side adaptive options (water demand management) is increasing. These options are focused on lowering or mitigating proposed demands in a more socially beneficial manner that rely on socio-economic techniques (like economic policies, water pricing, public education, recycling, laws, land use) and usually are not capital intensive structures. These kinds of options promote management of the water resources for sustainability.
Despite the importance of water demand management, we need a more holistic approach because water systems should be understood and managed as living ecosystems and as identity communal patrimonies, natural well being, beauty and arising of feelings.
This perspective attends to social, ecological, environmental and landscape values and needs an ecologically sustainable water management that permits to sustain or restore the ecological integrity of affected water ecosystems.
To deal with ecological integrity it seems necessary to have an adaptive ecosystem approach (Kay *et al*., 1999) that attends to a pro-active participation of stakeholders (by focus group and interviews) that will influence the scenarios' analysis and the formulation of adaptive actions.
This approach is characterised by flexibility in learning through change, integration of a new science with values and it must deal with multiple cultural perspectives, in a transdisciplinar way (Rosa, 2003).
The concept of "adaptive management" was developed by ecologists to shelter the uncertainty, the complexity and the coming of unexpected happenings in the natural ecosystems, having appeared in the literature of natural resources and environmental management.

Table 1 - Exemples of Supply-side and demand-side adaptive options by water-use sector

Supply-Side		Demand-Side	
Option	*Comments*	*Option*	*Comments*
Municipal water supply			
– Increase reservoir capacity Extract more from rivers or groundwater – Alter system operating rules – Inter-basin transfer – Desalination – Seasonal forecasting	Expensive; potential environmantal impact – Potential environmental impact – Possibly limited opportunity – Expensive; potential environmental impact – Expensive (high energy use) – Increasingly feasible	– Incentives to use less (e.g., through pricing) – Legally enforceable water use standards (e.g., for appliances) – Increase use of grey water – Reduce leakage – Development of non-water-based sanitation systems	Possibly limited opportunity; needs institutional framework – Potential political impact; usually cost-inefficient – Potentially expensive – Potentially expensive to reduce to very low levels, especially in old systems – Possibly too technically advanced for wide application
Irrigation			
– Increase irrigation source capacity	– Expensive; potential environmental impact	– Increase irrigation-use efficiency – Increase drought-toleration – Change crop patterns	– By technology or through increasing prices – Genetic engineering is controversial – Move to crops that need less or no irrigation
Industrial and power station cooling			
– Increase source capacity – Use of low-grade water	– Expensive – Increasingly used	– Increase water-use efficiency and water recycling	– Possibly expensive to upgrade
Hydropower generation			
– Increase reservoir capacity	– Expensive; potential environmental impact – May not be feasible	– Increase efficiency of turbines; encourage energy efficiency	– Possibly expensive to upgrade
Navigation			
– Build weirs and locks	– Expensive; potential environmental impact – Potential environmental impact	– Alter ship size and frequency	– Smaller ships (more trips, thus increased costs and emissions)
Pollution control			
– Enhance treatment works	– Potentially expensive	– Reduce volume of effluents to treat (e.g., by charging discharges) – Catchment management to reduce polluting runoff	– Requires management of diffuse sources of pollution
Flood management			
– Increase flood protection (levees, reservoirs) – Catchment source control to reduce peak discharges	– Expensive; potential environmental impact – Most effective for small floods	– Improve flood warning and dissemination – Curb floodplain development	– Technical limitations in flash-flood areas, and unknown effectiveness – Potential major political problems

Source: Intergovernamental Panel on Climate Change (2001)

It appeared as a type of application which enables learning through experience at the time of the implementation of politics of management of natural resources. It was then considered that in the most complex situations, where a high rate of uncertainty existed, a better effective use of the resources occurred, if adapting and learning were emphasized.
Adaptive management “is a synthesis of science and policy that treats policies as large-scale experiments. Bounded conflict (...) is a combination of politics, negotiation, and other means of promoting uncomfortable change, which provides tools for establishing shared goals and probing the bounds of co-operative effort. Like compass and gyroscope, the two parts of social learning are complementary” (Lee, 1993: 16). It considers the integration of experimentally focused policy design and negotiative political interaction. This combination of adaptive management and the bounded conflict of pluralist democracy is what Lee (1993) understands by “social learning”. For its realization it is necessary to build collaborative and adaptive capacity: individual, organisational, relational and governance capacity (Foster-Fishman *et al*,. 2001).
In these contexts the ecological introspections of “traditional” adaptive management are combined with social learning (Lee, 1993) and with the perspectives of the social institutions (Gunderson *et al.*, 1995) so as to include important stakeholders, to balance the distribution of power among the stakeholders and endeavour towards processes of solving conflicts and find agreements.
Above all one needs an efficient negotiation and so it is necessary an active participation where the public shares decision-making with government and where the public performs public tasks independently.
Adaptive model demand choices and trade-offs and the selection of these is driven by values through an active public participation which contribute to all process by the information gathering, analysis, decision-making, implementation and capacity-building, and monitoring and evaluation of projects.
This long-term process requires a continuous participation and "capacity building" which converge to a “collaborative and adaptive capacity” that turn possible building up awareness, knowledge, skills and operational capabilities. Societies need this adaptive capacity that reflects learning, flexibility to experiment and adopt innovating solutions, and development of multiple responses to multiple challenges.
Recently, one has applied planning and adaptive management to river basins (Cortner and Moote, 1994; Coape-Arnold *et al.*, 1995) and river flows (Richter *et al.*, 2003). The approach comes as a way to achieve a sustainable and resilient stage, providing solid principles to guide the integrated planning and management of the territory.
The introduction of the communities in this adaptive water management shows the necessity of distributing the social responsibility among the different actors and consequently create a contractual society and actions, so as to achieve consensus and establish agreements.

5. Conclusions

The need to address sustainability and the attendance of the complexity are demanding new approaches in water planning and management, which are converging to adaptive and collaborative approaches that emphasise active public participation and in sequence social learning.
Adaptive management corresponds to a permanent and continuous, prospective, interactive system and of a constant reformulation process, which needs coordination of the activities, of the people and resources, besides dealing with innovation and change.
This adaptive management will help to achieve a balance between water conservation, sustainable use and equitable distribution of benefits.

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