



■ 14.A. SOCIO-ECONOMIC ASPECTS OF ECOHYDROLOGY & PHYTOTECHNOLOGY APPLICATIONS IN INTEGRATED WATERSHED MANAGEMENT IWM

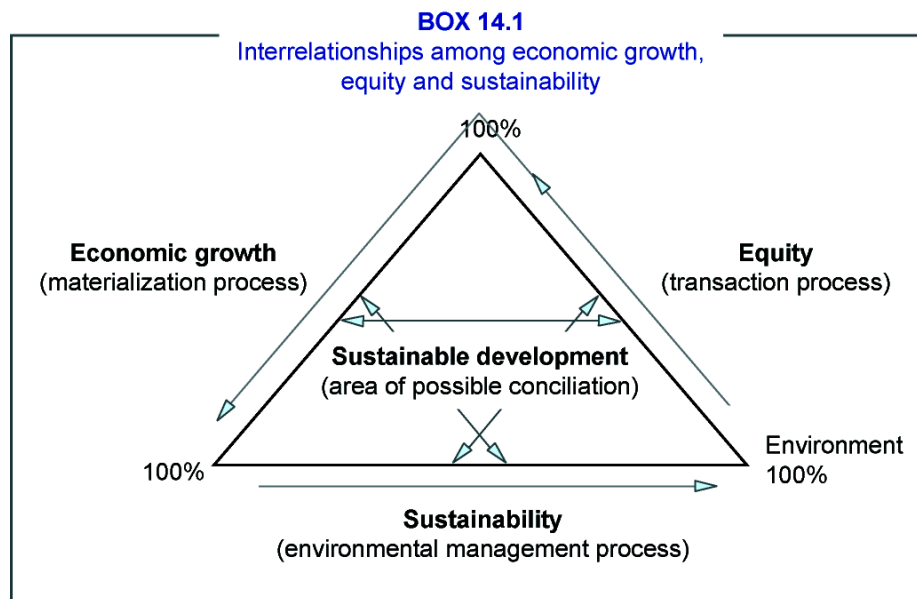
The maintenance of homeostatic equilibrium in an ecosystem in order to ensure its ability to continue to produce the desired resources, and to preserve and even enhance its resilience and carrying capacity to assimilate natural and anthropogenic stresses, is a key element in achieving sustainable development. The ecohydrological approach, by integrating knowledge of biota with that of a wide range of hydrological processes at medium or mesoscales (which includes microhabitats, river systems, and catchment areas), provides the scientific background for maintaining the integrity of ecological processes. This integration is one of the three key considerations on which the concept of sustainable development has been built, as depicted in Box 14.1.

Being that water is essential to human life and economic growth, sound management of water resources is central to sustainable development. Ecohydrology, therefore, recognises that sustainable development is dependent on the ability of an ecosystem to maintain evolutionary-established processes and patterns of water and nutrient circulations and energy flows at a basin scale.

In promoting the integration of a catchment and its biota into a single entity, the use of ecosystem properties becomes a management tool within which ecohydrology can address fundamental aspects of water resources management. In effect, it provides the sound scientific basis for adopting a watershed as the basic planning unit. By incorporating the concept of improved ecosystem resilience as a management tool, ecohydrology strengthens the rationale for adopting a preventive, holistic, and global approach to the watershed - as opposed to the reactive, sectoral, and site specific approach typical of present extended practices in water resources management. At the same time, ecohydrology stresses the importance of ecotechnological measures as an integral component of water management, complementing standard engineering approaches.

But water resources management goes beyond these fundamental aspects understanding natural processes and the adoption of technological approaches to address the optimum development and

use of water resources and their protection. Further, development, use, and protection, in terms of an ecohydrological approach, extend to present and intergenerational equity concerns and a full accounting for the economic, social, and environmental values of water. Thus, ecohydrology involves policy, institutional, economic, social, environmental and legal issues, configuring a multidimensional space that needs to be integrated by means of sound management tools and approaches. During recent decades, knowledge derived from successes and failures in the management of the environment and natural resources, particularly water, has contributed to the build up of a well documented set of basic principles for sound management of water and other natural resources, and for the protection of the environment, particularly aquatic ecosystems. These principles constitute a rationale founded upon scientific knowledge, which, according to generalized worldwide experience, guarantee a better approach to the global objective of „sustainable management of water resources, including the protection of aquatic ecosystems and freshwater living resources”. Mar del Plata 1977, Dublin 1992, Río de Janeiro 1992, and many other renowned international meetings are milestones at which some basic global understandings, such as the rational use of water; integrated management of water resources; use of the watershed as a basic planning unit; the social and economic value of water; the role of water in ecosystem protection; etc., have been achieved. Together with the need for sound management tools, such as proper regulatory frameworks, the incorporation and transfer of „clean” technologies, environmental education, public participation, access to information, use of economic and financial instruments, and the promotion of sustainable practices, etc., these principles have gained international consensus. In particular, Dublin’s principle 1 stands out among them because of its extended and complete recognition. The international community, in its search for universal truths and simplicity, attempted to summarize this global knowledge in „paradigms”, which express in a few words, a complex set of



scientific, technological, policy, institutional, social, economic, and environmental issues. At the United Nations Conference on Environment and Development (UNCED 92), „sustainable development” - based on the definition proposed by the renowned Brundtland Commission 2 - was incorporated into a broadly-accepted paradigm expressing the need to carry out developmental actions within the framework of economic efficiency, social acceptability, and ecological integrity.

With regard to water resources, Chapter 18 of UNCED’s Agenda 21 noted the concept of integrated water resources management was based on „the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization”. Including the Dublin principles, integrated water resources management is presently being widely adopted as the paradigm which should drive society toward sustainable development of water resources. The Global Water Partnership (GWP), which is intensively contributing to the spread of the concept, adopted the following definition: „Integrated water resources management is a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without com-

promising the sustainability of vital ecosystems.” The term „integrated” implies a multidimensional concept that calls for the simultaneous consideration of natural resources, social, cultural, institutional, regulatory, economic, and political issues in a watershed. As a reaction to the sectoral, thematic and geographical fragmentation that has characterized present water resources management in most parts of the world, integrated water resources management pursues integration within and between the natural and socio-economic components of the environment, utilizing the river basin as the natural planning unit.

The concept of Integrated Water Resources Management - in contrast to „traditional,” fragmented water resources management - at its most fundamental level is as concerned with the management of water demand as with its supply. Thus, integration can be considered within two basic systems:

- ▶ the natural system, with its critical importance for resource availability and quality, and
- ▶ the human system, which fundamentally determines the levels of resource use, waste production, and pollution of the resource, and which must also set development priorities.



Integration has to occur both within and between these categories, taking into account variability in time and space.

Ecohydrology is another „paradigm” which addresses the integrated study and use of ecosystems, including their hydrological characteristics and processes, and their combined potential to influence water dynamics and quality, particularly at the catchment scale. In terms of integrated water resources management, it addresses, and scientifically strongly supports, integration within the natural system as well as providing guiding principles and tools to integrate a consideration of ecosystem components within the development framework. Furthermore, it enhances a preventive approach, through improvement of ecosystem resilience that amplifies opportunities for achieving sustainable development.

Within the context of integrated water resources management, ecohydrology should be incorporated into the objectives and policy framework for water management at the highest institutional levels, as well as be disseminated at the community level to promote environmental awareness, enhance water resource values, and stimulate their protection.

Ecohydrology also provides scientific support for the use of a watershed as the planning unit of choice for water resources management. In this manner, ecohydrology contributes to building a basin approach to water resources management at the community level. In effect, ecohydrology creates a common watershed vision that is fundamental for promoting the active involvement and participation of stakeholders, and for putting into effect a process of „social negotiation” that should be at the root of all decision-making within a basin. Also, it facilitates the solution of downstream-upstream conflicts through enhancing so-called „hydro-solidarity”.

Ecohydrology also helps to strengthen the incorporation of social and environmental values into strategic water resources planning at the water-

shed level, facilitating technological approaches that will contribute to sustainability and, making use of ecosystem properties. Improved ecosystem resilience and ecotechnologies should be an integral part of pollution prevention and water quality restoration programs and measures.

By simultaneously addressing both hydrological and biotic processes at various levels (microhabitat, river systems, entire watersheds) within an ecosystem, ecohydrology provides a sound basis for land and water use, as well as for integrated surface and groundwater management. Thus, ecohydrological principles may strongly influence the conceptual basis upon which regulatory and economic instruments are devised to induce human behaviours compatible with the objectives and goals of strategic, basin-scale planning (TAC Background Papers No. 4. Global Water Partnership. Technical Advisory Committee, 2000).

Because of its holistic and basin-wide approaches, ecohydrology requires a strong commitment from governments and water users to strengthen the knowledge base, in terms of monitoring, data management, research and technological development. It also involves the joint efforts of governmental agencies and stakeholders across various jurisdictional boundaries within a basin to coordinate data gathering, information exchange, and joint interpretation of ecosystem functioning, root cause analyses, and the effects of human interventions on ecosystem components. It basically requires that stakeholders, users, and civil society become aware of its principles and guidelines for action, thus promoting a bottom-up process that will instil ecohydrological principles into institutional and legal frameworks.

Therefore, ecohydrology should evolve from a scientific approach to an institutional approach, within the framework of integrated water resources management, incorporating the economic, financial and social dimensions that currently characterize globally-accepted paradigms.

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Guidelines: chapters 1.D, 1.F, 10

■ 14.B. CAN GLOBAL CLIMATE CHANGES AFFECT MANAGEMENT OUTCOMES?

An assessment of potential water resources impacts associated with climate change, and the evaluation of possible water management strategies, deserves increased attention of the world's community. Although „No global crisis is likely to shake the world the way the energy crisis of the seventies did” [Postel 1992], the global and regional food supply and economic development may be affected by climate-induced changes in water availability in crop-producing regions and in large urban agglomerations. The assessment of climate change impacts on water resources management attempts to portray how the range of possible changes in temperature, precipitation and runoff is likely to affect the range of water uses and their socio-economic implications.

It is still difficult to predict or quantitatively assess the impacts of climate perturbations on water management. There is, moreover, no general consensus among most of national water institutions on the possible adverse consequences of change in climatic processes caused by anthropogenic forcing. In spite of existing uncertainties, the impact of climate on water systems may create serious social problems, at least in vulnerable regions of the world. In the long-term thinking about the Earth's economic future, this issue should not be neglected. Scenarios of possible trends in demographic, economic, technological, and geophysical processes must be investigated. The complexity of the global atmospheric/hydrologic system means that one cannot rule out abrupt changes, and the world's water community should be prepared to cope with them.

The progress in assessing the implications of climate change on water supply and demand, and consequently on management of catchment systems, as well as in assessing the impact of climate on physical, chemical and biological processes, is evident. However, most of the relevant theories and models still need to be improved in order to meet requirements of water resources practice. The IPCC reports (1996, 2001) outlined difficulties in analyzing climate change impacts on water management. Although a number of case studies have been conducted in specific river basins - almost exclusively in developed countries - the un-

certainties in climate change impact on water management remain large. Climate model will tend to estimate that the world as a whole become more „moist”, nevertheless some large areas may experience a decrease in precipitation, accompanied by increased evapotranspiration due to higher temperatures. It is necessary to distinguish between the physical effects of climate change and the impacts reflecting societal values placed on a change in hydrological quantities. This impact highly depends on the level of development of the water system: in some cases large climate change-induced hydrological effects may lead to insignificant increases of economic costs, while in water scarce regions a small change may have dramatic consequences. A conjunctive use system involving several reservoirs, river regulation and groundwater withdrawals will be affected differently than a simple supply system based on direct water abstractions from a non-regulated river.

Studies that have considered possible changes in regional water management for a variety of climate scenarios fall into three categories. The first infers changes in potential water supply due to changes in the water balance of a catchment. Problems in maintaining irrigation supplies from direct river abstractions may be inferred, for example, if summer river flows are simulated to decline. The second research group considered the sensitivity of managed supply/demand systems - usually containing storage reservoirs - to changes in hydrologic inputs. The third group of studies examined integrated water demand/supply systems, additionally taking into account climate impacts on physical and biological processes in rivers and lakes.

Demands may increase in all water-use sectors with an increase of temperature - the broadly accepted consequence of global climate change. Unfortunately, regional and local precipitation changes, having also important influences on water demands, are much less clear. Studies on domestic and industrial water consumption show a great deal of opportunity to adapt to changed climate. Many of the responses being proposed to adapt to climate change require reduction of demands and reallocation of water among water users. The big-



gest current pressure on water resources is caused by high population increases in some parts of the world, and by progressing concentration of economic activities in big urban agglomerations. Results of investigations on domestic water use reported in the literature lead to the conclusion that per capita water requirements will probably change insignificantly in a warmer climate. The amount of water needed for technological processes in industry is rather insensitive to changes in temperature and precipitation, with the exception of increased demand of water for cooling purposes. Hydropower production will decrease with lower river flow.

Serious problems may arise in agriculture, which is the largest consumer of water in the world, accounting at present for 2/3 of global water withdrawals. As human populations in developing countries increase during the next century, the amount of irrigated croplands may have to increase to guarantee global food security. Some recent studies indicate that for a 1°C increase of air temperature one may expect a 12 to 25 percent increase in irrigation demands. Another study shows that for a broad range of prescribed temperature increases, irrigation demand may increase even in cases of up to a 20% precipitation increase. Consequently, on a global scale the amount of water needed for sustainable agricultural production may double by the middle of the next century. This, in turn, may largely extend the number of countries suffering chronic water scarcity. It is important to emphasize that the ultimate effect of global warming on water demand for irrigation depends significantly on agricultural policy, food prices and more equitable distribution of food among nations. At least for the next two decades, non-climatic factors will probably dictate what kind of measures should be undertaken to secure sustainable water supplies. Climate change predictions will, however, add a new highly uncertain component to the challenge of managing water resources. There are still large uncertainties that are propagated through the numerous levels of analysis as one moves from greenhouse gases scenarios; through the comparison of different global climate models outputs; transference of climatic data to

runoff and to other hydrologic variables; impacts on water management decisions; and, finally, on the socio-economic and incremental impacts of response measures. In addition, incremental impacts due exclusively to climate change should be differentiated from changes (sometimes also highly uncertain) that would occur in the absence of climate change.

Water management at present is frequently concerned with reconciling competing demands for limited water resources. At present, these conflicts are solved through legislation, prices, customs or a system of priority water rights. A change in both the amount of water available and water demanded is likely to lead to increased competition for resources. Conflicts may arise between users, regions, and countries, and their possible resolution depends highly on political and institutional arrangements in force. Because different users have different priorities and risk tolerances, the balance point among them, in the face of feasible climate change scenarios, may be quite different from now on (e.g., hydropower production and in-stream uses may be lost compared to domestic and agriculture water supply). The marginal costs of reducing additional increments of water scarcity risk rises rapidly in the case of supply with required high reliability.

Relatively few research results have assessed climate change effects on intensity and frequency of extreme hydrological events: floods and droughts. Unfortunately, the state-of-the-art global atmospheric models may have produced until recently, scenarios at too coarse spatial and temporal resolutions to be useful for assessing expected changes in hydrological extremes. However, recently observed increased variability of some climatic variables seems to have affected flood and drought risks in many regions of the world. The number of major flood disasters world-wide has grown in the past decades: six in the 1950s, seven in the 1960s, eight in the 1970s, 18 in the 1980s, and 26 in the 1990s (Berz 2001). In the second half of the 20th century there has been an increased number of droughts in some areas. An observed upward trend in the number of deaths and in material losses due to weather related disasters

might be at least partly explained by the non-stationary nature of climatic processes.

The fundamental question is what kind of adaptive measures may be applied to cope with possible negative consequences of climatic perturbations? The answer is not simple because of high uncertainties accompanying the climate change issue. The IPCC reports contain an extended discussion on the philosophy of adaptation, and a list of adaptation options suited to the range of water management problems that are expected under climate change. Based on a review of the most recent literature, it may be stated that few additional water management strategies, unique to climate change effects, have been proposed, other than to note that nations have to implement action plans for sustainable water resources management as part of their obligation towards AGENDA 21. The principles laid out in that document may serve as a guide for developing a policy that would enable river basin authorities and water stakeholders to prepare for the uncertain hydrologic and demand conditions that might accompany global warming.

There are many possibilities for adaptation measures or actions. An overview of water supply and demand management options is presented in IPCC documents. A long-term strategy requires that a series of plausible climate and development scenarios be formulated, based on different combinations of population and climate change prediction, along with economic, social and environmental objectives. After development strategies are established, taking into account the possibility of climate change, a set of alternative long-term water management policies might be formulated that consist of technical measures, policy instruments and institutional arrangements, designed to meet the objectives of a particular development setting.

The range of response strategies must then be compared and appraised, each with different levels of reliability, costs, environmental and socio-economic impacts. Some of the water management strategies will be particularly well suited to deal with climate change uncertainty - i.e., to develop reliable, robust and resilient water sys-

tems focusing on environmental and economic sustainability. The performance of water systems should be tested under varying climatic conditions. After application of engineering design criteria to various climate alternatives, the selection of an optimal water resources plan must be based on social preferences and political realities. It should be added that engineering design procedures also evolve over time, and may be updated as meteorological and hydrological records are extended.

The nature of contemporary water resources management is such that countless factors, economic criteria, and design standards are incorporated because of the complexity of integrated water management and objectives (reliability, costs and safety). The key problem in responding to possible consequences of man-induced global warming is to decide when and what kind of adaptive measures should be undertaken to assure reliability of water supply and to protect against negative economic effects of hydrologic extremes. Water policy decisions always depend on local hydrologic conditions, economic situations, and national priorities. There is, for example, no reason to apply sophisticated decision-making techniques for river systems abundant of water when the results of any climate impact assessment will be trivial. On the other hand, even limited climatic disturbances may lead to a worsening water situation in arid and semi-arid regions, requiring urgent adaptation decisions.

There is no standard, prescribed approach. In watersheds that have little or no control of natural flows, and are largely dependent on precipitation, a different set of water management adaptation strategies should be implemented than in river basins with a high degree of control by storage reservoirs, canals, levees etc. Rapidly urbanizing areas will require different responses than agricultural regions. In general, if a rational water management strategy is undertaken to deal with reasonably foreseeable needs of a region in the absence of climate change, such a strategy may also serve to offset much of the range of possible adverse consequences of climate change. Two approaches are advocated in dealing with



adaptation of water systems to changed climatic conditions (Waggoner 1990). Firstly, a „wait and see” or „business as usual” strategy, which means to postpone decisions on adaptation measures until more reliable information on global atmospheric processes become available. Existing water schemes remain unchanged then, and the new ones will be planned and implemented according to standard procedures. In the case of large hydraulic schemes a very long time is needed for their planning and implementation. As a result, this approach may cause undesirable delays in taking

necessary decisions. Secondly, a „minimum regret” approach, when policy decisions are taken to solve current problems in the best possible way and, at the same time, to prepare water systems for possible changes and surprises by making them more robust, resilient and flexible for any future. The latter approach assumes that optimality rules should be applied to a range of climatic scenarios. Final decisions may be taken by comparing costs, benefits and losses for each scenario, and on a somewhat subjective interpretation of expected results.

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Guidelines: chapters 4.H

