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Integrated water resources management (IWRM): an approach to face the challenges of the next century and to avert future crises

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Abstract

The increase in population growth all over the world and the sectoral pressures have produced a number of unprecedented demands for water supplies both as consumptive and non-consumptive uses. These stresses have caused a reduction in the per capita usage of the limited fresh water resources in many countries to a scarcity level. They have also resulted in the degradation of the quality of water in large areas of the world. The overall objective for water management, which adopts integrated approaches, is to satisfy the freshwater needs of all countries for their sustainable development. Integrated water resources management is 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. The integration approach has to incorporate policy options that recognize these elements, develop national water policies and to base the demand for and allocation of water resources on equity and efficient use. An integrated water resources management (IWRM), if implemented, must consider the strengthening of human resources development in terms of awareness creation programs, training of water managers, the development of new institutions that will serve and match this goal, effective information management, environment and development, the integration of water planning into national economy and financing and scientific means. This paper will discuss the various water problems viz. (a) increasing water shortages, (b) deteriorating water quality and (c) stresses on water supplies and the challenges they represent to integrating the approaches of water management to ensure sustainability of the resource.

Keywords: Ecosystem; Management; Population; Quality; Resources; Stress; Scarcity

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1. Water problems

1.1. Uneven distribution

Earth's water is finite and vulnerable. Precipitation is generally unevenly distributed over different parts of the world. It is exceptionally abundant in some places where it exceeds 1500–3000 mm. annually, whereas arid desert regions are extremely dry and receive less than 100 mm rainfall. Two salient features characterize the poor distribution of water resources: (1) geographically, in some areas renewable fresh water resources drain north, and the majority of the population lives in the south; (2) abundant precipitation in winter and high water consumption in summer, or a monsoon-type climate, i.e., cold with little precipitation in winter and humid with abundant rainfall in summer.

1.2. Impact of world population growth on water resources

Water demand is driven by the rapid increase of world population as well as other stresses. World population reached 5.8 billion in 1996 and will probably increase to around 7.9 billion in the year 2020, 9.9 billion in 2050 and 10.4 billion by the year 2100 [1]. This rapid increase has produced unprecedented demands on the limited available water resources and has complicated the patterns of water consumption. The per capita water resources available and use have dropped sharply. The UN reported that a full of 35% of the world population will be living under the conditions of stress or scarcity, compared to 6% in 1990 [2].

1.3. Stresses

The major dynamic factor that causes stresses on the available water supplies is the growth of population. Population has increased sixfold (6 billion) during the last two centuries when compared to the population (1 billion) in the year 1800. This quick rate of growth explains the severe consequences that have resulted from these high stresses on the fresh water resources and their unprecedented impact on socio-economic development, increasing costs of water development and limitations on development.

Stresses include unprecedented demands for agriculture (particularly irrigation and drainage), the provision of domestic water supply and sanitation, industry, energy production, environment/amenity (including tourism), changes in the patterns of consumption as a result of industrialization, rural/urban shifts, migration, and unaccounted for water [3].

1.4. Widespread scarcity

Water scarcity is now a common occurrence in all countries. Water is a unitary resource and its scarcity is related to many factors which can be summarized as follows:

- Population growth is directly affecting availability of water resources. It has led to the decline in the per capita availability and use of fresh water resources. For instance, the rapid growth of urban population has put severe strains on resources and raises the condition to a scarcity level in many cities.
- Degraded water quality and pollution of surface and groundwater sources. Major problems affecting the water quality are inadequately treated domestic sewage and inadequate controls on the discharge of industrial waste waters.
- The loss of potential sources of fresh water supply. This problem is linked to the old and unsustainable management practices and that the government and water resource managers are constantly seeking to maximize the volume of water available for direct use.

1.5. Deterioration of water quality

Water pollution is one of the most serious global problems. Contaminants come from two

sources: points or non-point sources. Landfills, leaking gasoline storage tanks, leaking septic tanks and accidental spills are examples of point sources. Infiltration from farm land treated with pesticides and fertilizers is an example of a non-point source. Inadequate treatment of domestic sewage and the insufficient controls on the discharge of industrial wastewaters are some of the major problems that have affected the water quality of rivers and lakes which gave rise to the leaching of nutrients and pesticides. Harmful organisms and polluted run-off continue to pose threats to health, fish, and wildlife.

Another important aspect that has degraded the water quality is the environmentally destructive practices which disturbed the aquatic ecosystems and threatened the living fresh water resources. The rain forest is an example of an ecosystem that provides and regulates the quantity as well as the quality of fresh water supply.

1.6. Floods and droughts

Several types of ecosystems serve as a hydrological buffer, absorbing water to prevent flooding (wetland ecosystem) and releasing it in times of drought (rain forest ecosystem). However, to maintain these services, both the key components and the quantity and quality of water flow through the ecosystem need to be conserved [4]. After forest cover is removed an area can become hotter and drier because water is no longer cycled between plants and atmosphere. Higher temperature and decreased precipitation would lead to decreased water supplies and increased water demands and might cause deterioration in the quality of fresh water bodies.

Though there is uncertainty with respect to the prediction of climate change at the global level, still the potential impact of such climate change could pose an environmental threat of unknown magnitude and could even threaten survival in some small island states and low-lying coastal, arid, and semi-arid areas as a sea level rise [5]. Any rise in sea level will often cause the intrusion of saline water into estuaries, small islands and coastal aquifers and the flooding of low-lying coastal areas; this puts low-lying countries at great risk. The recent increase in the incidence of extremes, such as floods and droughts in certain regions, has consequently increased the frequency and severity of disasters. But whether these occurrences are related to the climate changes is an issue which still needs to be established.

2. Management approaches — general trend

The trend that featured the development of fresh water resources management over the last three centuries is greatly interconnected with the rapid growth of world population. This complex process can be simplified in order to make it understandable by segregating it (the trend) into various stages; initially the water resources managers and policy makers were driven to manage and supply water to people for their direct use. The direct and obvious uses were water to drink, grow and prepare food and provide power for domestic and industrial use. This stage that has continued until the end of the 1970s was characterized by maximizing the volume of water available for direct use.

During the 1980s and as a solution to the current water problems which were previously stated, and considering the limitations of the previous approach, i.e., supply-driven management, integrated water resources management (IWRM) is advocated. This approach suggests integrating the subsectors and the fragmented policies within a national economic framework and to adopt the demand-driven approach where indigenous and new technologies are used in water allocation and conservation of fresh water supplies.

Recently a group of experts has revealed in their work that although IWRM sees ecosystems as important users that need water for their maintenance; nevertheless, IWRM pays little attention to the ecosystems' role as a provider of water resources and other goods and services [4].

Concurrently an ecosystem-based approach is suggested as a long-term strategy for water resources management and as an integrated solution to the water problems at international, regional and local levels in order to protect water resources, the fresh water ecosystems and to maintain its functions as a user, a provider and a regulator of both the quantity and the quality of fresh water resources.

2.1. Supply-driven water management

In early times and until the end of the 19th century, the world population was around two billion. The available water resources were adequate, and in some places in excess of the human needs for the domestic, agriculture and industrial uses. These are the direct and obvious uses of water, and policymakers were traditionally driven to manage water to make it available to people for these purposes [4]. Fresh water resources were of good quality, and the fresh water ecosystems functioned as a user, a provider of goods and services and a regulator of both water quantity and quality that were basically undisturbed.

As a result of the rapid rise in human population, as the third billion was reached in about 60 years (1900–1960) and in order to meet unprecedented water demands, governments and water resources managers were seeking to maximize the supply (the volume of water available for direct use) by diverting water from original stores and pathways to new stores and pathways

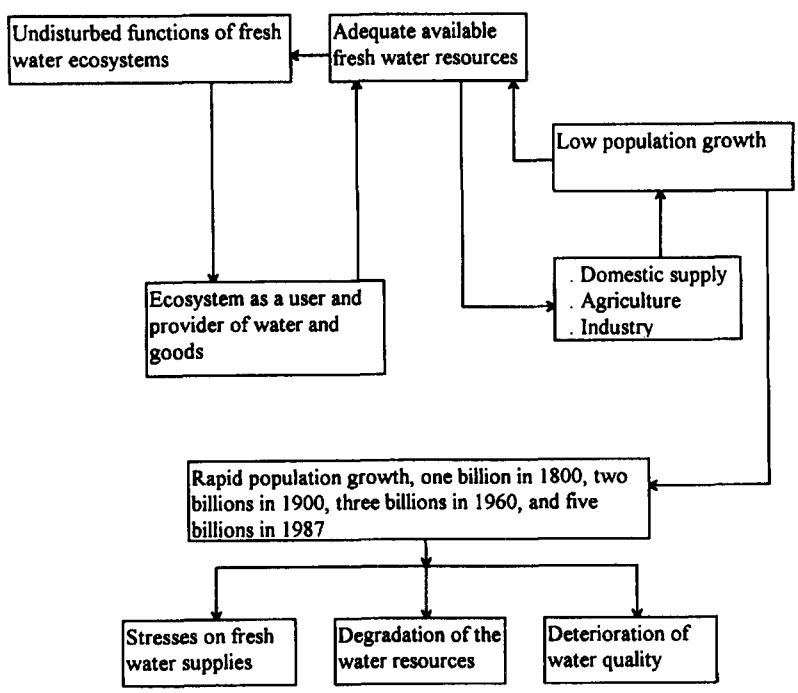

Fig. 1. Flow chart of main components of supply driven management.

that supply it to people for direct use. These policies led, as indicated in Fig. 1, to stresses on fresh water supplies, degradation of the water resources and deterioration of water quality.

The main components of the fresh water resources management which was tailored according to supply-driven principles are shown in Fig. 1.

2.2. *Integrated water resources management — demand-driven approach*

Integrated water resource management (IWRM) key elements, under which all water issues and relevant parties and their particular socioeconomic and environmental concerns can be brought together, are sustainability of water resources, water policy and integrated management, and management of the resource. The core of this management approach, which forms the basis for sustainable development, is the establishment of multi-disciplinary teams at various levels (local, regional, national and international) to communicate different perspectives on water resources, building consensus on the conservation of water resources and the maintenance of ecosystem functioning (see Fig. 2).

The local water user groups and stakeholders are represented in inter-sectoral teams in order to establish effective communication to ensure that local community experience and views will be integrated into the development and management plan and that the views of stakeholders can be better communicated to policy and decision makers.

It also integrates the technological means, socioeconomic aspects, environmental concerns, and health considerations.

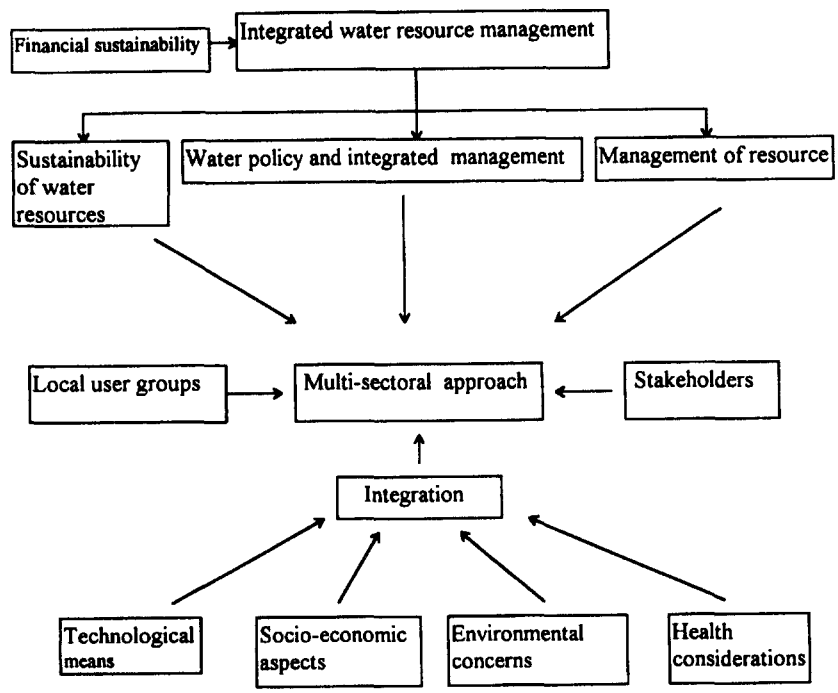

Fig. 2. Flow chart of integrated water resource management.

2.3. Strategic approach

2.3.1. Maintaining functioning of fresh water ecosystems

Ecosystems such as head waters, forests, wetlands, flood plains, riparian zones and coastal areas provide the four functions regarding regulation of quality and quantity of water resources, habitats, resources and information to human society. Some of the water is used along the way to support the various ecosystems and maintain their functioning. In return for the expenditure of water, the ecosystems provide functions to people, both throughout the catchment and globally [4].

2.3.2. Ecosystem-based management approach

In a similar manner to IWRM, the ecosystem-based approach aims to meet human requirements for the use of fresh water. However, the ecosystem functioning, water requirements and the services and goods it provides are seen as key elements of water resources management and planning. The four key components of this approach, which are shown in Fig. 3, are: (1) assessment of water resources, which is a prerequisite to effective management of them, (2) strengthening capacities through training at all levels, transferring the appropriate technology to local water managers and integration of

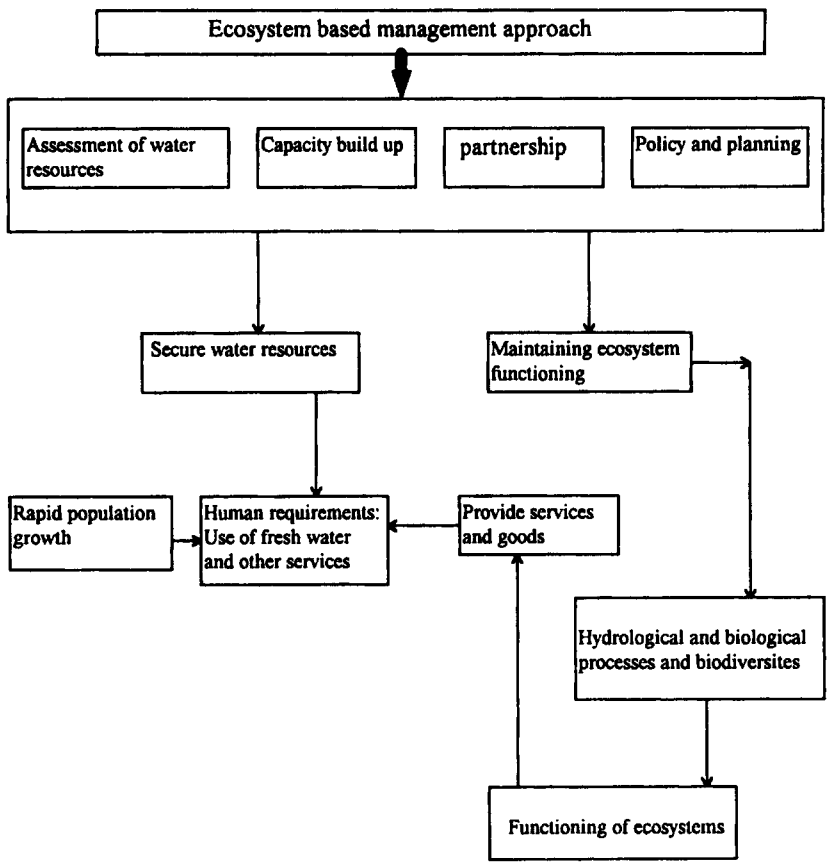

Fig. 3. Flow chart of components of the ecosystem-based management approach.

management and development planning, (3) improving communication through establishing partnerships and (4) adopt policies and planning that use the water appropriately and include environmental and economic costs.

3. Future patterns of water allocation

3.1. Factors that influence water allocation

Water managers allocate water demand to maximize the benefits that it provides to the communities. Fig. 4 shows how water is distributed among various competitors, i.e., domestic, agriculture, industrial, and ecosystems.

Old practices focused solely on maximizing the quantity of water available for direct use and only considered costs and benefits of the project. The new allocation strategies consider both the economic and the social and cultural benefits and the best use of water resources to ensure their sustainability for future generations. Health risks and loss of productivity in agriculture and fisheries — and that society may be forced to abandon its culture which is related to seasonal cycles — are clear costs that people will be subjected to because of unsustainable water allocation patterns.

3.2. Patterns of water allocation over the next century in relation to the population growth

Under the first quarter of the 21st century, the scarcity and stress of fresh water resources will persist [6]. The competition between various users on the quantity and quality of water will

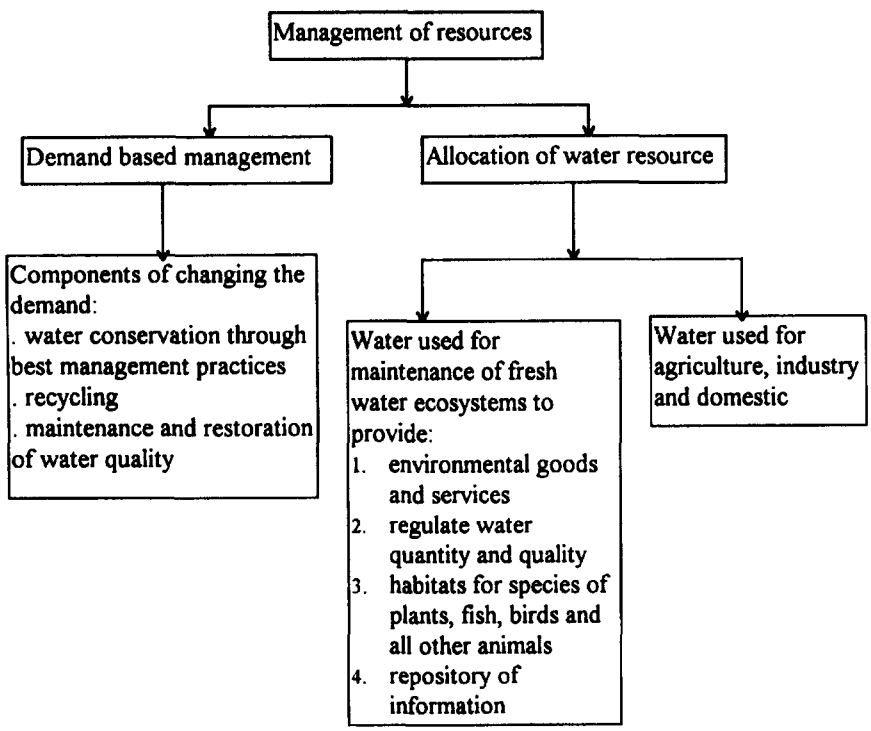

Fig. 4. Flow chart of allocation of water resources and components of changing the demand.

Table 1
Patterns of water allocation over the next century (see Section 3.2)

Years	Population growth (in billions)
1st quarter, 2000–2025	8
2nd quarter, 2026–2050	9.9
3rd and 4th quarters, 2051–2100	10.4

continue. The population growth will remain at its high rate, i.e., one billion every dozen years (see Table 1).

It is improbable that the international community, under the guidance of the Commission of Sustainable Development (CDS) and other relevant organizations, will be able to accomplish the programs that are set in their plan in accordance with Chapter 18 of Agenda 21 for two main reasons. First, this requires a general consensus among all countries. To reach an agreement on transboundary water resources and their water resources strategies and action programs, they must consider environmental concerns, sustainability of water resources and other considerations on an equal basis to their national and political interests. Second, the financial resources needed for the implementation of the recommendations contained in Chapter 18 of Agenda 21 have, so far, fallen short of the requirements [5].

A prerequisite to effective implementation of Chapter 18 is the provision of the required data which incorporate the assessment of water resources including the identification of potential sources of fresh water supplies, extent, dependability, and quality of water resources and of the human activities that affect those resources [5]. A scientific data base for national water resources utilization and a worldwide network are examples of the tools needed for establishing a long-term globally based information system.

During the 2nd , 3rd and 4th quarters of the next century, the world population may reach 10.4 billion, with about a 2 billion increase during the second quarter and half a billion during the third and the fourth quarters before it stabilizes at the end of the century. Forecast and planning beyond the first quarter of the century are speculative. However, population growth during the second quarter will represent a major element that will result in further increase in the stresses on water resources, especially in developing countries where birth rates will remain at high levels. On the other hand, the decline in growth during the third and the fourth quarters could be a major relief factor and may represent a shift towards improvement in the availability of financial resources that are required for the implementation of the ambitious programs that are included in Chapter 18 of Agenda 21 — an equitable and efficient use of fresh water resources and water distribution patterns that support the long-term conservation of water resources and ecosystem functions, services and goods for future generations.

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