Strategies for sustainable water resources management in water scarce regions in developing countries

GUOZHANG FENG
College of Water Resources and Architectural Engineering, Northwest Sci-Tech University of Agriculture and Forestry, Xingning (NWAU) Campus, Yangling, Shaanxi 712100, China
e-mail: gfeng@nwaau.edu.cn

Abstract Some strategies for sustainable water resource management for water scarce regions in developing countries are recommended as follows: (a) to transfer the focal point of water resource development from engineering water conservancy to resource water conservancy; (b) to make rational strategic visions and operational plans for water resource development; (c) to set up a water-saving society; (d) to protect water resources and to reconstruct water environments; (e) to construct conjunctive regional water supply systems; (f) to bestow reasonable priority on and to heighten reliability of water supply for different users; and (g) to intensify capacity building for sustainable water resource management.

Key words engineering water conservancy; resource water conservancy; water saving society

INTRODUCTION

In certain parts of the world, water scarcity has been and will likely become a fatal constraint to sustainable development. In some developing countries and/or regions facing water scarcity, especially those in arid and semiarid areas, sustainable development strongly depends on the availability of water resources for both society and nature, and the manner of water resource management. It is necessary for these developing countries and/or regions to seek theoretical, methodological and technological support to ensure their sustainability. This problem has attracted worldwide concerns (UNCED, 1992; World Water Council, 1998, 2000). Some topics related to the problem have been well addressed at a number of international and regional conferences/workshops and in journal papers (e.g. Gupta & Onta, 1997; Kundzewicz, 1997; Simonovic, 1997; ASCE, 1998; Xia & Takeuchi, 1999; Loucks, 2000). The purpose of this paper is to introduce a new definition to sustainable water resources and to recommend some strategies for sustainable water resource management for developing countries and/or regions suffering from severe water shortages based on the definition, experience and lessons in water resource management from north China with natural and human-induced water scarcity problems.

DEFINITION OF SUSTAINABLE WATER RESOURCES

There are several definitions of sustainable water resources (UNESCO/WMO, 1992; Chen & Wang, 1996; Li & Feng, 1997). For example, water resources can be defined
as the “water available or capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand” (UNESCO/WMO, 1992). Recognizing the principles of sustainable development (UNCED, 1992) and probable conflicts between currently available definitions and the goal of sustainable water resource management, this paper introduces a new definition to water resources based on the concepts of environmental security and sustainable development. Accordingly, water resources are defined as the water available for human and environmental uses that can be obtained from any natural water sources under the limitations of the combination of technological feasibility, economical effectiveness, environmental security, and human acceptability. This definition is in fact an extension of that of UNESCO/WMO’s for sustainable water resource management and may be regarded as a definition of sustainable water resources.

STRATEGIES FOR SUSTAINABLE WATER RESOURCE MANAGEMENT

According to the above definition, the strategies described below may be appropriate for sustainable water resource management in regions suffering from severe water shortages in developing countries.

From engineering water conservancy to resource water conservancy

Engineering water conservancy and resource water conservancy are terms introduced by Wang (1999), the Minister of Water Resources of the People’s Republic of China. Engineering water conservancy focuses on construction of water projects (Wang, 1999; Zhang & Chen, 1999). It is in engineering water conservancy that China has made notable achievements in water resource development and water-related hazard prevention in the past few decades. However, due to lack of experience in the operation, maintenance and management of water projects, some of them have become a serious threat to local society, economy and environment. Many water projects were developed with a single objective and lacked integrated or multi-objective functions. In addition, in the process of China’s reform and opening-up with rapid socio-economic development, urbanization of the rapidly growing population, industrialization of the economy, and intensification and modernization of agriculture, water demand has been increasing considerably and conflict between water demand and supply has become a severe constraint to the sustainable development of the country. In natural arid and semiarid areas, water scarcity has become the bottleneck of crucial impacts on sustainable development and environmental security of the region (Feng, 1999). In view of the crucial situation in water resource management, Wang (1999) pointed out that China has to transfer the focal point of water resources development and utilization from engineering water conservancy focusing attention on the construction of water projects, to resource water conservancy and intensifying integrated water resource management. This transfer has been recognized as highly beneficial to China (Zhang & Chen, 1999).
Resource water conservancy results from the concept of sustainable development and integrated water resource management as well as the experience and lessons of China. According to the definition of sustainable water resources, resource water conservancy should emphasize reasonable development, utilization, protection and management of water resources through integrated and sustainable methods. It will be possible through realization of resource water conservancy that water resources comprehensively play their societal, economic, and environmental or ecological roles. This will be highly beneficial to sustainable water resource management for ensuring socio-economic sustainable development and environmental security. This is also suitable for other developing countries and/or regions with water shortage problems and especially those in arid and semiarid areas.

**Rational strategic visions and operational plans for water resource development**

Sustainable water resource management should simultaneously satisfy social, economic and environmental demands. This means that water resources development should be based on a rational long-term strategic vision using appropriate planning criteria in accord with the goal of sustainable development and the definition of sustainable water resources.

In the long-term strategic vision for water resource development, one should specify an adequate quantity of water resources per capita as a long-term target. This target water quantity should be available or capable of being made available under the limitations of the definition of sustainable water resources. This target water quantity may be different in different regions and can be specified according to geographic characteristics, natural and human resources and their distributions, socio-economic structures, and characteristics of water resources. Once the target is legislatively confirmed or recognized, the socio-economic development of the region or country should be well planned and reconstructed according to the target water quantity.

Moving from the vision to action, an important procedure is to make operational mid-to-long-term water resource planning according to real socio-economic development. This is essential for the construction of water supply projects or enlargement of water supply capacity in water supply systems. In making the operational water resource plans, new water projects and other measures should be carefully planned and construction of the projects should be reasonably scheduled or arranged according to the patterns of water scarcity. For increasing demand-induced water scarcity, the best solutions may be water-saving and long distance interbasin water transfer, or reconstructing the water economy while the overall demand exceeds the target water quantity. For inadequate-quality-induced water scarcity, prevention of water pollution and purification of polluted or salt water would be feasible measures. For insufficient-project-induced water scarcity, the basic task is to intensify the construction of new water supply projects to expand water supply capacity and its reliability. These one-sided measures need to be considered with other measures in an integrated manner so as to become effective and efficient in solving water scarcity.
Setting up a water-saving society

Water saving is one of the key measures of resolving water scarcity. To set up a water-saving society, more attention should be paid to intensifying the water-saving awareness of every member of the society and developing highly effective and efficient water-saving techniques. Intensification of water-saving awareness needs comprehensive water education and should be regarded as a part of national or regional capacity building.

In many developing countries, the largest water-saving potential is in agriculture. For example, average irrigation water application efficiency in China is about 0.5. If the efficiency were increased to 0.6, China could save about 60 Gm$^3$ of irrigation water while if the efficiency were increased to 0.7 the total water saved could be up to 103 Gm$^3$. These are respectively equivalent to 1.04 and 1.78 times the total runoff of the Yellow River (long-term annual average: 58 Gm$^3$). China has developed quite a large number of water-saving irrigation model districts, on which various new techniques are applied that show high efficiency. However, the model districts are basically equipped with imported facilities that need clean water without silt while in arid and semi-arid north China, surface water usually contains much silt and needs to be treated. Furthermore, the model districts are costly in construction, operation and maintenance. Although water-saving efficiency and crop yields are high, they may not be highly beneficial to large areas growing low-value grain crops. Thus, each country should develop its own water-saving irrigation techniques appropriate for its own conditions.

Protection of water resource and reconstruction of water environments

Water pollution and environmental degradation are two key factors causing quality-induced water scarcity. Rapid economic development is usually accompanied by severe water pollution and environmental degradation. To prevent water pollution and to reconstruct the water environment, it is important to enact environmental protection laws and policies and efficient environmental management institutions, to carry out efficient water environmental education and to put sufficient financial investment in to the prevention of water pollution and reconstruction of degraded water environments. Meanwhile, a water environmental protection plan, including detailed measures for the reconstruction of degraded water environments as a part of integrated water resource planning is necessary for sustainable water resource management.

Conjunctive regional water supply systems

Conjunctive regional water supply systems can be effective in resolving local water scarcity, enlarging capacity, and heightening the reliability of regional water supply through sharing the capacities of the water projects involved in the systems. In construction of conjunctive regional water supply systems, one problem that needs resolution is localism. To overcome localism, proper laws and policies are needed for a fair benefit allocation of the systems and a reasonable limitation to over-demand.
Another problem is associated with the nationalities of minorities. On one hand, the habitats and customs of minority nationalities have to be respected and protected, and on the other hand, any local nationalism has to be overcome in the construction of conjunctive water supply systems in the regions inhabited by or with the minority nationalities. This concerns not only water resource allocation but also social stability and sustainable development.

**Reasonable priority and high reliability**

Unfair priority to and lower reliability of water supply for some users are common phenomena in most part of the world. Unfair priority generally exists in agricultural water supply, particularly farmland irrigation, and so does the reliability. This situation results from unfair criteria in the planning and design of water projects as well as the neglect of the importance of food production (Feng, 1999). Food security is of paramount importance for the developing world, especially the developing countries with a large population. This requires reasonable priority to and high reliability of agricultural water supply. This is in fact associated with reasonable water resource allocation among different water users, such as industrial, domestic, agricultural and environmental uses. Thus, an overall fair priority and reliability in water supply for each user is essential for sustainable water resource management.

**Efficient capacity building**

Capacity building is a complicated issue. First, capacity building is a comprehensive concept without a commonly recognized definition. Second, there are no commonly accepted criteria on capacity building. Different countries require different capacities at the same developing stages. Different developing stages need different capacities in the same countries. However, in general, for sustainable water resources management in developing countries with water shortages, the following two kinds of capacities are very important and should be properly built. They are hardware and software capacities. The hardware includes all the physical projects and facilities such as water storage, delivery, treatment, supply, utilization and any relevant projects or facilities, while the software includes all the administrative, legislative and technical measures, human skills, public morality, notions, religious belief, cultural customs, etc. The strategies just mentioned are in fact a part or some aspects of capacity building in relation to sustainable water resource management. They are suitable for water scarce developing countries and/or regions but may be different for different countries and/or regions and their different developing stages as well. Each country should make its own plans for capacity building according to its requirement.

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