Chapter 26
Efficient Use of Water Resources for Sustainability

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Abstract Strategies to achieve sustainable water management throughout the world are urgently needed as different regions are already experiencing high water stress with serious negative consequences on human health and ecosystems. Acknowledging the difference between efficiency and sustainability in water management, this paper considers the need of implementing actions that take into account future demand as well as the integrity of ecosystems. Consequently, recommendations are made regarding the investments that should be made on (1) access to clean water for human consumption, (2) ecosystem conservation and restoration, (3) watershed management, (4) collection and dissemination of data to the general public and decision makers, (5) finding ways to prevent and solve conflicts over water, and (6) encouraging community participation through local leadership, control over water resources, a fair allocation of benefits, and effective funding mechanisms.

Keywords Efficient water management • Sustainability • Community participation • Water observatories

26.1 The Urgent Need for Sustainability of Water Resources Management

26.1.1 Water Demand and Scarcity

According to the World Bank (2013), the main development challenges in this century, such as food and energy security, urban expansion control, human development, and adaptation to climate change, will only be met if water resources are managed adequately. Water is abundantly available globally, but it is unevenly distributed across the world and likely to become one of the most critical resources. For instance, Europe is densely populated and heavily industrialized, and it receives

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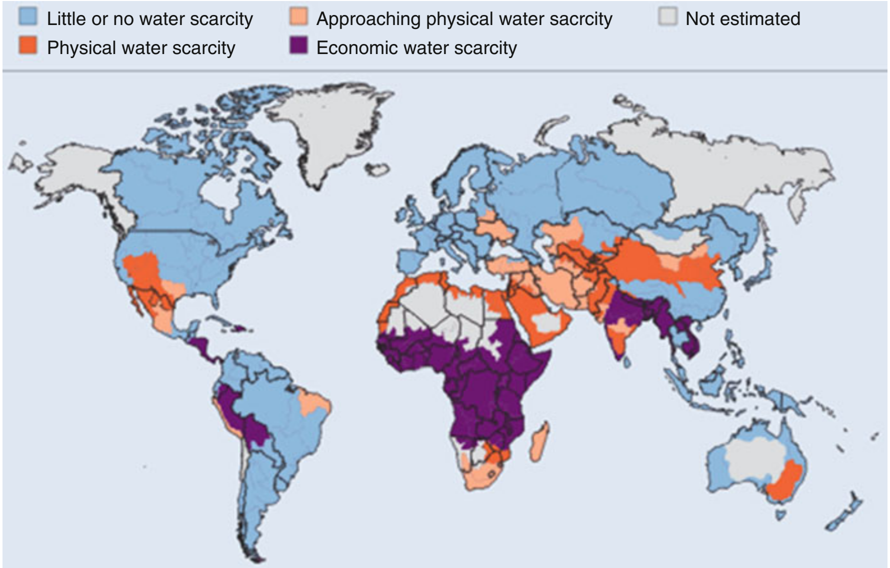

Fig. 26.1 Areas of physic and economic scarcity in the world (*Source*: Molden 2007)

only 7 % of global rainfall, and Asia accounts for 50 % of total world population and has only 30 % of rainfall. In contrast, North America with a share of less than 6 % of population receives nearly 14 % of rain (Gross 1986). In Mexico, for example, 77 % of the population lives in regions with only 31 % of the country's water availability. The northern region, which occupies more than 50 % of the territory, gets about 25 % of rainfall, while the southern region (28 % of the territory) receives nearly 50 % of rainfall (Comisión Nacional del Agua 2005).

Many regions are already experiencing moderate to high water stress (consumption level exceeding 20 % of availability supply). The United Nations assessment in 1997 determined that already one third of the world population was living in regions under this condition, and by 2025, it is likely that the share of the population undergoing this situation will be two thirds (Raskin et al. 1997). Figure 26.1 shows areas of the world approaching economic or physical scarcity. Economic scarcity is caused by a lack of investment in water or lack of human capacity to satisfy the demand for water, while physical scarcity occurs when there is not enough water to meet all demands, including environmental flows (Molden 2007).

While population triplicated between 1900 and 1995, water demand rose sixfold because of an increased demand for agriculture, industry, and domestic use (World Resources Institute 1999). Total global freshwater withdrawals are estimated at 3,800 km^3 of which 70 % are used by agriculture, followed by industry (20 %) and domestic use (10 %). Industrial and domestic uses are increasing relative to that for agriculture (Molden 2007). Industrial water use, for example, is predicted to double by 2025 (World Resources Institute 1999). Urban populations will expand from a current estimate of 3.5 billion (50 %) to 6.3 billion (69 %) by 2050 (United Nations 2010), while domestic and industrial demand for electric power will increase by about 50 %, of which hydropower is expected to supply about one third (Cook et al. 2011).

Water use in agriculture is expected to increase as world food demand rises. Agriculture already accounts for about 70 % of water consumption worldwide, and the United Nations projects a 50–100 % increase in irrigation water demand by 2025 (World Resources Institute 1999). Moreover, due to growing urban populations, demand for animal products will most likely increase by 74 %. This raise in food production is predicted to be achieved through intensification of production systems, but about 15 % is expected from expansion of agricultural lands (Cook et al. 2011).

Much of the projected increase in water demand will occur in developing countries, where population growth and industrial and agricultural expansion will be greatest. However, per capita consumption continues to augment in the industrialized world as well (World Resources Institute 1999).

In summary, current water stress is likely to increase in the near future due to water demands of a growing human population with increasing consumption needs. Additionally, climate change is already increasing the pressure on water resources. In consequence, strategies for sustainable management of water resources are urgently needed. The best way to do this is by implementing processes, institutions, and technologies that consider both efficiency and ecosystem conservation (Brooks and Brandes 2011).

26.1.2 Water Quality Degradation

Water availability is strongly related to its quality, because pollution is one of the main causes of its scarcity for uses such as human consumption, agriculture, industry, or biodiversity conservation (Peters and Meybech 2000). Studies show that human health is highly affected due to scarcity of water and pollution of water supplies, especially in rapidly urbanizing areas. Particularly, many developing countries are now facing pollution problems such as eutrophication, heavy metal deposition, acidification, and persistent organic pollutants while still trying to sort out typical problems of poor water supply and lack of sanitation services (World Health Organization 1997). The quality of both surface and groundwater in a catchment is a result of a combined effect of different processes affecting water in its hydrologic cycle. Its chemical composition depends on the solids, liquids, and gases generated internally or with which the water interacts. According to Peters and Meybech (2000), human beings have changed water quality by altering the lands in which the hydrologic cycle takes place with activities, such as agriculture, urbanization, dam construction, and deforestation, and also through the direct addition of substances (sewage discharges, application of pesticides and fertilizers, etc.) . Pollution is a very serious matter when it affects groundwater supplies, where contamination is slow to dilute, and it is quite expensive to apply purification measures (World Resources Institute 1999).

Some alarming facts regarding water quality degradation worldwide are the following (United Nations 2010):

- Every day, two million tons of sewage and industrial and agricultural waste are discharged into the water.
- Annually, 1, 500 km^3 of wastewater are generated.
- Worldwide, 2.5 billion people live without adequate sanitation, of which 70 % live in Asia (see Fig. 26.2).
- 18 % of the world's population experience open defecation.
- Infectious diseases such as waterborne diseases are the main cause of death of children under 5 years old (World Health Organization 2012).
- Unsafe or inadequate water, sanitation, and hygiene cause approximately 3.1 % of all deaths worldwide (World Health Organization 2012).
- 24 % of mammals and 12 % of birds connected to inland waters are considered threatened.
- Freshwater species have faced an estimated extinction rate five times greater than that of terrestrial species.
- Additionally, climate change is already putting more pressure on water resources. It is expected to increase hydrologic variability, resulting in extreme weather events such as droughts, floods, and major storms. As it is the case of most natural disasters, the poorest people will suffer most.
- But the other way around is also true: changes in water resources availability, water quality, and the destructive potential of storms and floods will determine, to a large extent, how climate change will affect human beings and the ecosystems (Miller 2008).
- Also, poor water management of reservoirs can also increase the release of greenhouse gases (GHG). It is estimated that emissions emanated from rotting vegetation and carbon inflow in watersheds account for between 1 and 28 % of the global warming potential of GHG emissions (Scanlon et al. 2004).

26.2 Efficient Water Management Is Not the Same as Sustainable Management

Kjellén and Mcgranahan (1997) pointed out that "The current burden of water-related diseases in urban areas is not, by and large, the outcome of the city-wide water supply and pollution problems that threaten sustainability. Low income urban neighbourhoods and households are more likely to lack water because they cannot access the city's water supplies due to limited availability. A comparatively healthy overall water balance can be accompanied by extremely unhealthy conditions in disadvantaged neighborhoods (. . .) Urban health essentially involves furthering the interests of today's poor, while ecological sustainability entails protecting the rights of future generations. When narrowly pursued, health and sustainability goals can conflict and create trade-offs between the interests of future generations and today's poor."

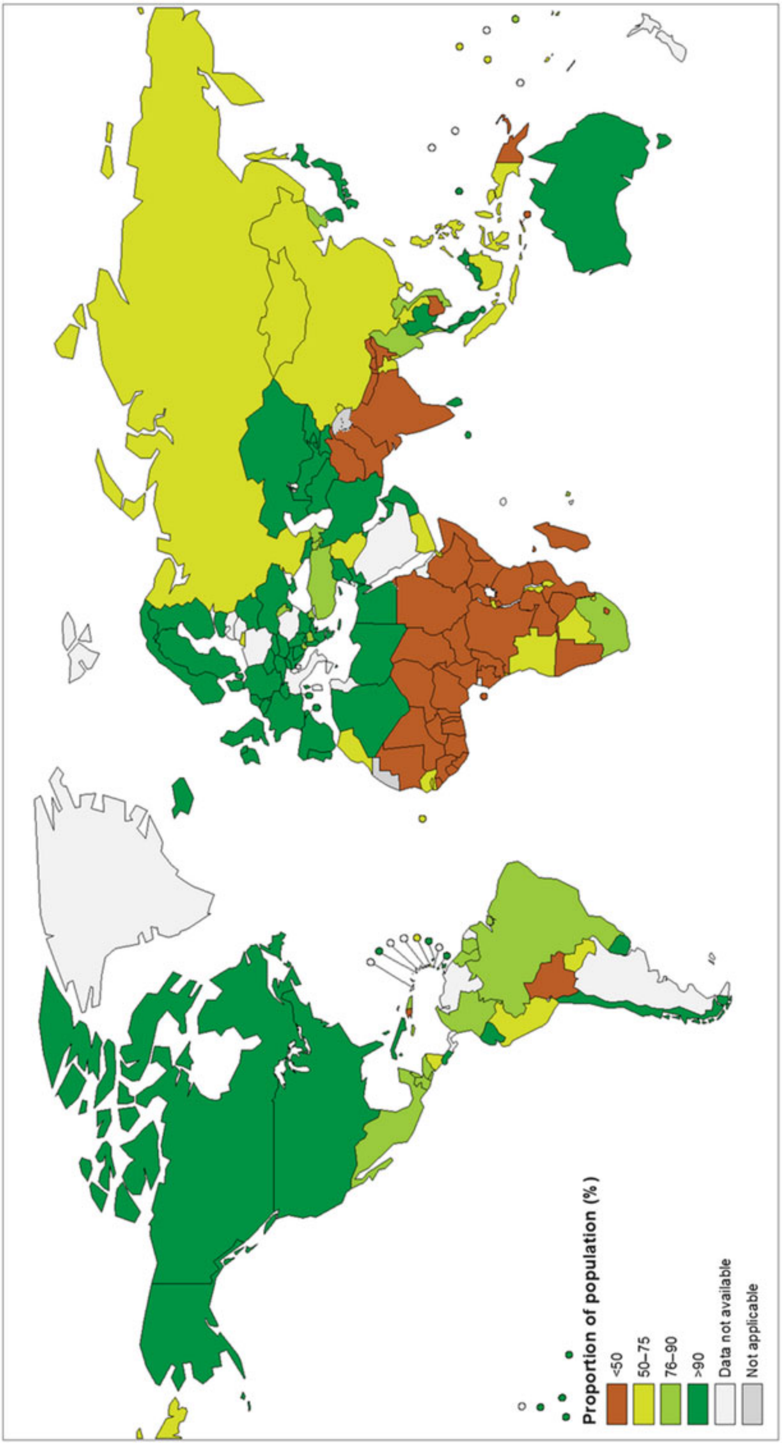

Fig. 26.2 Percentage of population with access to improved sanitation facilities, 2010 (*Source*: World Health Organization 2012)

Water used for agriculture is no longer available for wetlands, streams, deltas, and plants and animals. And as aquatic and terrestrial ecosystems are damaged, ecosystems change (Rosegrant 1997). According to the definition of the Brundtland Commission (World Commission on Environment and Development 1987), a system is sustainable if today's needs are met without compromising future generation to meet their own needs. Sustainability implies taking into account society, economy, and the environment, because people, habitats, and economic systems are interrelated. This interdependence may not be obvious in the short term, but sooner or later we are reminded of its existence by some alarm of crisis (Strange and Bayley 2008).

As the United States Environmental Protection Agency states: "Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future" (Environmental Protection Agency 2013).

When referring specifically to sustainable water management, Gleick's definition (1998) includes the importance of the hydrological cycle, as follows: "Sustainable water use is the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it." A similar definition is that of Mays (2006), ". . .the ability to use water in sufficient quantities and quality from the local to the global scale to meet the needs of humans and ecosystems for the present and the future to sustain life, and to protect humans from the damages brought about by natural and human-caused disasters that affect sustaining life."

26.3 Toward Sustainable Water Management

26.3.1 A Basic Water Requirement Will Be Guaranteed to All Humans to Maintain Human Health

In order to make decisions on how to allocate and use water resources, several criteria and goals can be established (based on Gleick 1998):

Goal number 7, target 10, from the Millennium Development Goals (MDG) formulated in 2000 by the United Nations, states as follows: "To halve, by 2015, the proportion of people without sustainable access to safe water and basic sanitation." According to the MDG Report 2013, although there has been huge progress in terms of access to drinking water, this issue is still a matter of serious concern, as 768 million people still drew water from an unimproved source in 2011 (United Nations 2013). Likewise, from 1990 to 2011, 1.9 billion people gained access to a latrine, flush toilet, or other improved sanitation facility. In order to meet the MDG sanitation target, this number must increase by another 1 billion people by 2015. As in 1990 only 49 % of the global population had improved sanitation; coverage must extend to 75 % to meet the target, up from the current level of 64 % (United Nations 2013).

According to the World Health Organization (2010), it is estimated that it would cost about US$ 23 billion per year to achieve the target by the year 2015. Taking into account that governments currently spend US$ 16 billion a year in building new infrastructure, only an additional US$ 7 billion a year would be needed to supply good water and sanitation. This amount is less than one tenth of what Europe spends on alcoholic drinks each year and half of what the United States spends each year on pet food.

The World Health Organization (2010) suggests concentrating efforts on the following issues:

- *Getting health back into the water agenda*, which means putting an emphasis on safe water supply, adequate sanitation, and environmental management, instead of relying only on strictly medical interventions to enhance health.
- *Better planning for water and health*, which includes not transferring costs of development to health sector and giving priority to well-being of people.
- *Reaping the benefits of science*. An adequate budget must be assigned to research on health and technological innovation. Also, what has already been investigated by researchers from different parts of the world must be integrated and disseminated.
- *Taking advantage of globalization*, i.e., the integration of the world could help to achieve a safer and cleaner environment.

26.3.2 A Basic Water Requirement Will Be Guaranteed to Restore and Maintain the Health of Ecosystems

In order to achieve sustainability in water management, it is essential that water storage and diversion for human purposes are programmed in a manner that does not affect ecosystems. This necessarily implies that there is a limit to the amount of water that may be withdrawn without compromising the ecological integrity of the affected ecosystems, resulting in the loss of native species and valuable ecosystem products and services for society (Richter et al. 2003). To determine this limit, a fundamental concept is environmental flow: the "quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihood and well-being that depend on these ecosystems" (Brisbane Declaration, River Foundation 2013). In order to sustain freshwater ecosystems, not only is a minimum low flow required but also a naturally variable regime of flow (Poff et al. 2010).

Poff et al. (2010) developed ELOHA, a framework to develop environmental flow standards based on both a scientific and social process. Hydrologic analysis and classification are developed in parallel with flow alteration–ecological response relationships, which provide scientific input into a social process that balances this information with societal values and goals to set environmental flow standards (Fig. 26.3).

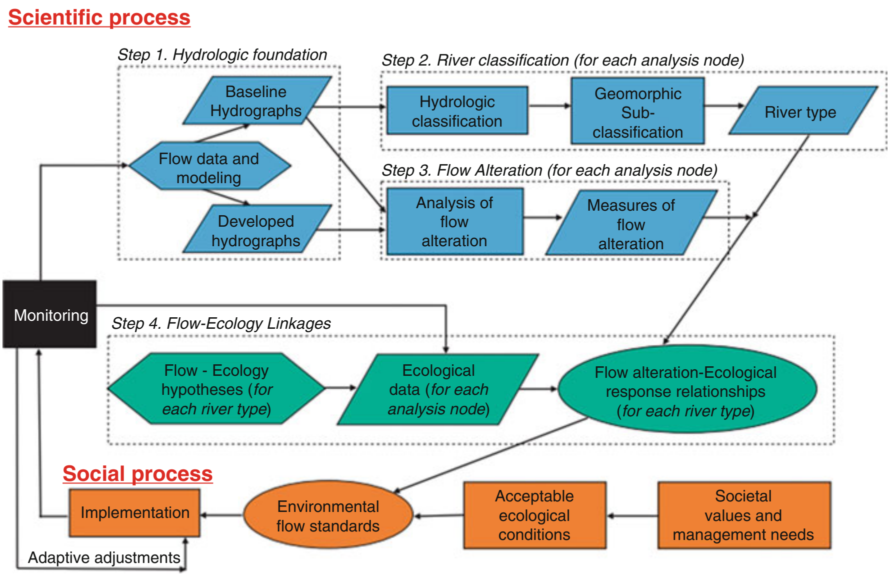

Fig. 26.3 The ecological limits of hydrological alteration framework. It comprises both a scientific and social process. Hydrologic analysis and classification (*blue*) are developed in parallel with flow alteration–ecological response relationships (*green*), which provide scientific input into a social process (*orange*) that balances this information with societal values and goals to set environmental flow standards. This paper describes the hydrologic and ecological processes in detail and outlines the scientist's role in the social process (*Source*: Poff et al. 2010)

In order to measure ecosystem health, indicators have been developed worldwide. An indicator is a measure, either qualitative or quantitative, of facts or conditions of particular issue. Environmental indicators should represent the key elements of a complex ecosystem or environmental issue, in this case, water. If the indicators are observed regularly, they can analyze changes during the observation period (Juwana et al. 2012). One example is the set of indicators established for the North American Great Lakes basin (Shear et al. 2005). First, the issues of the basin were determined according to its particular geographical, geological, and human settlement condition such as land use, climate change, toxic pollutants, nutrients, invasive species, ecosystem ecology, habitat status, and data collection methods. The indicators were then classified into state indicators, such as biodiversity; status of native species; pressure indicators, such as phosphorus concentration and fecal coliform levels; and response indicators, like human stewardship activities (Shear et al. 2005).

Another example is the set of indicators used in Queensland, Australia, by the Department of Environment and Health Protection (2013)and classified in physicochemical (including pH, nutrients, oxygen, temperature, and salinity), biological (or fish diversity, benthic algal growth and benthic oxygen demand, chlorophyll a), habitat indicators (width, continuity, extent of shading and species composition, bank erosion, presence of woody debris, among others), and flow indicators

Table 26.1 Components, indicators, and sub-indicators used by the West Java Water Sustainability Index

Component	Indicator	Sub-indicator
Conservation	Water availability	
	Land use changes	
	Water quality	
Water use	Water demand	Coverage
	Water services provision	Water loss
Policy and governance	Information disclosure	Education
	Governance structure	Poverty
	Public participation	Health impact
	Law enforcement	Sanitation

(changes in base flows, peak flows, no flow periods, seasonality of flows). Also, the Government of Canada developed a series of water indicators (Table 26.1).

Some indicators might be combined together to form an index or composite indicator. One of them is the Water Poverty Index (WPI) (Lawrence et al. 2002). Other examples are the Canadian Water Sustainability Index (CWSI), Watershed Sustainability Index (WSI), and West Java Water Sustainability Index (WJWSI) (Table 26.2). All these indices seek to measure sustainability, can assist decision makers and other stakeholders in achieving sustainability, and can be used to communicate the progress of sustainability to society (Juwana et al. 2012).

26.3.3 The Watershed: An Adequate Physical Unit to Manage Water Resources

Because water and soil are closely related, they must be managed jointly (Wang 2001). The most logical unit in which to carry out these management processes is the watershed, as it forms natural boundaries within a land mass and it is hydrologically defined. Using the watershed approach means focusing in water and other natural resources in a holistic way (Mylavarapu et al. 2012). A watershed approach is a flexible framework for managing water resource quantity and quality.

The watershed approach allows protecting water resources and water quality through proper land-use planning. It is of paramount importance to include all stakeholders as, for instance, water quality management and land-use planning are frequently implemented by different agencies with different objectives. Planners and policy makers at different levels should bring stakeholders together to implement a diagnosis of the watershed, identify sources of the problems, understand the relationship between the sources and consequences, and find out how to solve these problems. Some common solutions include implementing vegetation buffers, improving water quality of discharges to rivers, restricting certain land uses, and promoting others (Wang 2001).

Table 26.2 Components and water indicators used by Environment Canada

Component	Indicators
Water quantity	Water quantity in Canadian rivers
	Regional water quantity in Canadian rivers
	Local water quantity in Canadian rivers
	Canada's water quantity in a global context
	Water availability in Canada
	Residential water use
	Water withdrawal and consumption by sector
Water quality	Freshwater quality in Canadian rivers
	Regional freshwater quality in Canadian rivers
	Local freshwater quality in Canada
	Canada's freshwater quality in a global context
	Shellfish growing area quality indicator
	Polybrominated diphenyl ethers (PBDEs) in fish and sediment
	Drinking water advisories in Canada
Regional ecosystems	Restoring the Great Lakes areas of concern
	Phosphorus levels in the Great Lakes
	Phosphorus levels in the St. Lawrence River
	Reducing phosphorus loads to Lake Simcoe
	Phosphorus and nitrogen levels in Lake Winnipeg
Pressures on water quality	Land use impacts on freshwater quality
	Household use of chemical pesticides and fertilizers
	Municipal wastewater treatment
	Soil and water quality indicators for agriculture
	Release of toxic substances to water
	Managing disposal at sea

26.3.4 Access to Data on Water Resources Availability, Use, and Quality

According to the World Meteorological Organization (2012), in order to support sustainable economic and social development, there is a pressing need for accurate information on the condition and trend of a country's water resources. This information is used very frequently and in many different ways for planning, development, or operational purposes. As clean water becomes scarce and competition increases, water information grows in value. Several countries have demonstrated the benefits of hydrological information and analysis. For example, in Canada and Australia, a benefit-to-cost ratio for hydrological data collection of 9.3 and 6.4, respectively, has been found in studies.

The World Meteorological Organization (2012) also states that many countries have undertaken assessments of water resources at local, regional, or national scales, but in many cases there is a lack of good-quality data. Some of the necessary information are for instance, long-term records of climate, river flows, reservoir levels, and groundwater levels. However, in many parts of the world, governments have overlooked the importance of maintaining long-term, good-quality environmental records. Additionally, because of climate change, there is a need for new scenario-based approaches to future resource modeling and continuing reliable long-term records to determine trends in water availability.

Water observatories play an important role in data collection and analysis, in dissemination of information, and in involving citizens in planning processes. They are also an excellent means of enhancing public participation through a co-responsibility approach, where citizens are informed about water conditions, and institutional efforts to improve these conditions, and consequently they are exhorted to also "do their part." Some interesting water observatories throughout the world are found in Europe (PEER-EURAQUA Network of Hydrological Observatories 2013) and specifically in France (Observatoire Départemental de Vendée (http://observatoire-eau.vendee.fr/), Observatoire de l'eau en Bretagne (http://www.observatoire-eau-bretagne.fr/)), in the United States (for instance, the Chicago Waterway Observatory of the United States Geological Survey (http://il.water.usgs.gov/data/cwo/)), and also in Latin America, in countries such as Argentina (Observatorio del Agua Universidad Nacional de Patagonia San Juan del Bosco (http://observatoriodelagua.org.ar/)) and Mexico (Observatorio Ciudadano del Agua (http://www.h2observa.net/)). The National Autonomous University of Mexico (UNAM) has recently launched its water observatory (http://www.agua.unam.mx/observatorio/), with six indicators, referred to percentage of leaks, compliance of water quality regulation, and participation in responsible use of water of UNAM's authorities and the community.

26.3.5 Mechanisms to Prevent and Resolve Conflicts Over Water

Water conflicts normally arise from the fact that the freshwater resources of the world are not partitioned to match the political borders, nor are they evenly distributed in space and time (Nandalal and Simonovic 2003). Almost half of the land area of the earth is part of an international river basin, and more than 220 nations share water with a neighboring country. Sharing a limited water resource by several stakeholders can create conflicts among them when their requirements exceed availability (Gleick 1998).

Additionally, because of both, the global communication and the democratic revolution, conflicts over water that used to be local have been brought into the international arena. They usually result from the building of large infrastructure projects, changes in community access to water, or impacts of critical socio-ecological systems (Conca 2006). It is likely that climate change will jeopardize water conflicts as it may alter the flow of many rivers due to changes in precipitation patterns and increase the demand for water, due to more frequent droughts and greater stress being placed on other sources of water (Tir 2012).

For solving conflicts over water, there exist some treaties among river basin nations allocating water, setting up management oversight, and developing acceptable standards for operations and water quality. Unfortunately, many international rivers do not have such treaties and in other cases do not address current problems adequately (Gleick 1998). As climate change puts more pressure on water systems, for treaties to adapt to this stress, there must be institutional design that includes provisions for joint monitoring, conflict resolution, treaty enforcement, and the delegation of authority to intergovernmental organizations. Treaties that contain more of these features are expected to better manage conflicts caused by water stress (Tir 2012).

In order to solve the technical aspect of conflicts, computer-based models can prove to be effective tools. One of the major types of models are simulation models, which addresses "what if" questions. Given the assumptions for a system design and operation, a simulation model can predict how well it will perform. The other major types are optimization models, which address "what should be" questions and what design and operating policy will best meet the specified objectives (Loucks 2008).

Models can be used for many different purposes, such as predicting runoff from watersheds or interactions between groundwater and surface water bodies. They can also be used to study reservoir operation; to forecast floods and plan flood-control programs; to predict storm surges, embankment erosion, and dam breaks; and to plan for ecosystem restoration (Loucks 2008).

They can help to further understand the problems, formalize performance objectives, develop and evaluate alternatives, and provide confidence in solutions, and they can also work as negotiation forums, by employing the logic of model studies and development to structure the negotiation process; however, they only are useful when objectives and functions are well defined (Lund and Palmer 1997). According to Nandalal and Simonovic 2003, there are several alternative solutions, and the best one is not obvious, the impacts resulting from decisions are not evident without modeling, and there is readily obtainable data to estimate parameters.

Water planning and decision making will be democratic, ensuring representation of all affected parties and fostering direct participation of affected interests.

To improve the quality, effectiveness, and sustainability of development actions, community participation is fundamental. When people are placed at the center of actions, there is a greater possibility of empowering stakeholders who have a sense of ownership of results and therefore a strong interest on positive results (Fisher and Urich 1999). By community involvement, we understand that users participate to a project cycle by assuming a responsibility and exercising an authority and a control over the setting up of the water services (Tandia 2006).

For participation to be transformative, information needs to be available for all stakeholders preferably during the early stages of the project cycle. This enables stakeholders to engage in a dialogue with the project designers to negotiate parameters for participation and consultation (Fisher and Urich 1999).

Among the benefits of social participation, Von Korff et al. (2010) point out the following:

- Improved legitimacy for decision makers as stakeholders feel that they are responding to their value and thus start trusting them
- Better and less expensive decisions because stakeholders share information and participate with their ideas
- More possibilities of implementing decisions because people are unlikely to oppose to a project that they contributed to build capacity building of stakeholders during participant interaction

However, it is possible that participation does not bring benefits because stakeholders become disappointed as their expectations are not fulfilled, objectives are unclear, or some stakeholders receive more benefits than others (Von Korff et al. 2010). This lack of equity was found by Hoffet et al., (2012), where the authors state that uneven benefits persist because of issues of inequity in allocation at the national, regional, and local scales. They suggest that participation should go beyond the watershed challenging power differences between stakeholders (Hoffet et al. 2012).

Also, it is likely that participation does not occur properly due to conflicts among stakeholders or lack of inclusion of all the involved parties (Von Korff et al. 2010). Agrawal and Gibson (1999) present a recommendation that could foster efficient community participation in natural resource conservation: redefining the concept or community and instead of considering it as a fixed small spatial unit, as a homogeneous social structure, and as shared norms, a more political approach should be considered, examining communities in the context of development and conservation by focusing on the multiple interests and actors within communities, on how these actors influence decision making, and on the internal and external institutions that shape the decision-making process.

From Agrawal and Gibson (1999) and Haddad et al. (2007), the following are some aspects that could improve community participation and promote sustainable systems:

- Founding projects on principles of check and balances among stakeholders.
- Involving all who are directly involved in water management and making them feel that they have ownership over the resource and/or ownership for the way it is used and managed.
- Understanding the different roles of men and women to target action appropriately.
- Making strenuous efforts to empower local groups.
- Focusing on building capacities of local representatives of governments to intermediate between the local community and the government institutions.
- Strengthening local leadership to make changes.
- Developing management abilities of the different participating agencies.
- Seeking to implement reasonable processes of decision making instead of trying to ensure successful outcomes. Reasonable processes mean that all stakeholders' interests (especially those that are normally excluded) are represented in

decision making, that there exist mechanisms to guarantee that the outcomes of current decision processes are going to form part of the data on which future decisions will be based, and that decision makers are constantly evaluated by those affected by decisions.
- Ensuring that local groups have access to adequate funds for implementing the rules they create. It is preferable that funds are local instead of granted by central governments. This could allow communities to demand control over resources.

26.4 Conclusions

Water has become a pressing natural resource in large areas of the world. Its scarcity and poor quality have serious consequences on human populations and on natural ecosystems as well. There is therefore an urgent need for efficient water management in terms of both quantity and quality. For water management to be sustainable, future generations' welfare must be acknowledged, and environmental, economic, and social aspects must also be considered. Based on Gleick (1998), several goals and criteria for sustainable water management can be established:

- Meeting basic human requirements through sufficient clean water, by investing on infrastructure but also on health research and technological innovation.
- Meeting environmental water needs that promote conservation and restoration of ecosystems. For this purpose, it is helpful to develop indicators that represent the key elements of complex ecosystems.
- Using a watershed approach to manage water resources through proper land-use planning and focusing on adequate management of other resources in a holistic way.
- Collecting data and making it available for planning, development, or operational purposes. Observatories can prove a useful tool for these aims.
- Finding mechanisms to prevent and solve conflicts over water, which can include treaties that take into account provisions for joint monitoring, conflict resolution, treaty enforcement, and the delegation of authority to intergovernmental organizations.
- Involving communities in planning and decision making, strengthening local leadership, and making strenuous efforts on promoting equity among stakeholders.

References

Agrawal A, Gibson CC (1999) Enchantment and disenchantment: the role of community in natural resource conservation. World Dev 27(4):629–649

Brooks DB, Brandes OM (2011) Why a water soft path, why now and what then? Int J Water Resour Dev 27(2):315–344

Comisión Nacional del Agua (2005) Estadísticas del agua en México. Síntesis. Comisión Nacional del Agua, México

Conca K (2006) The new face of water conflict. Navigating peace. Woodrow Wilson Int Center Scholars 3:1–3

Cook S, Fisher M, Tiemann T, Vidal A (2011) Water, food and poverty: global- and basin-scale analysis. Water Int 36(1):1–16

Department of Environment and Health Protection (2013) http://www.ehp.qld.gov.au/water/monitoring/assessment/water_quality_indicators.html. Accessed 1 Aug 2013

Environmental Protection Agency (2013) http://www.epa.gov/sustainability/basicinfo.htm. Accessed 1 Aug 2013

Fisher KT, Urich PB (1999) Information dissemination and communication in stakeholder participation: the Bohol-Cebu water supply project. Asia Pacific Viewpoint 40(3):251–269

Gleick PH (1998) Water in crisis: paths to sustainable water use. Ecol Appl 8(3):571–579

Gross AC (1986) Water quality management worldwide. Environ Manage 10(1):25–39

Haddad HF, Al Zoubi R, Alaween M, Shraideh F (2007) Local community participation for sustainable water resource management. MEDA WATER international conference on Sustainable Water Management, Tunis, 21–24 Mar 2007

Hoffet N, Daoud I, Tourrand JF, Alay V, Moselhy N (2012). Participation, power and sustainable water resource management. A case study of the Rainfed Desert Region of Matruh, Egypt. Communication IFSA/International Farming Systems Association, Denmark, July 2012

Juwana I, Muttil N, Perera BJC (2012) Indicator-based water sustainability assessment – a review. Sci Tot Environ 438:357–371

Kjellén M, Mcgranahan G (1997) Comprehensive assessment of freshwater resources of the world. Urban water: towards health and sustainability. Stockholm Environmental Institute, Stockholm

Lawrence P, Meigh J, Sullivan C (2002) The water poverty index: an international comparison. Keele Economics Research Papers. Centre for Economic Research, Research Institute for Public Policy and Management, Keele University, Staffordshire

Loucks D (2008) Water resource management models. Bridge 38(3):24–30

Lund JR, Palmer RN (1997) Water resources system modeling for conflict resolution. Water Resour Update 3(108):70–82

Mays LW (2006) Water resources sustainability. McGraw-Hill Professional

Mylavarapu R, Hines K, Obreza T, Means G (2012) Watersheds of Florida: understanding a watershed. http://edis.ifas.ufl.edu. Accessed 28 July 2013

Miller M (2008) Climate change and water resources: the challenges ahead. J Int Aff 61(2):35–50

Molden D (2007) Water for food, water for life. A comprehensive assessment of water management in agriculture. International Water Management Institute, Sterling

Nandalal KDW, Simonovic S (2003) Conflict resolution support system: a software for the resolution of conflicts in water resource management. Division of Water Sciences, UNESCO, Paris, 134 p

Observatoire Départemental de Vendée. http://observatoire-eau.vendee.fr. Accessed 6 Aug 2013

Observatoire de l'eau en Bretagne. http://www.observatoire-eau-bretagne.fr. Accessed 6 Aug 2013

PEER EurAqua Network of Hydrological Observatories. http://www.euraqua.org/content/activities/hydrologicalobservatories.4.3cd20f1b1243376c116800033.html. Accessed 6 Aug 2013

Observatorio Ciudadano del Agua. http://www.h2observa.net/. Accessed 6 Aug 2013

Observatorio del Agua Universidad Nacional de Patagonia San Juan del Bosco. http://observatoriodelagua.org.ar. Accessed 6 Aug 2013

Peters NE, Meybech M (2000) Water quality degradation effects on freshwater. Water Int 25(2):185–193

Poff NL, Richter BD, Arthington AH, Bunn SE, Naiman RJ, Kendy E, Acreman M, Apse C, Bledsoe BP, Freeman MC, Henriksen J, Jacobson RB, Kennen JG, Merritt DB, O'Keeffe JK, Olden JK, Rogers J, Tharme RE, Warner A (2010) The Ecological Limits of Hydrologic Alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshw Biol 55:147–170

Raskin P, Gleick P, Kirshen P, Pontius RG, Strzepek K (1997) Water futures: assessment of long-range patterns and problems, comprehensive assessment of the freshwater resources of the world. Stockholm Environment Institute, Stockholm

Richter BD, Mathews R, Harrison DL, Wigington R (2003) Ecologically sustainable water management: managing river flows for ecological integrity. Ecol Appl 13(1):206–224

River Foundation (2013) http://www.riverfoundation.org.au/images/stories.pdfs/bnedeclaration.pdf. Accessed 29 July 2013

Rosegrant MW (1997) Water resources in the twenty-first century: challenges and implications for action, food, agriculture, and the environment. Discussion Paper 20. International Food Policy Research Institute, Washington, DC

Scanlon J, Cassar A, Nemes N (2004) Water as a human right? IUCN, Gland

Shear H, Bertram P, Forst C, Horvatin P (2005) Development and application of ecosystem health indicators for the North American Great Lakes Basin. In: Jorgensen SE, Constanza R, Xu FL (eds) Handbook of ecological indicators for assessment of ecosystem health. CRC Press, Boca Raton

Strange T, Bayley A (2008) Sustainable development: linking economy, society, environment. OECD insights. OECD Publishing, Paris

Tandia CT (2006) Involvement/community participation in hygiene and water in Central and Western Africa. In: International conference on community health in African region. World Bank, World Health Organization, UNICEF. Addis Ababa, Ethiopia, 20–22 November 2006

Tir J (2012) Weathering climate change: can institutions mitigate international water conflict? J Peace Res 49(1):211–225

United Nations (2010) United Nations, Department of Economic and Social Affairs, Population Division: World urbanization prospects, the 2009 revision: highlights. United Nations, New York

United Nations (2013) Millennium development goals report. New York

United States Geological Survey. Chicago waterway observatory http://il.water.usgs.gov/data/cwo/. Accessed 6 Aug 2013

Universidad Nacional Autónoma de México. Observatorio del Agua de la UNAM. http://www.agua.unam.mx/observatorio/. Accessed 6 Aug 2013

Von Korff YP, d'Aquino P, Daniell KA, Bijlsma R (2010) Designing participation processes for water management and beyond. Ecol Soc 15(3):1

Wang X (2001) Integrating water-quality management and land-use planning in a watershed context. J Environ Manage 65:25–26

World Bank (2013) Water resources management overview. http://www.worldbank.org/en/topic/waterresourcesmanagement/overview. Accessed 28 July 2013

World Commission on Environment and Development (1987) Our common future. Oxford University Press, New York

World Health Organization (1997) Health and environment in sustainable development: five years after the earth summit. World Health Organization, Geneva, pp 54–55

World Health Organization (2012) Public health information and geographical information systems. http://gamapserver.who.int/mapLibrary/Files/Maps/phe_Global_sanitation_2010.png

World Health Organization (2010) World water day report. http://www.who.int/water_sanitation_health/takingcharge.html. Accessed 30 July 2013

World Meteorological Organization (2012) Technical material for water resources assessment. World Meteorological Organization, Génève

World Resources Institute (1999) Water: critical shortages ahead? World Resources 1998–99. Washington