

There is enough water, food, and energy to meet everyone’s needs. Yet for the bottom billion (Collier 2007) they are not being properly met. Will everyone’s needs be met in the future? The answer to this question depends on what strategic steps we take today and on the day-to-day actions of consumers and the public at large. Learning from what has worked in the past and what has not, is important. Humans have the capacity to generate unprecedented wealth, but we are doing it in an environment of growing vulnerability, uncertainty, and stiffer resource use competition. Efficiency in the use of the limited water and other resources is necessary. Resource stewardship needs to be combined with strategies that ensure that all people have access to water and also the goods and services that water provides. In this regard the needs of the bottom one billion and the wants of the wealthier populations pose a double challenge.

2.1 Staggering Growth, Water Use, and Human Behavior

Imagine if we had asked people 100 years ago what they thought would happen during the coming century, in terms of economic growth, demography, water, and the environment. The term “environment” might have been explained with reference to the four elements identified by Aristotle—water, earth, fire, and air. Naturally, predictions would have varied because it is always hard to imagine what the future will bring. Yet it is important to try to understand how the future may evolve so we can be prepared and benefit from it—or try to change course.

During the past 100 years—the twentieth century—the aggregate global gross domestic product (GDP) multiplied 19 times (IMF 2000). With a population increase of less than a quarter of the growth in goods and services during the same period, there was an unprecedented opportunity to cater to everybody’s needs, while, at the same time, providing opportunities to meet human wants. Some of the goods and services that are included in the calculation of GDP do not contribute to human welfare, but the staggering increase on the supply side reflects an impressive

increase in demand and purchasing power for hundreds of millions of people. But the benefits have not been shared by everyone. Gaps between the rich and the poor have been, and remain, wide and are increasing (IMF 2000; Shah 2010).

Access to safe water is still a dream for about 900 million people and more than 2.5 billion lack access to safe sanitation. Food insecurity is a dire reality for close to a billion. Improvements were achieved after the beginning of the 1960s, but during the last 15 years or so, food insecurity, in terms of undernourishment, has increased in spite of a continuous increase in aggregate global *per capita* food production and supply (Lundqvist 2010; Fig. 2.2). Mr. Henry Kissinger's laudable pledge at the first World Food Conference (later called World Food Summits) in 1974, "In 10 years no child will go to bed hungry," has not become a reality.

Increased food insecurity during the last 15 years or so took place despite increases in production and supply being faster than the population increases during the same period. Production, and also supply—what is available in the market after losses and conversions—are at a level that is in excess of what is needed for food security. Today overeating is a more widespread phenomenon than undernourishment. It is estimated that 1.5 billion persons, aged 20 years and above, overeat (Beddington et al. 2012). Moreover, between one-third and one-half of the food produced on the farm is lost, wasted, or converted between "field to fork" (Lundqvist et al. 2008; Lundqvist 2010; Gustavsson et al. 2011). Increasing resource use efficiency—"more crop per drop"—is important, but if a large fraction of the produce is lost or not beneficially used the net result of gains in production are reduced.

These kinds of imperfections not only apply to the use of water and food. Similar observations can be made regarding other resources and commodities. With the strong linkage between food, water, energy, the environment, and human well-being (Hoff 2011) these kinds of imperfections affect all of us as well as the natural resources and Earth's environment. We need fresh thinking. In an era of growing water scarcity we need to identify how to use our technical capacity and sound and responsible human action to reduce these production and supply chain imbalances and imperfections. Reducing the losses and waste associated with the products we grow or produce from water is important. So far it has not been seriously tried.

2.2 Human Ambition and Capacity to Modify Our Planet

Promises to improve water and food security, among other things, for the poorest one billion are repeatedly given at international and national gatherings. At the same time, most of us who have enough want more. With higher incomes, many have the means to realize their wants. Within a generation, an additional two billion people will express their claims in terms of access to water, food, energy, and a range of goods and services.

The interdependencies between social ambitions, human well-being, and political promises, on the one hand, and natural resources and the environment on the other, are obvious and determine the kind of development that is realistic and stable. Yet there is a disconnect between the production and supply of goods and services

and the ability of our Earth to sustain this production and provide this supply. The tremendous expansion in the production and supply of goods and services in the recent past has meant jobs, income, and, generally, possibilities for a better life. It has also meant a heavy exploitation of natural resources, the generation of a number of side effects, and, generally, a modification of the Earth System at a level and speed that is now overshadowing geological and natural forces (Crutzen 2002).

While the quality of life and material standard of living for a majority of us has improved considerably, the effects on water and other vital components of the Earth System have moved in the opposite direction. Many river basins in the world are labeled as “closed” or are on the verge of being closed or reaching peak limits (Seckler 1996; Gleick and Palaniappan 2010). An estimated 1.4 billion people live in closed basins (Smakhtin 2008). The downstream segments of a growing number of rivers are occasionally dry as a result of the heavy withdrawals of water from the stream, e.g., Colorado, Nile, Amu/Syr Darya. A closed basin naturally has more limited development options, even if groundwater is available. As the availability of surface water becomes more and more constrained, the use of economically available groundwater tends to increase.

There is no escape from the fact that the need and demand for finite and vulnerable water will continue to expand and so will competition for it. More uncertainty in availability, higher frequency of extreme weather events, and more rapid return flows of water to the atmosphere are also to be expected in the future. Given the changes in the hydrologic cycle as a result of land use and climate changes and the closed character of many basins, allocations to, and patterns of future water use, for various sectors in society will deviate from past trends. It is critical to better understand how these complex interactions may develop and the associated social, political, and environmental implications over the coming decades. Clearly, water issues will become even more important in the lives and activities of people. Any vision of the future needs to recognize that water is everybody’s business (Cosgrove and Rijsberman 2000).

2.3 Visioning Our Future

Here we speculate on how the need and demand for water will unfold up to 2050. To do this we must first summarize the key drivers of past development and assess how they are likely to guide the future demand for, and management of, water. We can then identify which circumstances may change the course of the development trajectories. This process is illustrated in Fig. 2.1.

In many studies about possible futures, a range of drivers are considered. For the Scenarios Project of the UNESCO World Water Assessment Programme (UN WWAP 2012), for instance, in-depth research was carried out on ten drivers to examine possible future developments and also to look for inter-linkages between the drivers. Gallopin (2011) summarizes the work presented in several studies and talks about driving forces grouped into clusters. Ten clusters are identified and within each of them, on average, from 5 to 7 specific driving forces, trends, or

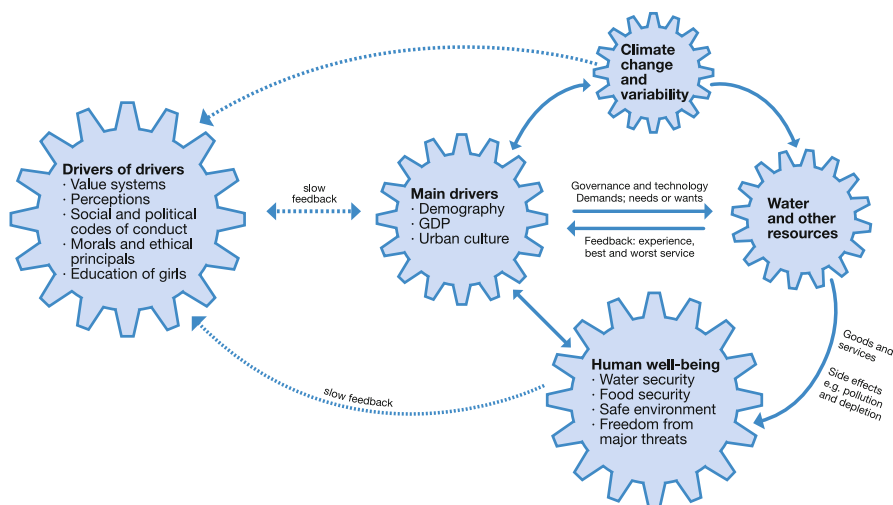


Fig. 2.1 An overview of the assumptions, contents, and purpose of this chapter (figure drawn by Britt-Louise Andersson, SIWI)

processes are identified. In other studies, a limited number of drivers are used. Kolbert (2011) used three variables—population, technology, and GDP—to estimate the dynamics behind the recent high rates of growth in many aspects of society, including GDP, energy, food, technology, and population (Steffen et al. 2011).

A common feature in these kinds of studies is that demography and GDP are regarded as the two main drivers of change. In addition to these two main drivers, a complex set of more basic, but also less concrete drivers, are at work. Social perceptions, political ideologies, and government strategies, knowledge, and value systems are examples of these kinds of underlying factors and forces. These are referred to as the drivers of the drivers in Gallopin (2011).

It is assumed that “Main drivers” and “Climate change” will increase in significance during the foreseeable future, whereas “Drivers of drivers,” “Water and other resources,” and “Human wellbeing” may either be more important as drivers or have a decreasing influence on the complex interactions in the system.

The main drivers are tangible and quantifiable whereas “drivers of drivers” are important, but hard to quantify. Demographic and economic trends can be projected with a relatively higher degree of likelihood as compared to changes in the underlying drivers. Many of these forces have typically been rather inert and their implications for water use and quality are difficult to evaluate. History provides, however, many examples of sudden and dramatic changes in, for instance, political systems. Contemporary political turbulence in North Africa and the “Arab Spring” illustrate that events in civil society may trigger processes of political change at national and regional scales. The distinction between main drivers and the indirect drivers is thus not necessarily reflecting which sets of drivers are more or less important.

2.3.1 Predicting the Future of the Planet

The effects of socioeconomic and political shifts on water demand and management are variable. Two examples shed light on drivers for policy change. The Water Act, introduced in South Africa in 1998, is often associated with the new political regime after 1994. However, by the early 1980s it had become evident that demographic and water use trends in South Africa had resulted in serious problems that could not be solved within the existing policy framework. Mackay (2003, p.51) explains how members of the scientific community realized early the need for policy reform, but “...they did not achieve high priority on the national agenda until 1994.” In addition, a widespread social discontent with the old regime paved the way for a new national agenda, which included a radically new perspective on water management.

Another kind of a water challenge is illustrated by the dramatic consequences of recent prolonged periods of drought followed by floods in Australia. As discussed in Box 2.1, the actors in this context are farmers, spokespeople for environmental sustainability, and government representatives. Pittock and Connell (2010) argue that the devastating drought in Australia can be seen as a “demonstration of the planet’s future.” Among other things, this example illustrates that the notion of “extreme events” refers to the painful and difficult social and political processes of adaptation to water and climate realities that may last for many years.

Obviously, a combination of circumstances, which vary from one country to another and over time, drive and constrain the management of water. A combination of socioeconomic forces, well-informed and articulate members of the scientific community, technological capacity, and climate context also play prominent roles in most countries. The political and administrative system is significant, but perhaps mainly as a means of enabling, implementing, and enforcing management plans and policies. The frequent reference to “political will” is relevant, but, as illustrated in Box 2.1, the critical issue is often “political skill,” that is, a visionary and strong leadership where opposing interests are balanced, where policy is informed by scientific understanding, and decisions are negotiated and socially accepted (Lundqvist and Falkenmark 2010).

Box 2.1 Policy and Management Responses to the Prolonged Droughts that hit Australia, Especially in the Murray-Darling Basin 2000–2009

Australia has always been subject to major climatic variation. The history of the development of the water resources of the Murray-Darling Basin demonstrates just how water scarcity can arise from a combination of biophysical and socioeconomic factors. It also indicates how climate change and variability may affect food production.

(continued)

Box 2.1 (continued)

In the Murray-Darling Basin, the drought also brought to the forefront of public debate the fact that past government policies had over-allocated the basin's water resources to the detriment of the environment. Historically water entitlements were granted to irrigators by state governments. By the last quarter of the twentieth century, entitlements exceeded water availability in some sub-basins, although this was managed by allocating water on an annual basis based on storage in the dams. Floodplain forests and riparian vegetation communities were under increasing stress, migrating birds' habitats were being reduced, fish stocks and biodiversity were threatened, the salinity of the Murray River was rising, and the terminal Coorong wetlands were becoming more saline than the adjacent ocean. Furthermore, the Murray stopped flowing into the ocean for most of this period.

As a consequence of these events, environmentalists lobbied the state and federal governments hard to try and recover water for the environment. This was opposed by the farmers that stood to lose water. The drought had, however, already triggered a number of responses to water scarcity, which were further encouraged by water reform policies being overseen by the National Water Commission. These included the separation of land and water rights and the development of a market for water trading. This enabled irrigators to sell and purchase water on either a temporary (annual allocation) or permanent (entitlement) basis.

In terms of the governance of the system, the ongoing drought and associated environmental consequences triggered a rethink on how the Murray-Darling Basin waters should be governed. The Murray-Darling Basin Commission (MDBC) had administered the waters of the Basin for many decades. The MDBC was comprised of state commissioners who oversaw a secretariat based in Canberra. Under conditions where relatively drastic action was required, the lack of independence of the commissioners, who essentially represented their states, did not facilitate the responses needed to deal with water scarcity. Consequently, the Federal Government dissolved the MDBC and established an authority that reported directly to the Federal Minister of Environment and Water Resources. The new Murray-Darling Basin Authority (MDBA) was charged with developing a Basin Plan that would deal with the critical issues of water allocation.

The initial draft of the plan recommended very significant cuts to irrigation water allocations and created a major furor among irrigators when released in 2010. The Chairperson and Chief executive of the MDBA both resigned and, late in 2011, a revised plan was released. Using 2009 as a baseline year, the environmentally sustainable level of extraction (10,873 gigaliter/year or 10.87 km³/year) would be achieved by reducing consumptive use of water by 2,750 gigaliter/year (2.75 km³/year) (MDBA 2011). Of this, an estimated

(continued)

Box 2.1 (continued)

1,068 giga-liter/year ($1.07 \text{ km}^3/\text{year}$) has already been recovered for the environment through buyback by the Federal Government and infrastructure improvement schemes. A further recovery of 214 giga-liter/year ($0.21 \text{ km}^3/\text{year}$) was announced recently, leaving 1,468 giga-liter/year ($1.47 \text{ km}^3/\text{year}$) to be secured. There are further caveats indicating that this will not come into force until 2019 and may be further revised based on new scientific evidence. Unfortunately, it has not placated irrigators, who stand to lose significant quantities of water. Nor has it placated environmentalists, who have argued in the press and via political lobbying that even this reduction of allocations will lead to further degradation and decline of the system (MDBA 2011).

2.3.2 Feedback Mechanisms

The interactive and dynamic character of water demands coincides with increasing uncertainty about the amounts of water that are available in rivers and other water bodies. Extreme weather events, during short or prolonged periods, increase the risk and cost of water development and use.

Increasing temperatures are speeding up the hydrological cycle, as evidenced by more intense rainfall patterns in some regions and more rapid return flows of water to the atmosphere. With higher temperatures, agricultural seasons are affected. Similarly, an increased frequency of extreme events increases the risks for the users and managers of systems for water regulation and supply, e.g., dam operators. Higher air temperatures increase vapor content, which adds to the severity of extreme events (see Chap. 3). Opportunities for reuse of water in agriculture are likely to be further curtailed, i.e., within the time span of a season. Uncertainty is bound to increase.

Societies are responding by implementing mitigation and adaptation measures. Some of these are slow, others are fast; some are going in one direction whereas others result in interactions (illustrated by arrows in Fig. 2.1).

It is mind-boggling that one of the most dramatic changes that has ever affected society—global warming—and the close link to an increasingly precarious water situation—has not resulted in more concrete efforts to cope with the threats. The result, in terms of climate and water changes, is likely to have a huge effect on agricultural systems, natural habitats, and economic systems, in addition to the hydrological cycle itself. Scientific arguments about the seriousness of the consequences of our increased greenhouse gas emissions expressed at international climate meetings are only marginally and slowly influencing political decisions and concrete action. Social pressure on the political system to design and implement effective adaptation measures is weak.

The scientific truth is inconvenient not only for politicians but also for existing economic systems and even parts of the public at large. Opinion surveys indicate a

widespread worry in countries, e.g., the member states of the Organisation for Economic Co-operation and Development (OECD), about climate change and its likely effects. But our readiness to modify behavior that is detrimental to our environment is a big challenge in any society.

2.3.3 Altering the Trajectory of Development Efforts

We offer some thoughts here on the importance of identifying the seeds for new thinking and how alternative or supplementary water management approaches could be formulated to gain the necessary political and social acceptance. The likelihood of a revision of established practices must be weighed against a tendency in society to stick to “sanctioned” thinking and entrenched prevailing practices. Many observers have noted a logic in the fostering of social and political behavior, usually referred to as path dependency (e.g., North 1994). Past investments and education tend to perpetuate a way of thinking among people, causing them to formulate and execute policies even if they are inferior to known alternatives. Investments made in water infrastructure (such as dams), storage, and conveyance facilities represent huge stocks of physical capital. The already existing structures and associated institutions and knowledge are, of course, very important for many people. Nevertheless, it makes sense to ask if alternative land and water management strategies may generate desirable livelihoods with less environmental risk for an adequate number of people, given the growing water constraints.

Path dependence is related to policy formulation. Hirschman (1975) eloquently argued that some problems attain a “privileged” status whereas other problems are “neglected” in policy. Projects and ideas in the former category receive strong positive attention and are tackled with “more motivation than understanding.” It is natural that the public, as well as policy makers, are fascinated by the grand schemes in ancient hydraulic civilizations and similar schemes in the contemporary era—the Hoover Dam, Aswan Dam/Lake Nasser, Three Gorges project, etc. They are all magnificent showpieces. Once the planning of these structures has started, strong forces will drive the process and follow-up steps will naturally be taken. Loans are granted, equipment is made available, logistical support is forthcoming, etc. There is certainly a momentum that pushes for a continuation along the same trajectory. In comparison, rainfed systems are less spectacular and political interest and budget allocations are generally less enthusiastic.

2.4 Lessons from the Past

Hydraulic works have played a pivotal role in the development of societies and civilizations from ancient times. Artifacts from the so-called hydraulic civilizations still attract attention and admiration in, for example, Egypt and other parts of the world. The ideas that generated these grand schemes in ancient times are reflected also in the more recent past. A new wave of construction occurred during the previous century.

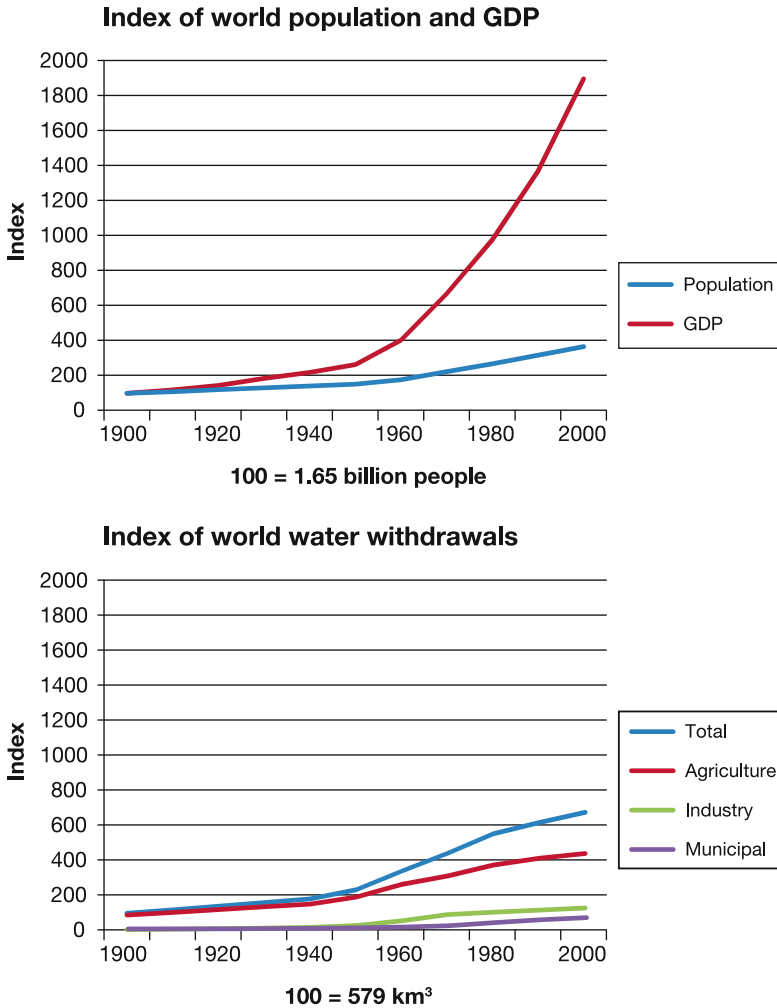


Fig. 2.2 Growth of population and GDP (*top* graph) and water withdrawals (*bottom* graph) between 1900 and 2000. The situation in 1900=100 for all three variables. *Source:* Data taken from UN population estimates (UN 2004); various publications on water resources; IMF 2000; Madison 1995 (figure drawn by Britt-Louise Andersson, SIWI)

While estimates of global water withdrawals are imperfect, total human use of water from streams and other surface and groundwater bodies went up over the last century by about a factor of 8 (Shiklomanov 1993). During the same period, the population increased about fourfold. The production of goods and services, as measured by GDP, increased about 19 times at constant prices, as illustrated in Fig. 2.2. The average annual rate of growth of the global economy during the last century was 3 % (IMF 2000), which is higher than the population growth rate.

The total amount of goods and services produced during the twentieth century exceeded the cumulative total output of human history from before 1900 (IMF 2000). The longer time perspective provides even more food for thought. Discussing the links, or the lack thereof, between prosperity and growth, Jackson (2011) mentions that the global economy was 68 times bigger in 2008–2009 than it was in 1800 and that global GDP in 2100 will be 80 times larger than it was in 1950, that is, if current growth rates prevail.

For all the variables illustrated in Fig. 2.2, the most rapid increases occurred after the 1950s. But the rate of increase of population and withdrawals of water slowed toward the end of the century, while the economy continued to grow at a high rate. This may be seen as a decoupling of population and economic trends, on the one hand, and trends in water withdrawals on the other. As noted in Gleick et al. (2003; see also Chap. 8), some regions have recently seen a complete leveling off of total water withdrawals, and even, as in the case of the United States, a decrease since the late 1970s or early 1980s.

2.4.1 Water Infrastructure as “Temples of Modernization”

Construction of large hydraulic works during the twentieth century took place in various parts of the world. One of the first, massive, and complex water projects undertaken in the last century was the construction of the giant Hoover Dam in the western part of the United States. Built in the 1930s, it became the greatest single source of electricity generation in the world, with provision of water and electricity not only to nearby communities but also to distant places like Los Angeles. It was part of a vision to colonize the West and to prove that the parched desert lands could be conquered by humankind and made to bloom (Reisner 1986; Postel 1999). As with other giant projects, it had been thought about for a long time. It was possible to transmit electric power over long distances, many plans for big water projects turned into something concrete.

Globally, the drastic increase in water withdrawals after the industrial revolution started in the 1960s, as is shown in Fig. 2.2. The introduction of the Green Revolution in the 1960s, with new seeds for higher yields, required an augmented and more reliable provision of water through irrigation systems. Increased use of chemicals, fertilizers, and other inputs meant a boost to water productivity in India as well as in other countries.

The examples commented upon above refer to the exploitation of surface water. The peak in the construction of big water infrastructure programs occurred in the 1970s (WCD 2000) as environmental issues became more evident and of concern. Yet big infrastructure projects are still being undertaken. More recent projects include the Great Manmade River groundwater project in Libya, the Southern Anatolia Project in Turkey (Oclay Ünver 1997), the Three Gorges, and numerous other reservoir projects, including the South–north water transfer project in China (Gleick 2009a; Skov Andersen 2011), and the planned hydropower development in the Mekong Basin. Various countries in Africa are considered to be ripe for

hydropower development in the near future. The challenge facing reservoir planners today is how to site, design, and operate them in ways that achieve the desired benefits while minimizing the social costs as well as the environmental and ecological degradation resulting from altered hydrologic and sediment regimes downstream.

2.4.2 Water Provision and Regulation Against Floods

Regulating and taming surface flows is vital to mitigate the risk of serious floods in many countries. For India, Lannerstad (2009) compiled information on incidences of failure of the monsoon and the related human sufferings in southern India during a 100-year period from the beginning of the nineteenth century. He noted “scarcity, desolation and disease” were rampant on 18 occasions with a duration of 1 year or 2 of consecutive years. For individual years, like 1808, failure of both monsoons “... carried off half the population.” (Lannerstad 2009, 4).

With the huge population in the region, the scale of the challenge is even more severe today. For the 540 million people living in the Ganges-Brahmaputra-Meghna Basin, 50 % of the annual precipitation falls in 15 days and 90 % of the runoff occurs in 4 months (Grey and Sadoff 2007); climate change and population growth continue to worsen the situation.

2.4.3 Increasing Dependence on Groundwater

The number of new reservoirs for impounding water peaked in the 1970s (WCD 2000). The reduction in the growth rate of new reservoirs since then does not, however, mean that the demand for water has reduced. Instead, reliance on groundwater has accelerated. Today, global groundwater withdrawals are estimated to total some 650 km³/year—about 20 % of total global withdrawals for irrigation (Wada et al. 2012). More than 70 % of that groundwater use occurs in just five countries. In India, for instance, the aggregate withdrawals increased from an average of 10 to 20 km³/year around 1950, to between 240 and 260 km³/year in 2000, which is roughly one-third of the total global withdrawals (Shah 2009). The changeover of irrigation from surface water supply systems to groundwater systems in India has been phenomenal over the last 50 years. The use of groundwater has helped improve production because farmers can access that water when they need it rather than when the irrigation authorities decide to supply it. But it has not come without significant cost. Shah (2009, pp. 29, 187) describes groundwater extraction as “... atomistic and anarchistic.” In some areas, particularly in western India where extraction exceeds the sustainable yield, a catastrophic collapse of some aquifers is likely unless better regulation and management practices can be developed quickly. Other countries with major withdrawal issues are the United States, Pakistan, China, Iran (Giordano 2009), and Libya, where groundwater supplies over 95 % of the total water demand.

2.5 Different Types of Water and Their Relative Significance

In addition to the water withdrawn from blue water sources—surface and groundwater—society depends to a large degree on rainwater stored as soil moisture. This is characterized as “green water” (see Chap. 6). Figure 2.2, therefore, only gives a partial illustration of the significance of the exploitation of water. In terms of quantity, the amount of water that is withdrawn from rivers and lakes and pumped from aquifers constitutes less than 5 % of the average precipitation over terrestrial systems. But this 5 % plays a tremendously important role in human lives and in any society. Households, industrial and other urban activities, and hydropower totally depend on this 5 %, with the largest fraction supplied to the irrigation sector. The relatively small amounts of the blue water resources are vital for human daily needs and indirectly for GDP. The much bigger green water resources are, in contrast, the blood stream for rainfed agriculture and for a number of functions in the landscape. Both blue and green water resources are derived from rainfall and their relative importance varies from one place to another and over time.

An estimated 75 % of the total freshwater withdrawals are allocated to agriculture and this sector accounts for an estimated 80–90 % of the consumptive use of this water (Foley et al. 2011). Most of the water used in agriculture or, generally, in the open landscape, returns to the atmosphere as vapor, whereas water used in the other sectors is much less consumptive. After use in industry and, generally, in indoor activities, water largely returns to rivers and other water bodies, but often downstream of where it was abstracted and of poorer quality.

Water use does, therefore, involve reliance on different categories of water and the consequences vary in terms of depletion, redistribution, and changes in the quality parameters of the resource.

2.6 Checks and Balances: Drivers That Modify Thinking and Policy

There is no doubt that the expansion of irrigation systems and the development of multipurpose water development schemes have resulted in a boost to global food production, hydropower, and urban, industrial, and rural development (CAWMA 2007).

At the same time, performance has often been below, or much below, expectations and a number of side effects have been serious. M. Reisner’s popular book *Cadillac Desert* (1986) is a thorough account of how development-driven policies in the United States, which were formed during a period when it was a major concern to settle the West, have had devastating and long-term negative effects on the environment (aquatic ecosystems, pollution loads, etc.) and water availability for downstream users.

Contemporary thinking on water issues tends to be a reaction to ideas that were considered modern, progressive, and informed by science just one or two generations ago. Policies, programs, and projects that were praised in the recent past are

now often regarded as a less wise manipulation of water to meet development objectives in society. Postel (1999) argues that water development technologies and related policies in the United States during the early parts of the last century, which were mimicked in other parts of the world, have generated a need for conservation methods that will protect Earth's water for the next century.

2.7 A Convenient Truth: Trend Break in Population Dynamics

Population projections have been of great public interest and concern since the days of Thomas Robert Malthus (1766–1834). Size and spatial distribution changes in populations naturally affect water demand and use. Projections about the future total size of the population are, generally, a most important piece of information. The biennial assessments of the UN Population Division (UNFPA 2011) projects three scenarios for the next few decades to 2050—nearly eight billion (low), 9.2 billion (medium), and 10.5 billion (high). Whether we will see a population peak followed by a decline or continued population growth will depend, primarily, on the assumptions about long-term fertility levels and, to a lesser degree, on mortality.

Population projections show continued growth for a few more decades. Whether the population will stabilize or start to decline after that is, however, rarely contemplated or discussed. As illustrated in Fig. 2.3, even small changes in fertility rates will produce significantly different levels of total population in the long run.

The world population passed the seven billion mark during autumn 2011—up some 0.8 or 0.9 billion in only a decade. Given the momentum of population growth and the still high fertility rates in many parts of the world, we can expect a continued increase by about 2 billion until 2050. Later in the century the population may

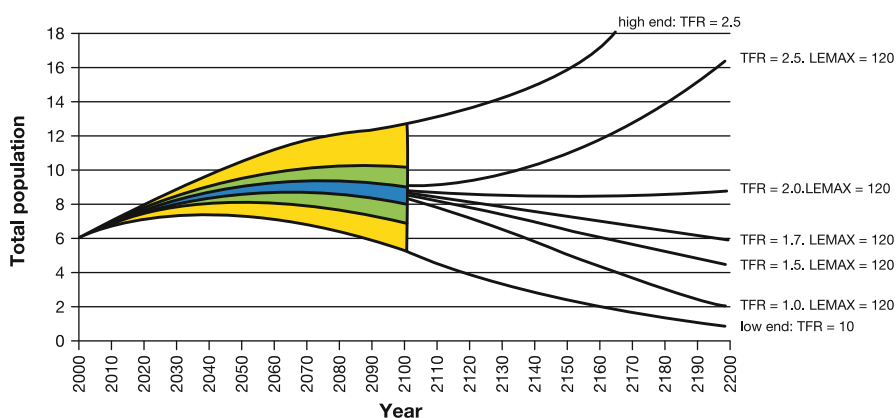


Fig. 2.3 Total world population in billions: probabilistic projections until 2100. *Yellow*, 95 % interval; *green*, 60 % interval; *blue*, 20 %; and extensions to 2200. TFR total fertility rate, LEMAX maximum life expectancy. *Source:* Lutz and Scherbov 2008

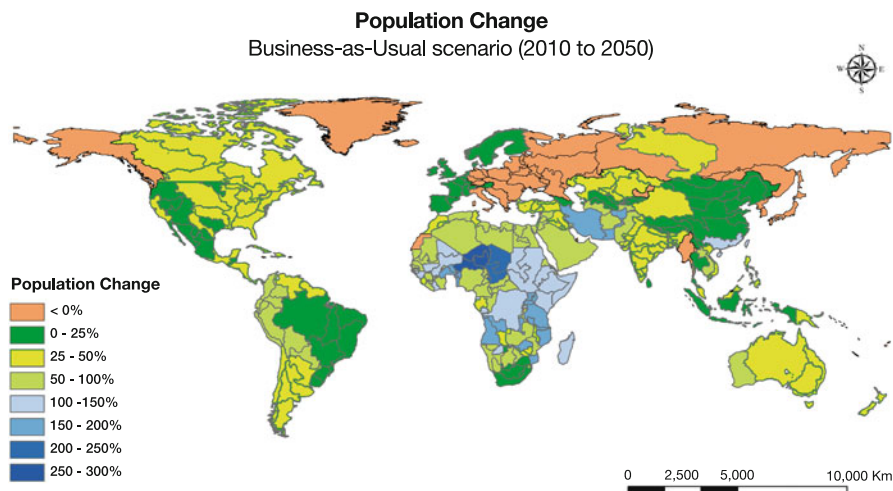


Fig. 2.4 Percentage population change 2010–2050. *Sources:* IFPRI 2010, calculations made by IWMI; Sood et al. (2013) (map prepared by Aditya Sood, IWMI)

continue to grow to between 10 and 12 billion or reach a peak and start to decline, depending mostly on the future course of fertility.

Fertility and mortality rates have decreased in several countries where, for instance, better education is available. In countries with a high population density, like Bangladesh, the number of children that would be born to a woman if she were to live to the end of her childbearing age, has dropped from about 7 to 2.3 during the last 25 years (UNFPA 2010). Fertility figures for neighboring countries, which together have about half of the world's population, have also declined. The number of children per woman is: for China, 1.6; for India, 2.7; for Pakistan, 3.5; and for Indonesia 2.1 (UNFPA 2010). These rates are much lower as compared to the situation in these countries in the recent past. Some demographers believe that fertility rates are even lower than those presented by the UN (Lutz, personal communication). In Lutz and Samir (2010) a set of long-term global projections based on scenarios covering a wide range of possible future fertility levels are presented. Selected findings are shown in Fig. 2.3.

However, fertility rates are higher in some areas that are poorly endowed with water and other resources. For instance, Chad has a fertility rate of 6.1 children per woman, Central African Republic 4.7, Congo Democratic Republic 5.9 and Congo Republic 4.6 (Fig. 2.4) (Lutz and Samir 2010). These are also areas where climate change is likely to cause increasing stresses, e.g., for agricultural production (see Chap. 6) and urban water supplies (see Chap. 5). A milestone in human history was passed in 2010, when the previous urban minority became the majority for the first time in history. Urban *per capita* water demands are generally higher than rural demands and the demand by urban residents for goods and services has direct implications for the use of water, land, and energy in rural areas.

2.8 The World Economic Map Turns Upside Down

The accelerated change and the staggering expansion of the world economy during the previous century (Fig. 2.2) were primarily associated with growth in OECD countries. Current economic prospects show that the world economic map is turning upside down (Fig. 2.5). A few distinguishing traits in this process are worthy of discussion here. The growth forecast for 2012 for high-income countries is projected to decrease while growth in sub-Saharan Africa remains robust with a rate of 4.9 % in 2011, accelerating to 5.3 % in 2012, and 5.5 % in 2013 (World Bank 2012).

Projections of economic growth rates are more uncertain as compared to demographic projections because they may change up or down in the short-run. However, the economic growth rate has generally been high over extensive periods and even accelerated in parts of the world in recent decades while there has been a gradual slow-down in the average rate of annual global population increase (UN 2004). Data on increases in population numbers and growth rates of GDP do hide important differences. In simple terms, two persons are double one person, but a doubling of GDP does not imply that purchasing power or disposable income will be twice as big. Of course, another major difference refers to the fact that it is important to recognize the implications of the social distribution of income, whereas demographic dynamics are different.

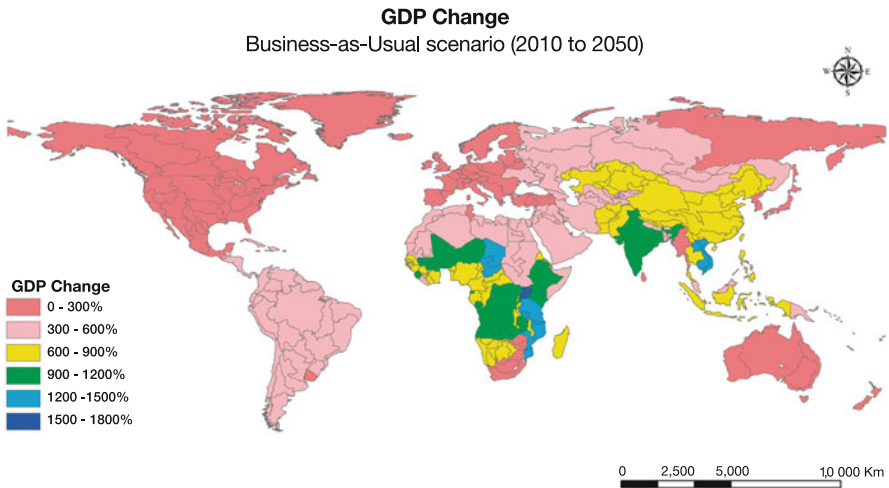


Fig. 2.5 Projections for growth of GDP 2010–2050 for the business-as-usual scenario. Sources: IFPRI (2010), calculations made by IWMI; see Sood et al. (2013) (map prepared by Aditya Sood, IWMI)

2.8.1 Income Distribution Determines Access to, and Mix of, Goods and Services

Even if aggregate economic growth has been rapid for many years, the uneven distribution of income means that a majority of the population, globally and in most countries, still have a low income. As a result, they have a limited access to the goods and services they need or want. These constraints hit producers, such as peasant farmers, who do not have the money to buy high quality seeds and other inputs for production. They also hit consumers with low and uncertain incomes. Even small increases in the prices of inputs for production as well as the prices for commodities may be disastrous for the poor.

More than 20 % (1.4 billion) of the world's population have incomes below a poverty line of USD 1.25 per person per day (Shah 2010). About half of the world's population has a disposable income of less than double the current poverty line, i.e., USD 2.5 per person per day. More than five billion have an average disposable income that is less than USD 10 per person per day (Shah 2010). These figures suggest that a majority of the world's population still has limited opportunities to effectively demand goods and services at a level that they might want.

For those segments of the population that are still in the low income bracket, we should expect that a considerable part of their extra income will be spent on more food, shelter, and other goods and services for basic livelihood. For people who are a bit higher up the disposable income ladder, the additional purchasing power, to a large extent, will be spent on higher quality food items, more travel, better housing, etc. Growth in GDP is likely to result not only in more commodities but also through a shift in composition in demand, toward a growing fraction of those that require higher fractions of water.

Income distribution, demographic features, and sociopolitical circumstances will largely determine the aggregate pressure on water and other resources. An increase in demand for water and other natural resources will occur in a diversified economy with stronger influences from the urban, industrial, and service sectors. As discussed in Chap. 8, these diversified economies have significantly stimulated improved resource use efficiency, while, at the same time, they have substantially increased the potential for human well-being. But improvements in GDP at national or global levels and the associated improvements in resource use efficiencies do not necessarily mean corresponding improvements in the social situation. One would expect that increases in *per capita* GDP and improved *per capita* food supply would result in a reduction of undernourished people, but, unfortunately, that is not the case globally.

2.9 Projecting Water Demands

Projections of water demand in the coming decades have been made based on various model studies carried out by various research centers (Reilly and Willenbockel, 2010). The International Food Policy Research Institute's (IFPRI) IMPACT model, the Food and Agriculture Organization of the United Nations' (FAO) World Food model, the Basic Linked System model of the International Institute for Applied Systems

Analysis (IIASA), and the International Water Management Institute's (IWMI) WATERSIM model are based on projections about population growth and the trends in GDP—a proxy for purchasing power/disposable income. The analysis for this study is based on the WATERSIM model and concentrates on three combinations of demographic change and economic growth—low population growth and high GDP growth, medium population and economic growth, and low population growth combined with high GDP growth. These three combinations of demographic and GDP trends are used to estimate the possible increases in the pressure on water.

The graphs in Fig. 2.6 show the estimated consumptive use of water in seven regions of the world from 2010 to 2050. Figure 2.7 shows the same information, but split for the main sectors of water use—irrigation, industrial (manufacturing, energy, and agro-based industry), domestic/household, and livestock. The consumptive use of water in agriculture refers to the harvested area. The estimates of consumption in Figs. 2.6 and 2.7 refer to the depletion of the water resources in terms of evaporation and transpiration. As such, they are considerably lower than the volumes of water that are withdrawn from water bodies and the amounts of water supplied or allocated, because evaporation and transpiration occur in several stages of water to harvesting throughout the growing season.

As shown in Fig. 2.7, the percentage of irrigated consumptive water use goes down substantially in 2050, especially for the optimistic scenario. The reason is related to the assumptions built into the model that there are limits concerning the amounts of water that are available in streams and other surface and groundwater bodies that can be exploited for supply to the various sectors in society. Environmental flow requirements are considered in this calculation. When aggregate demand exceeds the naturally given supply level, allocations must first be given to domestic and industrial uses. The logical consequence is that allocations to irrigated agriculture must be reduced. These findings are in line with an earlier estimate made through the same model (CAWMA 2007).

The irrigation water demand is based on the climatic conditions and the area of irrigated land. For the three scenarios presented in Figs. 2.6 and 2.7, there is no climatic change (as 30 years of historic monthly averages of hydrological inputs are used), while changes in irrigated land are limited to those due to either lack of water or price fluctuations.

The assumptions and parameters that are built into the model used to obtain these projections, and the estimates that are calculated, illustrate one possible trend in the future. Alternative assumptions would give other estimates. The validity of the assumptions and the degree of realism in the estimates arrived at are topics for debate and scrutiny.

The implications from these and other estimates on future water predicaments are several:

- In the foreseeable future, the natural availability of water will impose growing hydrological, technical, environmental, and financial constraints on society in many countries.
- With continued rapid urbanization and development of industrial and service sector activities, and with the increasing purchasing power among large segments of the world's population (most of whom will be living in urban centers) the mix

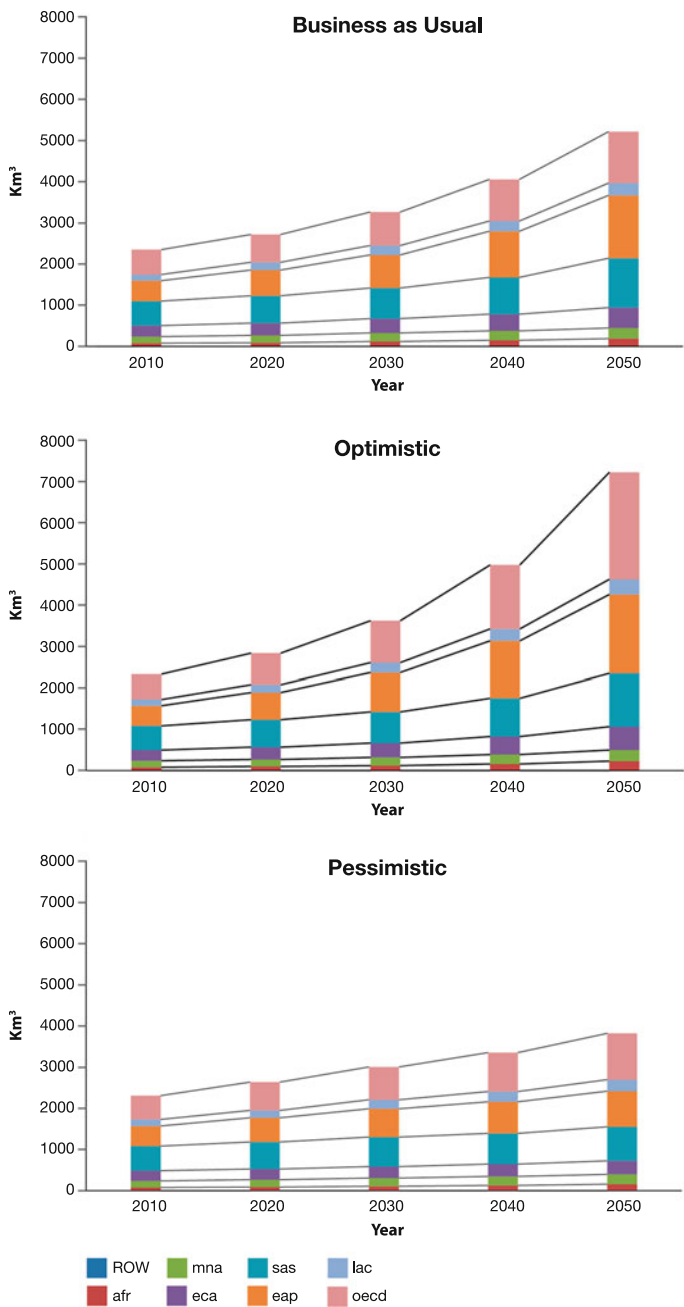


Fig. 2.6 Estimates of the consumptive use of water in seven regions 2010–2050. *BAU* business-as-usual scenario, *OPT* optimistic scenario, *PES* pessimistic scenario, *sas* South Asia, *oecd* Organisation for Economic Co-operation and Development (34 countries), *mna* Middle East and North Africa, *lac* Latin America and Caribbean, *eca* Eastern Europe and Central Asia, *eap* East Asia and the Pacific, *afr* sub-Saharan Africa (diagram prepared by Aditya Sood, IWMI)

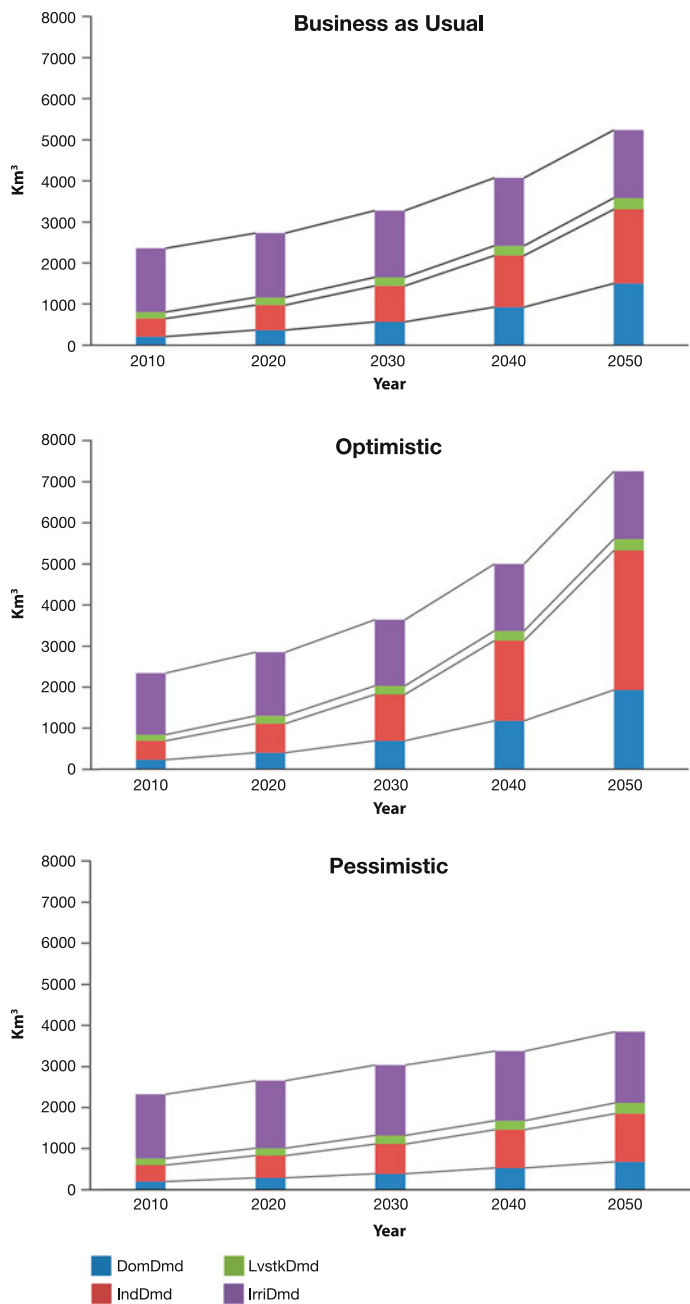


Fig. 2.7 Global consumptive use in the main water use sectors. The industrial demand also includes demand by agro-based industries. *BAU* business-as-usual scenario, *OPT* optimistic scenario, *PES* pessimistic scenario, *DomDmd* Domestic, *IndDmd* Industry, *LvstkDmd* Livestock, *IrriDmd* Irrigation. *Source:* Sood et al. (2013) (diagram prepared by Aditya Sood, IWMI)

of demands for water will change. Relative allocations of water to the urban and domestic sectors are likely to increase at the expense of allocations to the agricultural sector.

- The geographical disparities between countries that have adequate water resources and those that face development constraints because of water shortages will become acute.
- Remedies and options for mitigation and adaptation to the escalating challenges include tough changes in three major respects:
 - The actual harnessing, exploitation, and use of the various fractions of the water that are potentially available through annual precipitation must be more efficient.
 - The beneficial use of the goods and services that are more efficiently produced should increase through an improved efficiency in the supply chain, from “field to fork” (Lundqvist et al. 2008).
 - The access to basic goods and services for decent and secure livelihoods must improve for those segments of the population who are currently deprived of such an access.

2.9.1 Efficiency, Effective Goal Achievement, and Net Water Savings

The projections of the likely increases in the total consumptive use of water illustrated in Figs. 2.6 and 2.7 highlight the challenge of meeting expectations from a growing number of people who will need and demand more water, as well as goods and services that will require more water to produce. An intensified exploitation and use of water, in turn, will affect the food sector (see Chap. 6), energy sector (see Chap. 7), and our environment (see Chap. 4). With these kinds of challenges expected, and in an era of growing uncertainty and variability of water availability, it makes sense to focus on efficiency in resource use in terms of, for instance, “more crop drop,” “more employment per drop,” etc. Globally and in many countries, significant improvements have been made in terms of increased output per unit of water and other resources used in production, and it is important that this development continues. But improved efficiency in resource use alone does not guarantee that social and other development objectives are met. It is essential to consider two additional issues.

One refers to a tendency that increased efficiency in resource exploitation and use tends to stimulate exploitation rather than conservation of resources. A second important issue refers to the social distribution of and access to the goods and services that are produced. Improvements in the use of resources and an increase in total production do not guarantee that those who need more water and better access to goods and services will actually be the beneficiaries. Distribution of disposable income and sociopolitical circumstances will determine the access to the goods and services produced. It is, for instance, important to note that global increases in food production on a per capita basis has paralleled an increase in the number of

undernourished after 1995/96 (Lundqvist 2010). What seem to be paradoxes in the relations between efficiency, resource exploitation, and social benefits mirror the rebound effect or the so-called Jevons' paradox (see Box 2.2).

Box 2.2 The Jevons' Paradox. Also Referred to as the Rebound Effect

Well over 100 years ago, Mr. W. Stanley Jevons, a British economist, made an intriguing observation (1865). He argued that increased efficiency in the energy sector will not result in reduced total energy demand and use but, on the contrary, it will stimulate energy use over time. Mr. Jevons made his observation at a time when the steam engine, developed by James Watts a 100 years earlier, in 1765, became a major driver in terms of cheap energy for a dynamic industrial revolution. The technology was not new but had been gradually developed from the seventeenth century when the original application was to pump water out of mines. But it was with expanding markets for industrial products and a cost effective exploitation of coal that triggered the process that Mr. Jevon observed.

Arguments that highlight what seems to be paradoxes naturally attract attention. Since the publication of this seminal thesis, a large number of studies with reference to the energy sector have been made on what has been referred to as the rebound effect, or Jevons paradox. Not surprisingly, the concept has been refuted but also seen as intriguing and relevant. Rather, it is surprising that this phenomenon is referred to as a paradox.

The logic of the paradox is the following. Increased efficiency generally means that it will be possible to produce more output for a given amount of input or, inversely, that a certain output can be produced with less input. This distinction is important. In the first case, potential benefits refer to the possibility to better respond to unmet needs and wants in society. The second case hints at the opportunity for resource conservation, that is, a reduction in the exploitation of resources that are required to produce a given amount of goods and services in question. The concept may thus refer to many aspects. Key issues concern prices, elasticities and how the investments that are required for efficiency improvements will be covered and by whom. Similarly, it is important to consider how benefits will be distributed in society. Issues in this regard are social and political challenges that require a strategy for progress where communities walk on two legs: a combination of natural resources and social governance. Environmental concerns must be an integral component.

With increasing production of goods and services in relation to a given amount of input of energy—in Jevon's case—employed in production, the unit cost of production will decrease, given that other costs or inputs do not increase or increase at a lower rate. If these conditions are fulfilled it will be possible,

(continued)

Box 2.2 (continued)

in principle, for the producer to sell the produce at a lower unit price as compared to the situation before efficiency improvements. If the price on the market is reduced, the individual consumer will benefit and/or more consumers may be able to pay for that product, thus increasing the demand and potential social benefit. For the producer, lower cost per unit produced is likely to stimulate her/him to expand production, assuming that there is a demand for an augmented supply and assuming s(he) is in command over additional inputs for production. Restriction in exploitation/use rights could restrict this opportunity. Increased production may be rational with a new technology for which certain investments have been made, particularly if efficiency improvements can only be achieved with increasing scale of operation. Energy savings from efficiency improvements will therefore not necessarily result in net savings. i.e., conservation but may partly or fully be used to expand total output. It may even increase total resource exploitation, i.e., the opposite of resource conservation.

Consequently, it is conceivable that efficiency improvements yield social benefits and augmented output and supply on the market in the sector where these improvements are made, but not in resource conservation. In both dimensions, policies need to be added that ensure such objectives. The paradox doesn't say anything about the social distribution of the benefits of efficiency gains.

The concept is well known among colleagues dealing with energy issues but has hardly been applied and tested with reference to water.

While policies to increase resource use efficiency have generally been successful, progress in terms of catering for basic human needs is still below expectations.

Meeting the needs of the bottom billion and balancing the dynamic wants on the demand side is a social and political challenge. To do this requires a strategy which ensures both efficient resource exploitation and use and efforts that facilitate efficient, sound, *and* fair supply chains. Although there is a decoupling of the *rates* of GDP and population growth from the *rate* of water exploitation, the exploitation of water and other natural resources will continue, even if at a slower pace as compared to earlier periods (Figs. 2.2, 2.6, and 2.7). The estimates made in other studies vary. The FAO, for instance, has estimated that the additional water that will be required to produce the 70 % more food needed by 2050, as recommended at the World Food Summit in 2009, is of the order of 5,500 km³. Recently, this recommendation has been reduced to 60 % for the same period, i.e., between 2005/07 and 2050 (Alexandratos and Bruinsma 2012).

There are no signs of a diminishing gap between those who have and those who do not. Poverty has been reduced in many parts of the world, but not through redistribution. With about a billion people in poverty and suffering from a lack of access to a range of goods and services, more water will have to be exploited from a range of

sources. Increased efficiency in the harnessing of precipitation for productive purposes is one option but it will also be necessary to withdraw and use more of surface and groundwater. As illustrated in Figs. 2.6 and 2.7, the domestic and industrial sectors will, most likely, demand much more water. From where and how will the additional water be taken? The concern for in-stream functions in rivers and other water bodies suggests that additional withdrawals of water will be subject to physical limits—when the river is dry no water can be withdrawn—and a number of restrictions.

For agriculture, there are two major opportunities. One is to increase irrigation water use efficiency as, for instance, elaborated in the comprehensive assessment of water management in agriculture (CAWMA 2007). An alternative and complementary strategy is to better use the precipitation where applicable (see, for example, Wani et al. 2011). Depending on the amount of precipitation, in terms of the fraction of water that recharges soil moisture, may involve significant risk arising from climate variability, i.e., more irregular rainfall and more rapid return flows to the atmosphere. For food security, there is a third option—improve the efficiency in the supply chain by reducing the magnitude of the losses and waste between production and what is beneficially used, i.e., what is eaten.

2.9.2 New Thinking for Opportunities to Tackle Old and New Challenges

The miserable conditions for the bottom billion cannot be explained by a general lack of water, goods, and services, but rather by a lack of access to these. In this connection, it is relevant to point at the low level of efficiency in the supply chain. An estimated 30–50 % of the food produced globally is lost, wasted, or converted (Lundqvist 2010; Parfitt and Barthel 2010; Gustavsson et al. 2011). If a large part of the produce is not beneficially used or if it is not accessible to those who need it, the efficiency and the effectiveness in the supply chain is low (Nellemann et al. 2009). It is thus important to specify what efficiency refers to; if it is confined only to production, or if it also considers the flow of the goods and services from production to end-use.

Liberal subsidies to agriculture and also to other water-dependent sectors have been motivated with reference to poverty, regional disparities, and other objectives. Public debate and policies related to water and food security have been formulated with a thrust to expand production at a rate that is faster than the population increase (e.g., the decision at the World Food Summit 2009 regarding food production increases to 2050). But while statistics support the assertion that there is enough food produced and supplied to feed everybody properly, increases in food production and supply during the last 15 years or so have not increased food security.

2.9.3 Linking Sustainable Production to Fair Access

Notions, such as integrated water resources management (IWRM), have predominantly focused on coordination between sectors and involvement of water users in the

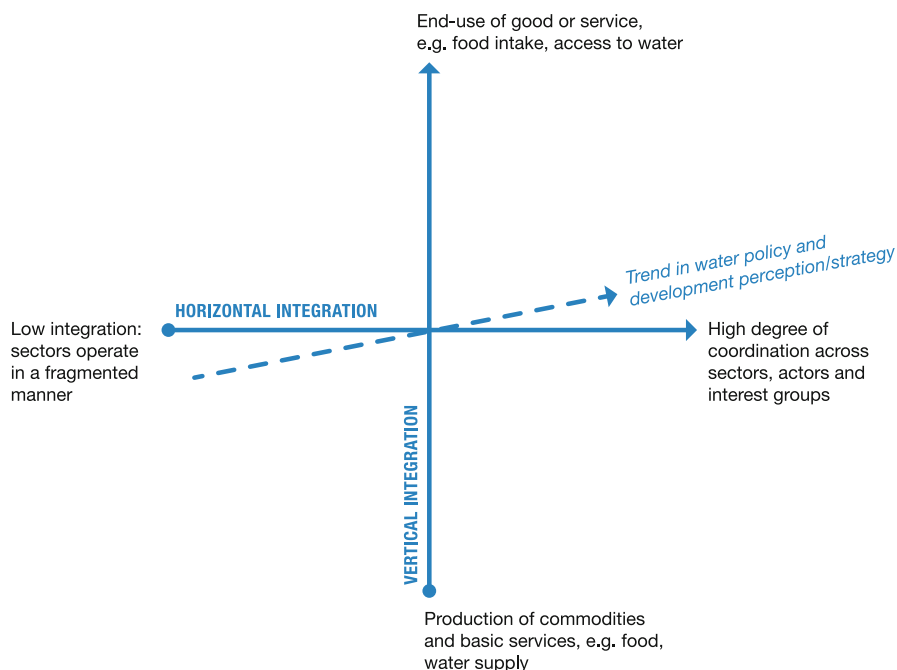


Fig. 2.8 A schematic illustration of the *horizontal* and *vertical* integration of policy and the management of resources and the goods and services produced (figure drawn by Britt-Louise Andersson, SIWI)

management and allocation of the resource between competing uses in the production of goods and services. Little, if any, attention is paid to what may be called vertical integration—from production to end-use of the produce, including the challenges associated with access.

A combination of horizontal and vertical integration is illustrated in Fig. 2.8. The arrow from the third quadrant to the first illustrates a trend in thinking and in actual strategies. Improvements have been more significant in the horizontal dimension as compared to the vertical dimension. If more attention is paid to the vertical dimension, the opportunities to provide people with goods and services can be enhanced without a corresponding increase in production. Policies directed at achieving these kinds of improvements would make it possible to meet the needs and wants in society in a more resource efficient manner.

2.10 Prospects for an Alternative “Privileged Problem Formulation”

This chapter has illustrated changes in the main drivers and the related implications for water demand and use. The purpose has also been to show that it is important to focus not only on the development and use of different types of water resources per se.

We need to pay attention to access to, and use of, the goods and services that are produced. Direct water use is, comparatively, much smaller than the indirect use, particularly water in food production. Thus it is profoundly relevant to link the figures on water use efficiency in production to information on how goods and services are distributed in society and how consumers access and use water and the goods and services produced.

A review of the main drivers and development during the period after the Second World War has been used as a reference to assess the possible and likely trends in the main drivers between now and 2050 and what might be the consequences for water use in different sectors and regions. Like other prospective studies, we recognize considerable uncertainties associated with these projections. Demographic trends are relatively more reliably predicted for the next few decades than are economic projections. Similarly, the projections about water availability, its variability, and estimates of how much of the available stocks and flows will be used are hard to make. But such projections are crucial for a better understanding of the consequences and opportunities of different courses of development.

There is a high degree of consensus in the literature that in a generation from now the world and, indeed, a large proportion of its nine billion inhabitants, are heading for a turbulent water future. Similarly, it is a common reflection that the strategies and trajectories of the past cannot continue in the same direction. Development has continuously changed course throughout history. Now and for the future, the drivers may alter the trajectory in important ways. A change of course is inevitable for the simple reason that sources of additional fresh water are literally drying up in many parts of the world. Large-scale production of water through nonconventional approaches, such as desalination, does not seem to be a viable option in the near future to meet the additional requirements pictured in Figs. 2.6 and 2.7.

One opportunity is to reduce the losses and waste in the supply chain and to improve access to the goods and services produced (Fig. 2.8). Making use of this opportunity is vital in an era when needs and wants escalate, but when water and other natural resources pose natural constraints and boundaries. The opportunities to make much better use of scarce water and other resources in *production* are thoroughly discussed in the literature and in policy. Indeed, laudable improvements have been made in this regard. No doubt, there is potential to further enhance efficiency and productivity in the use of resources. However, high levels of total production and productivity have been achieved with the help of a heavy input of fossil and other energy, high subsidies, and with a considerable effect on natural ecosystems.

Water and the Future of Humanity

Revisiting Water Security

Gulbenkian Think Tank on Water and the Future of
Humanity

2014, XXI, 241 p., Hardcover

ISBN: 978-3-319-01456-2