

1. INTRODUCTION: STATE OF WATER AND INTERSTATE WATER RELATIONS

Objectives

This chapter sets the stage for most of the concepts and jargon a “water person” uses. It considers global water issues, sectoral use patterns, and other water-related concepts such as water scarcity. The chapter will likewise demonstrate the link between a basin’s water situation and the potential **conflict** that can arise between the riparians. You will also be introduced to concepts relevant to international water agreements. Finally, you will note the distribution of international river basins and the nature of various **conflicts** over water.

Main Terminology

Access to water; Acre-foot (af) (1 af = 1235 m³); Brackish water; Conflict; Consumptive use; Cooperation; CuSec (cubic meters per second); Desalinization; Downstream riparian; Electrical conductivity (EC); Evaporation; Externality; Fresh water; Ground water; International water; Irrigation; m³ (cubic meter); Nonconsumptive use; Parts per million (PPM); Peace; Recycling (Water reuse); Salt water; Treaties; Upstream riparian; War; Water cycle; Water in circulation.

This chapter will set the basis for understanding the problem of water availability in the world, its regional distribution, and how humankind may affect it with human interventions. We will link in this chapter the notion of water scarcity to the evidence on water **conflicts** among nations and try to set the stage for the remaining chapters of the book. The chapter helps in establishing some of the language and concepts to communicate without getting too wet. The reader will not only be able to get a “free access” to the rest of the book’s chapters but also to other literature on water.

THE STATE OF WATER IN THE WORLD

Our world witnesses several phenomena that individually and jointly have led to an increase in water dependency among sectors and segments of society, as well as among nations. Population growth, increase in urbanization and industrialization,

and technological progress, just to name a few, have led to deforestation, water quality deterioration, and this affects the availability of water for human uses and ecological needs. As the, more or less, fixed amounts of the world's natural resources, such as land, water, forests, and other environmental amenities, have to be shared by a larger number of humans over time, increased competition and strategic decisions become more apparent at all levels of decision-making, starting with the household and ending with state level water managers.

How Much Water Is There and How Is It Used?

There is plenty of water in our globe. The problem is that it is either hard/expensive to extract or is available at the “wrong time” and/or at the “wrong places.” Countries that share the same water source may have different levels of access and this, alone, could be a source of **conflict**.

Box 1.1: Access to water.

What does “access” mean? For example, a river that is shared by two countries may constitute an upstream country with a steep terrain. Consequently, reasonable use of the water for production of any benefit is made difficult. Nevertheless, the water flows across the border and reaches the flat terrain of the **downstream riparian**, where it can be fully utilized. A good example is the case of the Blue Nile and two of its major riparians, Ethiopia and Egypt. While 85% of the water originates upstream, Ethiopia's terrain makes utilization of the resource difficult. For several decades, the two riparians have been conflicting over the amount of water allocated to Egypt in a water treaty. Alternative, approaches other than the allocation of the water among the riparian states have to be considered.

Most of the available water is generated in a continuous process called “the **water cycle**.” Figure 1.1 notes the many water-consuming sectors, interactions among them, and physical relationships that affect the **water cycle** — the way that water is generated, moves, and stored. In addition, Fig. 1.1 points to many interdependencies, or what economists term externalities, among sources, users, and locations. In other words, what one user does affects the availability of water to others. This makes water unique relative to other natural resources.

Since water can be transported, ownership becomes an issue and may affect relationships between riparians. Figure 1.2 demonstrates the contribution of oceans, rivers, and vegetation, and lakes to the global **water cycle**. In addition, it explains the transport of water from one place to another, not via the traditional conduits (of pipes and rivers) but rather through space.

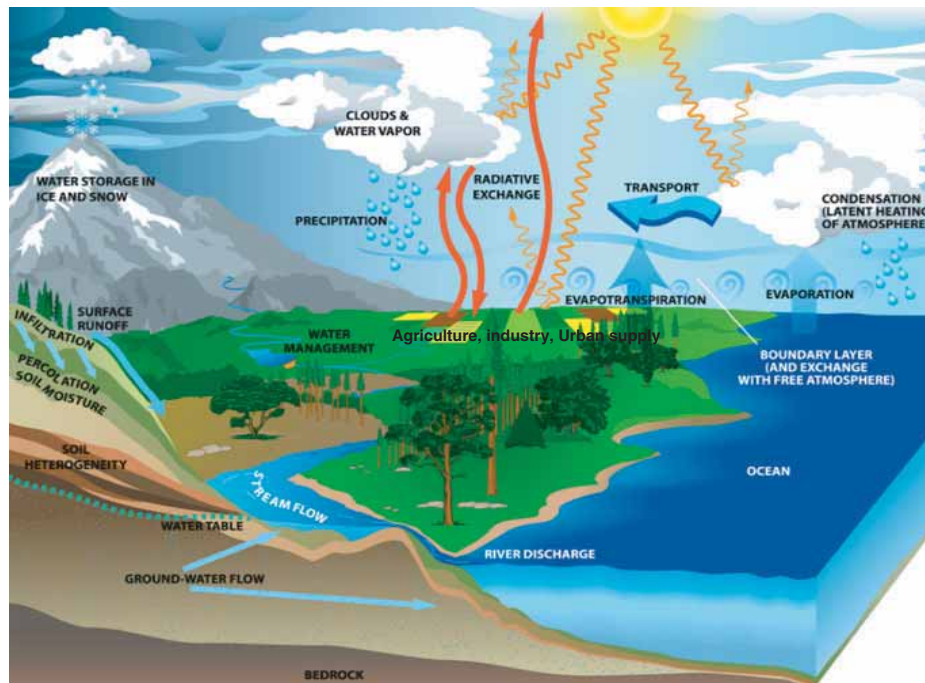


Fig. 1.1: The water cycle.

Source: Modified from US Climate Change Science Program (with permission to use), <http://www.usgcrp.gov/usgcrp/images/ocp2003/ocpsy2003-fig5-1.htm> (visited on July 7, 2006).

What are the main sources of water available for extraction, and how is water stored? There are four major water sources for human use: surface (rivers, lakes); **ground water** (renewable, nonrenewable, fossil, **brackish**); reused treated wastewater; desalinated water (sea and **brackish ground water**).

What are the water-using sectors and how do they utilize water? We will see that the distribution of water use by sectors across continents and countries varies a great deal. The composition of sectoral use of water may affect the relationship (**conflict/cooperation**) among riparian states. This happens for various reasons. First, time of use varies across sectors. While agriculture requires water for **irrigation** mainly during the summer season, hydropower utilizes the available water during the winter. Second, quality of water needs varies across sectors. While agriculture can use water of relatively low quality, residential uses are quite sensitive to water quality standards. In addition, water “quality” is actually a vector of various components, and may differ in nature among sectors. For example, level of minerals in the water affects the “salinity” of the water and its suitability for **irrigation** of salt-sensitive crops. For residential uses, quality takes into consideration stricter standards such as level of nutrients, and other chemical elements that make water harmful for residential use.

In the following paragraphs, we provide a very general description of water use by sectors. But first, take a look at the information in Table 1.1.

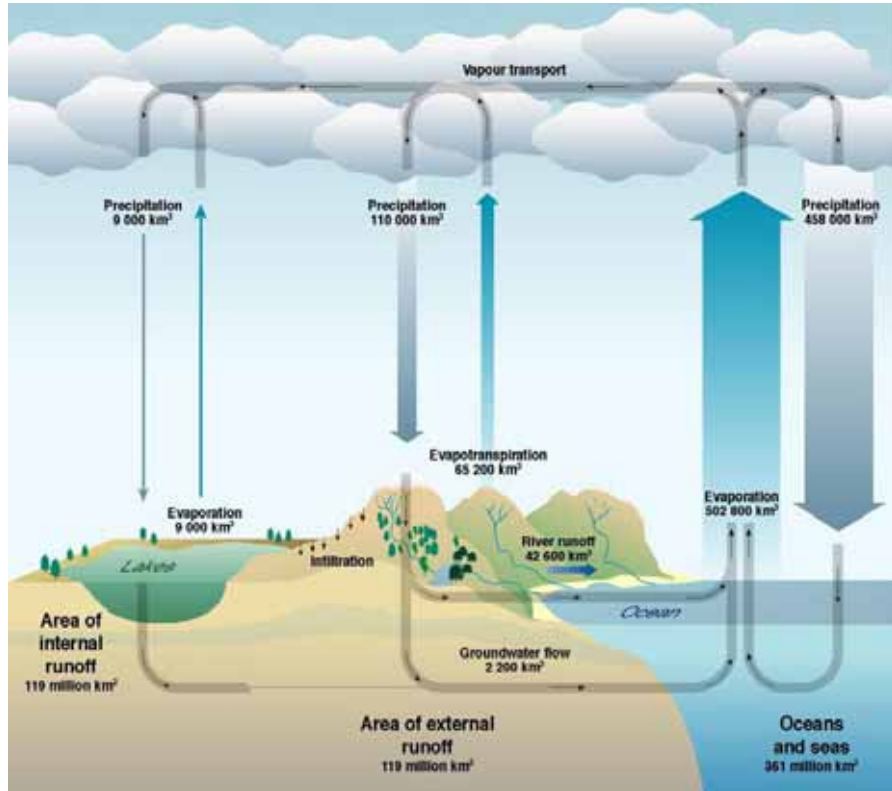


Fig. 1.2: The dynamic nature of the global **water cycle**.

Source: United Nations Environmental Programme (with permission to use), UNEP (2002) <http://www.unep.org/vitalwater/03-water-cycle.htm> (visited on August 20, 2006).

Table 1.1: Sectoral water withdrawals by region, rounded numbers (%).

Region	Residential	Industry	Agriculture
Africa	7	5	88
Europe	14	55	31
North America	13	47	49
Central America	6	8	86
South America	18	23	59
Asia	6	9	85
Oceania	64	2	34

Source: World Resources Institute (1998).

One immediate observation from Table 1.1 is the unequal distribution of water withdrawals among the continents, especially the share of agriculture. One rule of thumb is that the higher the share of agricultural use in the economy, the less developed the country. In addition, to the implications based on the share of water

used by agriculture, as is explained below, the shares of water withdrawals also imply the sectoral power relations and the status quo solutions, which may not necessarily be the most efficient ones.

Irrigation consumes the lion share of the available water, depending on the country. Therefore, **irrigation** dictates many of the characteristics of the water situation in the world. Soil is watered using various application methods such as flood, furrow, sprinkler, and drip, just to name a few. Some of the **irrigation** water is consumed by the plants, the remainder percolates, and evaporates. In most locations, 50% of the water that is being “sent” to the fields is lost to percolation and **evaporation** even before reaching its destination. **Irrigation** may cause many negative consequences, e.g., soil and **ground water** pollution by pesticides and fertilizers. Although the **irrigation** season could be long, most of the **irrigation** demand for water occurs during the summer months. **Irrigation** water use is consumptive in nature because the entire applied amount is used and may be removed from the water system. Consequently, some part of the **irrigation** water is returned to the water system at a different location or modified in quality. Therefore, it is important to correctly account for the water actually used by the plants when one calculates comparative water use efficiencies.

Residential customers use about 5–10% of the available amount, depending on the country. Water is used for drinking, bathing, gardening, swimming pools, and other related functions. In many countries, up to 60% of the water pumped into the residential system is unaccounted for, either due to leaking or illegal connections. Sewage is a result of urban water use, and requires disposal. If disposal is not undertaken appropriately, negative externalities affect other users and sources (e.g., **ground water**). Demand for residential uses is distributed over the year with some peaks during the summer months. The main uses are (Clarke and King, 2004) flushing and toilet (30%), cleaning (5%), cooking and drinking (10%), laundry (20%), and bathing and showering (35%). Urban water use is **consumptive**.

Industry uses about 5–10% of the available amount, depending on the country. Water is used in manufacturing processes, and especially for cooling or cleaning. Similar annual distribution features of demand are observed for industrial water use as for residential water use. Industrial water use is **consumptive**.

Hydropower uses stored water behind dams. Water runs through turbines to create electricity in a **nonconsumptive** manner. Then it returns to the river for other **consumptive uses**. Most of the demand for electricity is high during the winter months. Hydropower use may create changes in the composition of the water when it returns to the river, due to erosion and sediment removal, and thus affects the environment downstream.

Ecological (environmental) uses, also called environmental flows, utilize about 0–10% of the amount of the water system, depending on the country. Water is intentionally left in waterways, such as rivers and lakes, to support ecological functions in a **nonconsumptive** manner.

In the context of international water it is important to recognize the manner in which water is used by different sectors in each country. This may help in explaining

the sources for possible or existing **conflicts** over water and, more importantly, the possible ways of solving such **conflicts**.

How do we measure water availability? Water flows, stored, and changes quality. Therefore, we use both velocity and quantity units, and several measures of quality:

- In units of stock (**cubic meter**; cubic kilometer, **acre-foot**).
- In units of flow (**cubic meter per second**, **cubic meter** per hour, **cubic meter** per annum).
- Water quality affects availability. Water that is too polluted is unsuitable for consumption by people, plants, and machines. Level of pollutants in the water is measured in units of concentration (**parts per million** — ppm, or billion — ppb; salinity is also measured by **electrical conductivity** — EC).

The total amount of water on earth is very large. However, as was mentioned earlier, most of it is not available. Therefore, we need to introduce some vocabulary, and familiarize ourselves with several notations:

- Total water is the amount of all forms of water, some of which is not accessible at all.
- Renewable water is the amount that is being renewed either annually or along longer durations.
- Available water is the amount that humans can access and use for their consumption.

In addition to the natural differences in water availability, there are differences in availability that result from various aspects other than natural causes, such as man-made, population growth effects, technologies, and impact of quality deterioration.

Clarke and King (2004) estimate that water consumption per person per year was 350 m³ in 1900 and 642 m³ in 2000. These figures reflect only improved living standards (e.g., family swimming pools), advanced home technology (e.g., washing machines), and increased **access to water** (e.g., home connection to city water) in many countries. These increases coupled with population growth rates are one of the major sources for increased consumption of **fresh water** resources in the world.

Let us now view some of the information on the availability of global water resources. The amount of available water to the world today is relatively the same as it was when the Mesopotamian civilization prospered, even as global demand has steadily increased. Estimated values vary according to the source, but differences are not significant. Total water on earth is estimated to be 1,386 million km³ (Clarke and King, 2004). Of this amount, 97.5% is **saltwater** (e.g., oceans and seas). The remaining 2.5% is **fresh water** [34.65 million km³ according to Clarke and King

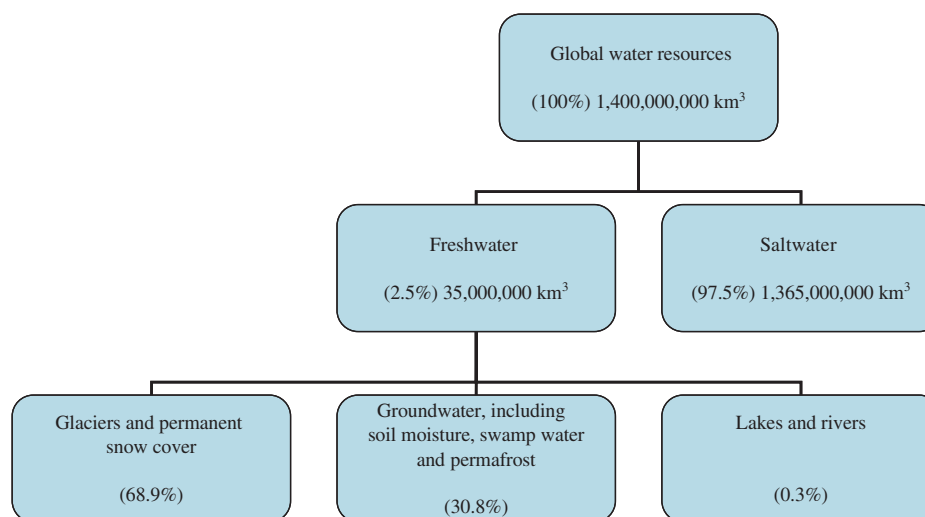


Fig. 1.3: Distribution of global water resources.

Source: Based on estimates in Shiklomanov (1996, 1999).

Note: As indicated in the text, a somehow similar estimate is provided by Black (1991) and Clarke and King (2004).

(2004) and 35.03 million km³ according to Shiklomanov (1993), or 27 million km³ according to Black (1991)].

As Fig. 1.3 demonstrates, of the 35 million km³ of water on earth (Black cites 27 million), only 0.3% is considered easily accessible for human use. (Black cites 0.6% and Clarke and King cite 0.4% as available, but since they refer to a larger base amount — 34.65 million km³ — the total available amount is very similar.) The remaining water is either technically or economically unreachable. Water is also stored in the soil and **ground water** aquifers, which could be extracted, depending on temporal economic considerations.

As was mentioned earlier, the increased water use per person per year has led to increased total annual water withdrawals [579, 1,382, 3,973 km³, in 1900, 1950, and 2000 respectively, according to Clarke and King (2004)]. The sector using the lion's share of **fresh water** resources — **irrigation** — has expanded during this period by more than fivefolds — to nearly 250 million hectare (ha) (1 ha = 2.5 acre), as can be seen in Fig. 1.4.

However, it is clear from Fig. 1.4 that starting in the mid-1990s the irrigated area per capita in the world began to slightly decrease (from 47 ha per 1000 people in 1980 to 43 ha in 2000). This does not mean that food per capita is decreasing. On the contrary, FAO (2005) suggests that food per capita (measured in calories per capita) is increasing. With technological and management improvements, the water required to produce food may therefore decrease over time.

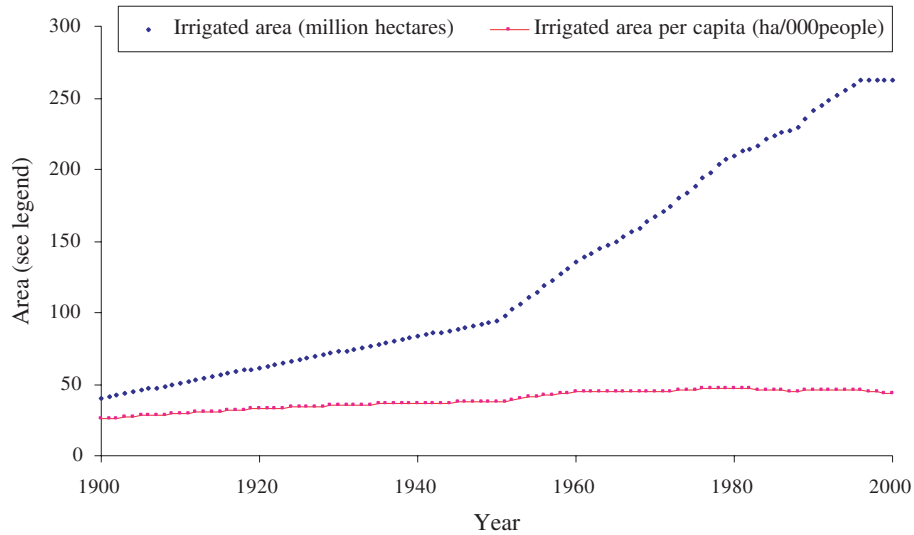


Fig. 1.4: Irrigated area of the world and irrigated area per capita 1900–2000.

Source: Modified (with corrections) based on data compiled by Worldwatch Institute from Postel (1998).

Box 1.2: How much water is needed to produce our food, cloth and computers?

Water (m^3) needed to produce 1 kg of various foods: Potatoes 0.5; wheat 0.9, rice 1.9, poultry 3.5, and beef 15 (Clarke and King, 2004).

Water (m^3) needed to produce 1 cup of various beverages: milk 0.25, coffee 0.14 (Waterfootprints, 2006), tea 0.034 (Chapagain and Hoekstra, 2003).

Water (m^3) needed to produce 1 medium size cotton T-shirt 4.1, one computer microchip 0.032 (WWF, 2006).

HOW DO WE MEASURE WATER SCARCITY?

Having said all the above, and considering just one parameter, the rate of population growth, water availability per capita¹ has been reduced by 60–80% over the last 50 years, as can be seen in a sample of countries. The declining trend of per capita water availability will continue so long as population is forecasted to grow (United

¹There are also other indexes that represent water availability (or scarcity) in a given country. For example, the ratios between rainfall (mm/year) or runoff (m^3/s) to **evaporation** (mm/year) are used as well. However, such indexes are stochastic in nature and are affected by annual climatic conditions in the country or the river basin. One index that has been used in the project on freshwater assessment of the WMO (1997) is the ratio between water withdrawal and availability in a country; see also Bjorklund and Kuylenstierna (1998).

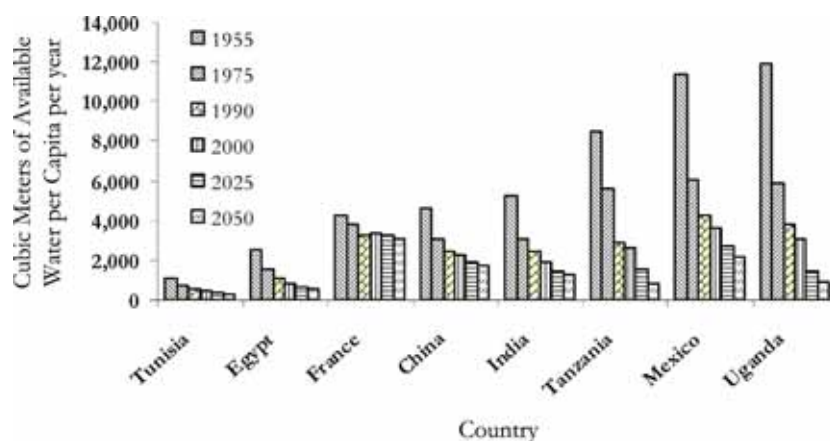


Fig. 1.5: Decrease in water availability per capita (m^3/year) between 1955 and 2050, using UN medium population prediction rates for 2000–2050.

Source: Authors' calculation based on data from Population Action International, 1993, 1995, 2004; United Nations Population Division, 2000.

Nations Population Division, 2000; Population Action International, 1993, 1995, 2004) at alarming rates in countries that face severe water scarcity (Fig. 1.5).

What is the common trend in almost all countries in the world (Fig. 1.5 includes only eight representative countries) and what does it mean in terms of future water scarcity and possible **conflict**? Well, it is clear that the water availability per capita decreases in a hyperbolic fashion decreasing from left to right. This is driven by the increase in population and the, more or less, stable water resource availability in the country. There are only a few countries in the world (e.g., Italy) where the water availability per capita is actually increasing because of decline in population growth over time.

The water availability per capita index, although very rough and controversial, provides a good upper limit to the state of water scarcity in a country. Are all countries, that face severe water scarcity, affected in the same way? What are the other factors that could be considered to either alleviate or reduce water scarcity in a country? There are three factors that affect the ability of a country to cope with water scarcity.² First, water quality is an important dimension of water scarcity. The available water in a country that is polluted is consequently no longer part of the usable quantity. Second, the standard of living in a country is a major factor affecting the way humans will consider water scarcity. Higher living standards are usually associated with elevated levels of water consumption (e.g., washing machines, swimming pools). Finally, the technological level of a country may allow its citizens

²Falkenmark and Widstrand (1992) suggested ranking of water shortage measure in m^3 per capita per year: (a) < 1000 is a water-scarce country; (b) $1000\text{--}1700$ is a water-stressed country; (c) $1701\text{--}3000$ is a water-insufficient country; $3001\text{--}10000$ is a water-sufficient country; and > 10000 is a water-abundant country.

to live quite well on relatively small amounts of water (e.g., **recycling**, seawater **desalinization**³). At the country level, we witness several cases of inter-basin water transfers (e.g., China, California, Israel) to ease local water scarcity situations.

Now that we have gained additional knowledge about the state of water, its regional and sectoral distribution and use patterns, and availability in various countries, we can introduce the concept of international river basin and discuss the **conflicts** that may take place over scarce water.

For Further Discussion. Consider the likely impact of future global warming on water supply across several riparians in a given basin. What could be the physical as well as the political–economical consequences? Consider further the sectoral water use (such as in Table 1.1). Would extreme use patterns exacerbated by global warming impacts be manageable? Are there mechanisms that the basin riparians may be able to consider in order to find a stable regional solution to the water scarcity in the basin?

THE STOCK OF INTERNATIONAL RIVER BASINS

What is an international water body — basin, lake, or an aquifer? A detailed answer can be found in Chapter 3. However, for the time being we will consider the straightforward definition to mean that it spans over the territories shared by two or more independent states.

Why has the number of international river basins grown over time?

Wolf *et al.* (1999) suggest three reasons for that:

1. national basins became international given the political changes;
2. appropriate tools were not available to delineate all existing basins and
3. previous counts (e.g., the 1978 FAO register) ignored many island nations.

The creation of new states, a result of **wars** or political changes, means that a basin is no longer categorized as domestic but rather considered international. But this is not the only change. Another change ensues the new riparian states may be *a priori* hostile to each other based on their pre-independence relations so that the level of **conflict** in the basin is quite likely to be elevated (e.g., nonwater, historical **conflicts** can likewise drive the **conflict** over water). Therefore, in addition to an increase in the number of the international basins, there is also an increase in the

³Israel is one of the most water scarce countries. However, with technological advances, it has been able to recycle about 250 million m³ per year and replace **fresh water** by treated waste waters for **irrigation**. Recently, the biggest water **desalinization** plant has been in operation, injecting 120 million m³ to the drinking water system. Saudi Arabia also extended its water supply ability by investing in many **desalinization** plants.

number of **conflicts**, both water-related and nonwater-related (that can indirectly be associated with water issues).

Examples of Newly Created International River Basins and Ensuing Conflict

The Aral Sea Basin, which is home to the Syr Darya (River) and Amu Darya, was part of the Soviet Union until 1992. With the collapse of the Soviet Union and the creation of the independent states of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, the Aral Sea Basin became international, consequently instigating dispute among the riparians. While related basin problems were internalized during the Soviet era and hence managed by a higher authority — Moscow — issues such as water allocation, pollution and **externality** impacts became international in nature after the collapse of Soviet Union.

Another illustrative example the 1999 **war** in the former Yugoslavia is created several new states and several new international river basins. Among these basins the Neretva and Trebisjnica River Basins shared by Bosnia and Herzegovina and Croatia. Although not yet declared a **conflict**, there are signs of looming problems in the management of the shared resource. The main problem is the pollution of the downstream tourist areas of the Adriatic Sea region of Bosnia and Herzegovina by industrial and urban wastes in Croatia.

While there has been an increase in the number of river basins due to geographical changes, international basins have actually “disappeared” due to the unification of a nation. Examples include Yemen (Northern and Southern Yemen) and Germany (East and West Germany). In general the net increase in the number of international basins between 1978 and 1999 amounts to 47 “new” international basins (Table 1.2).

While the number of international river basins in the various continents varies little, Africa is by far the continent with the highest share of land constituting international river basins (Table 1.3). Despite this finding, Africa is by far the continent with the least number of international **treaties** signed among international basin riparian states (see also Chapters 3, 7, 8, and 9).

Table 1.2: Number of international river basins by continents and sources of documentation.

Region	Barrett (1994)	1978 Register	Wolf <i>et al.</i> (1999)
Africa	55	57	60
Americas	60	69	77
Asia	40	40	53
Europe	45	48	71
Total	200	214	261

Source: Wolf *et al.* (1999).

Table 1.3: Percentage of land area within international basins.

Continent	1999 Update (%)
Africa	62
Asia	39
Europe	54
North America	35
South America	60
Total	45

Source: Wolf *et al.* (1999, Table 2).

For Further Discussion. Based on Table 1.2, the number of transboundary watercourses increased from 214 to 261 between 1978 (or before) and 1999. Globally, this is about a 20% increase, which indicates either better delineation of basin boundaries or results of political struggle, leading to independent states, or both improved cartographical tools and political unrest. If we look at regional distributions of such changes, we may come up with additional hypotheses. For our present discussion, let us focus on newly established states that must suddenly share a river basin. Would this be a factor in instigating more, or less, **conflicts**? Using the Aral Sea assess the problems, the five republics have had to contend with since independence and comment on their ability to contend with such issues. What type of differences in conflict or cooperation would you expect when comparing the Aral Sea Basin with the Tigris-Euphrates Basin, which is shared by only three states? While we have not studied yet any of these basins, still let us use our *a priori* knowledge.

A list of international basins and the number of countries that share them (except basins that are shared by 2, 3, and 4 countries) is presented in Table 1.4.

A visual documentation of the location, size, and distribution of the various transboundary river basins and lakes in the form of maps delineates the recent boundaries of all known basins (Maps 1.1–1.6).

WATER AND CONFLICT — GROUND FOR DESPAIR OR REASON FOR HOPE?

Whatever the situation regarding water scarcity may be, the overarching message, in many of the existing analyses and statements made by leading world experts is that our world is on the verge of a water quantity and quality crisis. Some are also sending alarming messages. For example, places on the front cover of his edited book Ohlsson (1995) quotes a statement by Ismail Serageldin (at the time Vice President of Environmentally and Socially Sustainable Development Vice Presidency at the

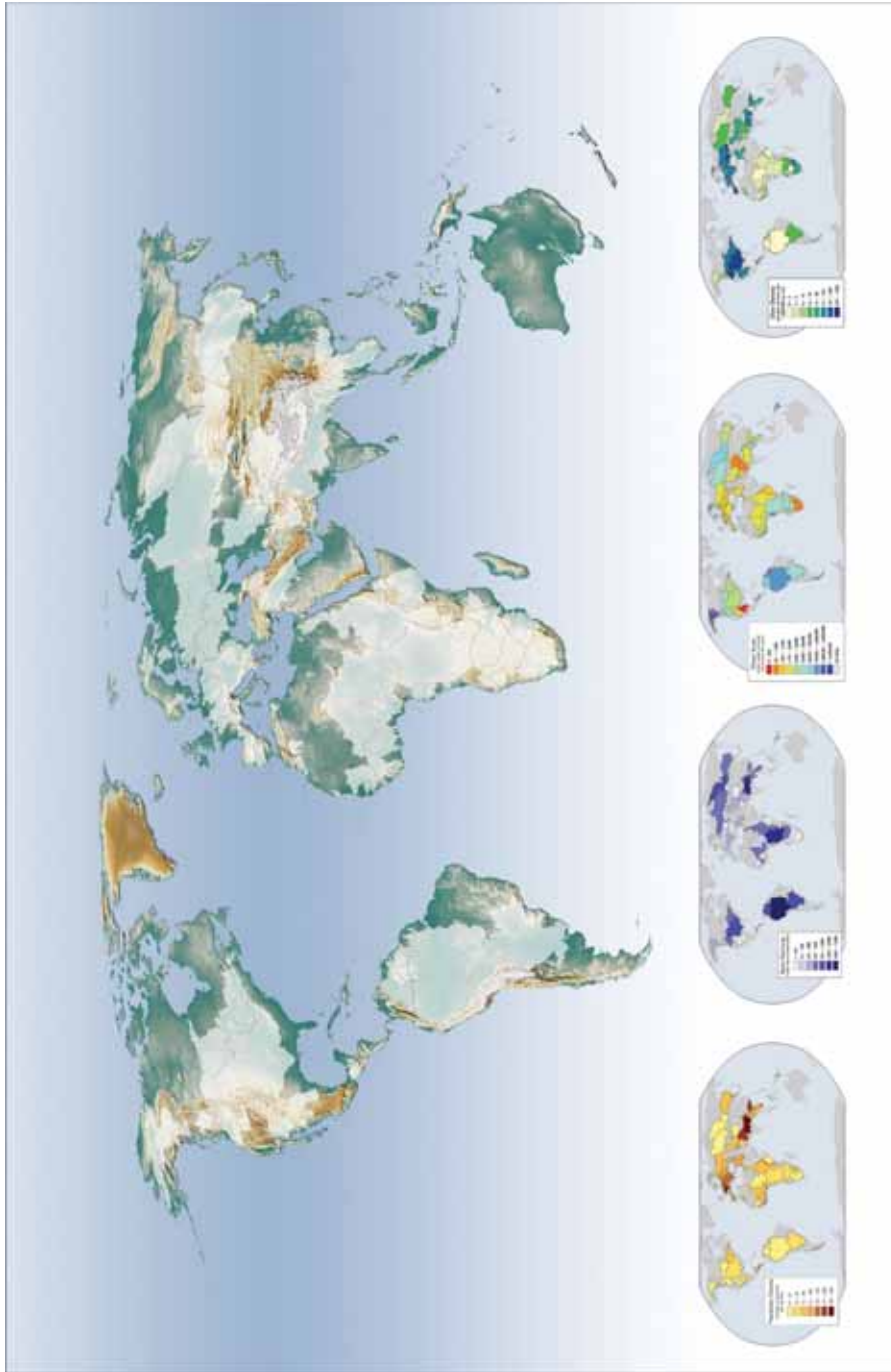
Table 1.4: Number of riparian states and the basins they share.

Number of countries	The shared basins
17	Danube
11	Congo, Niger
10	Nile
9	Rhine, Zambezi
8	Amazon, Lake Chad
6	Aral Sea, Ganges–Brahmaputra–Meghna, Jordan, Kura–Araks, Mekong, Tarim, Tigris and Euphrates, Volta
5	La Plata, Neman, Vistula
4	17 basins
3	49 basins
2	176 basins

Source: Wolf *et al.* (1999, Table 6).

World Bank) predicting that “The **wars** of the next century will be over water.” The United Nations Secretary General, Kofi Annan, has declared that “Fierce competition for **fresh water** may well become a source of **conflict** and **wars** in the future” (AAG, 2001). A featured article on preventing **conflict** in the next century (The Economist, 2000:52) includes a blurb on water violence. It argued that “Water shortages will grow even more serious; the stuff of future **wars**. . . . With 3.5 billion people affected by water shortages by 2050, conditions are ripe for a century of water **conflicts**.” The 2004 Nobel **Peace** Prize winner, Wangari Maathai (Int’l Herald Tribune, 2004:6) suggests that “. . . we face [the] ecological crises of deforestation, desertification, water scarcity and a lack of biological diversification. Unless we properly manage resources like forests, water, land, minerals, and oil, we will not win the fight against poverty. And there will not be **peace**. Old **conflicts** will rage on and new resource **wars** will erupt unless we change the path we are on.” Finally, on the cover of their book Clarke and King (2004) placed a slightly modified version of the excerpt used by Ohlsson (1995). Clarke and King use the statement, “If the **wars** of the twentieth century were fought over oil, the **wars** of this century will be fought over water.” The quote is attributed World Bank. Whether or not the world will experience water **wars** is to be seen, but the fact is that scarcity and water **conflicts** have been there for centuries and will be with us for years to come.

Is the future that gloomy? Have there been only **conflicts** over water? Or are there also “reasons for hope” (Elhance, 2000)? To be able to make educated arguments about the state of “future **wars**” over water, we invite the reader to consider the following chapters, gaining both information and analytical tools to consider the realm of transboundary freshwater. We believe that after reading the book the reader will be better equipped, and to assess the likelihood of future **cooperation**, **conflicts** or **wars** over water. Before we provide a synopsis of the



Map 1.1: World map of transboundary river basins.

Source: Transboundary Freshwater Dispute Database, <http://www.transboundarywaters.orst.edu> (Permission granted to reproduce maps from the Transboundary Freshwater Dispute Database).



Map 1.2: Africa map of transboundary river basins.

Source: Transboundary Freshwater Dispute Database, <http://www.transboundarywaters.orst.edu> (Permission granted to reproduce maps from the Transboundary Freshwater Dispute Database).

book's chapters, a glance into several important works which will set the tone for this volume, is essential.

Background Information on Water Conflict and Cooperation

Wolf and Yoffe (2001) record a total of 1831 conflictive and cooperative events between 1949 and 2000 in 263 international river basins. As can be seen in Fig. 1.6, the number of cooperative events surpass the number of conflictive events.



Map 1.3: Asia map of transboundary river basins.

Source: Transboundary Freshwater Dispute Database, <http://www.transboundarywaters.orst.edu> (Permission granted to reproduce maps from the Transboundary Freshwater Dispute Database).

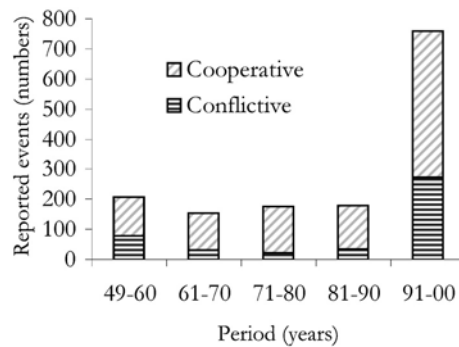
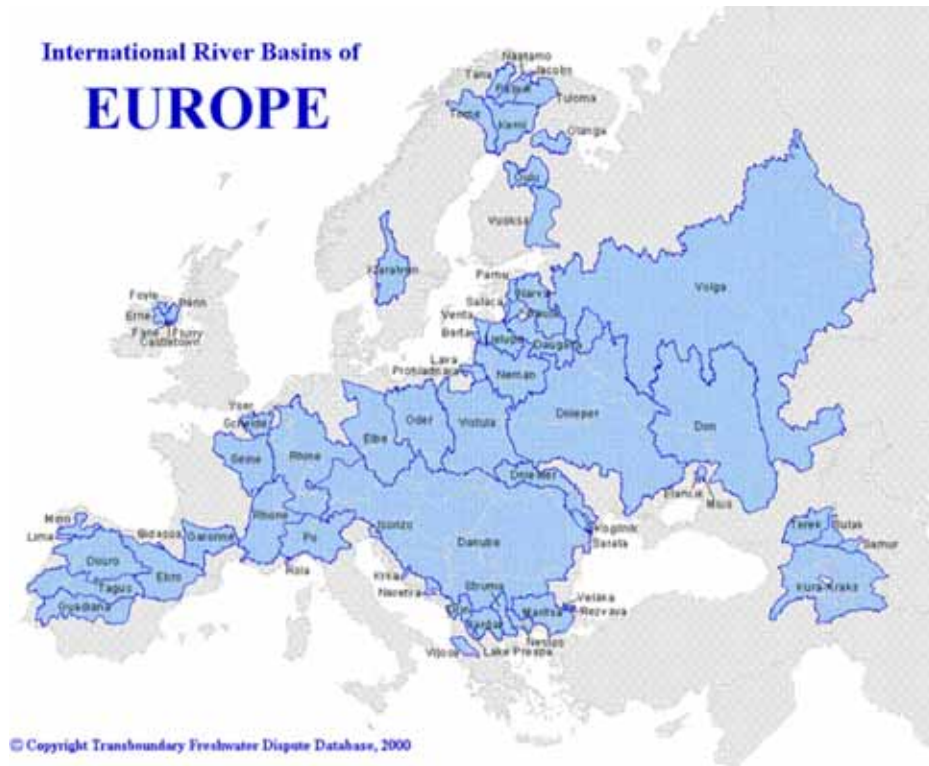


Fig. 1.6: Conflictive and cooperative water events over the last 50 years.

Source: Authors, based on Wolf and Yoffe (2001).



Map 1.4: Europe map of transboundary river basins.

Source: Transboundary Freshwater Dispute Database, <http://www.transboundarywaters.orst.edu> (Permission granted to reproduce maps from the Transboundary Freshwater Dispute Database).

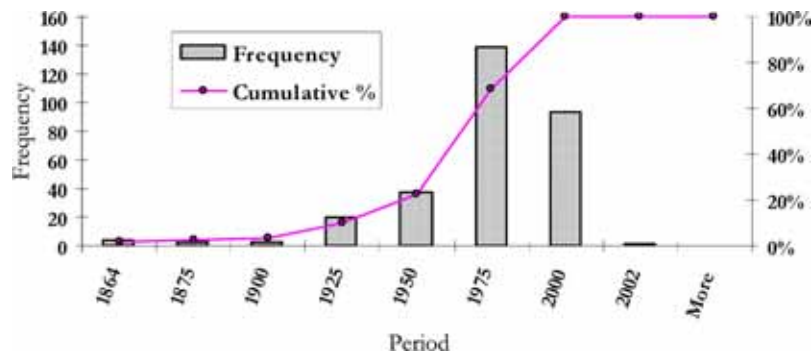


Fig. 1.7: Distribution of bilateral treaties during 1864–2002.

Source: Based on data in Dinar (2007).

In a recent work, Dinar and Dinar (2005) show that it is scarcity that drives the process of **cooperation** among riparians to rivers that are shared between two riparian states. A descriptive statistics (Fig. 1.7) of the 300 **treaties** (between 1896 and 2002) that were analyzed in their work suggest a similar pattern that



Map 1.5: North America map of transboundary river basins.

Source: Transboundary Freshwater Dispute Database, <http://www.transboundarywaters.orst.edu> (Permission granted to reproduce maps from the Transboundary Freshwater Dispute Database).

was depicted in Fig. 1.7, namely, **cooperation** (measured by treaty formation) has increased significantly in the last two decades. Thus, the claim that the next century will be characterized by **wars** over water is simply erroneous.

Conflict and **cooperation** over scarce water resources has taken a variety of forms. From the extremes of full **cooperation** to full-scale **conflict**, one always wonders ‘why a **conflict** ensues’, and ‘how **cooperation** may be enhanced.’ Sharing of water resources is a global problem, as international river and lake basins comprise nearly 50% of the world’s continental land area (United Nations, 1978). The economic and political costs of lingering international water **conflicts** are significant. Specifically, the economic development of river basins is likely delayed or halted. Short- and long-term damages to parties occur as a result of a unilateral action taken by another party. Finally, additional indirect social costs may also be the result of such **conflicts**.

For example, there are several ways in which cooperative international river development offers possibilities for mutual gain (Krutilla, 1969). An **upstream riparian** may wish to undertake measures on the domestic reaches of the stream to provide some protection from flood hazards and some improvement of flows during low-flow seasons. According to Krutilla (1969), documenting the Columbia River

International River Basins of SOUTH AMERICA



Map 1.6: South America map of transboundary river basins.

Source: Transboundary Freshwater Dispute Database, <http://www.transboundarywaters.orst.edu> (Permission granted to reproduce maps from the Transboundary Freshwater Dispute Database).

case, cooperative participation in design and scale, and mutually planned sharing of costs and attendant benefits, are likely to lead to more effective exploitation of the river's potential than if each party were to take an independent course of action, ignoring off-site effects. In general, where inter-dependencies exist, pooling the resource potential of an entire river system offers a wider range of technically feasible alternatives, and by avoiding duplication, pooling resources provides an

opportunity for selecting the most economical combination of sites and measures for attaining mutually desired objectives.

For Further Discussion. Can technology and trade ease water scarcity? At this entry point in this course, address the following scenarios: (1) Can a water-scarce, technologically-advanced country trade water saving technology for water and ease water scarcity and likely **conflict** among the two basin riparians? and (2) Can trade in commodities replace the need to manufacture or grow water-intensive commodities in countries or regions where water is a scarce resource? These two questions will open for us the way to the rest of the discussions in the book.

SUMMARY AND THE STRUCTURE OF THIS BOOK

This chapter is intended to set the tone for this book. Two initial observations have been made: (1) We noted that both the amount of water available, globally, per person and its quality are declining over time albeit not at the same rate in all locations; and (2) We argue that riparian states may adapt to water scarcity situations also by signing **treaties** that address their scarcity problems. Whether or not these two processes complement each other and provide solutions to water scarcity **conflicts** remains to be seen. The book will consider various approaches that will assist in addressing this quandary.

Chapter 2 provides a comprehensive literature review that is organized, more or less, by the main disciplines that are relevant for describing and analyzing water **conflict** and **cooperation**. The reader is exposed to the fields of economics, an hydrology and engineering, and international relations and other disciplines and is introduced to the methods used by each to address the issues of transboundary water. Chapter 3 provides the basis for understanding the development and application of international water law, providing several examples from various transboundary rivers around the world. Chapter 4 introduces principles of **cooperation** and demonstrates how they are implementing in international water management. Chapter 5 introduces various principles and solution concepts from the field of cooperative game theory. In Chapter 6, the reader is guided through a series of applications of these concepts to practical issues of water resource investment and management. Chapter 7 builds on the previous chapters and discusses **conflict** and **cooperation** over international water from an international relations and negotiations point of view. Chapter 8 serves as a primer for the legal aspects of international water **treaties** by providing an overview of selected international cases in their geographic and political contexts. Chapter 9 focuses on a framework that addresses the generic characteristics of treaty analysis. The first part of the chapter provides a descriptive exploration of the substance of **treaties** while the second

part suggests a theory for considering how water agreements can sustain participation by the relevant parties and promote **cooperation**. Chapter 10 demonstrates how river basin models can be used to assess and quantify **conflict** and potential **cooperation**. Furthermore, the chapter affirms that river basin models are crucial for providing data for the calculating certain solution concepts introduced in Chapters 5 and 6. Chapter 11 concludes the book, drawing lessons from the various chapters, and suggesting directions for future research work and teaching.

Practice Questions

1. When describing the global water situation, we have used several indexes. Some indexes are human neutral and some take into account human decisions. Which are the indexes used and which of them are human neutral?
2. How is it possible for people to live on $< 100\text{m}^3$ of available water per year, in some countries, while minimum standards for water consumption are 100 liters per day per person?
3. It is estimated that both water per capita and irrigated area per capita are declining over time. Do you really think that we are facing a food crisis?
4. How do you explain the relatively low number of **treaties** signed among basin riparians in the late 1800s and early 1990s, compared with the relatively high number of **treaties** signed in the mid to late 1990s?

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