Chapter 1
Introduction

In the world of today, people in Japan indirectly affect the hydrological system in the USA and people in Europe indirectly impact on the regional water systems in Brazil. When you ask somebody how this can happen, the reply will most probably be: through climate change. This answer is likely because much has been reported about the expected effects of past and ongoing local emissions of greenhouse gases on future global temperature, evaporation, and precipitation patterns. Most people are aware that local emissions of greenhouse gases contribute to global climate change and can thus indirectly affect other locations. Little is known, however, about a second mechanism through which people affect water systems in other parts of the world. This second mechanism, which is as "invisible" as climate change but which is today already much more significant, is global trade. International trade in agricultural and industrial commodities creates a link between the demand for water-intensive commodities (notably crops) in countries like Japan, Italy, Germany, and the UK and the water use for production of these commodities in countries such as the USA and Brazil. Water use for producing export commodities for the global market significantly contributes to changes in local water systems. By buying crop products imported from the USA, Japanese consumers put pressure on the water resources of the latter, contributing to the mining of aquifers and emptying of rivers in North America. Well-documented examples are the mined Ogallala Aquifer and emptied Colorado River. European consumers contribute to a significant degree to the water demand in Brazil by buying water-intensive crop and livestock products imported from this country. Well known is the ongoing deforestation of the Amazonian rainforest with its implications for biodiversity, erosion, and runoff.

Though consensus seems to exist that the river basin is the appropriate unit for analyzing freshwater availability and use, in this book we argue that it is becoming increasingly important to put freshwater issues in a global context. Although other authors have already argued thus (Postel et al., 1996; Vörösmarty et al., 2000), we add a new dimension to the argument. International trade in commodities implies long-distance transfers of water in virtual form, where virtual water is understood as the volume of water that has been used to produce a commodity and that is thus virtually embedded in it (Allan, 1998b). Knowledge about the virtual-water flows entering and leaving a country can cast a completely new light on the actual water scarcity of a country. For example, Jordan imports about 5 to 7 billion m^3 of virtual water per year, which is in sharp contrast with the 1 billion m^3 of water withdrawn annually from domestic water sources (Haddadin, 2003; Chapagain and Hoekstra, 2004). This means that people in Jordan apparently survive owing to the import of water-intensive commodities from elsewhere, for example the USA. Jordan's water shortage is largely covered up by intelligent trade: export of goods and services that require little water and import of products that need a lot of water. The positive side of Jordan's trade balance is that it preserves the scarce domestic water resources; the negative side is that the people are heavily "water dependent." A different case is Egypt, a country which has not been willing to become water dependent and in which water self-sufficiency is high on the political agenda. However, with a total water withdrawal inside the country of 65 billion m^3/yr, Egypt still has an estimated net virtual-water import of 10 to 20 billion m^3/yr (Yang and Zehnder, 2002; Zimmer and Renault, 2003; Chapagain and Hoekstra, 2004). This means that even Egypt's water balance is not immune to its pattern of international trade. In fact, there exist no countries in the world where the pattern of trade does not influence the pattern of domestic water use. Developing national water policies without explicitly considering the implications of international trade thus seems to be injudicious. Nevertheless, this is the common practice. In addition, formulating foreign trade policies in water-scarce countries without explicit consideration of domestic water resource availability would seem to be inadvisable as well. Yet, this is what generally happens.

In this book we address questions such as: Is it efficient to import water in virtual form if domestic water resources are scarce? And what are the implications of importing virtual water in terms of the resulting "water dependency"? But once we enter the area of "water and international trade" other questions also arise. If water-intensive products are imported from a distant location, the negative impacts of water use in the area of production will remain invisible for the consumer. Together with the fact that usually only a small fraction of the full cost of water use is included in the price of products, there is little incentive for consumers to change their consumption behavior or otherwise contribute to the mitigation of distant water problems. Thus new questions come up: What are the invisible tele-connections between intensive consumption of water-intensive products in some places on earth and the impacts of water use in other places? And does international trade in water-intensive commodities contribute to the unrestricted growth of consumption of water-intensive products in a world where water becomes increasingly scarce? In order to address these sorts of questions, we use in this book a number of novel concepts such as the "virtual-water content" of a commodity, the "water footprint" of a nation, and the "water saving" as a result of international trade. Let us introduce and explain these concepts one by one.

The virtual-water concept was introduced by Allan (1998a,b, 1999a,b, 2001) when he studied the possibility of importing virtual water (as opposed to real water) as a partial solution to problems of water scarcity in the Middle East. Allan elaborated the idea of using virtual-water import (coming along with food imports) as a tool to release the pressure on scarcely available domestic water resources. Virtual-water import thus becomes an alternative water source, alongside endogenous water sources. Imported virtual water has therefore also been called "exogenous water" (Haddadin, 2003).

The water-footprint concept was introduced by Hoekstra and Hung (2002) when they were looking for an indicator that could map the impact of human consumption on global freshwater resources. The concept was subsequently elaborated by the authors of this book (Chapagain and Hoekstra, 2004; Hoekstra and Chapagain, 2007a). The water footprint shows water use related to *consumption* within a nation, while the traditional indicator shows water use in relation to *production* within a nation. Traditionally, national water use has been measured as the total freshwater withdrawal for the various sectors of the economy. By contrast, the water footprint shows not only freshwater use within the country considered, but also freshwater use outside the country's borders. It refers to all forms of freshwater use that contribute to the production of goods and services consumed by the inhabitants of a certain country. The water footprint of the Dutch community, for example, also refers to the use of water for rice production in Thailand (insofar as the rice is exported to the Netherlands for consumption there). Conversely, the water footprint of a nation excludes water that is used within the national territory for producing commodities for export, which are consumed elsewhere.

The water footprint of a nation consists of three components: blue, green, and gray components. The terms blue and green refer to the source of the water (Falkenmark, 2003). Green water use refers to the use of rainwater, while blue water use refers to use of ground- or surface water. Rain-fed agriculture is fully based on green water, while irrigated agriculture is based on a combination of green and blue water. The industrial and domestic sectors are generally fully based on blue water. The blue water footprint of a nation is the volume of freshwater that evaporated from global blue water resources (ground- and surface water) to produce the goods and services consumed by its inhabitants. The green water footprint is the volume of water evaporated from global green water resources (rainwater stored in the soil as soil moisture). We have expanded the water-footprint concept by including a third form of water use: water use as a result of pollution. We have proposed to quantify this "gray" water footprint by estimating the volume of water needed to dilute a certain amount of pollution such that it meets ambient water quality standards. We have elaborated this idea in the cotton study discussed in Chapter 9.

Active promotion of the import of virtual water in water-scarce countries is based on the idea that a nation can preserve its domestic water resources by importing a water-intensive product instead of producing it domestically. Import of virtual water thus leads to a "national water saving." In addition to this, Oki and Kanae (2004) introduced the idea of a "global water saving." International trade can save water globally when a water-intensive commodity is traded from an area where it is produced with high water productivity (low water input per unit of output) to an area with lower water productivity (high water input per unit of output). Conversely, there can be a "global water loss" if a water-intensive commodity is traded from an area with low water productivity to one with high water productivity. All studies of global water savings and losses as a result of international trade that have been carried out so far indicate that the net effect of current international trade is a global water saving (De Fraiture et al., 2004; Oki and Kanae, 2004; Chapagain et al., 2006a; Yang et al., 2006).

Since the International Expert Meeting on Virtual Water Trade, held in Delft, the Netherlands, in December 2002 (Hoekstra, 2003) and the special session on Virtual Water Trade and Geopolitics during the Third World Water Forum in Japan in March 2003, interest in the concepts of virtual water, water footprints, and global water saving has greatly increased. As a follow-up to the Water Forum in Japan, the World Water Council organized an e-conference on virtual-water trade and geopolitics (WWC, 2004). During three months in Fall 2003 about 300 people participated in a web-based debate about questions such as:

- Does virtual-water trade contribute to the improvement of water availability and through that to local food security, livelihoods, environment, and local economy?
- In which conditions should virtual-water trade be encouraged?
- Does virtual water contribute to conflict resolution or will it increase tensions and conflict potential for those countries relying on trade?
- What governance structures would be necessary to enable a fair virtual-water trade?
- How can the concepts of virtual water and water footprints help in creating awareness about water consumption and saving water by modification of diet?
- What is required from whom to progress on the appropriate and fair introduction and use of the virtual-water concept?

After the e-conference, different workshops addressing virtual-water trade and water footprints were organized: by Stanford University (November 2004, March 2005), the German Development Institute (Bonn, September 2005), the Fourth World Water Forum (Mexico City, March 2006), the Global Water System Project (Bonn, June 2006), and the Institute for Social-Ecological Research (Frankfurt, July 2006), amongst others. In addition, a considerable number of Master and PhD students from all parts of the world have started to devote their studies to the subject. Apparently the issue of "trade and water" has quite suddenly been recognized as a relevant policy concern and an interesting research field. This book aims to summarize our current knowledge in the field, a somewhat tricky effort given the continuous stream of new research results.

In Chapter 2 we discuss how one can assess the virtual-water content of a commodity and show the resulting estimates for various products. In Chapter 3 we explain how international virtual-water transfers can be quantified and draw the virtual-water balance for each country of the world. Chapter 4 shows how international trade can result in both national and global water savings, but can also occasionally result in global water losses. In Chapter 5 we describe how to assess the water footprint of a nation and show the resulting estimates for all nations of the world. Chapter 6 contains a case study for the Netherlands, a humid country, and Morocco, an arid–semi-arid country. In Chapter 7 we elaborate on the virtual-water transfers within China, which surprisingly go from the water-scarce north to the water-rich south. In Chapter 8 we show the water footprint of coffee and tea consumption, and in Chapter 9 we do a similar but more detailed exercise for cotton. Chapter 10 shows how international trade has made many countries heavily "water dependent" and how water has thus become a geopolitical resource. In the final chapter we explore what sorts of global institutional arrangements are needed to make sure that international trade contributes not only to efficiency in water use, but also to sustainable and equitable water use across the globe.