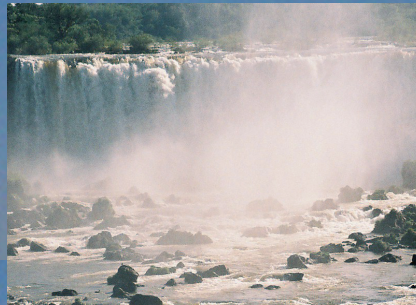




EDITORS : JOSÉ L. LOZÁN • HARTMUT GRASSL
PETER HUPFER • LUCAS MENZEL • CHRISTIAN-D. SCHÖNWIESE

GLOBAL CHANGE: Enough Water for all ?

Climate change - threats for more severe extremes and water crises
More climate protection – fewer risks for the future

WISSENSCHAFTLICHE AUSWERTUNGEN

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A contribution to realize and to solve water related problems

Water is of vital importance: Without water no life would exist and our planet would be a huge desert. Water plays a dominant role in the climate system as well. Atmospheric water vapour is the most important greenhouse gas; over 60% of the greenhouse effect of the atmosphere is due to water vapour. Without greenhouse gases the mean surface temperature of our planet would be around -18 °C.

Water is the basic condition for the high biodiversity on Earth. Plants, animals and humans are composed of 50–80% water. They are stressed, fall ill or die from water scarcity or polluted water. Therefore, our common future is endangered when water is not available in sufficient amount and quality. Water traverses an endless cycle (the water cycle), enabling a self-purification on its long way through the soil and rock layers. Water is a heritage of nature and it belongs to all living beings. The right of access to sufficient and clean water is a universal law and it is therefore anchored in important international treaties.

The uneven distribution of precipitation and water on Earth leads to water scarcity in many regions. Already today 1.2 billion people (20% of the world population) have no secure access to clean drinking water and 2.4 billion people do not dispose of or have access to sanitary installations. Millions of children die every year due to polluted water. While Europeans use 130–150 litres water per capita and day (in the USA this amount is even at around 300 litres), many people south of the Sahara Desert have less than 20 litres per day at their disposal.

Global climate change will intensify the water crisis. This is mainly caused by the emission of anthropogenic greenhouse gases, mostly from the industrialised countries. Glaciers in particular are sensitive to climate change. Most glaciers on Earth are shrinking. Global warming intensifies the water cycle and exacerbates the water problems on our planet. In humid regions (e.g. Scandinavia) the precipitation increases and in arid and semi-arid regions (e.g. the Mediterranean) the precipitation is decreasing. Arid and semi-arid areas are increasing in size in many regions.

The aim of this book is to contribute to the public discussion on our relations and dealings with water. It shall also shape the public opinion towards an integrated view on water and the necessity to ensure enough water for coming generations. ensure that coming generations will have sufficient amounts of water.

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Global water cycle

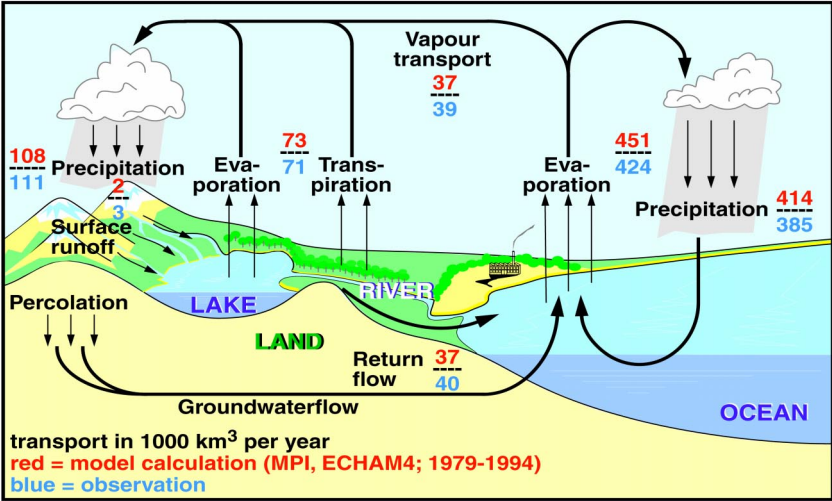


Chart 1: Global water cycle showing the processes taking part in all reservoirs. Numbers indicate the mean annual fluxes between reservoirs. The values in *blue* correspond to the observed flow and in *red* a circulation model result (see also Chart 4) (Source: Max Planck Institute for Meteorology, Hamburg, modified).

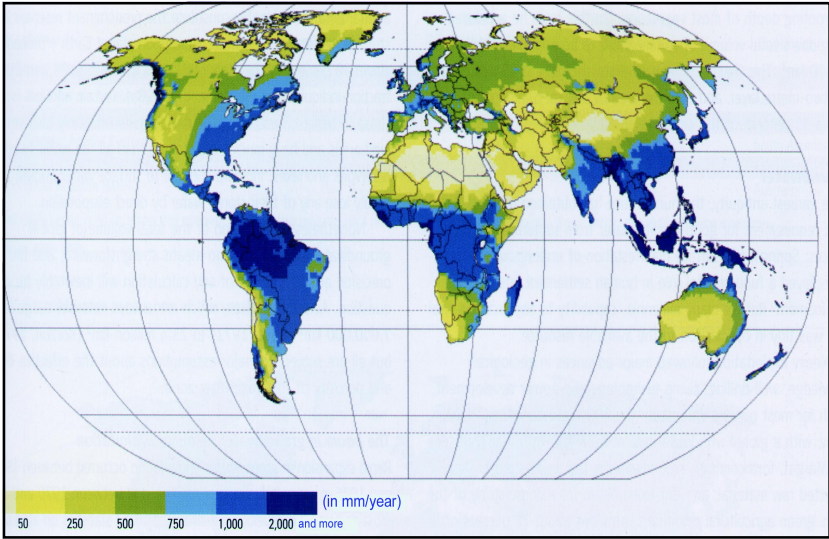


Chart 2: The mean annual distribution of precipitation on land areas in mm/year. The map shows the extremely unequally distributed precipitation between the tropics (partly > 10,000 mm/year) and the arid/semi-arid regions like the Sahara desert (< 50 mm/year). Especially significant are the differences on the African continent (Source: UNESCO 2003).

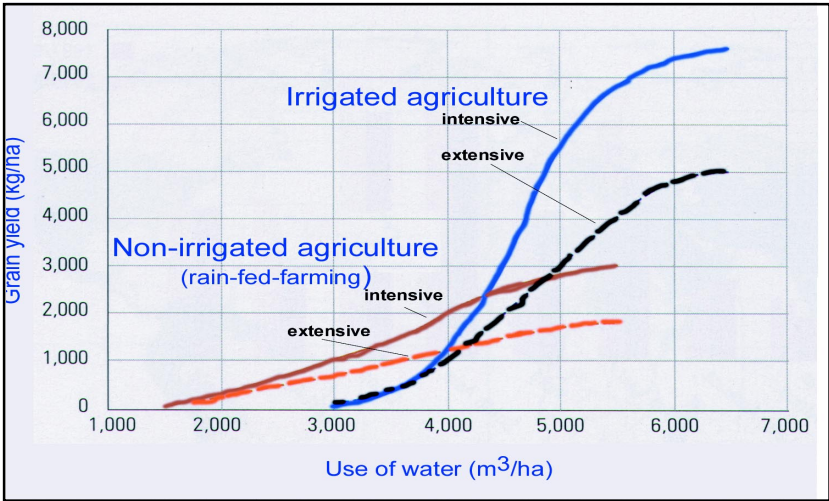


Chart 3: Grain yield and water use. The agriculture is the biggest user of water (see Chart 5). As the example of cereal production shows, the yield depends on the intensity of cultivation. An irrigated agriculture achieves a higher yield. In developed countries the irrigated areas reached in 1993 a value of 3% of the total agricultural area. As the population in these countries is growing only slowly there was a small increase of the demand for food (Source: WBGU 1998).

Chart 4: World water reservoirs. The numbers are based on data given by KLIGE et al. (1998, p. 339), partly modified.

	<i>Volume</i> <i>(10³ km³)</i>	<i>Volume</i> <i>(%)</i>	<i>Thickness</i> <i>of the layer¹</i> <i>(m)</i>	<i>Recirculation²</i> <i>(km³/year)</i>	<i>Renewal</i> <i>time</i> <i>(year)</i>
Oceans	1,476,000	94.23	2,894	507,000	2,911
Groundwater	60,000	3.84	118	12,000	5,000
Glaciers and permanent snow covers	30,000	1.92	70	4,000	7,500
Lakes and swamps	290	0.0185	0.6	39,000	7.4
Rivers	2	0.00013	0.004	44,000	17 Tage
Soil water / soil humidity	16	0,001	0.03	15,000	390 Tage
Water in plants and animals	2	0.00013	0.004	52,000	14 Tage
Water in the atmosphere	14	0.0009	0.03	577,000	8 Tage
Total water in the hydrosphere	1,566,324	100			

¹ Under the assumption of an even distribution above a smoothed Earth with a surface of 510×10⁶ km²

² Water flowing from the reservoir (compartment)

Chart 5: Water use 1995 in the World and in Germany, according to activities.

	<i>World</i>			<i>Germany</i>		
	<i>Total</i> <i>km³</i>	<i>Per capita</i> <i>m³</i>	<i>%</i>	<i>Total</i> <i>km³</i>	<i>Per capita</i> <i>m³</i>	<i>%</i>
Agriculture	3160	536	75	2 ¹	24	4
Thermal Power Stations	400	69	10	28	341	64
Industry	370	64	9	10	122	23
Households	270	46	6	4	49	9
<i>Total</i>	<i>4200</i>	<i>715</i>	<i>100</i>	<i>44</i>	<i>536</i>	<i>100</i>

Source: WBGU (1998), UBA (2001)

¹ Only water volume for irrigation

Chart 6: Fluxes in the global terrestrial water cycle in km³/year. From the total precipitation of 110,000 km³ onto land about 70,000 km³ are transformed into water vapour by evaporation and transpiration. About 40,000 km³ reach the oceans as runoff. The same water volume is transported by the atmospheric circulation from the oceans to the continents.

	<i>Total</i>	<i>Evapotranspiration</i>	<i>Runoff to the sea</i>
Natural evapotranspiration	50,000	50,000	
Evapotranspiration from rain-fed farming	18,000	18,000	
Inaccessible runoff	29,000		29,000
Accessible runoff	13,000		
Runoff from removal			2,000
Evapotranspiration from irrigation		2,000	
Rest from accessible runoff			9,000
<i>Total</i>	<i>110,000</i>	<i>70,000</i>	<i>40,000</i>

Chart 7: Estimated development of the efficiency of water use in percent from 1998 to 2030 for ninety-three developing countries.

	Africa south of the Sahara	Latin America	Middle East/ North Africa	South Asia	East Asia	All countries
<i>In the irrigated agriculture</i>						
1998	33	25	40	44	33	38
2030	37	25	53	49	34	42
<i>Relative removal (%) for irrigation from renewable water resources</i>						
1998	2	1	53	36	8	8
2030	3	2	58	41	8	9

Source: UNESCO 2003

Chart 8: Improvement of the access to drinking water and the availability of a sanitation facility from 1990 to 2000.

		<i>Drinking water</i>			<i>Sanitation facility</i>		
		<i>With access</i>	<i>Without access</i>	<i>Households with connection to water supply</i>	<i>With access</i>	<i>Without access</i>	<i>Households with Sanitation facility</i>
		(%)	(%)	(%)	(%)	(%)	(%)
Africa	1990	59	41	17	59	41	11
	2000	64	36	24	60	40	13
Asia	1990	73	27	43	29	71	13
	2000	81	19	49	47	53	18
Latin America and Caribbean	1990	82	18	60	72	28	42
	2000	87	13	66	78	22	49
<i>Total</i>	1990	72	28	41	38	62	16
	2000	79	21	47	52	48	20

Quellen: WBGU (1998), UBA (2001)

Chart 9: The daily water use (litres) *per capita* in the households according to countries.

USA	301
Japan	285
Switzerland	263
Germany	145
EU (average)	150
India	25
Sudan	19

Chart 10: Water required (litres) for major food products. Livestock use the most water (UNESCO 2003).

1 kg pulses, roots & tubers	1,000
1 kg palm oil	2,000
1 kg citrus fruits	1,000
1 kg cereals	1,500
1 kg fresh poultry	6,000
1 kg fresh lamb	10,000
1 kg fresh beef	15,000

Chart 11: Use of water (m³) by all activities in different countries *per capita* and year.

USA	1870
Canada	1600
Portugal	1090
Spain	1040
Italy	980
Greece	830
Japan	720
France	700
Belgium	690
Norway	600
Germany	536
Finland	480
Ireland	330
Sweden	310
The Netherlands	280
Great Britain	180
Denmark	180
Luxemburg	140

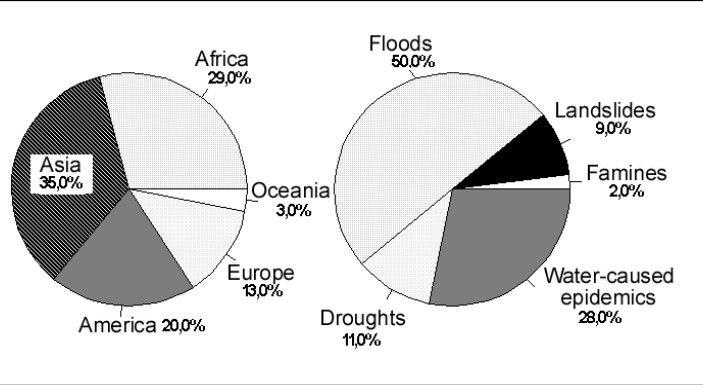


Chart 12: Relative numbers of water-related catastrophes according to regions as well as to impacts from 1990 to 2000 (Source: UNESCO 2003).

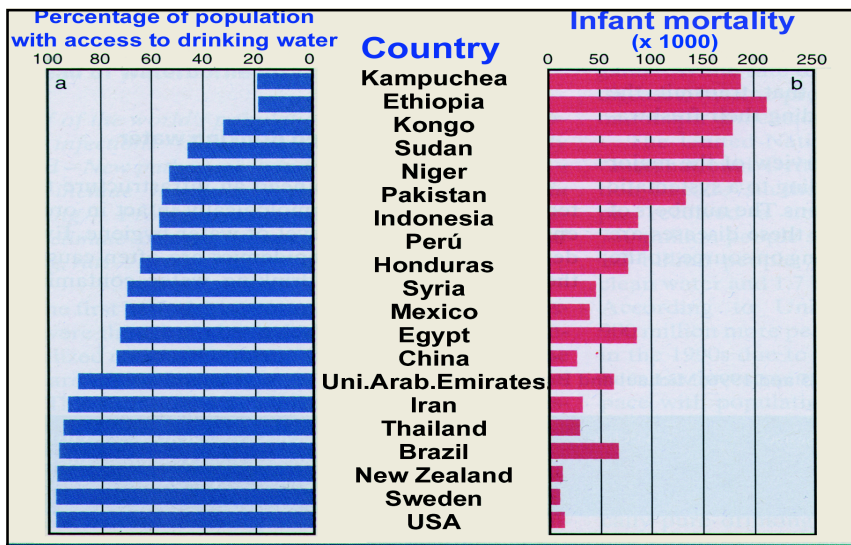


Chart 13: Percentage of population with connection to water supply system (*left*) and infant mortality (*right*) for several countries. The increase of infant mortality, when clean water is lacking, is obvious (Source: WBGU 1998).

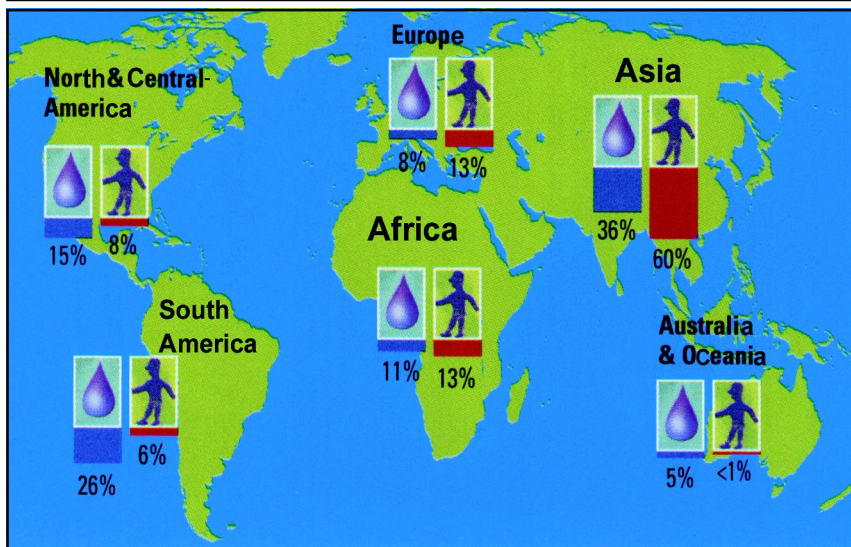


Chart 14: Availability of water and population for the different continents. In Asia about 60% of the world population have only 36% of the water resources. The data show only regional averages. For example, one might assume that South America has everywhere a water surplus; but one finds also desert regions there, like the coastal areas of Peru and Northern Chile, with very low precipitation (Source: UNESCO 2003).



Chart 15: Collective reinforcement of the embankments after the flood of the Glomma river in Norway (Foto: Birger Nesholen, Norway). There are indications that water related catastrophes have been increasing during the last decades. Therefore, measures have to be taken to mitigate the damages in the future as recommended, for example, by the International Water Conference 2001 in Bonn, Germany.

Foreword

by Prof. Dr. Klaus Töpfer

Executive Director (1998 – 2006)

United Nations Environment Programme (UNEP)

When I was born, in the year 1938, this wonderful blue planet Earth had to carry 2.4 billion human beings. In those nearly 70 years of my lifetime the global population has increased to 6.5 billion – and the population is scheduled to increase even further up to 9 billion people, luckily with a decrease in the increase rate.

Nearly in the same time the settlement structure in the world went through a fascinating revolution: It was around the time when the new millennium started that we reached the turning point of more than 50% of the global population living in cities, in large conurbations.

The economic structure has changed quite drastically, too. The industrialisation process was a basis for economic development and for decreasing the poverty situation of billions of people. Nevertheless the agricultural production increased dramatically, too. To feed this increased number of human beings it was and is necessary to cultivate more intensively, to integrate marginal land in agricultural production and to intensify food production by irrigation and industrialisation.

All over this time the availability of water hasn't changed quantitatively. But linked with those structural developments mentioned before, but also with numbers of other facts the water demand increased drastically: In the past the water demand increased twice as fast as the population did. The results are one of the most demanding challenges for common action: In the »Millennium Development Goals (MDG)« is integrated the target to reduce the number of people not having access to save drinking water by the year 2015 at 50%. It is estimated that this number of people without access of water is today nearly as high as 1.5 billion with all the consequences for water born diseases. Up to 5.000 children are dying daily due to water related diseases – a provocative figure, an unacceptable situation in this world of overconsumption in the developed world!

This development is especially a challenge on the regional and local level. Common used water

bodies like the catchment areas of a river system or a ground water body are more and more under the pressure of water shortages. This of course is not only the consequence of increases on the demand side, but also a result of the qualitative changes in the water supply having in mind that the recycling of all kinds of sewage water is at the global average only roundabout 10%. Taking all this into account it is not surprising that there is a broad global discussion concerning the relation between water availability and conflicts, even wars.

The wise reaction to those threats to peace and human misery is asking for concentrated and coordinated action, indeed for these »disarmament instruments« as precautionary measures to avoid these water conflicts. The first necessity in this context is linked with the speedy and scientifically based development of a systematic »early warning system«. That means to identify the water demand and the water supply now and for the future in all common used water catchment areas and to establish a priority list for urgent actions linked with the expected water shortages. A second step is combined with the facts and figures necessary for integrated water resource management plans and programs in these catchment areas. This necessity was discussed and decided at the »Summit on Sustainable Development« which took place in the year 2002 in Johannesburg. All Heads of States and Heads of Governments accepted at this conference in the »Johannesburg Plan of Implementation« that those IWRM have to be finalised for all catchment areas in the world until the end of the year 2005. Unluckily this target could not be reached until now.

The next step in this fight for safe drinking water for all human beings, in this »disarmament policy« for water conflicts are the negotiations for legally binding agreements in the use of the available water. The Environment Program of the United Nations (UNEP) published an Atlas of more than 250 regions of common used water bodies and the results of those negotiations. It is good to learn from

this publication that until now the common conviction for a peaceful use of water is much more stimulating negotiations, treaties and conventions than conflicts and war.

To avoid conflicts in the use of water in the future it is absolutely necessary to invest heavily in water saving technologies and in water recycling infrastructure. It has to be underlined that the water crisis is not at all a crisis with regard to the quantitative availability of water but a crisis of investment in water infrastructure and especially in the development of water administration and governance. These challenges must be tackled in common responsibility, knowing that it is wiser and more prudent to avoid conflicts than to handle the conflicts and their consequences later.

It is an outstanding achievement that in this book all the different facets of the important water sector

are integrated. So it is understandable that to protect nature with its huge storage capacity for water in wet lands and forests is an investment with high return on the invested resources. It is understandable that the consequences of climate change have destructive interrelations with the availability of water, that the pollution of water linked with industrial activities, with household sewages and with the intensification of agriculture are increasing the risk of conflicts in this area.

This book is at the same time also a great chance to learn lessons and to find answers for concrete problems on the local and national level. It is a great reader for university students and a basis for identifying common solutions on the official level. I am sure that this book will have a very broad based audience and that it will stimulate discussions and new ideas.

Höxter, in Autumn 2006

Preface

by THE EDITORS

Without water no life would have come into existence on our planet – it would be a huge desert. According to our present knowledge, the Earth is the only planet in our solar system where water occurs in its three phases. Water is the basic condition for the high biodiversity on Earth. Water is also an essential aliment for all organisms. The minimum daily water requirement for humans is at least two litres. This amount just upholds the basic metabolism processes in the body. But also the presence of water in the environment of living organisms is a prerequisite for their existence. Plants, animals and humans are composed to 50–80% of water. They are stressed, fall sick or die from water scarcity or polluted water. Therefore, our common future is not ensured when water is not available in sufficient amount and quality.

Water is a heritage of nature and it belongs to all living beings. The right for sufficient and clean water is a universal natural law and it is therefore anchored in important international treaties. A total privatisation of the water supply and effluent disposal infrastructures would no longer consider water as a public good but as any commodity which is subjected to the interest in profit maximisation. Hence the »human right for enough water« would be heavily at risk.

The largest amount of water on our planet is either ice or snow (solid phase) or salt water or brackish water (liquid phase). Less than 4% of the water on Earth is available as liquid freshwater. The largest part of it (99.5%) is groundwater (see Chart 5). However, there are still uncertainties in the assessment of the water resources and their distribution. Specifically, the data found in the literature regarding the estimation of groundwater resources are still different. On the average, the global water cycle supplies the continents with approx. 110,000 km³ precipitation per year. Since around 70,000 km³ of this amount evaporates back into the atmosphere, roughly 40,000 km³ water per year is available for anthropogenic use (see Chart 6). This is approx. tenfold the amount of the present mean annual use by human activities in agriculture, industry, households and power plants. Therefore, on the global average, there is sufficient water available for human use. The largest amount of precipitation falls however in already water rich regions. Therefore, the development and the prosperity of the industrialised countries on Earth

is among others based on their abundant water availability.

The uneven distribution of precipitation and water on Earth leads to water shortage or even water scarcity in many regions. Already today 1.2 billion people in the world (20% of the world population) have no secure access to clean drinking water and 2.4 billion people do not dispose of or have access to sanitary installations. Millions of children die every year due to polluted water. While Europeans use 130–150 litres water *per capita* and day (in the USA this amount is even at around 300 litres), many people south of the Sahara have less than 20 litres per day at their disposal (see Chart 9). The further increase in the world population from 6.2 to probably 9 billion in the year 2050 will exacerbate this problem. The share of regions with scarce water resources will accordingly rise. Already today several conflicts are also based on a fight for an access and use of water. Moreover, the industrialised countries domicile companies which currently try to lay claim to the world's water resources.

Global climate change will probably intensify the water crisis. It is mainly caused by the emission of anthropogenic greenhouse gases, mostly from the industrialised countries. The global warming trend intensifies the water cycle and exacerbates the water problems on our planet. An alarming fact is that many dry regions will probably become even drier and precipitation rich regions will become more humid. The rapid increase of the near surface air temperature within the last decades has already led to pronounced changes in the climate. The probability for the occurrence of extreme weather conditions, floods and droughts has already increased in many places. This includes also Europe, where a high number of both deluges and droughts (such as during summer 2003) has been observed in recent years.

In countries with temperate climate conditions like Germany, the agricultural water use is comparably small. Only 3% of the approx. 17 million hectares of agricultural land are irrigated. In average years, the costs for irrigation measures amount to 250–300 EUR per hectare. In years with extreme weather conditions however, costs of more than 500 EUR per hectare are possible. During the extreme dry year 2003, the soil moisture in many parts of Germany was so low that continuous irrigation was necessary between April and September – an exceptional situation. Soil moisture is usually at an optimum at values

between 60% and 80% of available field capacity. At a soil moisture status below 30–40% of available field capacity, obvious growth reductions and harvest losses occur, such as during the year 2003. On the other hand, soil moisture above 80% of available field capacity can also cause negative effects.

The United Nations proclaimed the year 2003 to the International Year of Freshwater in order to call attention to the global water crisis. The largest water use sector world-wide is agriculture, with a share of more than 75% of total water use. For example, the production of 1 kg of bread often requires more than 1,000 litres of water (see Chart 10). Therefore, new and more efficient irrigation measures are necessary. The United Nations estimate a minimum annual per capita water need of 1,000 m³ for all activities (agriculture, industry, households etc.) in countries with intense irrigated agriculture. According to this number, already today 500 million people suffer from water scarcity. Without precautionary measures, this number could rise to 3,000 million in the year 2025.

Water protection, water purification, water saving and a more efficient use of potable water are among the most important measures to overcome the global water crisis. This is also valid for the dire necessity to minimise anthropogenic climate change and its impact on water availability. Leading scientists and experts as well as the United Nations recognised that water will be the most important and most precious good in the near future. They also advocate for a water convention of the United Nations which shall ensure the protection of water and the human right for enough water.

A forward-thinking, comprehensive and globally oriented policy is required to avoid a global water crisis, with the aim to reduce hunger and thirst and to contribute to the preservation of peace. Trans-boundary water resources have to be shared in partnership and co-operation so that they can be used by all the neighbours. If necessary, the United Nations should supervise these agreements and their implementation. The risk of armed conflicts needs to be reduced since they cannot lead to long-term solutions of the water problems.

The aim of this book is to contribute to the public discussion on our relations and dealings with water. It shall also shape the public opinion towards an integrated view on water and the necessity to ensure enough water for coming generations. The broad range of water related topics and the limited extent of this book made it necessary to focus on selected water issues and to concentrate on basic aspects in many of the contributions. For a deeper analysis we recommend more in-depth literature, such as UNESCO (2003): *Water for People – Water for Life* (576 pp.) and WBGU (1998): *World in Transition – Ways Towards Sustainable Management of Freshwater Resources* (392 pp.).

Chapter 1 of this book highlights the importance of water from different views. *Chapter 2* is occupied with water use and the impact of humankind on the water budget. Aspects of climate induced changes of the water cycle are treated in *Chapter 3*. This book does however not only deal with the current water situation and the threat of an upcoming water crisis. Hence, *Chapter 4* includes a comprehensive discussion of recommendations and political measures for the solution of the actual and future water problems. It includes sensitive topics such as »Privatisation and liberalisation of water resources management« as well as »Human right for sufficient water« which are discussed from different viewpoints.

We are very grateful to the 118 authors of the different contributions, especially for the delivery of their manuscripts within due time. We would also like to express our thanks to the reviewers for their critical perusal of the texts and for the numerous suggestions. We are thankful to the GEO Magazine (Hamburg) for its support with editing and distributing of this book.

The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as well as the Ministry for Research and Education (BMFT), University of Hamburg, Max Planck Institute for Meteorology, Potsdam-Institute for Climate Impact Research (PIK), Heinrich Böll Foundation, Centre for Environmental Systems Research (University of Kassel), supported us in our efforts to distribute the present book to a wide readership. Thanks a lot to all of them.

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