Technical Report No. 17

PRELIMINARY SPATIALLY EXPLICIT ESTIMATES OF PAST AND PRESENT DOMESTIC WATER USE

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Contents

1. Introduction

In many countries, current levels of water use are unsustainable, with systems vulnerable to collapse from even small changes in water availability. Water availability and water demands are already heavily outbalanced as a result of natural and socio-economic variability. This situation and will become worse with global increases in consumptive water use over the next 20-50 years (Cosgrove & Rijsberman 2002; Kabat & van Schaik 2003; Vorösmarty et al. 2000). Water use has almost tripled over the past 50 years with growing wealth and population. This increase gives rise to shortages and conflicts between water use for the needs of humans and for the wider environment.

The need for a scientifically-based assessment of the potential impacts on water resources of future changes, as a basis for society to adapt to such changes, is strong for most parts of the world. Although the focus of such assessments has tended to be climate change, socio-economic changes can have as significant an impact on water availability across the main use sectors i.e. domestic, industrial, energy, agricultural and environmental.

WATCH will provide new insights into the inter-relationships between water, climate change, and the anthropogenic pressures upon global water systems. This report aims to describe trends in water use in the domestic sector over recent decades. It should be used to provide an indicative picture of domestic water use on global scale.

Water demand is basically a function of population dynamics (size and income) and land use. Studies of household water use have confirmed that consumption and vulnerability of people to the availability of water varies significantly between income and age groups. It follows that global water assessments can be improved by taking into account all occurring spatial and temporal differences. As a consequence a new spatially detailed global database of domestic water use was developed with stratification by rural/urban sectors and GDP per capita.

The WATCH project

The Integrated Project WATCH will bring together the hydrological, water resources and climate communities to analyse, quantify and predict the components of the current and future global water cycles and related water resources states. This will lead to the development and synthesis of consistent global long-term scenarios of changes in population, urbanisation, economic growth, land use and cover, and water use. A major aspect of freshwater resources is the water use within different sectors. Here we aim to give an overview of past and present water consumed in the domestic sector. This can be seen as the basis for future trends in domestic water use which will be described in another report.

2. Concept of the modelling approach

The WaterGAP model consists of two main components, a Global Water Use model and a Global Hydrology model. The Water Use model takes into account basic socio-economic factors that lead to domestic, industrial (split into the sectors manufacturing and energy) and agricultural (irrigation and livestock) water use. In the following sections, calculations focus on the presentation of total past and present domestic water use.
The domestic sector includes household use, small businesses and other municipal uses, which take high quality water directly from the municipal pipelines when it is available.
The basic approach is to compute the water use intensity (per unit use of water) and to multiply this by the driving forces of water use (in this case the total number of people living in a country). Two main concepts are used for modelling the change in water use intensity in the domestic sector, e.g. structural and technological change. This concept is demonstrated in figure 1.

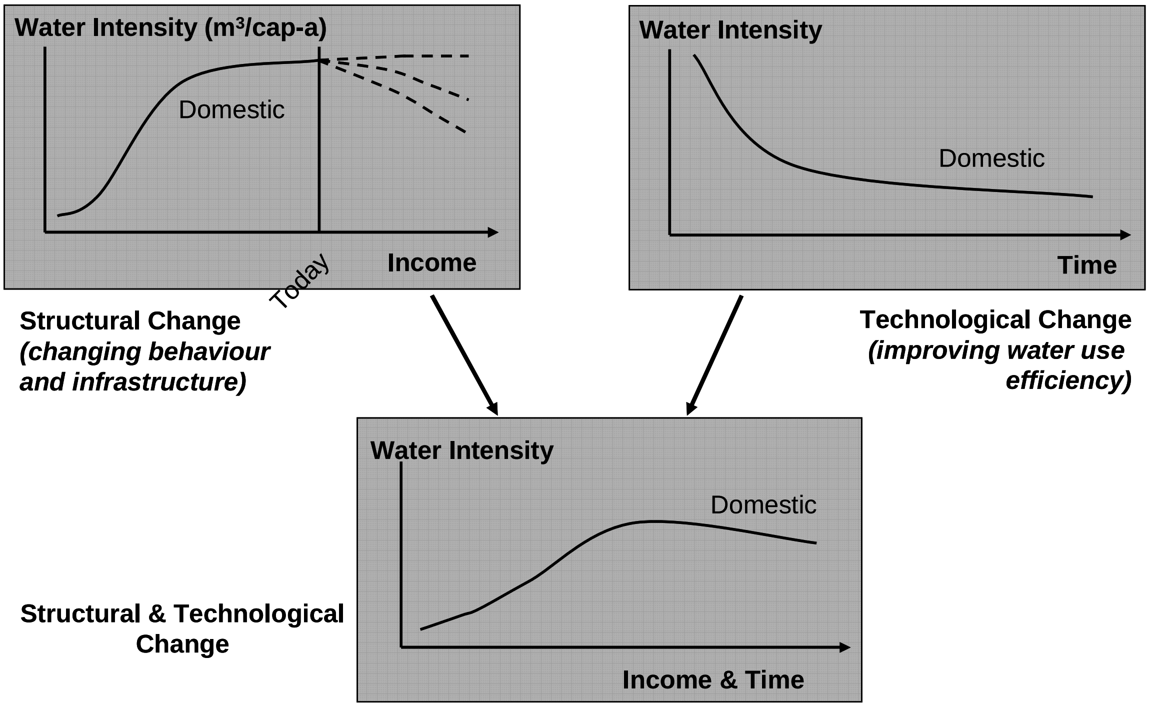

Figure 1: Main concepts of modelling the change in water use intensity in the domestic sector.

In the domestic water use model first the domestic water intensity (m^3/cap-year) is computed which is then multiplied by population of water users. Changes in water use intensity are expressed by structural and technological changes (Alcamo et al. 2003, Flörke and Alcamo, 2004).
The concept of structural change is a combination of water-using activities and habits. It is based on the observation that as average income increases, water consumers tend at first towards a more water-intensive lifestyle. Finally a maximum level is reached after per capita water use is either stable or declines. This structural change is represented by a sigmoid curve (baseline) which indicates how water use intensity (per capita water use) changes with income (GDP per capita). The relationship between water use intensity and income is derived for each country by fitting a sigmoid curve to historical data from each country. Data for these curves come mainly from national statistics or reports, covering up to forty years in the past.

While structural changes either increase or decrease water intensity, technological changes almost always lead to improvements in the efficiency of water use and hence to a decrease in water intensity. Within the model technological changes are taken into account since 1980.
The net water intensity can be computed by combining technological and structural changes (see also lower graph in figure 1).
For the time period 1960 to 2002, the annual domestic water use intensities per country are calculated following the country's baseline and then multiplied by the population. The economic data come primarily from the World Bank's World Development Indicators, but is filled in with data from various other sources as needed, including the CIA's World Factbook and Angus Maddison "Historical Statistics for the World Economy". The population numbers for countries come from the World Bank's World Development Indicators also, and from the United Nation's Population Division 2004 revision. Country-wide values are allocated to grid cells within the country based on the geo-referenced historical population density maps as part of the History Database of the Global Environment (HYDE, version 3), 5 x 5 arc minutes resolution (Klein Goldewijk, 2005). Annual values for the 1900 to 1959 time period are calculated by multiplying the water use intensity from 1960 by the gridded population data from HYDE.

Regional breakdown

Water withdrawals in the domestic sector are obtained on national scale first. For this study we calculated data for 176 countries all over the world. Countries are specified by the ISO 3166-1 standard (see also http://www.iso.org/iso/country_codes.htm). The information on water use provided here is generally summarised on a regional level in order to provide an appropriate amount of information. The regional groupings are based on the world regions defined in the GEO4-Report (UNEP 2007) and are listed in Table 1. The extent of these regions can be seen in Figure 2.

Table 1: Regional grouping within this study.

Region	SubRegion	
AFRICA (AFR)	Northern Africa	1
	Central Africa	2
	Western Africa	3
	Western Indian Ocean	4
	Eastern Africa	5
	Southern Africa	6
ASIA AND THE PACIFIC (ASP)	South Asia	7
	South East Asia	8
	North West Pacific and East Asia	9
	Central Asia	10
	Australia and New Zealand	11
	South Pacific	12
EUROPE (EUR)	Western Europe	13
	Central Europe	14
	Eastern Europe	15
LATIN AMERICA AND THE CARIBBEAN (LAC)	Caribbean	16
	Meso-America	17
	South America	18
NORTH AMERICA (NAM)	North America	19
WEST ASIA (WAS)	Arabian Peninsula	20
	Mashriq	21

However the detailed relationships between drivers and domestic water use are generally spoken only valid at national scales. Explicit spatially distributed values are derived from population density maps based on the gridded population data from HYDE.

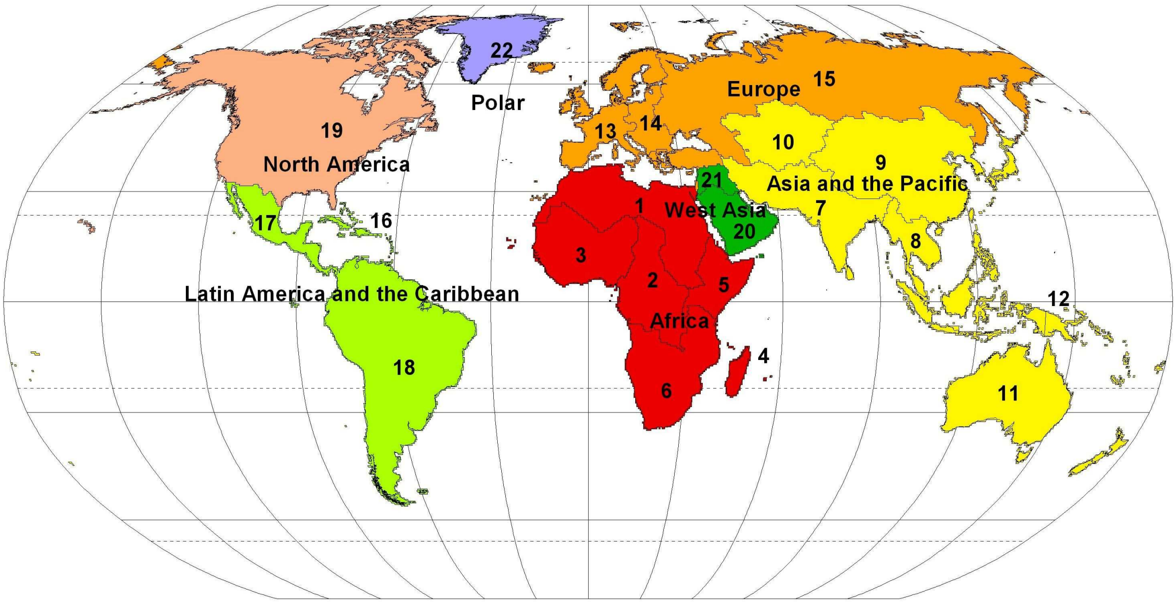

Figure 2: Map of defined regions and sub-regions (displayed as numbers; see Table 1).

3. Main drivers for domestic water use

Drivers for change are often of a long term nature. For instance, behavioural change is likely to take time to be fully achieved (e.g. by households to reduce water use). Individual driving forces and pressures may each decrease or increase water demands in the future.
All of the driving forces influencing the dynamics of domestic water use relate to socio-economic developments, such as population and economic growth which may lead to increased water withdrawals and wastewater discharges and technological developments which may reduce water use due to increased water efficiency.

This section presents the principal drivers of domestic water use, and illustrates how they have changed over past decades, to help explain the changes within the domestic water use sector. Here we want to focus on:

- Population
- Economic growth
- Technological change

All driver information is presented on a regional level to provide a better insight into general changes between world regions for the years 1960-2002.

Population

Within the domestic sector, water use is directly proportional to population, normally standardised as per capita water use. Recent changes in population within the regional breakdown (Figure 3) are described in this section as a background to changes in domestic water use.

For the period 1900 to 1959 the gridded population comes directly from the HYDE database and not from national statistics. Gridded historical population for this time span is available for a decennial period at a time. Therefore we will just show the development in population growth for the period between 1960 and 2002.
In total the population within the six world regions listed in Table 1 has risen, since 1960, from 3028.5 million to nearly 6196.6 million in 2002, with the majority of this increase in Africa (AFR) and in the Asian/Pacific region (ASP). In general there is a static trend of growing population in all regions, despite of some sub-regions where there also a decreasing trend can be detected in some years, particularly for North West Pacific and East Asia (23) in 1960/1961, in the Mashriq region (62) in 1989/1990, and in Central Asia (24) in 2001/2002 respectively. Even for Eastern Europe (33) the population has been declining since 1992.

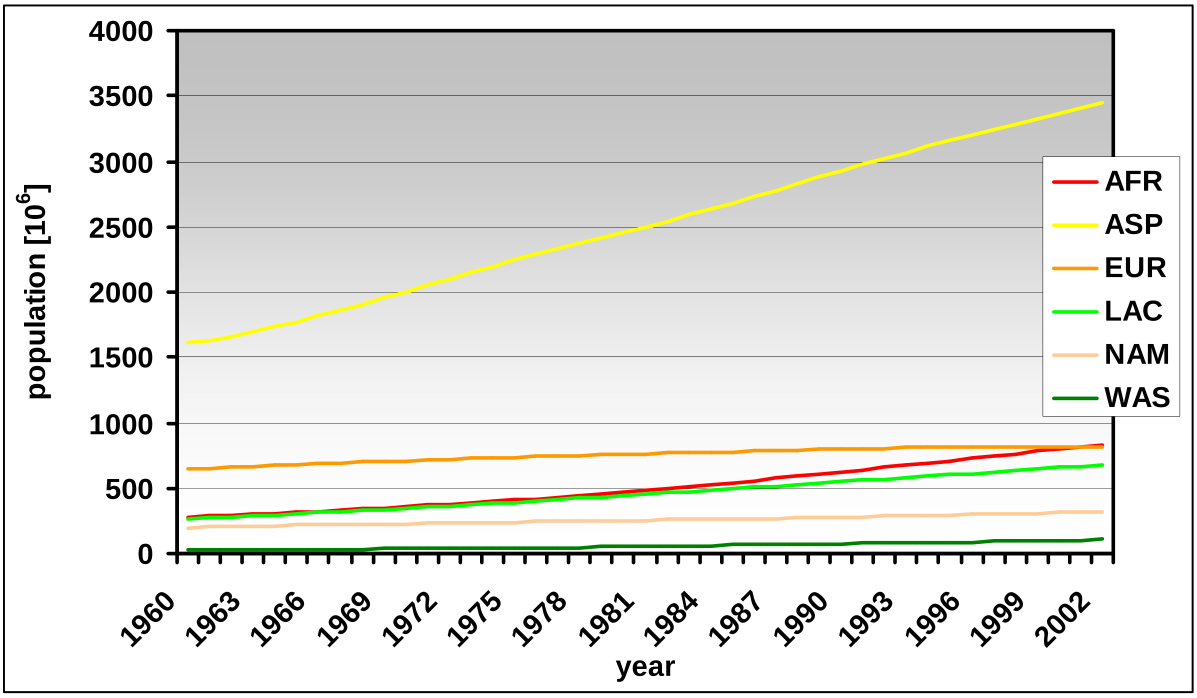

Figure 3: Population by regions (total numbers derived from the HYDE database).

Economic growth

In this study economic growth is expressed in terms of Gross Domestic Product (GDP). GDP is important for the modelling of water use, both as a directly and indirectly attributable driver:

- structural change is directly based on the average income;
- technological changes can be interpreted as an index of wealth and development within a country covering a range of factors that affect water use.

In Figure 4 recent developments in GDP per capita (upper chart) and total GDP (lower chart) within the world regions (see Table 1) are shown. GDP per capita has increased hugely since 1960 in most of the regions, e.g. more than tripled in the Asian/Pacific region (ASP) and more than doubled in Europe (EUR) and North America (NAM), although levels of income differ highly in these regions (ASP: 2640 US$ per capita; EUR: 11838 US$ per capita; NAM: 33726 US$ per capita). In Africa (AFR) and Latin America (LAC) almost the same level of increase of GDP per capita is observed (increasing factors of about 1.5 and 1.8 respectively concerning the time period from 1960 to 2002). Solely GDP per capita in Western Asia (WAS) has stabilised on the same level in 1960 and 2002 with a higher standard of income within the period 1971-1985.
Concerning the absolute values of GDP the factor of increase between the years 1960 and 2002 is in almost all regions of about 4, aside from the Asian/Pacific region where GDP more than octuplicated.

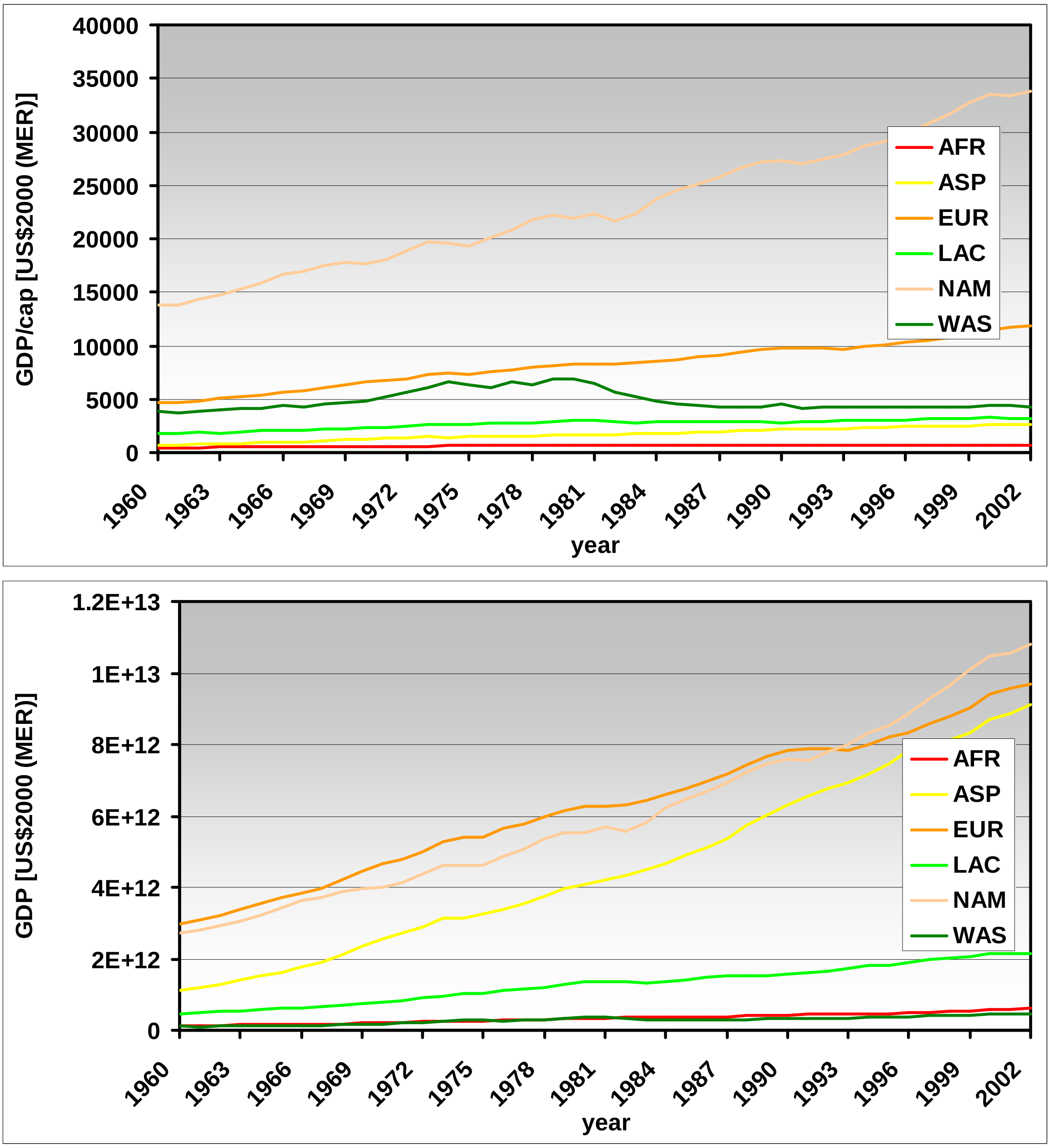

Figure 4: GDP per capita (upper graph) and total GDP (lower graph) by regions (values derived from World Bank's World Development Indicators).

Technological change

While structural changes either increase or decrease water intensity, technological changes almost always lead to improvements in the water use efficiency and decrease in water intensity.
GDP has a large effect on domestic water use intensity, e.g. allowing people to purchase and use washing machines, dishwashers, etc. This effect can be seen to peak when GDP reaches certain levels. At this point changes in water use can be heavily influenced by the market penetration of new technologies and policy/conservation programmes.
Therefore technological change is assumed to be different in different parts of the world. On national scale we separate countries in four different categories (definition of major areas and regions based on UN-classification [see: http://esa.un.org/unpp/definition.html]):

- more developed regions,
- less developed regions,
- least developed regions, and
- more developed regions with a lower rate of technological change.

Each of these categories was assigned a rate of technological change in terms of a percent change of water use intensities from year to year, which is listed in Table 2.

Table 2: Rate of technological change depending on the degree of development.

stage of development	rate of technological change
more developed regions	2
less developed regions	1
least developed countries	0.5
more developed regions with lower rate of change	1

The regional pattern of this assignment is outlined in Figure 5.

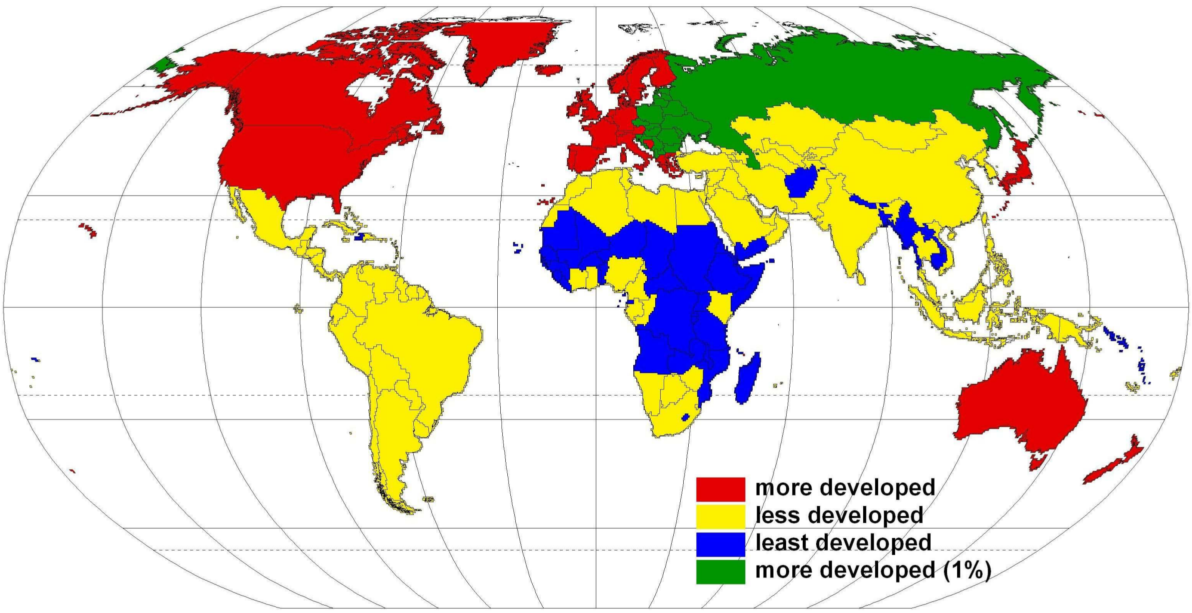

Figure 5: Rates of technological change by countries.

4. Trends in past and current domestic water use

This report aims to describe general trends in domestic water use over recent decades. It provides an indicative picture of different levels of water use across the global scale.
The domestic water sector comprises approximately ~10% of total water use on the global scale (Source: FAO. 2006. AQUASTAT database. http://www.fao.org/ag/aquastat). Trends in past and current domestic water use and water use intensities are shown in Figure 6. For water use intensities the time period from 1960 to 2002 is chosen, whereas for the domestic water uses data for the whole century is given (1900-2002).
Domestic water use is driven by population and GDP. Whilst population levels have been growing fairly slowly in Europe (EUR) and North America (NAM), water use intensities are highest in these regions (see Figure 6), and hence the total amount of domestic water use is also very high. Even higher values for total amount of water used in the domestic sector were obtained for the Asia/Pacific region (ASP). In the Asia/Pacific region (ASP), as well as in Africa (AFR) and Latin America (LAC) populations have been rising at high level, and were likely to produce huge increases in population over the past decades. Although the increase in water use intensity was likely to be small in countries within these regions, the total amount of domestic water use rose tremendously simply as a consequence of high population increase.
In countries with high GDP water use in the domestic sector is generally high in terms of absolute values (e.g. ASP, EUR, NAM). Wherever new water using technologies had lower levels of usage (e.g. LAC, ASP, AFR) total water use in the domestic sector increased with highest rates. In more developed countries, like in EUR, where high rates of technological change since 1980 were applied, even a decrease in water use could be observed. In total the amount of water used in the domestic sector increased from 76.9 km^3/year in 1900 to 349.9 km^3/year in 2002.
All the domestic water use values were calculated on national scale first. To get gridded values the national numbers were allocated on grid scale level according to the gridded population numbers based on the HYDE data.

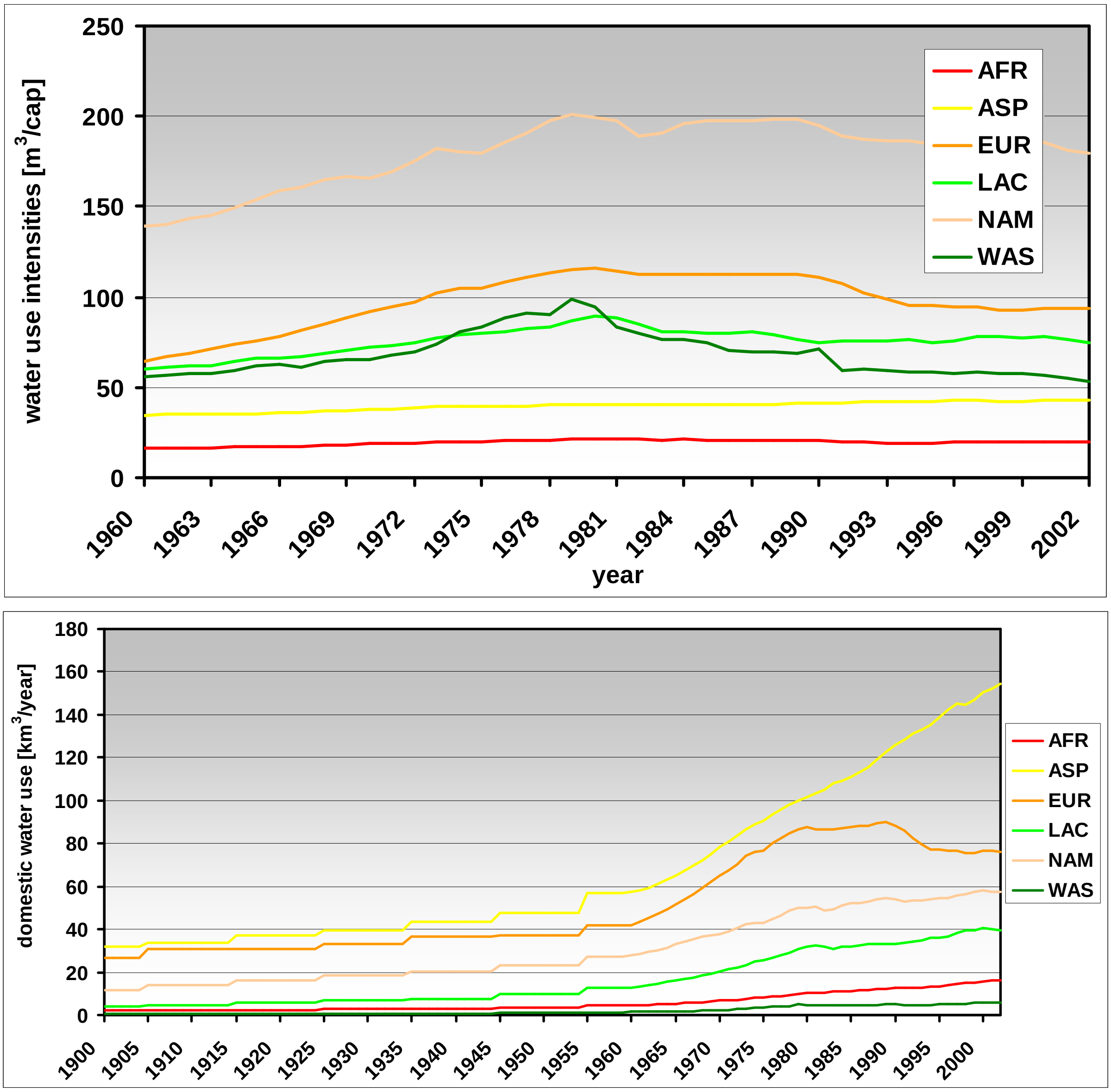

Figure 6: Domestic water use (in km³/year; lower panel; 1900-2002) and water use intensities in the domestic sector (in m³/cap; upper panel; 1960-2002) by region.

5. Conclusions and outlook

In this study preliminary estimates of past and present domestic water use were presented. The specific aim of this paper was to provide background information on the new global database of spatially explicit numbers of domestic water use. It provides an indicative picture of water use in the domestic sector across all continents.

Domestic water use is driven by population and GDP and calculated on national scale. Gridded numbers according to the allocation of land and sea cells used within WATCH were derived with stratification by rural/urban population based on population numbers within the HYDE database.

On a global scale, the amount of water used for domestic services increased from 76.9 km^3/year in 1900 to 349.9 km^3/year in 2002. In countries with high GDP water use in the domestic sector was generally high (NAM, ASP, EUR). In addition domestic water use rose tremendously as a consequence of high population increase (AFR, ASP, LAC). In contrast water use decreased in countries where new water using technologies have been applied (i.e. countries in EUR).
Although in many countries the current level of domestic water use is very small relative to other sectors, there will no doubt about an increase in competition of scarce water resources amongst sectors, and this is likely to remain so in future.

Domestic water use was calculated on national scale. To get gridded values the national numbers were downscaled and allocated to grid scale level according to the gridded population numbers based on the HYDE data. This data set of preliminary spatially explicit estimates of past and present domestic water use will be made available via the WATCH ftp-site.

Next steps

The specification and quantification of the key issues and driving forces that underpin the development of the future scenarios not only in the domestic sector are central to the next steps to be undertaken in the WATCH project. This involves an ongoing review of changes in general socio-economic variables, key sector policies that influence water use, economic growth and planned investment linked to existing water regulation, as well as assessment of how important water is to the economy and socio-economic development of the basin, and investigation of likely trade-offs between socio-economic development and water protection.
Scenarios of domestic water use will be formulated on the basis of current trends and projected economic development, and forecasted population distributions and urbanisation trends. Here we cooperate closely with other EU project (SCENES), and build extensively on other recent international scenario exercises e.g. IPCC, Millennium Assessment, and UNEP – Global Environmental Outlook.

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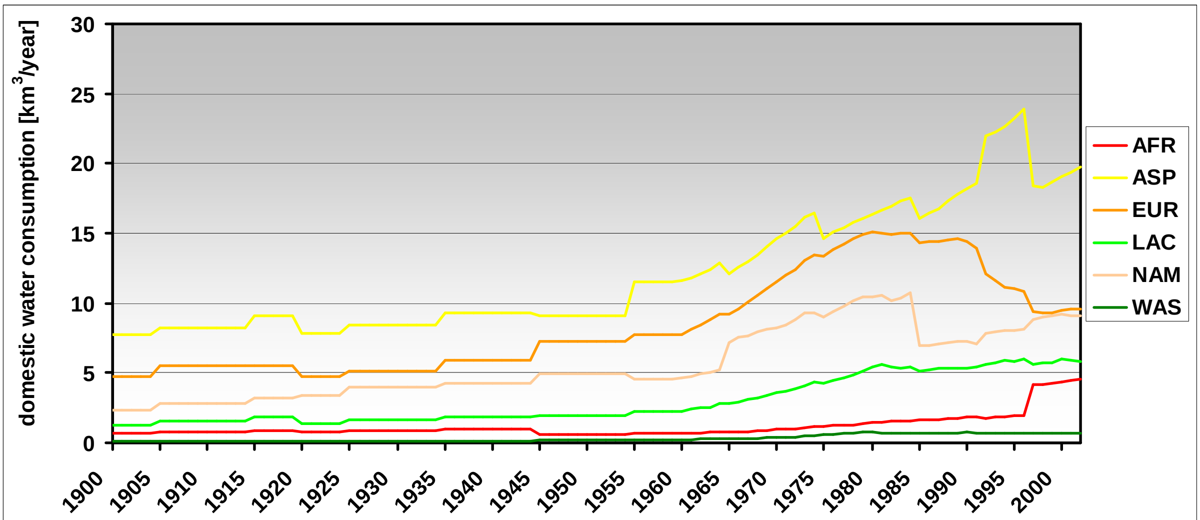
Appendix A: Domestic water use – withdrawals vs. consumption

The domestic water use model calculates the annual withdrawals and consumption of water by households and small businesses. In this context 'domestic water withdrawals' means the potential amount of water that would be withdrawn from available water resources to fulfil demands from the domestic sector. Whenever the term 'domestic water use' is mentioned in this report, it is meant to be the 'domestic water withdrawals'. But due to return flows into the water cycle, this is not the amount of water which would lead to water losses in water availability. This is subsumed in the term 'domestic water consumption'. Domestic water consumption is the real amount of water which is finally substracted from natural water availability.
But it is straight forward to calculate the domestic water consumption (DWC) on the basis of domestic water withdrawals (DWW). In the WaterGAP model this is computed just by applying a factor (fac_{DOM}):

$$DWC = fac_{DOM} * DWW$$

Basic principles for this factor are based on work of Shiklomanov (Shiklomanov 1997; Shiklomanov 2000; see also: http://webworld.unesco.org/water/ihp/db/shiklomanov/part'3/_Read'me.html). Herein 26 regions were defined to have unique values for fac_{DOM}. This factor is not constant all over the past century but varies with time. Following time periods were considered in which fac_{DOM} has unique values for the 26 regions: 1900-1919, 1920-1944, 1945-1954, 1955-1964, 1965-1974, 1975-1984, 1985-1991, 1992-1996, 1997-2002. Values ranges from 0.05 to 0.81.
In addition to Figure 6 the domestic water consumption for the whole period 1900 to 2002 is given in Figure 7. On global scale, the amount of water used for domestic water consumption increased from 16.9 km^3/year in 1900 to 49.5 km^3/year in 2002.



	1900	2002
domestic water withdrawals	76.89	349.86
domestic water consumption	16.90	49.48

Figure 7: Domestic water consumption (in km^3/year; 1900-2002) by regions.