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Water issues and indicator inventory

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Water issues and indicator inventory

A study on indicators for use in political science research on institutions and environment

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Summary

Water is a resource of fundamental importance for human well-being. However, the water resource is constantly exposed for pressures resulting from factors like human activities and population growth. A number of water issues have emerged of which one is water scarcity. Societal institutions, for example through governments, authorities or international cooperation, take action to mitigate the environmental impacts and ensure human well-being. This leads to questions of how different institutional arrangements correlate with changes in availability of water.

The purpose of this study is to identify a set of indicators related to relevant human and environmental aspects of water, which can be used as dependent variables in statistical studies of societal institutional arrangements.

The study was carried out mainly through a survey of water related literature, projects of international water programmes and research institutes and various databases for water related parameters.

The report gives a background to and an overview of a number of water issues. Human and environmental aspects related to the water cycle, briefly covering its function in nature and as a provider of ecosystem services, form the backbone of the inventory.

The main result is a recommended set of indicators and their data availability. Another set of tentative indicators are included in an appendix.

The report is the result of a project commissioned by the Department of Political Science at Gothenburg University.

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Introduction

It is well-known that human activities, like industry, mining, agriculture, forestry and other forms of land-use might degrade the environment and endanger the future of ecosystem services in various ways. The performance of societal institutions might indirect affect the environment due to the institution’s influence on human activities, both in terms of feed-back (diminishing, constricting) and feed-forward (enhancing, stimulating) control.
The links between the performance of societal institutions and environmental characteristics become key when construction of institutions for reaching certain (environmental) purposes is taken to the political agenda. Knowledge about these links can be reached through empirical studies using multivariate statistical methods provided that many independent representations (indicator values) can be established for many different aspects of institutions and the environment across a large number of different cases (so called *large-n studies*).
This report aim at the identification of a set of indicators related to relevant environmental aspects of “water”, which can be used as dependent variables in such statistical studies of societal institutional arrangements. The report also provides information related to the water cycle, and its function in nature and as a provider of ecosystem services, in order to give some background to the recommended choice of indicators which have bearing on the many issues related to water.

Background

In order to come up with recommendations on relevant indicators for describing water issues a background is given. This is done by first defining water and its use on the background of the growing attention to water’s fundamental role for human well being and functions in ecosystems (Falkenmark M 2005; WHO 2005; WRI 2005). Firstly indicating water issues is a particularly difficult undertaking since issues related to water have many dimensions which is related tp its availability as a natural resource, its use in society and its essential role in ecosystems.
The hydrological cycle is a major feature of Earth, and a necessary prerequisite for life in the forms we know it. The basic functions of water are related to its fundamental physico-chemical properties and the abundance of water. Our planet is covered by water to about two thirds. The properties of this watery environment is much related to the functions of water as a temperature regulator, a solvent for a large number of substances and a way of transport for all that can be moved in or on water. The different functions of water with regard to different forms of life are very varied. Life has evolved for about 3,5 billion years on the planet and is adapted to various extreme conditions, but despite this life completely without water is not known.
Human aspects of water are likewise very varied. Water is a necessary part of our daily intake. We consist of around 70% water which is in a flux moving into or out of our bodies. Water is also used for many purposes in the human society. Human water-use is adapted to the local conditions and the use is to be seen as a deflection of water in the hydrological cycle, from which it is taken, and also to which it is finally restored after use.
Water is a flowing resource meaning that the momentous resource is limited at a particular place but that it can be extended over long periods of time, often with a time dependent variation in flow.
Since water is such a fundamental constituent of nature and human societies, strong human interests are related to its use, amount and distribution. Therefore representing and indicating

various aspects of the hydrological cycle and human water use have since long been a human undertaking and since human interests in the various aspects of the hydrological cycle also indicators reflect this multidimensional character. To rightly assess the water resource and to increase the ability for a wise water resource management there has been efforts made on the global level, mainly during the past 10 years, through the United Nations and its sub-organisations like WHO as well as on regional and national level, for example through the European Union (WHO 2000; UN 2001). The choice of indicators to describe the use of water will relate to this development.

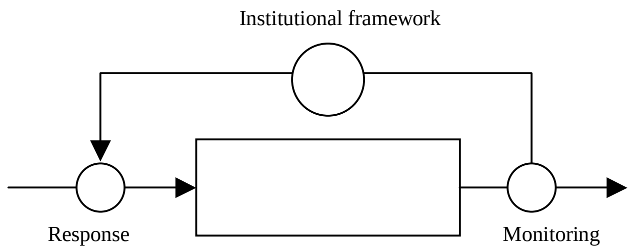

Figure 1 Simplified picture of societal control of a general activity where e.g. water is handled.

Society usually chooses to monitor the water use and its effects and then takes action to address perceived problems. An idealized picture of the water use is a metaphor with a system of management of the water resource, society's monitoring of effects on the surroundings and the controlling feedback-mechanism resulting in responses that are created to attend to undesirable effects, as is shown in Figure 1. To find relevant variables for monitoring might at first seem a simple task, but the water issues are complex. For example, there are at one level the biological functions of water, carrying out chemical reactions in aquatic ecosystems. At the same time and at another level there are social aspects, which in practice can be seen as ruling the choice of water source, quality of water and consumption pattern. At another analytical level, cultural differences in the perception of water use and availability may directly cause damage if a technology for water extraction and irrigation is exported to another place without adaptation to the constraints posed by the particular ecosystem, culture, and hydrological conditions.

Since the water issue cannot be reduced to, for example withdrawals of available volumes and resulting pollution, it follows that a good description of the water resource and its use has to take on different perspectives. One example is water's essential role for the ecosystem to continuously provide services. Also water is equally important for many technical systems to provide desired services. Services in socio-technical and ecosystems include, among many others, the provision of drinking water, water for hygiene purpose and food. Thus systems need water of certain amounts but also certain qualities to fulfil the needs for the human being.

The water cycle and the fundamental role of water in the global life support system

The water cycle (or the hydrological cycle) is the movement of water between the different parts of earth in its different forms and through the broader biophysical environment. According to Falkenmark & Rockström (2005) a useful way of describing the movement of water can be done by categorizing the cyclic flowing water into “green water” and “blue water”. The notion ”green water flow” aims at describing the biologically productive flow of water from the precipitation through the transpiration of plants when they grows, and the non-productive process of evaporation directly from the soil. “Blue water”, in turn, is formed by the surface or subsurface runoff formed from precipitation and the blue water flow continue as it enters watercourses and wetlands and lakes. The blue water flow also includes the water flowing underground to recharge water tables and aquifers (Falkenmark M 2005). It follows that while blue water can be reused several times during its journey to the sea, while green water is lost from the water budget once it has passed through the stages of evaporation or transpiration.

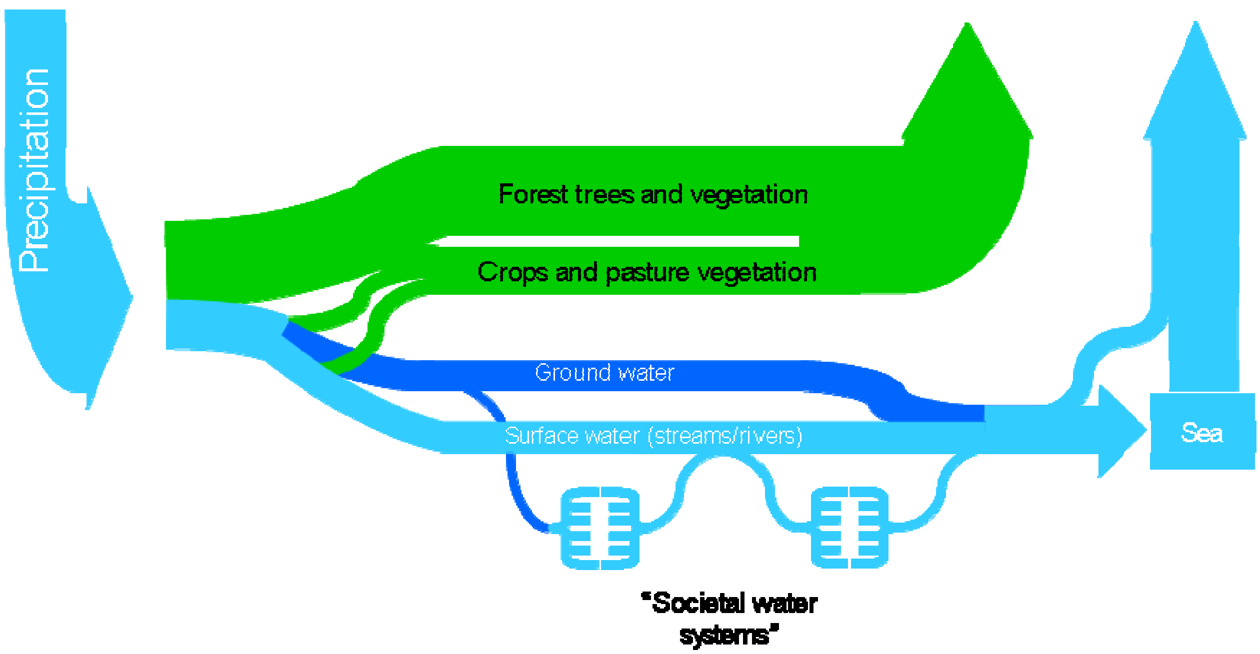

Figure 2 Schematic representation of the water flow through society and ecosystems that provides goods and services to human society.

Throughout the water cycle, water has different roles and performs a variety of functions. The balancing roles and functions includes physical processes where the interaction of evaporation and condensation is affecting the distribution of energy around the planet, chemical processes with the interaction between crystallization and dissolution which is important for the distribution of soluble substances around the planet and biological processes where the splitting of water molecules is the first step of the photosynthetic process (Falkenmark M

2005). This means that there is a dynamic interaction between the water cycle and the roles and functions of water in the ecosystems. One example is when hydrological conditions (the aquatic ecosystems) in wetlands affect abiotic factors that in turn determine the biota, which is established in the wetland. The biota in turn determines the hydrology and other physicochemical features of the wetland in a cyclical feed-back (Falkenmark M 2005). In this way water plays a fundamental role and a description of water and the use of water needs to "take off" from this point.

Water issues

"Water issues" stems from the fact that human society and the ecosystems share the same limited flow of water. There are links between the cyclic movement of water, society and the ecosystems. For example, the blue water that is used directly by society serves many functions. It is the source of drinking water, directly or after purification processes, of water in industrial processes or for hygiene and irrigation purposes. The blue water, which passes an aquatic ecosystem, has received its properties during its path through the biophysical environment. After use, the properties of the blue water have once again changed, for example through pollution, which is an addition of "unwanted" substances to the water. Hence, the society is affecting the aquatic ecosystems, which in turn affects the society located downstream since water might be reused. Another example is the way society is affecting the green water flow, which mainly occurs through land-use changes and through agriculture where blue water can be transformed to green water as land is irrigated. The surface runoff used, through diversion of for example river water used is then transformed to evaporation and transpiration. At the same time severe consequences may occur downstream in the river's ecosystem.

From a human perspective rainfed agricultural production is turn the most important role for the green water, since rainfed food production stands for around 60-70 % of the total food production in the world (Falkenmark M 2005). Since water is a prerequisite for food production and food production is a necessary prerequisite for human life the definition of human water use also include the green flow of water maintaining agricultural plants. Green water is also essential for human well-being determining the ability for other non-agricultural terrestrial ecosystems to provide services. Blue water is equally important for aquatic ecosystems, ecosystem services provided by them and in the different sectoral uses in the human society.

Water availability

There is only a certain amount of water falling on land and water, the precipitation. After a full cycle the same amount returns to the atmosphere. The precipitation is in principle the only source of fresh water[1]. The annual amount of precipitation over land surfaces is on average 115150km^3, where the blue water flow counts for 42650 km^3 and the green water flow for 72500 km^3 (Falkenmark M 2005) .The partitioning of blue water into different flows (surface run-off, groundwater and various watercourses) is dependent on several factors, which are both biophysical and human in nature. Natural factors influencing the partitioning include the structure and actual wetness of soil, the slope of the landscape, its vegetation cover. Other

[1] A noteworthy exception is fresh water production through desalinisation processes ~~occuring~~occurring in a few special places where precipitation is extremely small and energy available at low cost.

influencing factors are the content of organic matter in the soil, which affects the water holding capacity, and water uptake of plants that influence the partitioning at the point where the water has past through the soil moisture and groundwater recharge start. Human activities which affects the surface and soil properties are land-use changes, agriculture and the construction of manmade artificial surfaces (mostly asphalt), which in turn affects the blue water and green water flows. On a catchment scale, land-use upstream will affect water availability downstream. While green water sustains all biomass growth, local blue water flows sustains wetlands and human water use in small catchments before the water reaches downstream areas. Thus, rainfall is the fundamental water resource that determines the available amount of water (Falkenmark M 2005). The human appropriation of green water (evapotranspiration) is 26% of the available water (UNESCO 2003).

According to Falkenmark and Rockström global blue water withdrawals were 3800 km^3 in 2000, with the most demanding human activity being irrigation, counting for 2500 km^3 (Falkenmark M 2005). The per capita need for water for food production is around $1200m^3$/year, to be compared with the domestic need, about 300 m^3/year. According to UNESCO the human freshwater withdrawal is 8% of the total amount, and the appropriation of accessible runoff 54%, respectively (UNESCO 2003). Here, freshwater together with runoff has been defined as blue water. The environmental need for water, water for sustained functions of aquatic ecosystem, the instream flow, is estimated to be 2350 km^3 per year (FAO 2002).

The increasing water scarcity has been noted by WHO (2005) which states that ”the availability of water per person has declined markedly in recent decades”. One third of the world's population now lives in countries experiencing moderate to high water stress[2]. Also the fraction countries that are experiencing water stress will continue to increase as both population size and per capita water demand are growing - reflecting the escalating use of fresh water for irrigated agriculture, livestock production, industry and the requirements of wealthier urban residents (WHO 2005). Moreover, the pollution of water is reducing usability of the fresh water resource even further. The rough estimate is that 12000 km^3 is more or less polluted. The poor are the worst affected, with 50% of the population in developing countries exposed to polluted water sources (UNESCO 2003)

The climate change may also have an affect on the availability of water, with temporal and spatial variations. UNESCO estimates that precipitation will probably increase from latitudes 30° and 30°S, but tropical and subtropical regions will get lower and more erratic rainfall. Extreme weather conditions, such as floods and droughts, will be more frequent. Stream flows at low-flow periods may decrease. There’s a risk of worsened water quality, because of increased pollution loads and concentrations and higher water temperature (UNESCO 2003).

Water in society and ecosystems

As pointed out above the total available flow of water is limited. Both humans and ecosystems, which provide various services to humans, share the same amount of water. Therefore a

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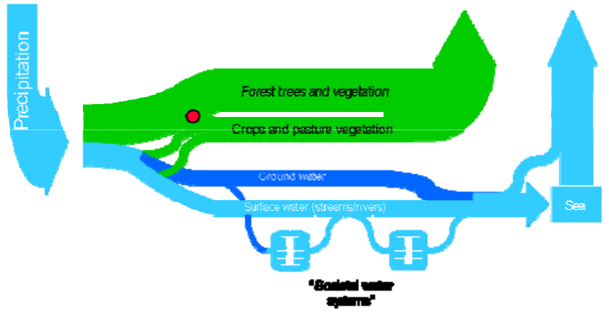
[2] Water stress occurs, using UNEP’ s definition, when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use.

rationale for an appropriate partitioning of the available water between various water dependent processes becomes necessary. In the following various aspects of the multi-facetted water issues are sketched together with a figure illustrating where in the hydrological cycle the particular issue is situated.

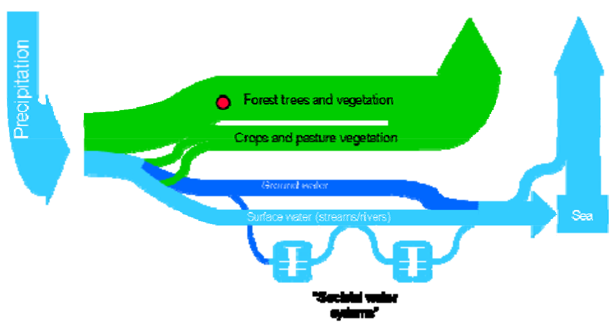
Green water in rainfed crop production



Rainfed crop production is an important part of the worlds total food production, but the possibilities for its application vary from region to region. About 95% of the agriculture is rainfed in Europe and sub-Saharan Africa, while half of the amount of blue water used for irrigation is used in paddy rice production primarily in Asia. Falkenmark and Rockström (2005) also suggest that there should be more attention on the green water use through rainfed agriculture. In many countries there is already a high and increasing pressure on the freshwater resources, so to include rainfed agriculture more in the discussions on water in food production would be a valuable step in the process of mitigating hunger.

Some problems associated with agriculture are the reduction of all outflows or "losses" (e.g. drainage, seepage and percolation), except for the productive use through crop transpiration. Furthermore it's a need for more effective use of rainfall, stored water, and water of marginal quality. Loss reduction and water control are considered parts of basin-wide integrated water resource management (IWRM), which gives an essential role to institutions and policies in ensuring that upstream interventions are not made at the expense of downstream water users (Falkenmark M 2005). The latter is occurring indirectly in rainfed crop production. The deforestation, which may be occurring to promote agriculture, also affects subsurface flows are and the ability of the tree canopies to hold moisture changes. In this way blue water and green water flows may be affected, directly and indirectly, through rainfed agriculture.

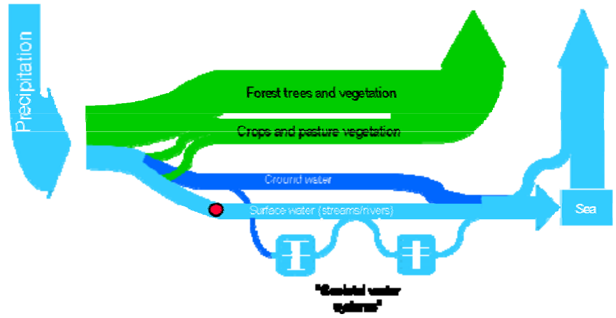
Green water in terrestrial ecosystems



The terrestrial ecosystems are represented by savannahs, steppes, forests and woodlands. On savannah and steppes, the non-productive loss of green water through evaporation is high, because of the low (30%) plant cover. Much of the precipitation does not pass through plants at all. Forest and woodlands have a higher water productivity, meaning that there's more yield of biomass per amount of water available through rainfall.

Trees and soil conditions influenced by tress also play an important role in the water cycle and in the landscape, serving as the point where rainfall partitioning occurs, determining whether rain infiltrates into the ground, is taken up by vegetation, recharges groundwater or forms rapid runoff. Therefore societal attention is many times oriented towards protective actions in upper catchments where groundwater is recharged. Forests are also feeding the atmosphere with water vapour, thereby influencing precipitation in neighbouring areas. Though, the role of forests for rainfall partitioning is subject to discussion (Falkenmark M 2005). Whereas in developing countries deforestation leads to reduced dry season flow, in temperate zones streamflow is known to increase with deforestation. Nevertheless, a recommended response with consideration to the green water's role in terrestrial ecosystems is the protection of upstream forests for a stable blue streamflow downstream (Falkenmark M 2005).

Blue water in aquatic ecosystems



Wetland ecosystems (including lakes, rivers, marshes, and coastal regions to a depth of 6 meters at low tide[3]) are estimated to cover more than 1,280 million hectares, an area 33% larger than the United States and 50 % larger than Brazil. However, this estimate is known to under-represent many wetland types, and further data are required for some geographic regions. More than 50% of specific types of wetlands in parts of North America, Europe, Australia, and New Zealand were destroyed during the twentieth century, and many others in many parts of the world are degraded. Ecosystem services, primarily relevant to the water resource and its availability, that contribute to human well-being includes,

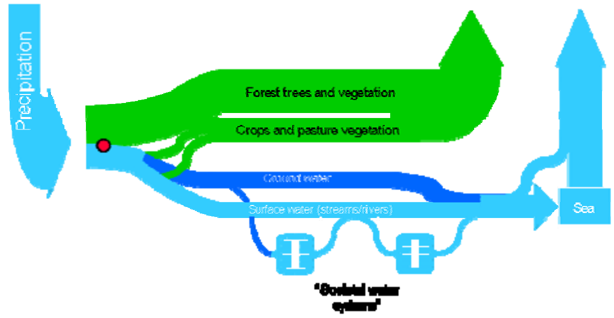
- water supply
- water purification, for example through denitrification processes
- climate regulation

In addition wetlands also provide services like food (fish and shellfish) and fibre, flood regulation, coastal zone protection, recreational opportunities and tourism (WRI 2005).

Problems associated with wetlands are the rapid degradation and loss of wetlands, which is more extensive than that of other ecosystems. Similarly, the status of both freshwater and coastal wetland species is deteriorating faster than those of other ecosystems. (WRI 2005) Since the physical and economic blue water scarcity and limited or reduced access to water, are major challenges facing society many water resource developments undertaken to increase access to water have not given adequate consideration to harmful trade-offs with other services provided by wetlands (WRI 2005). To add to the complexity, there is also established but incomplete evidence that changes being made in ecosystems are increasing the likelihood of nonlinear and potentially abrupt changes in ecosystems, with important consequences for human well-being (WRI 2005), pp 44) Among others Moberg and Falkenmark (Falkenmark M 2005; Moberg 2005) and others have described resilience as a factor indicating the increasing vulnerability of ecosystems.

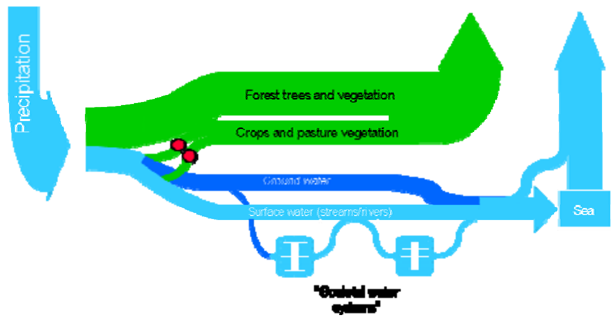
[3] Here we use the definition of wetlands used in Millennium Ecosystem Assessment 2005,

Blue water and terrestrial ecosystems



There are also other social and ecological aspects on water use, which relates to flooding. As touched upon above forests play an important role in the regulation of stream flow. In water dams, the longer the residence time is, the larger is the buffering capacity to attenuate peak flood events. Large rivers have greater attenuation capacity than smaller rivers. Nearly 2 billion people (in highly populated areas) live in areas with a residence time of one year or less and are thus in areas of high flood risk with low attenuation potential (WRI 2005).

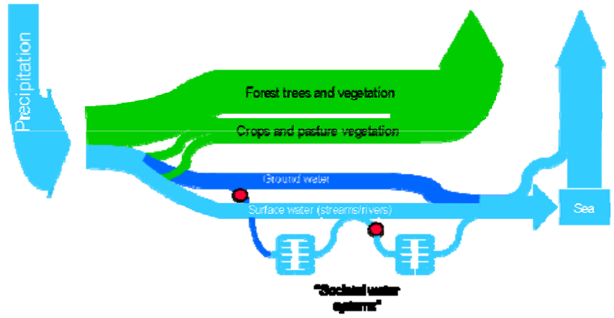
Blue water and irrigated agriculture



As mentioned earlier irrigated agriculture is the most blue water-demanding sector. Therefore attention has been paid to comparisons of blue water availability and human water needs or demands. However, in many countries in the world only a small fraction of the present human water use is supplied from a blue water resource (Falkenmark M 2005). This is due to a large dependence on rainfed agriculture in conjunction to a relatively limited use of blue water for industrial and other societal purposes.

Blue water for irrigation is gathered through collection and diversion of surface water and from groundwater extraction. This also includes the infrastructure of dams and channels needed for the diversion of water to the desired farming site. In the world 175 million hectares are irrigated by surface water and about 95 million hectares by groundwater. According to Ochs & Plusquelloc problems associated with irrigation are among others the overexploitation of ground water resources leading to falling water tables, and effects on downstream water quality and availability (Ochs Walter 2003). Ochs and Plusquellec also make the judgement that 40-50% of the worlds irrigated lands are associated with problems of waterlogging or salinization. The efficient use of water, with regard to minimization of losses through evaporation, leakage and percolation are other important aspects.
Another aspect is related to the measurement of important statistics. Since only freshwater withdrawals are measured, and not the use of green water, this doesn’t lead to an accurate representations of flows in the water budget.

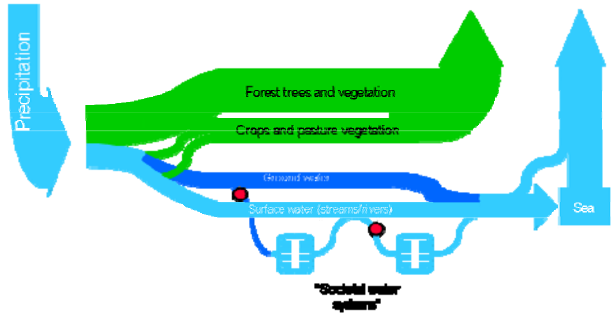
Blue water for the provision of safe drinking water and basic sanitation



The provision of a sustainable access to safe drinking water and basic sanitation is one among the Millenium Development Goals, set by the UN (UN 2005). This is already achieved in the developed world, but remains as a challenge for most developing countries. In 2000, 82% of the worlds population had access to an improved water resource, while 60% had access to basic sanitation (UNESCO 2003). Since both the world population and the per capita consumption are increasing, the pressures on the world's water resources are rising. The systems to provide water use for drinking water and basic sanitation are very different in scale and technology, ranging from a drilled well and a pit latrine in rural areas in developing countries to large and complex urban water systems in developed countries. The majority of the people without safe drinking water and basic sanitation live in Africa and Asia, about one-half of the people in Asia lack basic sanitation and two out of five people from Africa lack access to an improved water supply (UNESCO 2003). Thus water issues is very different from one region to another. While a step forward in developing country would be relatively small improvements financially, the issue in developed countries is totally different. The aged water infrastructure, the maintaining of large flows of water with high quality and increasing demands on the treated wastewater means high costs. Also the problem of wastewater is not only nutritient loads but also loads of hazardous substances, for example rests from medicines and urban run-off.

An urban water system means the provisioning of safe water which includes extraction of surface or ground water followed by purification processes to achieve desired water quality and sanitation meaning the treatment of outgoing wastewater. Today 48% of the world's population live in urban areas, with varying access to an urban water system (UNESCO 2003). In the urban water system, both the water purification and wastewater treatment process need chemicals and energy. After treatment the cleaner water is released to the nearest watercourse, thus joining the blue water flow again. Many times, at least in developed countries, the wastewater is mixed with faeces and urine, thus using water as transportation fluid. In Sweden, for example, water with high quality (drinking water) is used as transportation fluid in this way. This may be criticized since the use of water of high quality for such a low-value service may mean an inefficient use of resources. In addition the mixing of faeces and urine with wastewater and also storm water, means that the treatment process becomes more complex. The more and varied the components the more difficult and resource consuming the treatment process becomes.

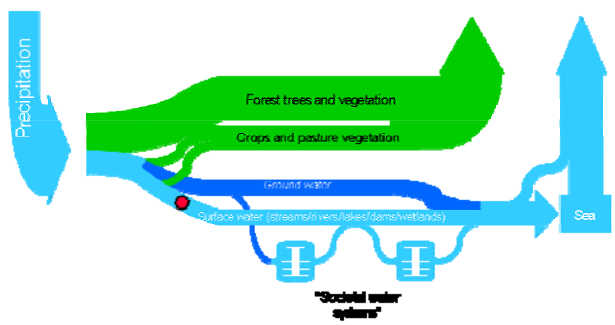
Blue water used in industrial processes



Water withdrawals for industrial purposes are very significant , and might be a threat to water resources. At the same time there's a great variety of services provided thanks to the functions of water in the industrial processes. One example is the Swedish pulp and paper industry, where water is part of practically the whole industrial process from the primary product tree until the paper is produced. Often the process is nearly closed, and water is recycled to a large extent and wastewater, which is released to the recipient, is treated at the site. With a global outlook this is not the case. Water discharged from industries may be of poor quality and may threaten the surface and groundwater resources. In Sweden the water withdrawals of the industry don't cause any drama, but globally an increasing industrial demand may have consequences also quantitatively. With a 20% share of the total blue water withdrawals and considering temporal and spatial variations in water availability, industrial water use becomes a factor to include also when considering amounts (UNESCO 2003).

In a shorter time perspective, the major threats from industry can be considered to be the pollutants. While there have been efforts mostly in the developed world to address these problems, the lack of proper wastewater treatment still makes pollution an issue in developing countries. Even in developed countries, it can be argued that there still exist problems, that the control of pollutions of chemical substances, other than nutrients, is not enough. Damages to water resources are not not only a local freshwater resource issue, but also an issue for coastal areas, on the background of both increasing population and industrial activities in coastal zones (UNESCO 2003).

Blue water and Hydropower



Hydroelectric power provided 19% of the worlds total electricity production in 2001. Only one third of the total sites deemed economically feasible have been developed. Hydropower has mainly been developed in developed countries with 70% of the electricity potential exploited while the degree of exploitation in developing countries is 15% (UNESCO 2003). Hydropower can be described as having a double role in relation to ecosystems. On one hand the use of electricity can replace the use of fuel wood, thus saving forest and woodlands, which in a longer perspective could result in less erosion. On the other hand dam constructions, at least larger ones, is creating multidimensional problems in and conflicts between upstream and downstream regions. The aquatic ecosystems in and around the river are greatly affected, through the varying stream flows and flood schemes, and subsurface flows changes. Regions downstream can expect very different conditions to sustain agriculture.

Water resources management

The growing attention to water's fundamental role for human well-being and ecosystem's functions, reflected through the beginning chapters here, is also the background to a changed approach in water management, towards an Integrated Water Resources Management (UNESCO 2003). There are several reasons for this, where one major reason is the need to consider the watershed as the management unit. Also, aquatic and terrestrial ecosystems don't respond to gradual change in a smooth and linear way. Rather a stressed ecosystem can suddenly shift from a seemingly steady state to an undesired state that is difficult to reverse. This together with the water use frames the challenge to co-manage water and water-dependent ecosystems (Moberg 2005).

Cross-sectoral and ecosystem-based approaches to wetland management — such as river (or lake or aquifer) basin-scale management, and integrated coastal zone management - that consider the trade-offs between different wetland ecosystem services are more likely to ensure sustainable development than many existing sectoral approaches and are critical in designing actions in support of the Millennium Development Goals (WRI 2005). Regarding policy: Many of the responses designed with a primary focus on wetlands and water resources will not be sustainable or sufficient unless other indirect and direct drivers of change are addressed. These include actions to eliminate production subsidies, intensification of agriculture, slow climate change, slow nutrient loading, correction of market failures (others than subsidies), encouragement of stakeholder participation, and increased transparency and accountability of government and private-sector decision-making.

Of particular importance is the fact that future decisions will have to address trade-offs between current uses of wetland resources and future uses. Particularly important trade-offs involve those between agricultural production and water quality, land use and biodiversity, water use and aquatic biodiversity, and current water use for irrigation and future agricultural production (WRI 2005).

Water issue indicators and institutions

The more specific purpose with this report is to identify indicators that can be of particular interest when trying to shed light on the outcome of institutional arrangements at different levels and in different countries with regard to water issues in a broad sense. In Figure 3 we have depicted our perception of the task, where the filled box represents a set of water issue indicators that fulfil certain criteria. One of which is to be used for multivariate statistical treatment in conjunction to a set of indicators representing institutional arrangements. Such indicators are out of the scope for this report but their existences are indicated by the double-headed arrow.

To meet the general need of, mostly formal, institutions (Figure 1), and in order be operative, and to have a broad acceptance, indicators have to address the water issues in several ways. So given the background above it is easy to conceive that there exist a huge number of different indicators that have been used for various ends in different countries. More recently indicators have been utilized on a global level in order to compare the status of water issues in different states. This opens for the possibility to compare national institutional arrangements with the status of water issues.

However, the development of indicators, and the spread of their use, is ongoing and there is no reason to assume that the present set of indicators is the final one. This development is represented by the dashed arrow in Figure 3. This development both includes the geographical spread of the use of a particular indicator and an increased frequency of use.

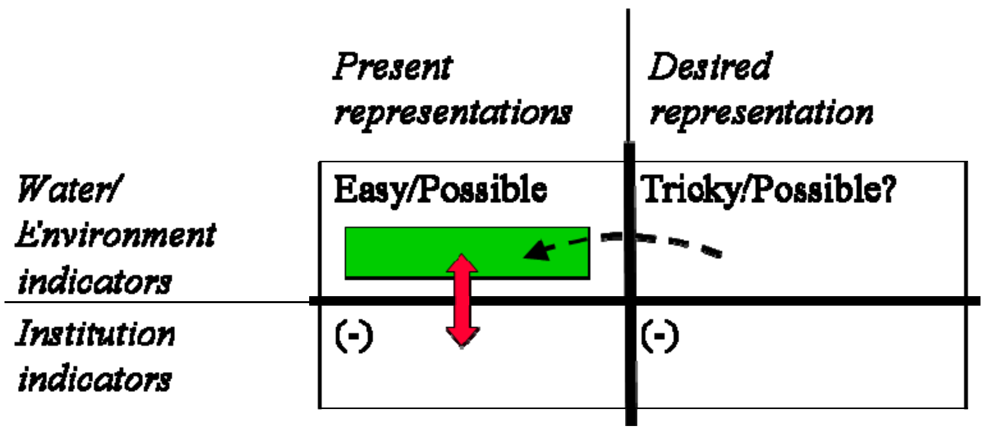


Figure 3 Framework for the identification water/environment indicators for use in political science research relating Quality of Government to water issues in a broad sense.

Searching for water issue indicators – organisations and databases

The search in databases for possible indicators of water issues was guided by an initial *ad hoc* indicator inventory based on earlier studies (see e.g. (Lundin, Molander et al. 1999; Palme, Lundin et al. 2005) and intensified through further literature and internet searching. The growing concern for water scarcity and a changing understanding of how the water resource should be managed has resulted in a number of efforts during the past decade to gather information regarding water. On European level European Environmental Agency, assesses the water resource by applying the DPSIR-model (see below) and European Environmental Agency (EEA) is also gathering data from the member countries of the European Union. While there are data available on the European level through EEA and OECD databases, the data availability on the global level is associated with large temporal and spatial variations.

On the global level some major projects (programmes) have been established in order to gather information. Some are related to United Nations and its sub-organisations like WHO, UNESCO and other through organisations like World Bank or institutes like Water Resources Institute (WRI). Through World Water Assessment Programme (WWAP) the UN has addressed problems associated with indicator development relating to water and also identified a range of indicators, of which some has been extracted to the table of possible indicators (see below). In the water sector specific challenges relating to indicator development includes the slow progress of the sector in adapting existing earth systems modelling data into water resource assessments (like green house warming impacts). There is also a poor understanding of drainage systems functions in relating to anthropogenic challenges in comparison to a good understanding of hydrology at the local scale (UNESCO 2003). Furthermore, the UN (through WWAP) concludes that there has been a decline in measuring stations and systems for hydrology, which limits good data acquisition. The resulting consequences is however relatively small, since new monitoring opportunities have developed. These include remote sensing, capabilities and capacity for computerized data analysis. For example, geospatial indicators of water stress can be assessed using Earth System Science data and GIS (Vörösmarty, Douglas et al. 2005). Some examples of rather developed global databases or global data centres are Global Environmental Monitoring System (GEMS), FAOSTAT, Global River Discharge Database, Famine Early Warning Systems Network, Global Groundwater Information System and Global Runoff Data Centre. There are also databases under development which orientation reflects the change of perspective occurring in water management. Some examples are the Eco-Hydrological Database and AQUASTAT. The complete set of used databases is shown in Table 1.

There is also a need for a broad set of socio-economic variables to quantify the use of water (UNESCO 2003). This could result in the indication of the relative water use (consumed water related to available water). However, estimates of global water withdrawals are rough which, at least on global level, makes good assessments difficult to achieve. Besides the measuring of geophysical and socio-economic data sets, there's also a need to include the geography of water supply, issues of technical capacity, population growth, levels of environmental protection and health services, and investments in water infrastructure in future analysis (UNESCO 2003). In WHO Joint Monitoring Programme (JMP), also indicators for investments in water infrastructure are included (WHO 2000).

Table 1 Major global and regional studies and databases related to water issues in general

Study/database	Organization	Spatial scope and resolution	Time period	Major parameters	Methodology
AQUASTAT (FAO 2006)	FAO	Global scope Global, regional, and national data	1958-1961, 1962-1965, etc. (various[4])	Water withdrawals, annual renewable freshwater resources, percentage of arable land irrigated etc.	International surveys, national statistics etc.
Earth Trends (WRI 2006)	WRI	Global National data	1980-2000	Industrial water pollution	Statistics, data from various sources. World Bank, WHO, national authorities etc.
FAOSTAT (FAO 2006)	FAO	Global National data	1961-2003 (various)	Crop yield, irrigated area, area arable land	Data provided by countries. Based on national surveys, national statistics etc.
FEWS NET (USGS 2006)	USGS	Regional scope National data	Various, 1970-now (various[5])	Crop yield, irrigated area	Data provided by member countries
Global Environmental Monitoring System (GEMS) (UNEP and WHO 1999)	UNEP	Global National/ Watershed level data	1979-1999	BOD, COD, nitrogen, faeces coliform etc	Physical measurements (raw data)
Global Reservoir and Lake Elevation Database (USDA-FAS 2006)	USDA-FAS	Global scope National data	1992-2003 historical, 2003- (various[6])	Water levels	Satellite imagery
Aral Sea Database (SIC-ICWC 2006)	SIC ICWC	Regional Scope, Watershed level data	1960-now	Lake area, quality parameters	Satellite imagery, maps, physical measurements
Joint Monitoring Programme (WHO 2000; WHO 2004; WHO 2006)	UN/ WHO	Global scope National data	1990, 2000, 2002	Urban Water Supply Coverage, Urban Sanitation Coverage etc.	Information reported from countries, historic data, surveys,
Weekly epidemiological record: cholera articles (WHO 1996)	UN/ WHO	Global scope National data	1996-now	Number of people with cholera, Number of deaths caused by cholera	National surveys, reported cases to WHO
World Water Resources and their Use (Shiklomanov 1999)	UNESCO-IHP	Global Regional, National data	1900, 1940, 1950, 1960, 1970, 1980, 1990, 1995	Water withdrawals, consumption, renewable water resources, irrigated area	Inventory of data from various sources. Other reports, studies, surveys.

[4] For most developing countries there is only data for two or three points in time, starting from around 1980. Data availability also varies with parameter.
[5] Data are only available for member countries, and availability varies in time.
[6] Data for some 100 lakes in the world >100km^2 which are important for agriculture.

Choice of indicators – the suggested indicator set

A developed set of indicators rely on two wide criteria. The first is related to the water issue relevance of the indicator and the second to data availability. The intention is not only to accept existing indicators, for example the ones that are used by WHO, as the only ones plausible. It is also the intention to make an attempt to point out indicators, which for example could be proxies to desirable indicators that may be needed to give a good representation of the broad water concept.

Relevance and categories

The intention here is to identify indicators that capture the broader environmental characteristics of water issue. Therefore chosen indicators have considered the water flow through the water cycle, the ecosystems and the human socio-technical systems (Figure 2). It has also been an intention to follow the identification of issues used in the chapter "Water in society and ecosystems".

Trying to generalize we can see two broad categories of indicators. First, indicators that aims for a capture of the present situation and trend regarding *quantity* and *quality*. Secondly, indicators focusing on *availability* (potential quantity) and *use*, often in relation to some specific management activity. However in Table 2, which contain the set of suggested indicators five categories are used:

- General indicators on water resources and water use
- Water and wastewater management
- Indirect effects of agriculture and other activities on water availability
- Parameters directly related to institutional/legal conditions
- Indicators where present water resource or socio-economic conditions may have had an impact on institutional type and condition

Positions of suggested indicators in the hydrological cycle are illustrated in Figure 4.

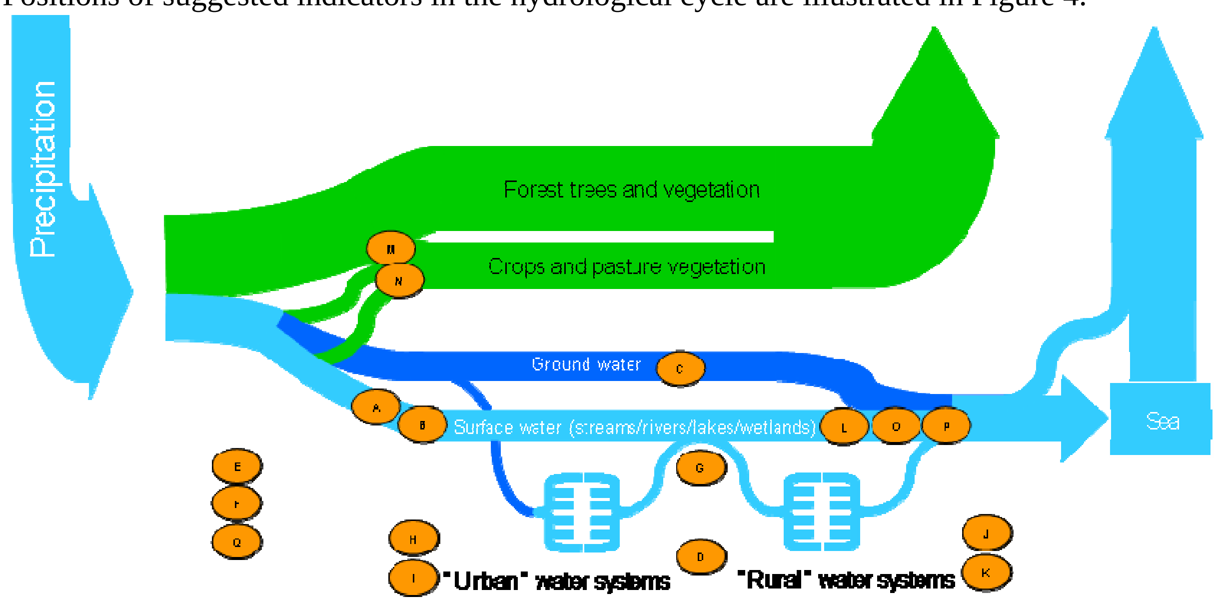


Figure 4 Positions of suggested indicators in the hydrological cycle. For indicator names see Table 2.

Table 2 Suggested indicators for evaluation of quality of governance (QoG) and sustainable development (SD) related to water and water use.

Category and indicator	Data availability	Relevance for SD and QoG	Main data sources
General indicators on water resources and water use			
A. Total lake area	Poor/Good[7]	Low/High	Aral Sea Database, World Lakes Database
B. Water level of reservoirs and lakes	Medium	Low/Medium	USDA/ GRLED
C. Groundwater reserves – water table	Poor/Medium?	High	Case studies, national assessments. Needs further research.
D. Water consumption	Good	Medium	FAO/ AQUASTAT
E. Water stress	Good	Medium	AQUASTAT, UNESCO-IHP[8]
Water and wastewater management			
F. Relative water use	Medium	Medium	FAO/ AQUASTAT, WRI/ EarthTrends
G. Waterborne diseases – Outbreaks of cholera	Poor/Medium	High	WHO/ Weekly Records
H. Urban Water Supply Coverage	Medium	High	WHO/ JMP
I. Urban Sanitation Coverage	Medium	High	WHO/ JMP
J. Rural Water Supply Coverage	Medium	High	WHO/ JMP
K. Rural Sanitation Coverage	Medium	High	WHO/ JMP
L. River water quality – Faeces coliform	Medium/Good	Medium/High	UNEP/ GEMS/Water
Indirect effects of agriculture and other activities on water availability			
M. Productive use of water in rainfed crop production	Poor /Medium	High	USGS/ FEWS NET, FAO
N. Water Use Efficiency in irrigated agriculture	Poor/Medium	High	USGS/ FEWS NET, FAO
Indicators directly related to institutional/legal conditions			
O. Water quality – BOD	Medium/Good	Medium/High	WRI, UNEP/ GEMSWater
P. Water quality – Nitrogen	Medium/Good	Medium/High	UNEP/ GEMS/Water
Indicators where present water resource or socio-economic conditions may have had an impact on institutional type and condition			
Q. Population size/Annual renewable water resource	Good	High	UNESCO/IHP[5]

[7] Availability of time-series data for area of lakes are low, except for special cases like the Aral Sea Basin. Thehe major data source for area of lakes and wetlands is Global Lakes and Wetlands Database.

[8] Shiklomanov I.A. (1999) ~~Shiklomanov, I. A. (1999). "WORLD WATER RESOURCES AND THEIR USE." Retrieved 20060221, 2006, from http://webworld.unesco.org/water/ihp/db/shiklomanov/index.shtml.~~

~~Shiklomanov, I. A. (1999). "WORLD WATER RESOURCES AND THEIR USE." Retrieved 20060221, 2006, from http://webworld.unesco.org/water/ihp/db/shiklomanov/index.shtml.~~

Suggested indicators

The indicators developed by WHO are used here to indicate the fulfilling of human water need. These indicators are *urban and rural water supply coverage* (H & J) and *urban and rural water supply coverage* (I & K). WHO also have figures on access to improved water sources and improved sanitation, but were the first version of water and sanitation indicator that later were split into the four indicators mentioned above. The WHO-definition of the four indicators are,

- urban/rural water supply coverage. Percentage of urban/rural population connected to an improved water source, defined as household connection, public standpipe, borehole, protected dug well, protected spring and rainwater collection.
- urban/rural sanitation coverage. Percentage of urban/rural population having improved sanitation, which is defined as connection to public sewer, connection to septic system, pour-flush latrine, simple pit latrine and ventilated improved pit latrine. (WHO 2000)

Water stress (E), defined as the ratio of renewable water volume per population number, is a further indicator for (actual) water availability, also known as the Falkenmark indicator (Falkenmark, Lundqvist et al. 1989). Ratios below 1700 m^3 per year and capita are defined as water stress, ratios under 1000 and 500 m^3 per year and capita means water scarcity and absolute scarcity, respectively. Some limitations are the fact that the indicator doesn't address scarcity on smaller scale, it doesn't address the "enhanced" availability occurring when the water resource is wisely managed (which the indicator water use efficiency reflects) and the thresholds doesn't reflect lifestyle and climate issues like interseasonal changes (Rijsberman 2006).

The cases of "enhanced" availability suggest that there is a need for an indicator that reflect more of the complexity of water use. This can be illustrated by the diversion or damming of water for irrigation purpose, which could be monitored as a problematic decrease in river flow or of the surface area of lake. In fact the diversion only changes the path of the water flow through the hydrological landscape, which doesn't necessarily have negative impacts on the availability of water. This example illustrates the relevance of the indicator *relative water use* (F), defined as annual renewable water use compared to the total renewable water resources available on annual basis. Following the water flow one step further water can be used more or less efficiently to enhance the available water resource, which can make it irrelevant to look at water withdrawals as a sustainability indicator for water. Indicators such as *water use efficiency* (N) and *productive use of water in rainfed crop production* (M) then become relevant as indirect indicators, monitoring (actual) water availability. The latter indicator is a proxy to water productivity and is defined as crop yield per non-irrigated crop production area.

Monitoring the water flows at different points in the hydrological cycle also means monitoring water quality occurring as a result of human activities. Parameters include *industrial water pollution* and *levels of Biological Oxygen Demand* (*BOD)* (O) in watersheds, an indicator of organic matter in wastewater. An indirect measure of water quality is the *urban sanitation coverage* and *rural sanitation coverage* (I & K). One broader indicator for the monitoring of the effectiveness in the way that a country can provide its population with water-related services can be records of outbreaks of waterborne diseases such as cholera (G). Such an indicator not only measures "hard" water quality factors of water use but also to some extent "soft" factors like awareness of how to use and manage water of different qualities.

Data availability

Parameters of hydrology and climate have been monitored for a long time. As a result there are quite a lot of data available on variables like water tables, river flows and precipitation, variables that are needed in hydrological models. That said, there are still wide variations in the availability and reliability of such data.

Based on the inventory of possible indicators and from the investigation of databases for monitored parameters relating to water, it is possible to divide parameters and indicators into (at least) four categories. The *first category* is data that is the result of time-series, or is shown as average values, which becomes time-series when an indicator is constructed together with another parameter. These indicators may thus be said to have **good** data availability. The *second category* is characterized by **medium to good** data availability, meaning that time-series with values on at least yearly basis exists for many countries. The *third category* doesn't have values on a strict yearly basis but there are at least two points in time where also data exists and it does so for many countries. These values may be the results of aggregations of data from various sources, and the points in time may be three-year-periods. The data availability is therefore considered **medium**. The *fourth category* is parameters with gaps in data availability on the global level, meaning country data are missing or that data exists as only one point in time. Thus, the data availability is **poor**. Instead their high relevance for quality of governance and sustainable development motivates their existence in the table.

Following the idea of measuring at points in the hydrological cycle it would be desirable to measure the state of the water resources as water availability in volumes. Desirable data would result from continuous monitoring for or assessments of parameters like volumes or levels of water in lakes, wetlands and aquifers, and their changes over time. In this context it would also be desirable to measure the availability of green water. Time-series on these parameters doesn't exist, for a number of reasons, which includes the large number of lakes and aquifers that would need monitoring. To some extent this could be solved using remote sensing techniques and computer modelling, but until now this hasn't happened to the extent that data is reliable.

Many desirable and important aspects of water resources and the water use are missing through the recommended set of indicators. For instance, the importance of the green water has been described which suggests thorough monitoring. But to monitor the green water flow is difficult and therefore enough reliable data is not available. Also it is desirable to indicate the state and use of the groundwater resource, but not much data are available globally, with the exception being developed countries. Table 1 show an overview of the some major databases that are relevant for the chosen indicators. For most parameters where time-series exists, data often originates from global water assessments or UN-related environmental programmes where data have been gathered from various sources like reported national statistics international and national surveys and other studies. Area of lakes (A) and wetlands have been measured or assessed and data exists for example through Global Lakes and Wetlands Database, but not as time-series data (Lehner and Doll 2004). Even if it would be possible to construct time-series data of lake areas from satellite images the relevance for such a parameter as an indicator of the state of freshwater resources would not necessarily be very high. This is due to the fact that the water resource is not depleted, rather the water flow, or part of it, has been diverted in the hydrological landscape. Such a diversion may lead to a higher actual availability of water, for example through irrigation activities. Despite these objections there may be special cases, with the Aral Sea Basin as an outstanding example, where such an indicator would be highly relevant as a sustainability indicator for water use. For the Aral Sea Basin data is available not only for changes in lake area but also for water quality parameters (SIC-ICWC, UNECE et al. 2006). Regarding the link between water use and institutional conditions problem arise as the Aral Sea Basin is crossed by several national boundaries. Still lake area may in special cases be relevant as an indicator, but attention has to be paid to national boundaries before a comparison with institutional conditions can be made.

Also the river water quality indicators (O & P) is associated with shared watershed issues as the raw data, resulting from physical measurements, shows the accumulated pollutants from upstream in the watershed. The pollutants originate from several upstream point or non-point sources and the water flow collecting the pollutants may cross national boundaries one or several times, which calls for corrections of data to make the mapping to national boundaries possible. It may even not be possible to use the data if national boundaries doesn't map with the boundaries of the watershed. Of course this may also depend on how the statistical analysis to compare water use and institutional condition is done. Furthermore local conditions need consideration, for example the indicator needs to reflect population size. For river quality parameters time-series exists for a relatively long time-period (~1979-1999) through Global Environmental Monitoring System on parameters like BOD (O), COD, nitrogen (P), Faeces Coliform bacteria (L) and others (UNEP and WHO 1999). This is a factor arguing for the construction of indicator based on this data even though, as expected, data are less available for Africa and Asia. Further statistics, especially for developed countries, may be found in national statistics, sometimes for longer time-periods then the datasets from UNEP. As an example, data exists for BOD to indicate release of organic waste in Göta älv between 1894-2000 (Lewander 2002), and mass loads have been registered for 6 major British rivers for the time-period 1975-1994 (Littlewood and Marsh 2005).

Water consumption and water withdrawals are associated with medium to high data availability, as for most countries data exists for at least 2 years during the last 20-year period (Shiklomanov 1999; FAO 2006). For water consumption and total country freshwater withdrawals data are available even for some 10^{th} years further back in time through UNESCO-IHP (Shiklomanov 1999). AQUASTAT includes data also annual available renewable resources, sector water withdrawals, meaning a subdivision in domestic, agricultural and industrial withdrawals, and also parameters like irrigated area, approximately with the same resolution in time as described above (FAO 2006). Major limitations for the indicator are accuracy of data, data may be scarce and result from computations. Also available water volumes can be enhanced through developments of the water resources and policy measures, which means that the actual water availability may rise without an increase in available volumes (UN 2001).

The indicators for access to improved water sources, improved sanitation, coverage of water supply and sanitation (H, I, J and K) are fairly rough indicators based on national surveys. Data availability is medium-good, meaning that data exists for many countries but few points in time have been monitored. So far there are WHO has estimates for the years 1990 and 2002 (WHO 2006). Among a number of statistics around diseases, WHO also has compiled data on outbreaks of cholera (G) in the world's countries from year 1996 and onwards, with good data availability (WHO 1996).

Concluding remarks

The report has recommended a set of indicators for use in statistical studies of societal institutional arrangements for which there is data available as time-series to various extents. While some of the indicators can be used directly others may need to be used together, hence there is a need for construction of indices, using "supplementary indicators" like *e.g.* population size, in order to give good accurate descriptions of trends in water quantity and quality. In other cases, for example for river pollution, considerations need to be made to population size. Also, though data is said to be of varying availability in databases, in some cases this means that data needs to be adapted to a desired format.

The recommended set of indicators covers several of the water issues described in the report and means that it covers both blue water and green water flows of the hydrological cycle. Indicators of important blue water flows in urban water systems and through irrigated crop production are included, as well as an indicator of green water flow; rain fed crop production. Some important aspects are missing though, due to poor data availability. Some important missing aspects are a measure for the state of the groundwater resource and information on data availability on sub-national level. The latter is important since water issues many times differ from one site to another within a country.

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Appendix: Indicator development and frameworks

Development of indicators can be guided by a number of frameworks. First there are general socio-economic parameters of the use of water like consumption levels. To address the complexity of water availability the development of indicators is also made through an attempt to cover the important monitoring points in the hydrological cycle that are needed to describe constraints and water availability in the water flow's.
While some indicators will be straightforward and available meaning that monitoring are made today and data exists in the form they are needed here, such as water table as an indicator for water availability, there are others that needs to be constructed in order to give a desired representation of the water issues.

Frameworks for the design of sustainability indicators

Depending on the nature of the perceived problems considering use of resources, the approaches vary. Here only a few major frameworks are described in short, focusing on environmental quality and the internal societal resource use. Through the DPSIR framework, Driving forces (activities), Pressures, States, Impacts are indicated and also the societal Responses (SEPA 2006). The DPSIR framework is used to monitor and evaluate the environmental work to achieve environmental goals on national and regional level.

The development of socio-ecological indicators is instead focused on early mechanisms in the causal chain of environmental problems, rather than environmental quality (see Azar et al 1995) The development of socio-ecological indicators, as proposed by Azar et al (1995), are guided by four principles of sustainability, which leads to sets of indicators. The four sets of indicators deals with: the societal use of lithospheric material, the emissions of compounds produced in society, the manipulation of nature and the long-term productivity of ecosystems and finally the efficiency of the internal societal resource use, including indicators for a just distribution of resources (Azar et al 1995).

Nilsson and Bergström have proposed Sustainable Development Records, a social science based framework, in order to measure the sustainability of society's provisioning of services (Nilsson 1997). The model of the service provision is built up by the societal *system* generating flows from and to (the so called *throughput*) the *resource base* in order to provide humans with *services*. The performance is measured at three points, categorized as,

- margin. A ratio of a measure of the size of the throughput and a measure of the size of the resource base.
- thrift. A ratio of a measure of the size of the operation and a measure of the size of the throughput.
- effectiveness. A ratio of a measure of the service delivered and a measure of the size of the operation. (Nilsson 1997)

The interesting aspect of Sustainable Development Records framework is that it splits the actual provisioning activities in a way, which makes it possible to address function of management. This could for instance lead to a question on how many people are served with water compared to the depreciation of financial assets of the municipality? When comparing water use and institutional conditions it may be very adequate to address water issues by pointing at parameters, which generally are of more concern in the actual water management situation.

Desirable and future indicators – possible indicators

Some indicators that may be desirable in order to represent important aspects of the water issue but they may be difficult to monitor over time or be hard to measure. There may also be lack of data or data may be unreliable. Proxies to the desirable indicators may in those cases be a relevant option and may be necessary in order to give good representations of in this case, the water use. A proxy would be a variable, which has a direct relation to the desirable indicator. One example of such a desirable indicator is the level of bacteria in drinking water, for which there will probably be lack of data. If instead the number or people with cholera per year are measured, it can be expected that data are more complete.

Here the development of a set of *possible indicators* is made through an integrated method including,

- a brief inventory of existing indicators of water in literature,
- an initial investigation of databases for possible parameters,
- identification of important aspects of water issues and using described frameworks for indicator development.

The resulting set of desirable, or in future possible, indicators will be relatively large in number.

The initial resulting inventory of indicators was a relatively large set operating on varying scales, from variables on the wastewater treatment plant scale to values on water withdrawals on the global scale. This large set of indicators is shown in Tables 3-8. The scopes and/or motivations for the indicators are described and for some of the indicators also major limitations. Some important aspects of the water use are discussed in the following paragraphs.

Some general water use parameters, for example water withdrawals or water consumption, are monitored with decent availability. Other water use parameters, whose trends would be desirable to follow over time, are on the global level associated with nearly no data availability meaning that data have not been compiled in global databases. However, this doesn't mean that data doesn't exist. For parameters like groundwater levels or groundwater recharge data may be found in case studies on sub-national level. For instance an IWMI[9]-report includes a collection of references to studies of groundwater situations in among other countries the US, South Korea, China, India, Jordan and Mexico, where for example the water table (ground water level) and its change over a time-period is included (Shah, Molden et al. 2000). Unfortunately, the scope of this report doesn't allow for a collection of enough datasets that can form a basis for even a medium degree of data availability. But it is likely that data on water tables can be found through further literature search and probably personal contacts with possible data holders. The same holds for data on salt-water intrusion, an indicator for the ability for water management to balance the long-term availability of water with short-term demands. The latter indicator is therefore not included in the recommended set of indicators.

[9] International Water Management Institute

As the water issue has been described green water flows are of great importance for human well-being. There is though low reliability of the data for desired parameters like *vegetation density/cover*, *evapotranspiration, biomass growth* in ecosystem (net primary productivity) and *plant available soil moisture*. All these parameters are to various extent available through databases and are for example used in modelling flows in the hydrological cycle or the effect of climate change on the hydrological cycle, or are themselves the result of modelling (Vorosmarty, Federer et al. 1998; Huntington 2006). Because of the low data reliability monitoring instead has to focus on related parameters to the green water flow, which is a fair assumption to make since there is a direct link between for example plant-available soil moisture and biomass growth (Rockström and Gordon 2001). Here it is implicitly understood that a productive use of green water, occurring when green water is occurring as biomass is growing in terrestrial ecosystem or crop production, means an increase in (actual) water availability.

The indicator water productivity can be increased by obtaining more production with the same amount of water or by reallocating water from lower- to higher-valued crops or from agriculture to other sectors where the marginal value of water is higher. According to IWMI the "the greatest increases in the productivity of water in irrigation have not been from better irrigation technology or management, but rather from increased crop yields due to better seeds and fertilizers. As yields on irrigated land have doubled or tripled over the past three decades, the productivity of water, the "crop per drop" has increased accordingly"[10]. In reality the water productivity, or the "crop per drop" ratio is hard to measure since it involves the parameter evapotranspiration. Therefore a proxy to the indicator could be used instead, a ratio of production volume and non-irrigated land, called *productive use of water in rainfed crop production*. The denominator non-irrigated land is needed in order to correct for an increase in cultivated land area. An increase or a decrease in the ratio can be the result from of a number of activities, which already have been mentioned above. One argument in favour of using the indicator is that either way, it will indicate an enhanced use of the available green water resource.

Table 3 and Table 6 includes some indicators for water availability which tentatively can be examples of indicators which can be expected to have influenced what kind of institution that is in place. A few examples are *precipitation*, *annual renewable water resource* and *population size/annual renewable water resource.*

Table 7 shows some of the indicators proposed by Nilsson and Bergström (1997). An indicator such as the ratio of actual purification and national standards seems like an indicator very relevant for assessing quality of governance. Just as for many other indicators data availability for purification is poor on the global level. Even though this is the case for many other indicators it may be interesting to construct other indicators. One example could be a ratio of the number of people served with adequate quantity and quality of water and the actual water availability. In a way this indicator is a combination of the indicators Urban Water Supply Coverage and annual renewable freshwater volumes.

[10] Quote from a description of one of IWMI research areas. Available at: http://www.lk.iwmi.org/textonly/pubs/WWVisn/vision.htm#under (20060223)

Table 8 may be interesting on a global level in the context of comparison to institutional conditions. Some outstanding examples are the number of protected water sources, area of protected wetland, leakage during distribution and various parameters for water treatment efficiency and water quality indicators (suggested by (Lundin 2003). One further indicator which where developed for urban water systems in developed countries is reliability (Palme 2004). It is interesting since it may be an important aspect of water availability in developing countries.

Table 3 Indicators resulting from monitoring water availability and quality along the hydrological cycle.

Indicators	Unit	Scope & Motivation	Limitation
Precipitation	m^3/yr	Addresses the actual site-specific availability of freshwater water	Temporal and spatial variations of precipitation may make the indicator irrelevant for comparisons of water availability between countries. Also the possibility of sea water desalination may sometimes be needed together with precipitation in order to address the total water availability. Furthermore, the correlation to good governance may rather be caused by water scarcity affecting institutions than the opposite mechanism.
Precipitation class	Qualitative value	Types of rainfalls. Interseasonal rainfall pattern affect what kind of water issues management need to cope with.	
Disturbance of vegetation cover[11]	Percentage	Changes in type and extent of vegetation cover changes the partitioning of water into blue and green water.	
Forest cover	Area	One of the changes which results from deforestation is changes in the partitioning of water into green and blue water. The canopy of the tree holds vapour and the deep roots of the tree causes a high uptake of water infiltrating the soil. Deforestation thus changes the partitioning of water into blue and green water flows.	
Green water flow- *biophysical indicators*	Climate, soil type, plant species	Genetic/Physiological components determining green water flow, thus also water availability	
Green water flow- *management indicators*	Timing of plant water uptake, vegetation density, soil nutritients status, soil biophysical status	Management component determining green water flow, thus green water availability	
Evapotranspiration, sectorial- *agriculture, ecosystem*		Evapotranspiration (ET) is correlated to biomass growth, in agriculture and ecosystems. ET can be a measure of the productive use of water, or the ability of land and water management to "virtually increase"[12] available water volumes.	:::
Plant available volumetric soil moisture		Soil moisture is the main source of natural water resources for agriculture and natural vegetation, but is also the result of, for example, the type and size of the vegetation cover. Either way trends in soil moisture changes can indicate success or failure of	

[11] Walker et al (2005)
[12] By changing agricultural activities, for example by changing crops, more water will "virtually" be available, though in reality there haven't been any increased volumes.

		water management.	
Lakes-area	m^3	Changes in lake area can act as a measure of surface water resource depletion, as it is in the case of Aral Sea	It may only be possible to do “extreme case” comparisons, between major watersheds, like the Aral Sea Basin.
Wetlands-area	Area, number, coincidence with population intensity?	Changes in area and number of wetlands can act as a measure of surface water resource depletion or presence. May be important particularly in areas with large temporal variations in water availability, for example the semi-arid regions in Sub-Saharan Africa. Many water poverty relief projects, for example, focus on preserving natural or constructing manmade wetlands in order to increase water availability over time and gain benefits from the ecosystem services provided.	
Length of river	Length ratio of unaffected, affected?	Points out major changes in the water’s cycle through the hydrological landscape. A river affected by dam or water diversion is an indicator for existence of water problems in downstream areas, through the changes in water flows. Furthermore unaffected rivers can to a larger extent provide a local population with freshwater and ecosystem services.	
Degradation of blue water resource – *Groundwater depletion*[13]	Number	Qualitative estimate of number of locations or zones with depletion of groundwater due to overexploitation.	
Salt water intrusion	Area	Area affected by salt-water intrusion indicates an excessive groundwater abstraction, i.e. too much pressure on the groundwater resource.	
In stream river flow		The instream river flow determines the type and amount of biological life that can be sustained in a river.	
Groundwater level	Level (m)	Trends in groundwater level, or water table, is a measure of increasing or decreasing pressure on a groundwater resource. In the long-term perspective the necessary condition is a balance between abstraction and recharge.	
Groundwater storage flux	Volume	Same purpose as above, measuring pressure on the groundwater resource, but in volume instead of level in meters.	
Concentration of arsenic, fluoride, nitrate,		Indicator of groundwater quality, and at the same time also addressing need for water treatment. This factor is not covered by the indicator Water Supply Coverage as a factor limiting water availability.	

[13] Global Groundwater Information System

Table 4 Indicators showing vulnerability for water shortages and eventual enhancements of available water.

Indicators	Unit	Scope & Motivation	Limitation
Relative water use	M^3/m^3	The ratio of water withdrawals compared to available volume measures a countries vulnerability to water shortages.	A high ratio value originating from low value of available water may mean exportation of a water problem. Thus, that upstream-downstream or transboundary water issues exists and that there's a major limitation on the indicators ability to address the broader sustainability.
Relative sectorial water use	M^3/m^3	As above	As above
Relative groundwater use		Ratio of groundwater extraction and groundwater recharge	
Water Use Efficiency – *Rainfed agriculture*	Unit amount of evapotranspiration per crop yield	Ratio for measuring the ability of the management to efficiently use the available water or to "virtually increase"[14] the present resource. Determined by crop yield, surface area, crop water requirements, the linear proportionality between biomass production in croplands and evapotranspiration.[15]	
Water Productivity – *Irrigated agriculture*	Irrigation water volume required per unit of crop yield	Measure the ability of the management to efficiently use blue water withdrawals.	

Table 5 Ecosystem health indicators as indicators for stream water quantity and quality.

Indicators	Unit	Scope & Motivation	Limitation
Intream health	Diversity, abundance	Fishes and insects indicate quality and quantity of water, as water is a determinant for biological life.	
Riparian vegetation[16]	type, size	Riparian vegetation affects instream health by giving shade, filtrating sediments and pollutants.	

[14] By changing agricultural activities, for example by changing crops, more water will "virtually" be available, though in reality there haven't been any increase in measurable volume.

[15] The definition of Water Use Efficiency according to Rockström and Gordon (2000).

[16]Walker (2006), Pedersen (2003),

Table 6 General indicators on water use and pressure on the water resource.

Indicators	Unit	Scope & Motivation	Limitation
Population intensity	cap/m^2	High population intensity will always indicate a higher pressure on present water resources.	
Water consumption	m^3/cap, yr	The level of the water consumption acts as a measure for the general pressure on a water resource	When comparing countries/areas with major differences in hydrological conditions, the indicator may be irrelevant, exaggerating the degree of unsustainable use. Depending on the start point of observation a change in water consumption, either there is an increase or decrease, can be both positive and negative from the broad sustainability point of view.
Sectorial water consumption – *domestic, agricultural, industrial*	As above	As above	As above
Water stress		Water stress[17] is defined as occurring when renewable fresh water annual resources is below 1700 m^3 per capita, will experience water stress. Below 1,000 m^3 per capita a country will experience water scarcity and below 500 m^3 per capita country will experience absolute water scarcity.	
Waterborne diseases	Number	The trend in the number of people or outbreaks of waterborne diseases, like diarrhea or cholera, indicating water contamination, acts as a measure for improvements in provision of water of good quality. Together with Water Supply Coverage and Sanitation Coverage it may give a more accurate picture of the access to water of good quality, at the "low access end" of the scale.	
Urban Water Supply coverage	%	Percentage of people with improved water source is a measure of the provisioning of water to an urban population.	Mostly quality-oriented
Rural Water Supply coverage	%	Percentage of people with improved water source is a measure on the	
Urban Sanitation coverage	%	Percentage of people served with basic sanitation	
Rural Sanitation coverage	%	Percentage of people served with basic sanitation	

[17] Water stress is occurring, using UNEP' s definition, when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use

Table 7 A set of Sustainable Development Records Key Indicators developed for urban water systems. Source: (Nilsson 1997)

	Indicators	Scope & Motivation
Margin	Chemical margin	The ratio of water withdrawals per chemicals needed
	Recirculation of phosphorous	The ratio of phosphorous to farmland and phosphorous to sewage treatment plant
Thrift	Sewage water thrift	The ratio of number of people served and sewage water produced
	Financial thrift	The ratio of number of people and depreciation of assets
	Phosphorous thrift	Chemicals used
Effectiveness	Phosphorous	The ratio of actual purification and sanitation standards
	Chemicals	The ratio of value of sludge and the cost of chemicals

Table 8 Indicators of urban water systems. Source: (Lundin et al 2003; Palme 2004)

Indicator	Scope/Construction
Protection	Number of water sources protected
Protection	Wetland area, type
Distribution	Leakage (unaccounted water/produced water)
Distance	Distance from water source or treatment facility
Quality	Coliforms count
Reuse of water	Reused water/Water consumption
Production	Wastewater production per day
Treatment performance	Removal of BOD_5, P,N (%)
Loadings to retrieving water	Loadings of BOD_5, P,N
Resource use	Chemical use per P removed
Energy use	Energy use per BOD_5, P,N removed
Sludge use	Amount of sludge disposed or reused (%)
Recycling of nutritients	P and N recycled
Reliability	Accessibility per site and year (%)[18]

[18] Suggested by Palme (2004)