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Measuring Water use in a Green Economy

United Nations Environment Programme

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Editor: International Resource Panel Working Group on Water Efficiency

Lead author: Jacqueline McGlade

Contributing authors: Beate Werner, Mike Young, Marty Matlock, Donna Jefferies, Guido Sonnemann, Maite Aldaya, Stephan Pfister, Markus Berger, Carole Farell, Kylie Hyde, Mathis Wackernagel, Arjen Hoekstra, Ruth Mathews, Junguo Liu, Ertug Ercin, Jean-Louis Weber, Alessandra Alfieri, Ricardo Martinez-Lagunes, Bram Edens, Peter Schulte, Sabine von Wirén-Lehr, David Gee.

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Measuring Water use in a Green Economy

Foreword

Without doubt water and its abundance or its scarcity will define human well-being, environmental sustainability and economic activity in the 21st century.

The world is awash with reports warning about water stressed areas now and in the future; the relative demands of competing industries locally and regionally and fears that without sustainable management, cooperation and improved and more efficient use water resources may become a driver and an escalator of tensions and conflicts over the coming years and decades.

Meanwhile a raft of important studies and assessments have equally underlined the importance of water to wider society in terms of its role in maintaining healthy ecosystems whose services not only underpin economic activity but the viability of the planet as a home for seven billion people, rising to over nine billion by 2050.

This report by the UNEP-hosted International Resource Panel marks a serious and critical analysis of the way societies are managing water supplies including how those supplies are allocated across sectors, interests and the environment.

It provides a critique of the various regimes and systems that have evolved over time alongside new and evolving initiatives that together may illuminate a pathway to the ultimate goal of decoupling resource use—in this case water—from economic development and growth and environmental degradation.

Importantly it makes a case that at some scales and linked with globalization water must be considered as a global issue, rather like the atmosphere: not least because water is being traded and used across continents as a result of the shipment and exchange of goods and products—so called 'virtual water'.

There are clearly many interesting and innovative ways of achieving the adage—if you can measure it, you can manage it. The report looks at Water Registers and Water Footprinting up to Life Cycle Assessments backed up by case studies of places and countries where such management regimes have been piloted and tested including in Australia's Murray Darling River Basin and within river basins in China to innovative approaches by a company like Volkswagen in respect to car manufacturing.

The study also looks at countries where national circumstances are already triggering the kinds of comprehensive management, policies and technological innovations that are leading to 'decoupling' of per capita water use: Singapore being a case in point.

The *Measuring Water Use in a Green Economy* report is the first of a triumvirate of assessments by the International Resource Panel on this issue and an important contribution to the Sustainable Development Goals that are likely to emerge from the Rio+20 process post June 2012.

I would like to thank the members of the Panel for taking on this complex but important task and in particular Jacqueline McGlade of the European Environment Agency who has been the lead author and intellectual engine-room behind this work.

Achim Steiner

UN Under-Secretary General and Executive Director,
UN Environment Programme (UNEP)

Preface

The world is entering a period of growing water scarcity. We estimate that by 2030, global demand for water could outstrip supply by over 40% if no changes are made.

The growing demands placed on our supply of water are not merely the result of the world's growing population, but the way in which our economies develop. Since 1900, our consumption of water for human use has grown at twice the level of population growth, jumping from 600 billion cubic meters in 1900 to 4,500 billion cubic meters in 2010.

Fortunately, this means that there is nothing inevitable about the strains we currently see in global water supply. Many of the problems we are now encountering in our use of water are economic, social and political in character. This means that it is within our power to change the structures governing water use and prepare more intelligently for our current and future needs.

But these needs are complex as they involve nearly all sectors of our economy, society and government. Those involved include politicians and administrators at all levels of government, as well as a host of private actors, such as agriculture and the food industry, transport and energy suppliers, water utilities, manufacturing industries, and enterprises of all sizes, making water an obvious economic resource. It also involves the general public, and by implication, the advocates for their interests (consumer, social and environmental NGOs). The art of water management between these different actors is one of integration and balancing powers for the common interest of further welfare and growth.

This need to balance welfare and growth places the issue of water management at the heart of the debate on the green economy. Water is arguably more important than any other natural resource, sustaining as it does all human life and the wealth of ecosystems on which human life depends.

It is with awareness of this complex context that the Sustainable Water Management Working Group of the International Resource Panel (IRP) has set out to examine the contours of a new, sustainable approach to water management.

This report is the second in a series of reports on sustainable water management. The first report in the series drew on existing literature, and conceptual frameworks developed by the IRP in other research, to provide a conceptual and analytical basis for decoupling policy and decision making in water resource management.

In this report, we develop these concepts further. We follow on closely from the first report in emphasising 'decoupling' as the prism through which future water management should be considered. The first Resource Panel report on decoupling (UNEP, 2011a) used the term decoupling to denote a reduction in the amount of resources used or environmental impacts caused per unit of economic output.

This second report aims to provide a more detailed account of how a decoupling policy can be measured. While we cannot provide specific practical tools for water administration, we do aim to introduce and discuss the analytical methods and policy frameworks needed to ensure that water use can be properly quantified over the life cycle and integrated into other measures within the green economy.

The challenge we set to out to address in this report is how best to measure and quantify these different types of decoupling. We do this by introducing various analytical methods focused principally on the water balance, which includes fluxes (flows available for immediate use) and stocks (resource from past inputs) but not future inputs. We also discuss methodologies of water accounting and water footprinting to help quantify water scarcity.

Jacqueline Mcglade

Executive Director of the European Environment Agency (EEA)

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Abbreviations and acronyms

AWS	Alliance for Water Stewardship
CICES	Common International Classification of Ecosystem Goods and Services
DI	Decoupling Index
DPSIR	Drivers, Pressures, State, Indicators and Responses framework
ECWA	Ecosystem Capital Water Accounts
EEA	European Environment Agency
ETA	Actual Evapotranspiration
EWP	European Water Partnership
EWS	European Water Stewardship Scheme
FAO	Food and Agriculture Organization of the United Nations
GEMS	Global Environment Monitoring System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IRP	International Resource Panel
IRWS	International Recommendations for Water Statistics
ISIC	United Nations International Standard Industrial Classification
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life-Cycle Impact Assessment
MA	United Nations Millennium Ecosystem Assessment
NACE	Nomenclature Générale des Activités Économiques dans les Communautés Européennes
OECD	Organisation for Economic Co-operation and Development
REP	Rivers Ecosystem Potential
SEEA	United Nations System of Economic and Environmental Accounting
SEEA–W	United Nations System of Economic and Environmental Accounts – Water
SNA	System of National Accounts
TEAW	Total Ecosystem Accessible Water
TEEB	The Economics of Ecosystems and Biodiversity
UNEP	United Nations Environment Programme
UNSD	United Nations Statistics Division
WBCSD	World Business Council for Sustainable Development
WEAP	Water Evaluation and Planning System
WEI	Water Exploitation Index
WIS	Water Information System
WF	Water Footprint
WFA	Water Footprint Assessment
WFN	Water Footprint Network
WMO	World Meteorological Organization

Executive Summary

Humanity's key challenge over the coming decades will be to meet the energy, land, water and material needs of up to 9 billion people, while keeping climate change, biodiversity loss and health threats within acceptable limits. Countries are already facing common but differentiated challenges requiring a range of solutions specific to each situation. A key factor in determining which solution is most appropriate will be the availability of data and information on how much water is available and how it is being used, and the frameworks for assessing the distributional needs of each society.

The International Resource Panel (IRP) considers that achieving sustainable patterns of consumption and production equitably while maintaining the integrity of the natural environment requires the decoupling of economic growth from resource use and environmental degradation. The two main objectives of the panel are:

- to contribute to a better understanding of how to decouple economic growth from environmental degradation;
- to provide independent, coherent and authoritative scientific assessments of policy relevance on the sustainable use of resources and their environmental impacts over the full life cycle.

The IRP Working Group on Integrated Sustainable Water Management is examining ways of achieving decoupling through improved water productivity, for example in the harvesting, use and reuse of water, and of defining a measurement framework for achieving efficient, effective and equitable water use. This first working-group report covers the analytical methods and policy frameworks needed to ensure that water use can be properly quantified over the life cycle and integrated into decoupling measures within the green economy. Following this report, and using the conceptual and methodological analysis set out in it, the IRP will publish two further assessments – an overview of the scope of the water management problem around the world and an analysis of the economic and social elements of water productivity and efficiency together with aspects of governance and institutional arrangements.

This modular approach aims to provide a comprehensive overview of the policy options available to implement sustainable water management in a green economy in a way that recognises water as vital natural capital while at the same time developing a healthy and productive water sector within an economy that cares for and enables social equity.

The conceptual and methodological analysis

As water availability is not only highly dependent on the global hydrological cycle but also on local and regional water management regimes, much data and information need to be brought together. Accounting is seen as a crucial tool for the purpose of overall water management and the generation of economic assessments, alongside GDP growth and other economy-wide indicators such as greenhouse gas emissions. There is a need to address ecosystem services within such resource accounting schemes, to enable the links to be made between resource efficiency, biodiversity and ecosystem services and hence the connection to the social values of water.

An important trend that emerges is a significant and growing interest from the corporate world in taking water resources into account when considering future business. For public bodies involved in determining water balances, there is a need not only to produce quantitative estimates of stocks and flows but also to assess the impact of fluctuations and uncertainties coming from the global hydrological cycle on water abstraction licenses and access rights and on the quality of water.

One of the key features determining the balance between water demands and availability is the emerging view of how best to take the water needed to sustain the many different types of ecosystem services into account. One important conclusion is that there is a common need across all methodologies and approaches for data and information at the river basin scale.

A comprehensive examination of the various methodologies for quantifying water use and environmental impacts, their underlying assumptions and the context in which they can be effectively used, forms the core of this report. It considers water registers, water and ecosystem capital accounting, water scarcity and vulnerability indices, water footprint assessment and life-cycle assessment. Conclusions from this, and associated case studies, are that:

- water registers provide a key to the fair distribution of access to water;
- accounting can provide governments with knowledge of how water, as one part of the natural capital of ecosystems, is linked to the economy and human well-being;
- water footprint assessment can provide a tool for awareness raising to highlight water issues in production and consumption, especially in areas such as agriculture and food industries;
- life cycle assessment and the various standards associated with it can provide benchmarking for industries; and
- water stewardship can help improve quantification in corporate water monitoring.

It is also clear that, while there are differences between the various methods, there is a sufficiently robust set of tools and methods currently available to be able to include water in all major economic and social considerations.

The report concludes that there is an absolute need to asses water-resource use and management against ecosystem resilience and the limits of sustainability when developing policy options in order to balance the competing needs of water users.

It recommends that the environment's water needs should be treated as a vital priority in order to ensure the steady supply of the basic regulatory ecosystem services that underpin the delivery of social and economically-valuable provisioning services. In essence, water ecosystems must function properly and make clean and sufficient water available to ensure food production – crops, husbandry and fish, drinking water supply, energy and cultural values.

Effective and targeted assessments depend on open data access and optimal data availability to function in a transparent and equitable dialogue of relevant stakeholders. The methodologies applied for the assessment of resource use and allocation as well as for the assessment and tracking of pollution loads need to be transparent and comparable between regions up and downstream of the connecting water bodies and scalable between the local and regional or pan-regional scales. Further efforts are needed to provide this comparability and the link between different scales, as shown by the differences between the accounting methodologies, life-cycle and footprint assessments.

1 Introduction

Humanity's key challenge over the coming decades will be to meet the energy, land, water and material needs of up to 9 billion people, while keeping climate change, biodiversity loss and health threats within acceptable limits. Countries are already facing common but differentiated challenges requiring a range of solutions specific to each situation. A key factor in determining the success of these solutions will be the availability of data and information on how much water is available and how it is being used, and the frameworks for assessing the distributional needs of society.

In 2010, UNEP responded to this challenge by establishing the Green Economy Initiative, which proposed a major transformation in the use of energy and materials (UNEP, 2011b), together with an International Resource Panel (IRP) to provide the scientific impetus that will be needed to support the transition to a Green Economy.

The International Resource Panel considers that achieving sustainable patterns of consumption and production equitably while maintaining the integrity of the natural environment requires the decoupling of economic growth from resource use and environmental degradation: 'Decoupling at its simplest is reducing the amount of resources such as water or fossil fuels used to produce economic growth and delinking economic development from environmental deterioration' (UNEP, 2011a). The two main objectives of the panel are:

- to contribute to a better understanding of how to decouple economic growth from environmental degradation;
- to provide independent, coherent and authoritative scientific assessments of policy relevance on the sustainable use of resources and their environmental impacts over the full life cycle.

The first panel report on decoupling natural resource use from environmental impacts and economic growth (UNEP, 2011a) provided a foundation for the concept of decoupling, clarified key terms and concepts and identified many applications for resource management.

The green economy report (UNEP, 2011b) stressed that the massive investments needed to improve resource efficiency would need to be complemented by strategies for greatly enhanced resource productivity and the development of circular flows of materials and water. The IRP Working Group on Integrated Sustainable Water Management is therefore examining ways of achieving decoupling through improved water productivity, e.g. in the harvesting, use and reuse of water, and of defining a measurement framework for achieving efficient, effective and equitable water use.

This working group report covers the analytical methods and policy frameworks needed to ensure that water use can be properly quantified over the life cycle and integrated into decoupling measures within the green economy. The second report covers decoupling within integrated water resource management, including innovative approaches and technologies to maximise water-use efficiency and productivity gains in different sectors.

The two reports aim to provide a comprehensive overview of the options for implementing sustainable water management in a green economy that recognises water as vital natural capital while continuing to develop a healthy and productive water sector within the economy.

The tools described in this first report, for quantifying and prioritising water use and the needs of economic sectors and healthy ecosystems, are seen as essential for sustainable development and thus represent important elements for the United Nations Conference on Sustainable Development.

1.1 The need for common frameworks and methods for water policies and analysis

Water is an essential resource for all aspects of human enterprise: for agriculture, energy production, industrial production and human health. Freshwater represents only 3% of existing water on the planet, of which 0.3% is available for humans. Yet over the past 50 years global freshwater withdrawals have tripled. Today, a quarter of freshwater use exceeds accessible supplies (MA, 2005; UNWWAP Water, 2009; OECD, 2007). By 2030, the OECD estimates that nearly 3.9 billion people will be living under conditions of severe water stress.

The 2030 Water Resource Group[1] estimates that global demand for water by 2030 will be 40 per cent higher than it is today. This implies that more than a third of the world's population will be living in river basins with significant water shortages, including many in countries and regions that drive global economic growth.

Climate change is projected to cause major shifts in precipitation and seasonal patterns, and to have a major impact on physical water scarcity. Socially-induced water shortages caused by political priorities, policies and socio-economic differences could also be exacerbated by population growth, urbanisation, pollution and increased demands for high-quality water (UNFPA, 2009). Equally, the many uses of water will create pressures on the natural systems that supply water and which themselves rely on water to function and deliver valuable services.

Water management will continue to have a decisive influence on the generation and distribution of wealth and well-being. Yet despite numerous reports on inefficient water use, poor harvesting and water pollution, there remains a general lack of knowledge about how water is being used across the economy, how much water is needed to support ecosystems and how much will be available in the future as a result of climate change, population growth and shifts in economic activity.

The current setting in which water policies are developed is not well suited to the task of ensuring that water is an integral part of the green economy. The UNEP report 'Towards a green economy' states 'We cannot hope to *manage* what we do not even *measure'.* Therefore, it argues that notwithstanding the complexity of an overall transition to a green economy, appropriate indicators at both a macroeconomic and a sectoral level must be identified (UNEP, 2011b).

In the future, a better understanding and quantification of water use throughout the life cycle of uses will be needed, involving the integrated needs of ecosystems and society, the pressures arising from climate change and environmental degradation, economic drivers and the impacts of pollution and abstraction on water availability and quality. Many quantitative approaches are available, including hydrological modelling, water accounting, water footprinting and life-cycle and impact assessment. From a policy perspective, indicators and measures across a simplified DPSIR (Drivers, Pressures, State, Indicators and Responses) framework will also be needed (EEA, 1999; Stanners et al., 2007).

All these approaches and methods can help to articulate where and how water productivity and efficiency can be improved to facilitate

1 2030 Water Resource Group members include McKinsey & Company, the World Bank Group, and a consortium of business partners: The Barilla Group, The Coca Cola Company, Nestlé SA, New Holland Agriculture, SAB Miller PLC, Standard Chartered and Syngenta AG.

decoupling of economic growth from water resource depletion. The aim of this first report is to explain how the different analytical methods and approaches fit together and how they can best be used across the policy cycle and in water management.

indicators and the different approaches available to measure water use, efficiency and the environmental impacts on different geographic scales arising from different economic and social activities. The chapter covers the extraction and provision of water, as captured in the reports of the national statistical agencies,

1.2 Report outline

This report consists of 5 main chapters with final conclusions and recommendations. Chapter 2 presents the main concepts and definitions of the different aspects of water used in the economic, policy and scientific literature. The chapter looks at the general concept of decoupling as applied to water and examines various types of policy targets, water potential within key sectors such a food and agriculture and water use at the local industrial installation level.

Taking the green economy as its entry point, the chapter defines the data, information and knowledge needs for maintaining the water components of the natural capital stored within ecosystems, the manufactured and financial capital in the economy, and the social capital linked to human well-being.

It is clear that water availability is not only highly dependent on the global hydrological cycle but also on local and regional water management regimes, so many sources of information are needed. Accounting is seen as a crucial tool for the purpose of overall water management and the generation of economic assessments, alongside GDP growth and other economy-wide indicators such as greenhouse gas emissions. There is a need to address ecosystem services within such resource accounting schemes, to enable the links to be made between resource efficiency and biodiversity and ecosystem services and hence the connection to the social values of water.

An important conclusion that emerges is the significant and growing interest in the business world in taking water resources into account when considering future business. For public bodies involved in determining water balances, there is a need not only to produce quantitative estimates of stocks and flows but also to assess the impact of fluctuations and uncertainties coming from the global hydrological cycle on water abstraction licenses and access rights and on the quality of water.

In chapter 3, the data and sources of information on water balances globally and within river basins and ecosystems are described, with a view to providing knowledge of how they are derived, and the strengths of a series of common classifications and water reporting processes are analysed. One of the key features determining the balance between water demands and availability is the emerging view of how best to take into account the water needed to sustain the many different types of ecosystem services. Here, we present examples of the data used to quantify the condition and changes in services across a river basin and its landscape though time, and show how the impacts of land transformation on ecosystem service loss can be demonstrated. One important conclusion from the analysis is that there is a common need across all methodologies and approaches for data and information at the river basin scale.

Chapter 4 looks in detail at the various methodologies for quantifying water use and environmental impacts, their underlying assumptions and the context in which they can be effectively used. This chapter provides the core of the report, covering water registers, water and ecosystem capital accounting, water scarcity and vulnerability indices, water footprint assessment and life cycle assessment. Case studies are used to exemplify how the different methods are currently used and where they are developing. It is possible to conclude that water registers provide a key to the fair distribution of access to water; accounting can provide governments with knowledge of how water as one part of the natural capital of ecosystems is linked to the economy and human well-being; water footprint assessment can provide a strong analytical perspective on production and consumption of water, especially in areas such as agriculture, crops and the food industry; life cycle assessment and the various standards associated with it can provide benchmarking for industries; and water stewardship can help improve quantification in corporate water monitoring. There are trade-offs between the various methods, but it is clear that today we have a sufficiently robust set of tools and methods to be able to include water in all major economic and social considerations.

Chapter 5 summarises the main conclusions of the report. It provides information on how to address decoupling through the adoption of targets and policies on water efficiency, innovation, appropriate market signals, and water rights, so as not to deplete water resources and to increase water productivity.

2 Concepts, frameworks and definitions

2.1 Green economy

Natural resources are a key factor in the transition to a green economy. As the United Nations World Water Assessment Programme (2009) observed: 'Quantifying the way that water flows through the global hydrological system, different ecosystems and economies is essential for managing water resources, maintaining ecosystem services and ultimately protecting human health and the environment.'

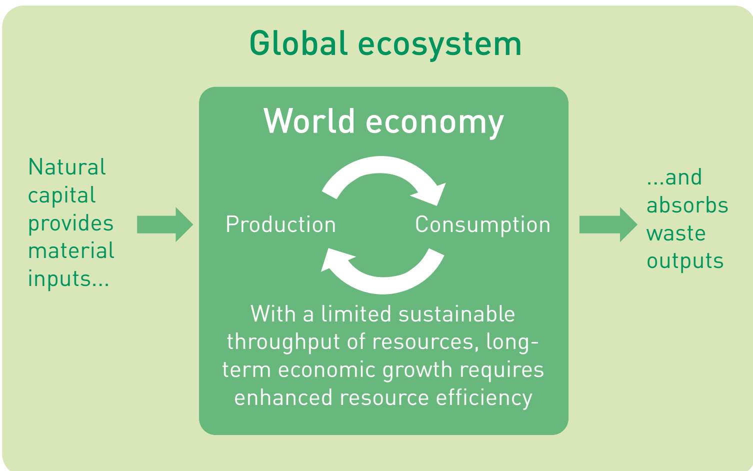
Before exploring the types of indicators needed to guide this transition, it is worth reflecting on what a 'green economy' entails and how it relates to other concepts such as sustainable development, natural capital, resource efficiency and sustainable consumption and production.

At its most basic level, a green economy is one that generates increasing prosperity while maintaining the natural systems that sustain our societies and our economies. Historically, economic growth has imposed ever-greater pressures on natural systems, in terms both of demand for resources and the burden of emissions and wastes. But, as is increasingly understood, economic development can only continue in the long term if we break the link with environmental harm.

Central to the notion of a green economy is the recognition that economic activities operate within the global ecosystem and rely on it to provide resource inputs and assimilate wastes and emissions. Crucially, the Earth is a closed material system which in turn shapes the way in which economies can grow sustainably. Using resources or emitting pollutants beyond

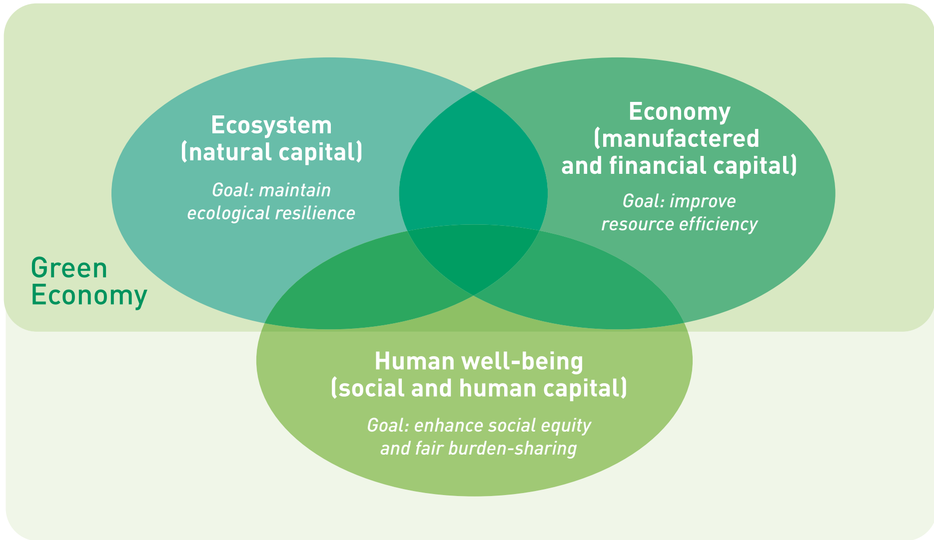
Figure 2.1

The world economy operates within and depends on the global ecosystem



Source: EEA (2011a).

Figure 2.2
Creating a green economy: a triple challenge



Source: EEA (2011b)

ecosystem limits damages the natural capital base, reducing its ability to provide goods and services. In this sense, ecosystems are seen as a form of capital. Maintaining the world's natural capital will contribute to economic output by providing valuable renewable resources and services. Over-exploiting the natural capital, for example by emitting excessive pollutants, will reduce its ability to provide further goods and services.

The transition to a green economy presents a triple challenge. First, there is a need to focus on the economy, finding ways to increase prosperity without increasing resource use and environmental impacts - put simply, being more resource-efficient. By itself, however, resource efficiency cannot guarantee steady or declining resource use or sustainability: the world could become more efficient but still put excessive demands on the environment. So the second challenge, to achieve sustainability, is the need to maintain ecosystem resilience, which is governed by the status, trends and limits of natural systems. The third element is human well-being, including health, employment, job satisfaction, social capital and equity. This also includes a fair distribution of the benefits and costs of the transition to the green economy.

In balancing environmental, economic and social elements, the green economy concept evidently has much in common with some models of sustainable development, which sees the triple challenge of economic efficiency, ecological sustainability and social equity.

2.2 Water and the green economy

2.2.1 Water management as part of the economy

Shifting to a green economy requires careful management of all resources, especially water, which differs from other resources in some very important ways.

First, water is arguably more fundamental than any other resource - to life itself, supporting a huge array of ecosystem services, and to every economy and society. As the United Nations Millennium Ecosystem Assessment (MA, 2005) and the subsequent valuation project, The Economics of Ecosystems and Biodiversity (TEEB, 2010) noted, ecosystem services include:

- water cycling as a supporting service;
- water-flow regulation, and water purification and waste treatment, as regulating services;
- water as a provisioning service, including the provisioning of plants, fish and other organisms grown in or with water.

Water contributes directly and indirectly to virtually all other ecosystem services but the area of water supply and sanitation also comprises an economic sector in itself. Furthermore, as well as being needed for all biotic and economic production processes, in most societies water also has important recreational, cultural and spiritual values. This fundamental threefold value, sustaining life, economies and cultures, creates an enormous range of competing demands on water resources but also economic opportunities. Assessing the socially-optimal allocation of water resources is extremely complex, involving balancing and trading off many pressing but often extremely diverse interests. However, this complexity also offers opportunities for win-win situations, even though scrutiny of the various elements, including a break with traditional concepts, might be needed to realise them.

Water also differs from other resources with respect to its high variability in time and space. Seasonality and catchment characteristics are key features that need to be considered in the complex task of quantifying and managing water. First, although water is globally abundant and non-depletable in aggregate, it is very unevenly distributed and local stores of water can easily be exhausted. Localities vary in terms of water abundance and scarcity, with climatic and seasonal variations (affecting precipitation, evapotranspiration, etc.) also having an important influence. This means that the impacts of the same amount of water use will differ enormously between locations and periods of time. In addition, water use can affect water quality as well as the abundance of local resources and this can influence the provision of ecosystem services.

Water is mobile (via flows and the water cycle) and water resources are often transboundary. These factors frequently give water some common property resource characteristics. Problems with allocating complete property rights can mean that users lack an incentive to manage water resources sustainably both in terms of extraction and pollution: the rational pursuit of individual interests can lead to socially suboptimal outcomes. These problems are often reflected in water prices, which fail to account for scarcity or the externalities implicit in resource use.

While these different characteristics of water give it a unique role in the green economy, they also significantly complicate concepts and efforts to quantify water use and impacts and to design tools to manage water resources.

The UNEP report 'Towards a green economy' (UNEP, 2011b) highlights the economic and societal opportunities that arise from adapting the water sector to the needs of 'green' and sustainable water management. For example, by investing in green sectors, including the water sector, more jobs and greater prosperity can be created. This is most pronounced in developing countries where limited access to clean water and adequate sanitation affects health, education and the well-being of citizens, limiting their contribution to a more prosperous economy.

In a similar way, maintaining and restoring ecosystems in the short term pays off in terms of the benefits these ecosystems can provide reliably and in the long term. It also avoids unnecessary restoration costs and secondary investments in health care in areas where people suffer from polluted drinking water and inadequate sanitation.

Perhaps most important is the cross-sectoral significance of water. Its pervasive role in ecosystems, societies and economies means that strategies for sustainable water use need to engage people in all sectors. Shaping governance to achieve efficient and equitable allocation of water requires an effective stakeholder dialogue within a catchment and at other relevant scales, which can help foster cross-sectoral integration and exchange.

2.2.2 Water in society

Ecosystems, societies and economies all depend on water resources to exist and prosper. Ecosystems require water to function and provide ecosystem services; they therefore represent an additional major 'water user' alongside agriculture, industry, urban centres and households, leading to competition between the needs of the sectors and the environment. But ecosystems, in turn, provide services such as ensuring water quality and flow regulation.

Growing populations and economies, changing diets, as well as climate change, are leading to increasing water use plus the associated demands on the environment (Liu et al., 2008). The allocation of water to competing but highly interdependent users and sectors will thus strongly influence the sustainability of economic growth and the distribution of wealth and well-being across societies and generations. To maintain the sustainability of water supply and use, the allocation of water to different uses, including both consumptive and in-stream, needs to operate within environmental and social sustainability limits.

More efficient use of all resources in all sectors can help reduce water demand and water pollution, thus alleviating pressure on the environment and related ecosystem services. However, inequity in water use and allocation, when linked with social and political imbalances, risks impairing the ability of ecosystem services to deliver water and is also likely to jeopardise human well-being. Thus a green economy requires clear governance structures and carefully, perhaps differently designed economic, regulatory and normative tools to allocate water among competing users and thereby ensure healthy ecosystems. The UNEP report 'Towards a green economy' (UNEP, 2011b), for example, discusses enabling conditions, such as the establishment of sound regulatory frameworks, prioritising government investment to stimulate specific areas and shifting market-based instruments towards promoting green investment and innovation. The OECD report 'Towards green growth' makes similar suggestions (OECD, 2011c). In a broader context, 'soft measures' which include the social aspects of governance (including public participation in water boards and round tables, as seen under the EU Water Framework Directive) are highly relevant and a precondition for the transparent implementation of a green economy.

Data, indicators and national water-accounting systems are essential tools for recognising the challenges and designing appropriate responses. At the same time, investments in certain sectors will increasingly need to reflect the intensity of water usage and will need to be assessed on the basis of the hydrological and climatic conditions in the river basin, as well as the local and regional social and economic realities.

2.2.3 Water in international trade

The impacts of water use also have to be considered from an international perspective. The concept of 'virtual water' (Allan, 2003) presents a way of investigating and understanding the implications of water in connection with the international trade of goods in which or for which water is used. It builds, as a volumetric approach, on the water footprint concept (further developed in Hoekstra et al., 2011) and uses an expression of water intensity (efficiency) for the amount of water consumed in agricultural production, industrial processes and domestic water supply related to a certain traded product.

By calculating the water consumed by different economic activities in certain regions throughout the whole supply chain it is possible to identify regions that have a comparative advantage or disadvantage in water efficiency for a certain product, enabling analysis of the water efficiency of an activity in one specific location compared with others. This comparative information can inform economic development policy. The information however has to be analysed throughout the whole supply chain as the highest water use often occurs in the location of agricultural production of raw materials, often in developing countries, and the opportunity costs of blue, green or grey water (see Chapter 4) also have to be considered. The concept gives, however, a useful entry point into discussing inequities in international trade.

2.2.4 Social aspects of water management

In addition to the environmental concerns, water management in a green economy is also shaped by other issues such as human health and fundamental rights, as well as social aspects of well-being, in which water plays a key role. At the 2000 United Nations Millennium Summit, world leaders committed themselves to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. More recently, in July 2010, the General Assembly of the United Nations adopted a resolution declaring that safe and clean drinking water and sanitation is a human right essential to the full enjoyment of life and all other human rights.

The tools and methodologies needed to measure the distance to achieving such societal goals are similar to those presented in this report for the water environment. There are also some common approaches, as in the case of determining water registries and water allocation rights. Overall, decoupling water use from economic growth serves both environmental and societal goals. For example, absolute decoupling of resource use and environmental impacts can benefit human health and preserve environmental assets of cultural, recreational or religious importance, while enabling economic growth to continue.

However the full range of social and political issues connected with water and sustainable development cannot be covered in this report, which focuses only on the environmental aspects from a conceptual and methodological perspective. Another report would be needed to enlarge in this very important area and fully integrate the approaches here into the political debate.

2.3 Policy framework and the knowledge base

2.3.1 Policy framework

When the green economy is understood in the sense outlined above, it is clear that decision-makers will need to draw on a substantial knowledge base to be able to embed water resource considerations into related policy cycles in order to achieve a transition to a green economy. It is not enough to know about the amount of water used. Inputs differ hugely: some sources of water are renewable, some depletable, some in more or less finite supply. To target resources and design appropriate policies, decision-makers need information about the natural capital base, including what resources are available and their location, how much ecosystems can provide sustainably, what effects particular pollutants have on ecosystems, and how to offset the loss of depletable resources by investing in other forms of (natural) capital.

The interplay of resource use and environmental impacts from a life-cycle perspective can be simply conceptualised using the DPSIR framework, which portrays the dynamics and interactions of drivers (D), pressures (P), state (S), impact (I) and responses (R). Figure 2.3 illustrates how population growth and economic activities such as agriculture, energy production and industry act as driving forces to build up pressures on the environment through the use of water, materials, energy and land. This in turn affects the state of the natural environment (biodiversity, air and water quality) and the state of human health and well-being. Specific impacts can be distinguished, for example by considering thresholds related to the state of ecosystems in the context of their resilience. Evidently, water is itself an essential component in all elements of the DPSIR framework. Water supply and sanitation can be considered as a driver with its own dynamics of pricing, infrastructure and governance. Water is a vital good and service represented in the pressure (water use), and it is a core element in the state of an ecosystem in terms of water scarcity, quality, and the state of water and wetland ecosystems.

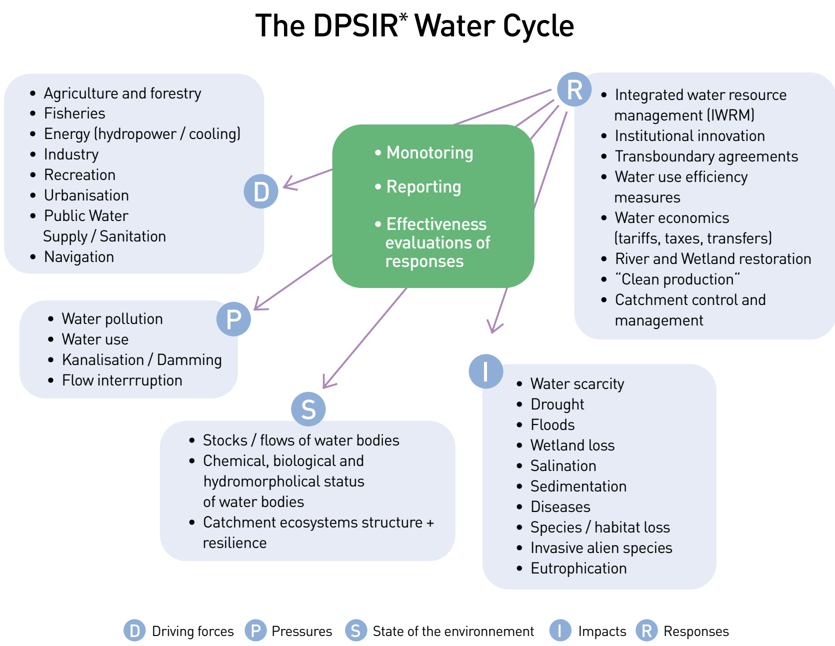
Across the policy cycle there is a need for indicators that can show the source and availability of water, the extent and nature of resource inputs required and taken, and the relationship to economic outputs globally, nationally and in individual sectors. Consumption-focused indicators, which measure the use of resources in products and services across the whole life cycle are also valuable, particularly when resources are not reused, to help designing policies to address resource use embedded in international trade.

2.3.2 Water as a natural resource

There are many aspects to quantifying water resources. Many terms are used in everyday speech, others have specific definitions. For

Figure 2.3

The DPSIR framework



Source: EEA (1999), Stanners et al. (2007)

example, the Food and Agriculture Organization of the UN (FAO) uses a type of water accounting approach to calculate the world's national water balances. The method consists of a set of rules and guidelines (FAO/BRGM (1996)), in which renewable water resources are determined on the basis of the hydrological cycle and represent the long-term average annual flow of rivers, surface waters and groundwater, and non-renewable water resources are groundwater bodies (i.e. deep aquifers) that have a negligible rate of recharge on the human time-scale. It is from here that we understand the regional aspects of global water availability.

Below are some of the most common phrases and the way in which they are more specifically defined in the water-resource literature.

Water availability varies around the world and depends on both precipitation and evapotranspiration. It is given as a percentage of global runoff, usually by region. Latin America is the most water-rich region with about one third of the world's run-off, and the Middle East and North Africa the least with only 1 per cent of global runoff.

Water consumption, or water abstraction, is usually described in terms of annual water withdrawal as the gross amount of water extracted from all sources, either permanently or temporarily, for a given use. Some may be returned to the original source, the rest may be consumed in the use. Consumptive use refers to water that is made unavailable for reuse in the same basin or irrecoverable, for example through seepage to a saline sink, evapotranspiration or contamination (Gleick, 1996; 2003). Most agricultural water use is consumptive, being bound up in plants or consumed by evapotranspiration, whereas water abstracted for electricity generation is nearly all returned to a water body. In Europe, total abstraction is 288 km^3 per year. Of this, 44 per cent is for energy production, 24 per cent for agriculture, 21 per cent for public water supply and 11 per cent for industry. However regional differences are very pronounced: for example, in the south the largest extraction is for agriculture which can be as high as 80 per cent (for irrigation).

Water withdrawal usually describes the amount of water used per person. This varies considerably around the world, from 20 m^3 per year in Uganda to 5 000 m^3 in Turkmenistan; the average is 630 m^3 per person per year from surface and groundwater sources.

Water scarcity can be described as a physical or a social measure; it is a measure of the relationship between the use of water and its availability. For clarity, the physical term will be used in this report to denote a lack of enough water (i.e. quantity) and/or access to safe water (i.e. quality).

Water shortage is an absolute lack of water, where the available amount does not meet defined minimum per capita requirements for water use. In some cases it is measured as the number of people that have to share each unit of water resource (Falkenmark et al., 2007). Global and regional trends in water shortages show that in 2005 2.3 billion people lived under chronic water shortage conditions (Kummu et al., 2011).

Water stress describes the consequences of water scarcity on ecosystems and human populations. It can be related to a decline in quality or to the level of conflicts.

Water exploitation index (WEI) is a relatively straightforward indicator of the pressure or stress on freshwater resources. It is calculated annually as the ratio of total freshwater abstraction to the total renewable resource. In Europe it is given as a national index; a value above 20 per cent implies that water resources are under stress and values above 40 per cent indicate severe water stress and unsustainable use of water resources (Raskin et al., 1997; EEA, 2009). Despite its limitations, the WEI shows a broad correlation between river basins with a high WEI value and detrimental impacts.

2.3.3 Water as an economic resource

There is also a need to move beyond physical indicators to those linked with efficiency, conversion of water as a resource into goods and services, and ultimately measures of monetary value. There are two key concepts:

Box 2.1 Measuring water use — Jordan Water Information System

Jordan is one of the most water-scarce countries in the world. Delivering sufficient water and wastewater services to meet the needs of a growing population and national economic development targets is a significant challenge. Clearly, determining how to allocate water efficiently and equitably demands detailed information on the country's water resources and use.

This challenge has been met through the establishment of a detailed metering system and a thorough accounting system which relates physical water flows to the economy and enables an environmentally extended input-output analysis. Those two elements have been joined and made operable within an extensive Water Information System (WIS).

Data are collected and analysed via the system that brings together raw data from across the country, including real-time meter and telemetry data, and stored in a centralised database for analysis. A range of software-based analysis and planning tools such as Water Evaluation and Planning System (WEAP), the Water Information System and ArcGIS have been integrated into the national planning and operations processes. A key aim of the water information system is to compile physical and monetary data on water use and supply and on environmental protection and management expenditures, all disaggregated according to International Standard Industrial Classification (ISIC) specifications.

These data are further analysed to serve multiple purposes. They can be disaggregated to give a more detailed picture of water use in products and activities; used to elucidate the physical flows of water in the economy; analysed using environmentally-extended input-output analysis to deliver policy-relevant information on indirect water use by final demand categories; used to support the development of environmental resource and flow accounts; and used to prepare modified national accounts that include consumption of national resource stocks and impacts of pollution.

However, there are challenges in generating all these data and indicators, particularly on the relevant time and space scales. Existing administrative data are often insufficiently developed to support the elaboration of environmental accounts for resources and flows. Multiple new surveys will be needed to deliver physical and monetary data on water use and supply and on environmental protection expenditure that are compatible with national accounts. To address these needs and support the preparation of physical and economic water accounts, which began in 2006, the project envisages three new water surveys, addressing industry, agriculture and households.

Further work by Ministry of Water Infrastructure (MoWI) experts in cooperation with the Department of Statistics (DoS) is needed to link national methodologies to the System of Economic and Environmental Accounts – Water (SEEA–W). To support recent initiatives to develop a national water information system for multiple governmental stakeholders, existing agreements on data sharing will be reviewed and modified to ensure lasting cooperation between data providers. These actions should enable the national water information system to make an important contribution to the development of a more comprehensive Shared Environmental Information System (SEIS), through strategic cooperation with the Ministry of Environment.

efficiency and productivity, defined below:

Water productivity (*product units/m³ water*) measures how a system converts water into goods and services. It captures the ratio of net benefits derived, for example, from crops, forestry, fisheries, livestock and industrial systems, to the amount of water used in the production process. In general terms, increased water productivity means increasing the amount of benefit - i.e. output, service or satisfaction - from a unit of water input. When the output per unit of water is monetary rather than physical, it is referred to as *economic water productivity.*

Water-use efficiency (m³/product units) is defined as the ratio of the water input to the useful economic/product output of a system or activity. It is thus the inverse of water productivity. Greater water-use efficiency would imply using less water to achieve the same or more goods and services. In statistical publications the ratio (m³/product units) is also neutrally referred to as *water intensity*.

Improving water-use efficiency entails finding ways to minimise water intensity and so maximise the value of water use and allocation decisions within and between sectors for sustainable social and economic development. It involves getting the most not only out of scarce water resources but also out of other natural, human and financial resources. Such an approach is based on four key inter-related concepts: technical efficiency, productive efficiency, product-choice efficiency and allocative efficiency (Global Water Partnership, GWP, 2006a).

Product choice efficiency and allocative efficiency can be considered at different levels (Hoekstra and Hung, 2005). The first is the user level, where price and technology play a key role. This is the level where 'local water-use efficiency' can be increased by creating awareness among water users, charging prices based on full marginal costs and stimulating water-saving technology.

At the second, the catchment or river basin level, a choice has to be made on how to allocate the available water resources to the different sectors of the economy (including public health and the environment). People allocate water to serve certain purposes, which generally implies that other, alternative purposes are not served. Choices on the allocation of water can be more or less 'efficient', depending on the value of water in its alternative uses. At this level we speak of 'water-allocation efficiency'.

In the context of international trade it is relevant to consider water beyond the catchment level with the important aspects of 'local water-use efficiency' and 'water-allocation efficiency'. The virtual water concept considers water as a global resource and talks about 'global water-use efficiency'. Overall efficiency in the appropriation of global water resources can be defined as the sum of local water-use efficiencies, meso-scale water-allocation efficiencies and global water-use efficiency. This includes the need to look at the comparative advantages of certain water uses in particular regions and for particular local economies as well as to consider opportunity costs for these local economies.

However in all cases it is most important to consider the direct physical impacts of the water abstracted in a certain river basin and the impacts caused. For that it is also vital to distinguish the actual source of the water - rainwater, surface water, groundwater, grey water or fossil water, each of which have different implications for the sustainability of the management.

For many economists, a key solution lies in calculating the monetary value of externalities and ecosystem resources and services that are currently unpriced but have a huge influence on human well-being. Such values can then be incorporated into decision-making by reflecting them in economic cost-benefit analysis, using them to design economic policy instruments (taxes and subsidies or cap-and-trade schemes) or integrating them into 'green' national accounts.

The last point is crucial since some would argue that faulty pricing is the core factor driving unsustainable economic decision-making.

According to classical economic thinking, in idealised market conditions the pricing mechanism should ensure the allocation of resources to their most productive uses and thereby maximise social well-being. Reality differs markedly from optimal market conditions, however, and prices often provide highly distorted signals of resource scarcity and the full costs and benefits of our actions, leading to inefficient investments and resource use.

Economists assessing market failures and responses often seek to derive prices for human preferences. Such values represent a very important analytical tool. They render diverse ecosystem services commensurable with each other and with other economic and social costs and benefits, and make it possible to integrate these values into decision-making and policy incentives.

This last point leads us to an additional area where decision-makers require knowledge to guide the transition to a green economy: information on the policies, tools and technologies that can be deployed within the economy (at national, regional and other scales) to extract more value from resources, while minimising waste and emissions. Market-based tools are clearly important as a means to correct price signals and thereby incentivise an adaptive water management and better allocation of resources. But there is also a role for regulatory information-based approaches. Clearly, the underlying knowledge base on resource use and natural systems will be essential for designing effective tools and setting and monitoring appropriate targets for keeping the limits of sustainability, as outlined in the following chapter.

As examples from Jordan, Singapore and Netherland show, knowledge of available and used resources is key to developing the governmental and institutional setting for sustainable water management. The availability or constraints of water resources, particularly in water-scarce areas, pose a significant risk to political and social stability (i.e. Jordan, Singapore but also in the African and Chinese case studies). Climate change is further increasing these risks. In this sense, knowledge management and risk management go hand in hand, using appropriate tools, reliable information and indicators on the status of the resources and the impacts on ecosystems and their social and economic consequences.

2.4 Decoupling concepts

At the core of the concepts of sustainable development and the green economy is recognition of the need to break the link between economic development and resource use - to 'decouple'. The notion of decoupling is intuitively simple to grasp but scrutiny reveals various nuances.

The first Resource Panel report on decoupling (UNEP, 2011a) used the term to denote a reduction in the amount of resources used or environmental impacts caused per unit of economic output. Figure 2.4 represents a simplified diagram differentiating possible developments of GDP, different trends of resource use and human well-being.

The IRP decoupling report (UNEP, 2011a) introduced terminology for several forms of decoupling:

- *Resource decoupling* in general means reducing resource use per unit of economic activity. This can be expressed by comparing economic output over time with the resource input (water use). The resource use itself can increase or decrease in relation to a reference value (100 per cent). This principle of resource decoupling is specified in more concrete cases:

- *Relative decoupling* occurs when resource use still increases but at a lower rate than economic growth.

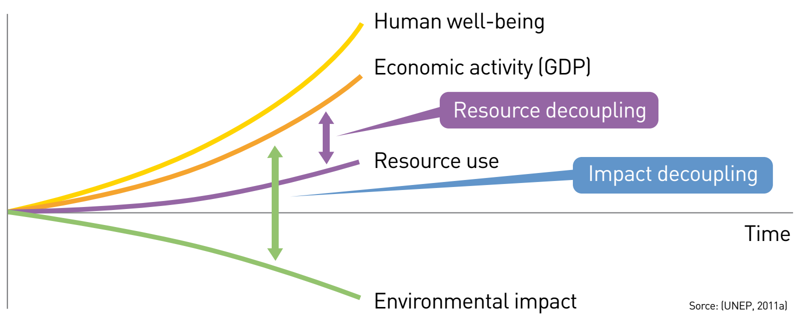
- *Impact decoupling* occurs when the scale and character of resource use causes no negative environmental impact so that natural systems can function and provide ecosystem services sustainably, respecting the limits and resilience of the respective ecosystems; this is often used synonymously with *double decoupling* which captures the notion of decoupling resource use from both economic activity and environmental impacts.

- *Absolute decoupling* in contrast occurs when resource use declines irrespective of the growth rate of the economic driver. Absolute reduction in resource use only occurs when the growth rate of resource productivity exceeds the growth rate of the economy (UNEP, 2011a). However, depending on the nature of the environmental impact, this can, but does not necessarily, also lead to impact decoupling.

Coupling or decoupling can be described, as in Figure 2.6, by a decoupling index, which

Figure 2.4

Stylised representation of resource decoupling and impact decoupling



Box 2.2 The case of Singapore – an example of significant relative decoupling of economic growth from freshwater abstraction and use

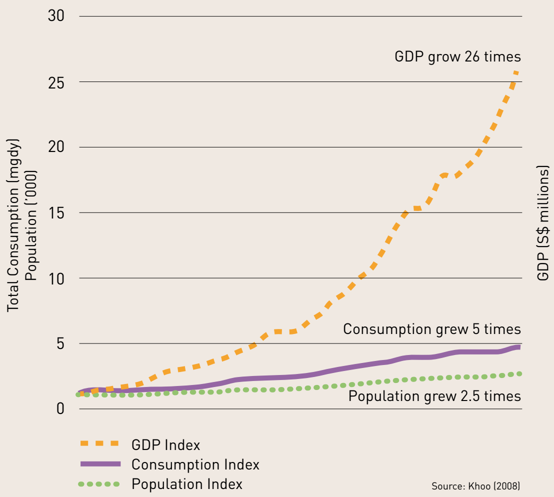
Singapore's 4.4 million people live within a city-state that has an area of about 700 km². The main source of freshwater has been imported water from Johor, Malaysia via three large pipelines across the 2 km causeway that separates the two countries. This was necessary because, despite an annual rainfall of 2 400 mm/year, Singapore has no large water catchments external to the city or groundwater aquifers from which to draw water to meet its needs and is considered a water-scarce country. These factors have focused attention at Singapore's water utility, the Public Utilities Board (PUB) to reducing the demand for water by improving efficiency, cutting waste and expanding alternative sources of supply, resulting in the achievement of significant levels of relative decoupling (PUB, 2009).

Over the last 40 years, Singapore's economy has grown by a factor of 25. It has had one of the fastest transitions from a 'developing' to a 'leading first-world' country in history, with the highest per capita incomes in Asia. The population has grown by a factor of 2.5 in the period, from 1.7 million to 4.4 million today, yet water use has only increased five-fold. In terms of water consumption in absolute terms this represents a five-fold relative decoupling for the whole Singapore economy (Figure 2.5).

This has been achieved through effective, purposeful and long-term demand management, water efficiency and water-leakage prevention programmes. Per capita residential water use has fallen

Figure 2.5

Singapore GDP, population and total water consumption, 1965–2007 (index, 1965 =1)



consistently for the last 15 years providing an exception to an otherwise worldwide increase. This result is no accident. The Singapore government is one of the few with a publically stated target for residential sector per capita water use of 140 litres per capita per day by 2030.

Singapore and its Public Utilities Board have also reduced growth in water consumption by minimising water leakage throughout the city's water infrastructure which is tracked by measuring the level of 'unaccounted for water (UFW)' (Tortajada, 2006b). This has been reduced from 9.5 per cent of total water production in 1990 (Khoo, 2005) to 5 per cent by 2002. This is a level that no other country can match at present and contrasts with the fact that unaccounted for water in most Asian urban centres now ranges between 40 and 60 per cent.

Singapore has also reduced absolute freshwater consumption by 60 per cent through the development of alternative sources such as extensive stormwater harvesting, treatment and reuse, treated and recycled municipal water, and desalination. Today, 35 per cent of Singapore's water comes from rainfall captured on its own limited territory, about 15 per cent is high-quality recycled water produced from wastewater by its 'NEWater' treatment plants, 10 per cent comes from desalinated water, and around 40 per cent is imported from Malaysia (ADB, 2005).

In 2010, the Singapore government and its Public Utilities Board announced that it has now committed to replacing the final 40 per cent of imported freshwater usage with further water-efficiency improvements as well as the development of greater levels of water recycling and desalination so as to eliminate the need for imports from Malaysia by 2060.

This remarkably integrated and holistic approach to sustainable urban water management has been institutionally possible because Singapore's Public Utilities Board currently manages the entire water cycle of Singapore, as well as electricity and gas. This includes sewerage, protection and expansion of water sources, stormwater management, desalination, demand management, pricing, community-driven programmes, catchment management, and public education and awareness programmes, leading to wastewater treatment and reuse on an unprecedented scale.

quantifies the different trends (growth rates) of resource use or the economy (e.g. as GDP against time).

In the resource-constrained world we inhabit, increasing resource use has already reached physical limits and causes environmental impacts (e.g. in fisheries, soil erosion or with CO_2 emissions). The impact per unit of resource use is increasing, meaning that impacts do not decouple and, instead, the state of ecosystems declines.

In Figure 2.6 this scenario is represented in Case I. Here, a decoupling index DI ↗ 1 means that the increasing rate of resource consumption keeps pace with or is higher than economic growth, and no decoupling takes place. This in turn could lead to adverse effects on human well-being and GDP: prices could rise further as resources are constrained, while human well-being goes down.

When DI equals 1 it is the turning point between absolute coupling and relative decoupling. Case II describes relative decoupling where resource consumption falls short of economic growth. In Case III resource use decreases while the economy keeps growing.

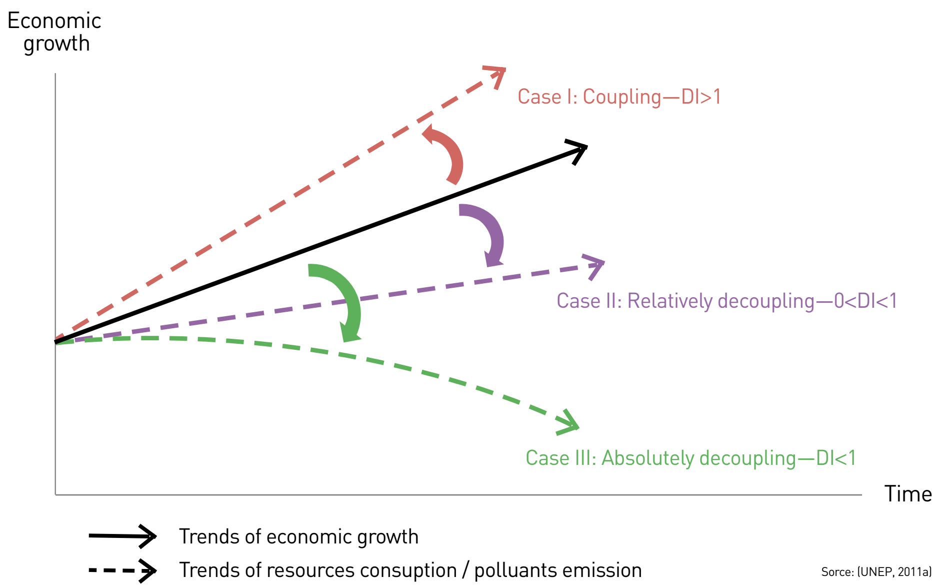
Neither Figures 2.4 nor 2.6 depict whether the coupling or decoupling between resource use and economic growth ultimately leads to maintaining and preserving ecosystem services. Whether economic growth decouples from actual environmental impact depends on the status and resilience of the affected ecosystems, over time and space. While very robust and resilient ecosystems may not show impacts as a result of increasing resource use, it is nevertheless important to follow the precautionary principle, reject the thinking of 'filling up everything' and turn the trend of resource use in comparison with the reference value (absolute decoupling).

2.4.1 Decoupling and efficiency

The concepts of *resource efficiency* or *productivity* are also used to express changes in the amount of resource inputs used to generate economic outputs. The key difference is one of scale: water-use efficiency has a greater micro-level focus on the output of processes

Figure 2.6

Scenarios for economic growth and its pressures on resources



Sorce: (UNEP, 2011a)

and products while water productivity embodies a more macro-economic view relating water to GDP. However, although all forms of decoupling involve an improvement in efficiency, it is not necessarily the case that increased efficiency will lead to all forms of decoupling.

Clearly, greater efficiency will always result in relative decoupling, but it will not guarantee a decline in resource use or environmental impacts. Efficiency measures cannot, by themselves, provide adequate indicators of sustainability or indeed stand-alone targets. Only metrics that convey the full relation of economic activity to environmental impacts at the relevant hydrological unit and time period can guarantee sustainable water management.

The need to focus on resource-use impacts on ecosystems derives partly from the potentially mixed effects that can arise from efficiency improvements. The adoption of technologies that reduce the resource inputs required to produce a unit of economic output may not result in a commensurate fall in demand for the inputs. It can even, paradoxically, result in an increase in the use of those resources. This 'rebound effect' occurs because greater efficiency reduces the price of the goods produced, incentivising higher levels of consumption, which can partially or wholly offset the declines in demand for resource inputs.

Leaving aside the rebound effect, however, the characteristics of water resources mean that it is particularly important to focus on ecosystem impacts rather than the amount of water used in production processes or in economic output as a whole. The enormous variation in water abundance and scarcity at differing locations and times means that the impacts of water use will vary enormously depending on the source and timing of the water extraction.

This is not to say that technologies and other innovations that enhance the water efficiency of production are not important for societies to sustain economic development while preserving environmental and social systems. On the contrary, they will be absolutely essential. At the same time, however, it is obvious that navigating the shift to a green economy, designing the necessary targets, instruments, indicators, etc., requires us to look beyond efficiency and focus on the impacts of resource use and the status of natural systems.

2.5 Challenges in quantifying water impact decoupling

2.5.1 We can only manage what we measure

A significant challenge in establishing 'sustainable water management' is to quantify decoupling, particularly in terms of developing accurate measures of water use and its impacts on ecosystems. This knowledge is essential to support efforts to set targets, design policy instruments and monitor progress. Unfortunately, the availability of relevant data is currently limited. As the IRP noted in its first decoupling report (UNEP, 2011a):

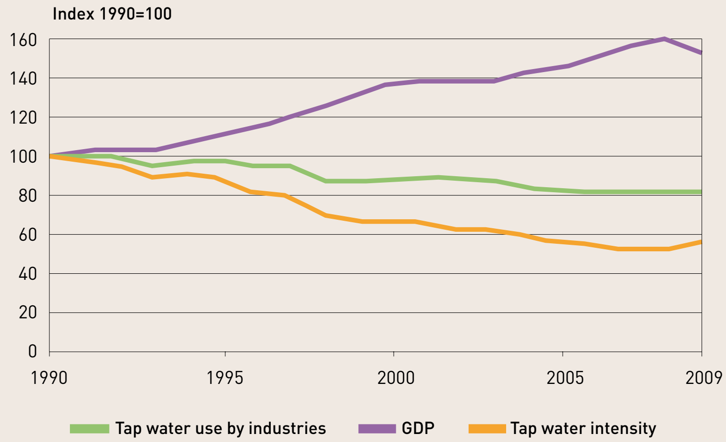
Box 2.3 More efficient use of tap water by the Dutch economy

Although water itself is not scarce in the Netherlands, groundwater stocks in particular are coming under increasing pressure. This is caused by competing uses, especially in warm summers, as well as the minimum standards required for drinking water. Lowering groundwater tables and the resulting desiccation are having an impact on nature conservation and biodiversity in certain areas. The water industry is responsible for 75 per cent of groundwater use.

As Figure 2.7 shows, Dutch industries have been using less and less tap water (and therefore less groundwater) since 1990: there has been a 17 per cent reduction in water use, although industrial production has been rising. As a result the tap water intensity has decreased by 46 per cent, although tap water use has been stable since 2006. Industrial tap water use has been absolutely decoupled from GDP as a result of efficiency gains from water-saving measures and from the mid 1990s onwards by substitution of tap water by surface water, triggered by the introduction of a groundwater tax.

Figure 2.7

Tap water intensity, total tap water use and GDP



Note: tap water intensity, defined as the amount of tap water used per unit of value added (in constant prices), is an indicator of the water efficiency of economic production.

Household use of tap water per capita and per household continues to decline

Households account for nearly two-thirds of overall tap water use in the Netherlands, industry using most of the rest. Agriculture and horticulture have an average 4 per cent share of the total amount of tap water used in the Netherlands, which shows a slight downward trend. Since 1990, the total annual amount of water used by households increased by only 1 per cent, despite population growth. Through efficiency measures such as water-saving toilets and shower heads, and new and improved household appliances in the form of dishwashers and washing machines, household water use per capita fell from 47.9 m^3 in 1990 to 43.6 m^3 in 2009.

For more information see CBS (2010, 2011)

> *'While estimates of global freshwater use in long time series are available ... no country-by-country database is available to support an analysis of the coupling between economic activity and water use. This paucity of data is related to the fact that water use is often considered a free common good not reflected in economic statistics. System boundaries also raise problems, as the same water can be used many times over.'*

Assessments should adopt a systematic life-cycle perspective, considering both direct and indirect water use for products and all relevant impacts at production sites and water uses along the supply chain all the way to the end-user. However, the ubiquity of water in biotic and economic processes means that linking numerous instances of water use to specific ecosystem impacts is very complex.

Each instance of water use and consumption in production processes and at different stages in the supply chain occurs at a local, spatially-distinct scale but in many cases has a global reach. Equally, impacts on human well-being or ecosystems are felt locally in distinct catchments but are often influenced by long supply chains, not only reflecting human activities in the same river basin but also via interbasin exchanges and international trade. In addition, these supply chains and interdependencies are not restricted to single sectors (e.g. manufacturing, agriculture or public water supply) but evolve into interdependencies between sectors.

There are therefore substantial difficulties in linking water use and consumption back to impacts in specific river basins at specific times (see also the case study on the Mississippi River Basin below). This in turn complicates the design of consumption-focused instruments, which represent important tools in incentivising and delivering sustainable water management.

Beyond the consideration of quantifying allocation decisions or shifting water-intense production processes away from water-scarce regions, accounting for water efficiency should also help to find new and better production technologies for use in such regions.

2.6 Targets and tools for water decoupling

Ultimately, sustainable water management rests on using the information generated on water use and impacts to design and develop policy targets and their respective measures, and then to monitor their implementation. Such mechanisms can help society to put water to its most productive use, whilst maintaining ecosystem function, human well-being and social equity.

2.6.1 Water-management targets

Targets are essential to achieve a genuine decoupling of economic growth from environmental impacts. As water management is tightly bound to the geographical, climatic and hydrological conditions in a river basin, targets must be set within appropriate spatial and temporal boundaries. The distance to target must be evaluated regularly to assess and guide water management and determine the success of water decoupling efforts. To be able to assess and quantify environmental impacts it is usually necessary to evaluate a cause-effect relationship between a certain water use - consumptive, polluting, in-stream or causing structural effects - and ecosystem changes.

A variety of different forms of targets (whether legally binding or otherwise) are available for use in water management. Targets can be set for water quantity, water quality and pollution, biological elements and their abundance, and structural features of water bodies in support of ecosystem functioning. However, the key factors guiding the process of setting targets and monitoring progress should be the functioning of ecosystem services and scientifically-based multidimensional cause-effect relationships.

In setting targets, a useful starting point is the recognition that, just as the world economy operates within the global ecosystem, 'the human water economy is a subset of nature's water economy and is highly dependent on it' (Postel, 2003). As such, ecosystems must be afforded the 'quantity, quality, and timing of water that they need to continue to provide

Box 2.4 Dairy impact on water resources in the Mississippi River Basin

A study by Matlock and colleagues (Thoma et al., 2011) shows that the impacts of agricultural activities such as US dairy milk production on water quantity and quality are highly dependent on location. Nutrients such as nitrogen and phosphorus from crop and dairy production facilities can flow to local water bodies where they cause eutrophication, and in aggregate can contribute to regional impacts such as the Gulf of Mexico hypoxic zone. This case study shows the impact of on-farm dairy practices on water quantity and quality with additional analysis of the off-farm impacts of the production of dairy feed on water quality.

On-farm dairy water use was typically overshadowed by use in other sectors, and within the agricultural sector by crop irrigation. Areas of high dairy herd populations that overlapped areas of high water stress were mostly located in the southwest and California. The largest proportional impact of on-farm dairy production on water quality came from phosphorus. Nitrogen impacts from the dairy life cycle were associated with feed production, predominately corn.

Dairy production water use was less than half of agricultural water use in most locations. With the exception of the southwest US and the California Central Valley, dairy production is not currently located in water stressed regions in the US. The challenge for dairy producers in sustainable water supply appears to be more related to irrigation for growing feed (corn and corn silage) rather than stress from direct on-farm use.

The main impacts from nitrogen were associated with corn production, mostly at the regional scale i.e. Gulf of Mexico. The impacts from phosphorus on eutrophication were more complex; corn produced the largest local and regional loads, but on-farm contributions of phosphorus to the Gulf of Mexico were significant. The most effective approach to reducing the impact of US dairy producers on eutrophication would be to reduce nitrogen loss from corn, reduce sediment loss from fields to reduce phosphorus transport, and reduce phosphorus loss from on-farm manure application.

the goods and services society values. Only after adequate water is provided to meet basic human needs and to safeguard ecosystem health is water allocated for irrigation, hydropower, navigation, industrial use and other water-related benefits' (Postel, 2003).

The key point is that the requirements of the environment and ecosystem services have to be accorded priority in relation to other competing users, and targets must be set for achieving environmental flow requirements; only in this way can the maintenance and restoration of all ecosystem services and sustainability be ensured in the long term.

2.6.2 Water management tools

A visualisation of competing users within the human water economy (Figure 2.8) draws attention to the fact that sustainable water management must integrate all sectors to ensure that the totality of water uses is confined within the sustainability limits of the relevant water body or river basin over an appropriate time period.

Policymakers have a variety of tools at their disposal to achieve this goal. Political will is needed to respect the inherent resilience and sustainable limits of ecosystems and grant the environment the water volumes and quality need to provide ecosystem goods and services. This requires norm setting and clear and efficient but effective legislation. In Europe the Water Framework Directive (WFD) sets such limits of sustainability in form of the requirement to reach "good status" for all water bodies by 2015. To implement measures to achieve these targets fully, a wider range of policy options needs to be used to encourage the most cost-effective and innovative developments, based on an active, multi-stakeholder approach. The main policy options include technological innovation, flexible and cooperative governance, public participation and awareness, and economic instruments and investments

Since historic mismanagement of water resources can often be perceived as a market failure, economic instruments such as taxes or auctioned emission permits can have an important role. Market-based approaches potentially have the advantage of applying to all users equally, encouraging the allocation of water resources to their most productive use in an adaptive way.

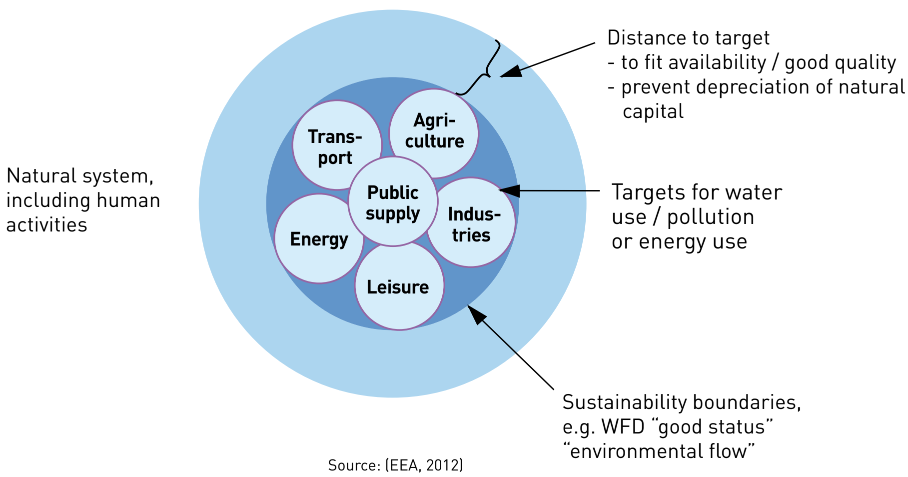
However, pricing approaches obviously have limitations. In reality, governments often have an important influence on water pricing, setting prices based on criteria other than economic efficiency. The criteria can range from equity concerns (e.g. ensuring that poorer groups or regions have adequate water at a reasonable price), to cultural values (e.g. supporting traditional land-use or lifestyles), to pressure from lobby groups. For example, based on a combination of these considerations, a government might set prices for farmers at levels that fail to reflect water scarcity or promote the most efficient use of resources in terms of crop selection or watering methods.

There is certainly considerable scope for improving water management by correcting prices to equal the full marginal costs of supply. However, markets are not necessarily the ideal mechanism for distributing an essential good such as water. Governments may have sound reasons for using other allocation mechanisms, including, most fundamentally, the need to ensure that ecosystems have adequate water to function and deliver services. These alternative approaches can include water volumes when dealing with water scarcity questions or quantities of pollution loads, or indexing a combination of both.

Of course, regulatory mechanisms of this sort face their own challenges. For example, monitoring, volumetric metering and

Figure 2.8

Sustainable water allocations to ecosystems and competing users



Source: (EEA, 2012)

enforcement of legal limits on water use or pollution is often costly and varies in its efficacy due to information asymmetries between regulators and water users. There is clearly a case for using a combination of approaches, including information-based tools such as labelling and education of producers and consumers. Operating together, this mixture of tools should incentivise innovation and the adoption of new processes and technologies, enhancing efficiency across all sectors and thereby enabling them to decouple water use and impacts from economic growth.

Technical and productive efficiency depends on good water stewardship applied by the main actors and stakeholders in key sectors. Global activities to promote environmental stewardship and sustainability in the economic sector are increasingly focused on corporate water management in industry. There are several initiatives aimed at improving corporate water management and ensuring that the manufacturing and beverage industries, for example, use water efficiently in their production processes. In doing so, they support sustainable development in their nation or region, contribute to a greener economy and reduce business risks from water scarcity and other related sources.

2.7 Decoupling indicators addressed in this report

There is a basic need for indicators of water decoupling. Essentially, decision-makers require metrics that can convey the impact of water use and consumption, in order to support the design and implementation of targets and tools. However, given the huge diversity of water uses and the huge complexity of linking uses to impacts, it should probably come as little surprise that no single approach can meet all these needs.

The remainder of this report discusses different accounting and assessment approaches and their applications. The approaches to assessing impacts and thereby contributing in a policy-relevant way to water efficiency and decoupling are also discussed. All approaches share a focus on water resource management and are based on a physical water balance between water available as a natural resource and the different kinds of water use (consumptive, non-consumptive, in-stream) in the environment and the economy.

One of the key steps, when considering water decoupling, is the development of quantified estimates of the stocks and flows of a country's water resources. Fluctuations within and uncertainties about the global hydrological cycle make these calculations inherently difficult. This complexity is one reason why a number of accounting approaches have emerged in recent years, capable of informing allocation decisions at the scale of river basins or national parts of river basins.

Such methodologies can illustrate water issues at the product level, displaying interdependencies across the supply chain and between spatially-remote river basins via production processes. Nevertheless, for any production process and water use in a region facing scarcity problems, the basic balances of water use and availability must be compiled in order to quantify scarcity. Accounting and allocation systems must reflect hydrological integrity and a clear reference to local conditions.

The quantification approaches described below depend mostly on the context and purpose in which they are applied and are usually not to be compared with each other, but should be considered complementary.

A clear and transparent knowledge base is indispensable for all methodologies and approaches.

3 Data and information sources

The core elements of any methodology and information system needed to quantify how water flows through the hydrological system, ecosystems, and the economy are the water inventory and temporal and spatial assessment of the stocks and flows in and through the different compartments. The data flows and methodologies needed to tackle the challenges of sustainable water management need to be temporally and spatially specific and need to address both the environmental impacts and the socio-economic dimension of water efficiency. It is also vital that the sources of data and information become well-established, along with the governance structures that use them. Given the complexity of management of freshwater today, the focus of this report remains for the most part on water resources on land. There are, however, certain considerations to be made with respect to some coastal and transitional ecosystems, e.g. coconut groves and mangroves, which rely on seawater to provide ecosystem services on land. Where these occur, they are included in the quantitative methods described below.

3.1 Elements of the water balance

All methodologies that quantify relevant aspects of the hydrological and economic water cycle rely on sound basic data. Water balances (also known as inventories or registers) represent the fundamental approach to accounting for the flow of water into and out of a system. But to provide a robust basis for analysis and decision-making, such accounts must meet certain criteria.

When considering resource efficiency and sustainable use, a hydrological balance must include fluxes (flows available for immediate use) and stocks (resource from past inputs) but not future inputs. Future resources must not be treated as currently exploitable. That means, for example, that the time span for allocations has to be chosen carefully. Availability and accessibility shall be evaluated on a monthly basis, depending on the specific climatic variability in the eco-regions and catchments. A seasonality signal may be stronger and therefore can be used instead. Classical water balances, which calculate an overall balance over one year or over national territories larger than natural hydrological units, may ignore this point and should therefore be used with caution.

The key components of the hydrological balance have been specified since the second half of the 20th century: evaporation, precipitation, soil water, transfers to groundwater and rivers, storage in lakes, aquifers and ice caps. In classical balances, the volume in a certain compartment is presented without reference to its residence time, which can vary significantly between different compartments. For example, the global average residence time in oceans (standing stock 1 370 million km^3) is approximately 2 600 years, whereas in rivers (standing stock 0.0012 million km^3) the average residence time is 12 days. The main elements of the water balance are shown in

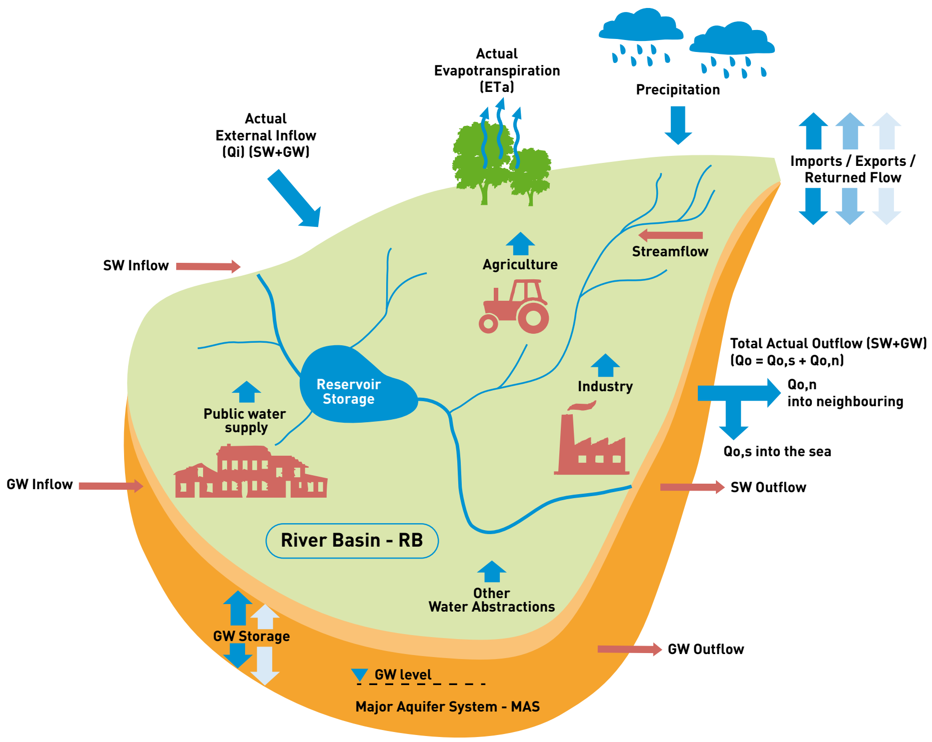
Figure 3.1, however a static model is shown, not including the time-space variability of the water cycle impacted by climate change. In a further development of Figure 3.1, blue water resources are referred to as the sum of surface and groundwater; green water resources are referred to as rainwater insofar as it does not become run-off.

The large differences in residence times make it necessary to address the stocks and flows from the perspective of their potential use. Residence time is an intriguing indicator. It expresses the claim that a storage project makes into the future, as a kind of temporal footprint. It also expresses, in a temporal unit, its spatial dependency and area of influence. 'The larger the residence time of a reservoir, the greater its dependence on the water resources generated in the upstream catchment area, and the larger the impacted area downstream [cf. Vörösmarty et al., 1997].' Van der Zaag and Gupta, 2008). Large reservoirs and their operations for agriculture and hydropower can cause large changes in flow regime which can be a major cause of ecosystem degradation. There is no simple method to depict the complexity of the situation. The role of all quantification methods included here is to present the balances at levels of temporal and spatial disaggregation that are practically useful (both in themselves and in supporting other methodologies). They should be as free as possible from misleading errors resulting from misunderstanding of the flux and stock issues, and they should specify the location of water consumption and the (potentially distant) location of impact or water stress.

This report uses terminology derived from the International Recommendations for

Figure 3.1

Simplified water budget at the river basin scale



Water Statistics IRWS) adopted by all the UN member countries through the UN Statistical Commission in 2010; the UN Statistic Division (UNSD) System for Economic and Environmental Accounting for Water (SEEA-W); the last provision of the glossary of the World Meteorological Organization (WMO); life cycle assessment and Water Footprint Assessment. Each of the quantification approaches sets up a water balance between the physically-available water and the water used or consumed. Since all the methodologies quantify water flows and balances in an economic context, the basic terminology used is similar, although certain differences in interpretation exist.

3.1.1 Water availability and accessibility

In basic hydrological terms, 'water availability' refers to the total amount of water available for human use and/or the environment in a river basin. However, the precise definition often depends on the context in which it is used. In the literature there are basically three ways to understand the term water availability:

- all the water potentially available in a river basin (i.e. precipitation + stream or groundwater inflow into the river basin);
- all the water technically available (i.e. all the water that can be extracted technically and economically);
- all the water technically available minus the water needed to maintain ecosystem function.

The term accessibility is also used for the third of these to underline the fact that, after accounting for environmental needs, only a reduced amount is accessible for human use. Other references (e.g. Smathkin et al., 2004; or Poff et al., 2010) account for environmental needs by subtracting environmental flow requirements from total run-off.

In the Water Footprint Assessment Manual (Hoekstra et al., 2011), blue water availability is also understood in the sense of the third definition, as the volume of natural run-off, through groundwater and rivers, minus environmental flow requirements, or, for green water, evapotranspiration of rainwater from land minus evapotranspiration from land reserved for natural vegetation or land not in production.

Other authors (e.g. Alcamo et al., 2003) consider 'water availability' to refer only to blue water availability, without subtracting the amount required for environmental flow.

3.1.2 Evapotranspiration

Evapotranspiration is the combination of evaporative losses from the soil surface and transpiration from plant surfaces (FAO, 2011a). These occur simultaneously and are an important component of the water balance in a river basin and can occur due to natural vegetation, agriculture and forestry. The most relevant issue in the context of a river basin is how the increased or decreased evaporation losses and evapotranspiration due to human activities affects downstream runoff[1].

Total actual evapotranspiration is essential for understanding the green water footprint, where it is equal to the sum of green and blue water evapotranspiration. The green component of evapotranspiration corresponds to rainwater and the blue to irrigation from surface and groundwater.

1 **Actual evapotranspiration** is 'the total volume of evaporation from the ground, wetlands and natural water bodies, and transpiration of plants when the ground is at its natural moisture content' (WMO, 1992). In hydrology, the concept excludes evapotranspiration resulting from all human interventions except rain-fed agriculture and forestry. Actual evapotranspiration is measured or calculated using mathematical models, ranging from very simple algorithms and corrections related to vegetal cover and season, to schemes that capture the hydrological cycle in detail. It is the very relevant parameter in water balances but difficult to measure.

Potential evapotranspiration is the 'maximum quantity of water capable of being evaporated in a given climate from a continuous expanse of vegetation covering the whole ground and well supplied with water. It includes evaporation from the soil and transpiration from the vegetation from a specific region in a specific time interval, expressed as depth of water' (WMO, 1992). It is estimated in order to estimate actual evapotranspiration but has no direct practical application in water balance calculations.

3.1.3 Water use

Economic sectors and the environment both use water, and various key concepts can be distinguished:

- *Water abstraction* or *water withdrawal* occurs when freshwater is taken from any source (for example a river, surface water or an underground reservoir) for any use, either temporarily or permanently.
- *Water consumption*, *consumptive water use* or *off-stream use* occurs when water is abstracted or withdrawn but not returned to the catchment or the return is sufficiently delayed. This includes all water incorporated in products, evaporated, or evapotranspired via soils or vegetation, or discharged into water bodies different from where they are withdrawn or into seawater.
- *Return flows* are water used by an economic unit and restored to the same catchment after a certain period. Such water use is sometimes referred to as 'degradative water use' to distinguish it from consumptive water use. Returns can be classified according to the receiving medium (i.e. the type of water resource) or the type of water (e.g. treated water, cooling water). The characteristics of return flows are particularly important for downstream users because of their potential ecosystem impacts.
- *In situ*, *in-stream* or *non-consumptive* water use occurs when there is no water withdrawal. Examples include using a water body for navigation or to transport timber, fishing, recreation, effluent disposal and some hydroelectric power generation.
- *Water transfers* refers to water removed from a catchment physically via channels or pipes. All water-accounting methodologies should specify very clearly whether such transfers are counted separately or incorporated in one of the preceding categories.

- *Virtually traded water* refers to water that is either incorporated into traded products that are removed from the catchment or water used for the growth of traded products, but which might return to the catchment after evapotranspiration.

3.2 Sources of water-balance data

Many different sources of information are needed for water accounting, including national and international compliance reporting; monitoring networks and observing systems; scientific programmes and modelling; and various geographic information systems. For economic and product-related water use, sectoral statistics and national accounts can be used.

3.2.1 Spatial classifications and aggregates

Spatial aggregates and classifications are vital to track hydrological realities and maintain hydrological integrity in terms of upstream/downstream relationships. The calculation of any water balance has to be specified in terms of hydrological units - river basins, catchments and water bodies (groundwater bodies and aquifers in the case of groundwater) - and as administrative units used by catchment authorities. Since statistical information is often collected in administrative units (national, communal or municipal), however, re-aggregation of water-related data is often required in cooperation with statistical, environmental and hydrological services and administration.

3.2.2 Time aggregates

To assess water imbalances and possible environmental impacts it is vital to consider seasonal effects. Annual averages of physical and economic water-related information are not useful for monitoring water resources. To take account of seasonal effects the aggregation should be monthly or more frequent.

3.2.3 Sources of hydrological and water-quality data

Collection of stock and flow information throughout the natural hydrological cycle is mostly managed by hydrological services, which collect or model information on water availability using meteorological and hydrological models. Globally such data are often very poor or almost completely absent.

The collection of water-quality data as environmental information is mostly in the hands of environmental agencies or ministries responsible for fulfilling legal reporting obligations.

One key global source of data regarding water quality is the United Nations Environment Programme (UNEP) Global Environment Monitoring System (GEMS) Water Global Network. It collates information on water quality from more than 2 800 stations worldwide using numerous biogeochemical and physical parameters including a wide range of metals, temperature, turbidity, alkalinity, nitrate and phosphates, biological oxygen demand and pesticides (UNEP/GEMS, 2004). Another important source regarding quality and quantity is the FAO's AQUASTAT programme. The national water statistics databases address resources, time-series of water withdrawals at the point of delivery and agricultural water management (FAO, 2011b).

Reporting and compliance information requirements under legal instruments usually produce data that are regularly updated, tightly specified, precisely monitored and quality-controlled. Today, there are more than 167 compliance data sets in the water area, compiled pursuant to conventions on transboundary pollution, large international waters and river management and coasts (EEA, 2011c; UNEP, 2006). The limitation of these datasets compiled for legal purposes lies in the original purpose for which they were established. For example, they may refer to limit values or progress towards legally-fixed targets (simply in terms of compliance or non-compliance) rather than any information about the actual environmental trends. The interpretation of compliance data is also complicated by the scale to which it relates. For example, it may refer to a national territory, rather than a natural feature such as a river basin.

Reporting pursuant to legal obligations generally provides quality-assured data. However, the monitoring networks and observation systems that generate such data are often broad in scope and may not be quality-assured at every level. For example, the methodologies used to derive figures for statistical purposes are often restricted to updates of yearly data. In contrast, the water-monitoring data collected by environmental agencies are often derived from in-stream instruments, which measure parameters in real time. Time-histories can then be derived for different spatial scales to meet specific operational demands.

Scientific programmes and modelling can provide a wide array of data types but are often restricted in time and space and may change in the light of new theories and ideas. In

Box 3.1 Open geospatial data standards for water

A significant improvement in the exchange of spatial information on water is the development of common standards between the World Meteorological Organization and the open Geospatial Consortium (OGC).

Water resources, weather, and natural disasters are not constrained by local, regional or national boundaries. Effective research, planning and response to major events call for improved coordination and data sharing among many organisations, which requires improved interoperability among their diverse information systems.

The historic time-series records of surface freshwater resources compiled by US national agencies alone today comprise more than 23 million distributed datasets. Cataloguing and searching efficiently for specific content from so many datasets presents a challenge to current standards and practices for digital geospatial catalogues.

Sponsored by the Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI), OGC has completed a water information concept development study on applying OGC web service standards in the domain of water information. The study investigated architectures and practices for cataloguing, discovering and accessing selected water resource data from very large numbers of distributed datasets.

The study built on current best practices within OGC, as well as experimental research by CUAHSI and other OGC members of the Hydrology Domain Working Group. It resulted in a report (OGC, 2011) which provides the basis for further development and possible future OGC Interoperability Program projects.

The report provides guidelines and recommendations for open information system architectures that support publishing, cataloguing, discovering and accessing water observations data using open standards. The intended audience is US federal, state and local agencies as well as international organisations and agencies, and universities and research organisations that collect water data and need to make the data widely available. The audience also includes data consumers who need to discover, access and integrate data from multiple sources in studies related to hydrological science and water-resource management domains where this kind of information is the only type available, for example in some areas of climate science, stratification and ex-post sampling can provide possible solutions if the databases are rich enough. However, there is often a mismatch between the scales used in modelled data and observations and the data reported within national statistical systems. To be of use in water accounting, modelled data, observations and statistical information all need to be correctly inter-calibrated.

One way to harmonise data is by using a standard classification scheme. Examples of this include the Land Use and Land Cover nomenclatures in the United Nations System of Environmental and Economic Accounts and the draft common international classification of ecosystem services, which contains classes for water resources and flow regulation (EEA, 2010). At the global level the Group of Earth Observation System of Systems (GEOSS) work programme has set up tasks with international high level scientific participation to develop an operationalised and sustained global network of in-situ observation sites and an increased availability of information products and services for monitoring changes in the water cycle (GEO, 2010).

Spatial data derived from earth observations, such as Gravity Recovery and Climate Experiment (GRACE) are an additional source of information for water accounting (GRACE, 2011). In recent years the resolution of the sensors and the orbital positioning of platforms have improved considerably, with the result that global observations of parts of the hydrological cycle can be obtained on a daily basis. The main concern with these sources is that detecting change is not straightforward; simple algorithms for image processing and change mapping are often insufficient and can give rise to misleading results. Despite these challenges, information from satellite sources is becoming increasingly important.

3.2.4 Sectoral statistics and classifications

In some parts of the world, sectoral statistics are an important source of information for water accounting. Regular questionnaires and a clear framework for calculating different components of a country's water resources can generate important data and statistics, especially in developing and transition countries and for specific parts of the economy, e.g. households (MA, 2005). Household budget surveys can address issues such as use of water resources by type, volume of water consumed, quality of drinking water in wells and springs, and attitudes of the state to problems relating to water use.

Shiklomanov and Rodda (2003) is a key source of information on national water balances across the globe. The information is based on systematic surveys of country figures plus information on stream flows from a wide range of sources. Global data on water are collected by the FAO (FAO, 2011b), and combined with information from other global sources including the World Resources Institute and its data base EarthTrends (WRI, 2011), the Pacific Institute (2011), Gleick (2000), and the St Petersburg State Hydrological Institute.

The FAO Aquastat programme conducted country surveys in 150 countries between 1993 and 2000, providing a major global source of water-resource data. The system systematically prioritises national sources rather than international reports, as global data sources often do not indicate the method used to compile and validate their data sets. A compilation of the sources by country, including those from the grey literature, is available on the Aquastat website.

Statistical communities use a variety of sectoral classifications. The most relevant in the present context are the United Nations International Standard Industrial Classification of All Economic Activities (ISIC) and the Nomenclature Générale des Activités Économiques dans les Communautés Européennes (NACE).

ISIC is the international standard for classifying productive economic activities. Its main purpose is to provide a standard set of economic activities so that entities can be classified according to the activity they carry out (OECD, 2011a).

NACE is the industrial classification used by Eurostat (OECD, 2011b). These classifications are used in the statistical categorisation of information, following the United Nations Statistics Division's Standard for Environmental–Economic Accounting for Water (SEEA-W).

National and sectoral statistics play a vital role in collecting information, in particular with respect to the economic water cycle: withdrawals, consumptive uses and returns. Most water-cycle information related to the economy is collected for macroeconomic purposes by statistical offices at the national level or at smaller scales such as the county or commune. This represents a problem because such administrative units do not match hydrological boundaries and are not comparable with them.

3.2.5 Water-flow information at the corporate level

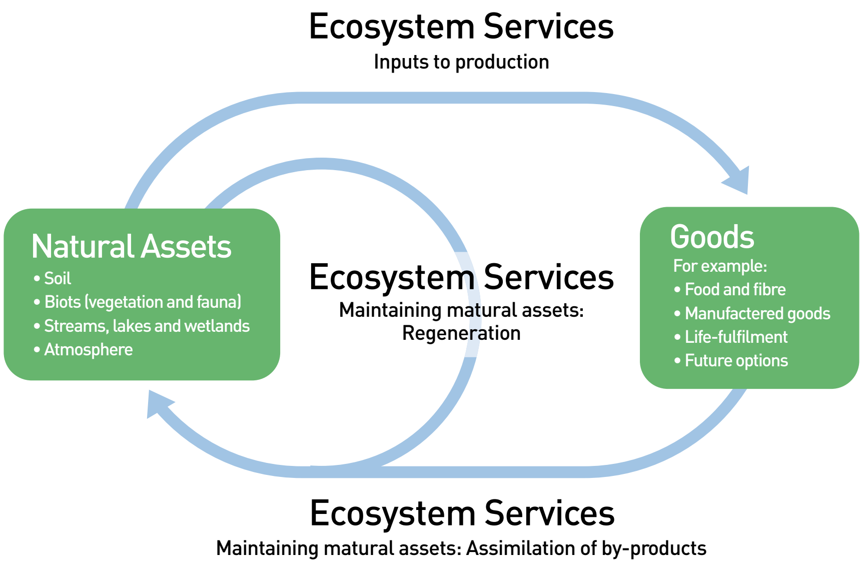
The collection of corporate water-use data (for example using Water Footprint Assessment or Life Cycle Assessment) often does not correspond to natural boundaries. In the case of large corporations, data may be aggregated over sites in different river basins. It has to be stressed that underneath this aggregation, data have to maintain hydrological integrity.

Data on water flows in the economy are often less readily available than information on the hydrological cycle and they do not have the long traditions of hydrological and meteorological monitoring data but are dealt with in the context of water supply and sanitation and industrial production processes.

Companies address water management at two levels: facility and supply chain. Consequently the information sources and accessibility of data differ. Facility level assessment is associated with all direct appropriations

Figure 3.2

Conceptual framework for ecosystem services



Source: Rutherford (2001)

and uses of water necessary for a particular enterprise. Water is often purchased from municipal utilities and in many cases pumped from groundwater from company-controlled wells or from rivers or reservoirs. There is high variability in company awareness and metering or monitoring of water from these various sources. At the facility level, the volumetric use of water in the various processes is often available, but it is seldom harmonised or reported to national or river basin authorities or to statistical units.

Information about water flows in the supply chain often requires good international cooperation and transparency. This provides an entry point for stewardship programmes.

3.3 Information on ecosystem functioning

Ecosystems are continua, so segregation of specific units and categories is largely a function of definition and context. This report uses the definitions of ecosystem services set out in the Millennium Ecosystem Assessment (MA, 2005) in a revised version proposed in the context of the SEEA-W revision.

Ecosystem services are the goods, functions, and processes we derive from the biosphere. They include the flow of energy, materials and information from natural capital, and the stock of materials or information that exists at a point in time and space (Costanza et al., 1997). Ecosystem services are crucial for all human activities. However, they can provide only a limited flow of services sustainably, whereas human demands are increasing due to growing populations and economic activity. The Millennium Ecosystem Assessment report (UN, 2005) found that 63 per cent of ecosystem categories were in peril or decline, with the status of wild fisheries and freshwaters causing greatest concern. A global population projected to reach 9.25 billion by 2050, and with much higher per capita prosperity, could increase pressure on remaining ecosystem services dramatically.

A clear challenge for the 21st Century is therefore to reduce our impacts on the natural capital base, to maintain healthy ecosystems and the resulting supply of services. To guide sustainable water management, tools are needed that quantify impacts on ecosystem services. Such tools can support the elaboration of targets that ensure the integrity and functioning of all services but particularly the supporting and regulating services that maintain and restore our basic natural assets.

3.3.1 Demands and availability

Ecosystem services support both human endeavours and non-human life. While all life benefits from almost every ecosystem service, some users rely more explicitly on certain services than others. The Millennium Ecosystem Assessment report (UN, 2005) categorised various services and specified their relation to human well-being and the environment.

In many instances, different users compete for access to an ecosystem service, potentially leading to overexploitation of the underlying natural capital and reduced capacity to maintain and provide numerous services. For example, water used in agricultural production may reduce or degrade the resources available to a river ecosystem, potentially impacting a range of regulatory and maintenance services which are essential for supplying a variety of provisioning and cultural services. Such competition is a key issue to be addressed when allocating water-use rights, whether for consumptive, degradative or in-stream uses.

Sustainable management requires that we maintain the natural capital stocks that deliver the most effective and efficient array of services. Regulating services should often be prioritised, however, because they maintain and restore natural capital, thereby underpinning provisioning and cultural services.

Rutherford et al. (2001) describe this relationship of ecosystem services and the maintenance of natural capital (or natural assets) in terms of three types of transformation:

- transformation of natural assets into products valued economically and in other ways by people in a catchment;
- transformation and (re-)assimilation of the by-products of ecosystem services back into natural assets;
- internal transformations among natural assets to maintain those assets.

3.3.2 Categorisation of ecosystem services

Since the publication of the Millennium Ecosystem Assessment in 2005, extensive work has focused on further refining the categories of ecosystem services (for example, evaluating the differences between regulating and supporting services).

To account for the special role of the supportive and regulating functions in the ecosystem service categorisation, EEA and partners in the United Nations Statistical Division working on the revision of the overall SEEA have proposed a revision of the Common International Classification of Ecosystem Goods and Services (CICES) for the purpose of integrated environmental and economic accounting (EEA, 2010) (see Table 4.1 and Section 4.2.2).

In response to the European Union Biodiversity Strategy to 2020, the European Environment Agency and the European Commission are developing a European integrated ecosystem assessment. The biodiversity strategy addresses the productive sectors (agriculture, forestry and fisheries) and establishes links to targets for the conservation sector. The RUBICODE project (Rationalising Biodiversity Conservation in Dynamic Ecosystems) plays a key role in European assessments of ecosystem services and biodiversity. RUBICODE is a pan-European project that is reviewing and developing innovative concepts for conservation strategies that concentrate on managing dynamic ecosystems for maintaining their capacity to recover from disturbance, while retaining the functions, services and control mechanisms (ecological resilience) of the ecosystems and the services they provide.

The integrated assessment will consist of multiple single assessments with specific modelling approaches that reflect the relevant relations between services and ecosystem classes and will build on results from RUBICODE and the proposed CICES. The services will be related to the four major classes of ecosystem: terrestrial, freshwater, marine and atmosphere.

3.3.3 Ecosystem service sustainability index used to manage ecosystem services

Numerical and comparable indices can be used to describe the interrelationship between competing ecosystem services, allowing prioritisation between them, whilst recognising the importance of their regulatory and maintaining services. They can be used in particular in the design of ecosystem service management systems with the aim of supporting their governance in the most sustainable way for environmental and human well-being, taking account of their costs and benefits.

To ensure that demand does not exceed the availability of ecosystem services at a specific location and time requires careful management. Such management requires the right information on the state and trends of ecosystem service supply.

Box 3.2 Measuring ecosystem services at the river-basin level in Ghana

A case study by Leh and colleagues showed that managing ecosystem services requires quantification of the condition and changes in the services across the landscape over time. Eco-regions are the minimum land-forms for quantifying ecosystem services, as they represent areas of relatively homologous plant and animal communities and underlying soils and geology. The landscape of Ghana has experience significant transformations in the past 50 years, in particular shifting from forest to agricultural land use. The impacts of these transformations on ecosystem services were quantified for 2000–2009. Ecosystem service status by eco-region was indexed to 2000 conditions for reference.

Ecosystem services were quantified using best available data for provisioning services (food/feed/fibre, and water), regulating services (climate change and soil erosion control), and supporting services (net primary productivity). The Ecosystem Services Loss Index (Matlock and Morgan, 2011) was calculated by eco-region (Figure 3.3).

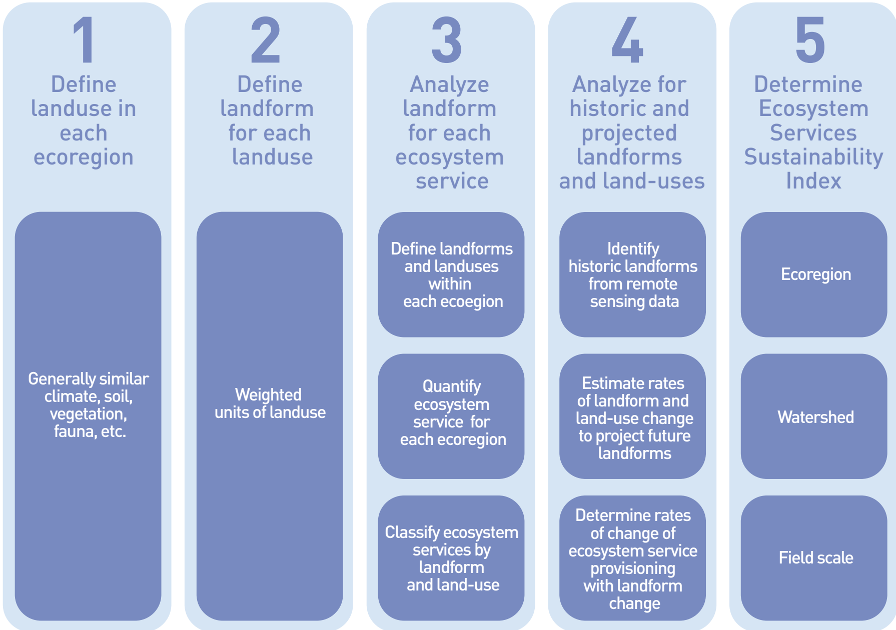
Provisioning Services. Ecosystem services were quantified for those parameters where data were available to make reasonable geospatial estimates. Production of primary food crops for each administrative region was aggregated for each eco-region (Figure 3.4). Provisioning services were mapped as tonnes of food production per hectare per year. The InVEST ecosystem model was used to calculate water yield, the amount of runoff water less storage and evapotranspiration losses (Tallis et al., 2011). Soil characteristics data for the region were estimated from the FAO Harmonized World Soil Database (FAO, 2009).

Regulating Services. Carbon storage was mapped by measuring the biomass carbon stored in above and below-ground living vegetation from 2000 (Ruesch et al., 2008). Erosion was mapped as the interaction between rainfall, land-cover characteristics, soil characteristics and topography using the Revised Universal Soil Loss Equation modified for complex terrain (RUSLE2d) (Mitasova et al., 1996).

Supporting Services. Net primary productivity (NPP) was derived from the improved MODIS dataset (Zhao et al., 2005) weighted by land-form to obtain NPP per land-form.

Figure 3.3

Process diagram for determining the Ecosystem Services Loss Index in Ghana



Matlock and Morgan (2011) proposed the development of an ecosystem service sustainability index that analyses the trends of different ecosystem services and their interdependencies over time.

Ecosystem service distributions are as varied as the landscape itself. The obvious macro-scale for assessing ecosystem services is the eco-region. This is a reasonably large area for evaluating overall trends and changes. However, the temporal and spatial scales of provisioning and regulating services, especially those directly associated with water resources, require a much more refined scale, such as the river basins within eco-regions. Management decisions are often made at even smaller (site) scales which are often hundreds of hectares or less in size.

At any scale (site, local or regional), ecosystem services can be inventoried according to their landform type, for example, temperate deciduous forest, short-grass meadow or stream riparian zone. Each ecosystem service within an eco-region has a historic state, a current state, a potential condition and a potential design level.

If the relevant ecosystem services can be quantified within a spatial unit (eco-region), the interrelation between the different services and the possible prioritisation of the indispensable ones can be quantified. Each state and scale of ecosystem service informs the design goals differently. The index of the current state of ecosystem services provides a benchmark from which all potential management strategies can be evaluated. The goal of ecosystem service management should be to inform resources users of the most effective and efficient uses. This is particularly critical for water resources.

4 Methodologies for quantifying water use and environmental impacts

Approaches to the quantification of water uses and their environmental impacts are needed at several levels of water management. There are three complementary methods of quantification that can help to identify opportunities for decoupling water use from economic growth:

- statistical water accounting on a macroeconomic level and as input-output analysis;
- Water Footprint Assessment (WFA);
- Water-use assessment and impact assessment in the context of Life Cycle Assessment (LCA).

In another perspective, the methodologies can be distinguished between approaches based explicitly on hydrological units (water registers, ecosystem capital water accounts, and some of the water-scarcity indicators) or focused on products and commodities and using statistical units regarding spatial resolution. The WFA and LCA approaches aim to include the hydrological unit as reference in the impact assessments.

For all the methodologies, it is essential to identify the way environmental concerns are taken into account. This could be in the form of environmental flow requirements related to hydrological units or in other ways of assessing sustainability.

All accounting approaches should distinguish clearly between the different water sources, in blue, green or grey water and should consider the opportunity costs in a given situation or river basin against the local social and economic background. The opportunity costs of blue water are always higher than that of green water, as reallocating green water can only be done in situ through land-use changes (Falkenmark and Rockström, 2004).

These approaches can be used for different purposes, such as corporate sustainability reporting and internal performance benchmarking, and they involve different criteria and contexts.

The approaches may not be comparable, but should be considered complementary to each other.

In the following sections the word 'accounting' is used with two slightly different meanings. 'Accounting in the water area' can mean any kind of calculation in which a water balance between inputs and outputs from a certain unit is calculated. In this sense also, WFA and LCA start with an inventory of inputs and output. In a more narrow sense, 'water accounting' in the statistical area is the water-related process of setting up statistical accounts, which is described with the statistical system of environmental accounts from SEEA-W in section 4.2.

The following subsections provide details on these methodologies.

4.1 Water registers

In most parts of the world, the development of water availability and access registers is in its infancy. The same is true of systems that enable the efficient management of allocations during times of scarcity.

Rather than developing registers and systems in isolation from more general water-accounting arrangements, it is possible to develop them so that they become the primary source of information about how, where and when water may be and is used.

It is then possible to construct registers and systems that can be used to help introduce water charging systems and develop arrangements that allow the transfer of entitlements and allocations from one user to another. For these systems to work well, however, there is a need for institutional rigour and administrative arrangements that ensure compliance with allocation arrangements. In fully allocated systems, it is critical that whenever one person is allowed to take more water, parallel arrangements are put in place to ensure that someone else takes less.

Systems built in this manner typically begin by partitioning a water resource into a number of 'pools' of differing allocation priorities. Entitlements to access water allocated to each pool are then distributed among users or user groups. As the volume of water within these pools is likely to change from season to season, each entitlement is defined as a share of any water allocated to the pool. Sustainable diversion limits are set for each pool in a manner that ensures that enough water is set aside for conveyance, maintaining the environment and meeting other needs.

Good data is needed to prioritise water uses efficiently and equitably: the Murray Darling Basin in Australia provides one of several examples.

4.1.1 Pools

The approach to defining each water-management 'pool' requires careful consideration. For a surface water system, the approach typically involves:

- a pool of sufficient size to maintain enough base flows to convey water to the end of the system (Poff et al., 2010). This base flow provides benefits to all entitlement holders and also for non-consumptive uses like recreation and transport;
- one or more consumptive pools. In some situations, it is appropriate to establish pools of varying reliability, for example, to give a city a much more reliable water supply than a dairy farmer;
- when entitlement systems are put in place, it is normally necessary to define and manage flood waters and flood risks outside the entitlement system;
- when a shared system is used to define entitlements and the degree of compliance with entitlements is high, it is possible to use market arrangements to encourage each group of users to manage risks associated with climate change. However, an appropriate governance mechanism may be necessary to correct socially iniquitous effects of the market.

Intense stakeholder dialogue and risk-management arrangements are necessary to ensure that all water users and relevant stakeholders understand the complexity of the hydrological system, including how rivers and aquifers interact with each other or how adverse climate change, or alterations of policy, are likely to affect the value of their access entitlement and allocations of water. System-wide planning arrangements are needed to specify how water is allocated to the environment and all other users, and to each pool.

4.2 Water accounting

Water accounts are developed to provide decision-makers with indicators which they can easily use with economic variables. Such indicators can be expressed in physical units or as monetary values. Accounts primarily take stock of the past, although they can support forward-looking modelling.

Most economic agents - water agencies, local government, industrial and energy companies, farms and even households - record their water use and in many cases also the associated expenditures and benefits. However, such accounts (sometimes called budgets or balances) are incomplete, imperfectly connected to the natural condition of the water resource, and not standardised with auditing rules and fiscal control. Existing water 'accounts' cannot to be compared and aggregated to support decision-making. This shortcoming has motivated the development of national water accounts in several countries since the mid-1980s and the inclusion of water accounts in the United Nations Standard for Environmental-Economic Accounting (SEEA) (UNSD, 2003) 2003. In 2007, SEEA-Water (UNSD, 2007) was adopted by the United Nations Statistical Commission (UNSC) as an 'interim standard', subject to revision when SEEA is revised.

Although comprehensive in its approach, SEEA-Water 2007 put the emphasis on physical supply and use tables which analyse the origin of the water abstracted by economic sectors, transfers within the economy, returns to land and rivers and final uses. It is however not able to relate to hydrological units as the natural physical basis nor to include environmental constraints such as environmental flows. Details of sectoral analysis are also proposed. This description of the management and use of water is linked to related expenditures. However, water assets and quality issues are not fully developed in SEEA-Water 2007. Pursuant to a decision of the United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA) in June 2011, however, water assets and quality issues will be developed in the second volume of SEEA-Water. Water will be measured in natural capital accounts, focusing on the water-provisioning service, security of access for human and environmental use based on long-term probabilities, impacts of water use on other ecosystem services, and the state of environmental infrastructure more generally. This more recent development is outlined in section 4.2.3 and should, when finally applied, complement the SEEA-W accounts as described in 2007.

4.2.1 Initial approaches to water accounting in SEEA-Water

SEEA-2003 provides natural resource stock accounts and environmental protection expenditure accounts but also shines a spotlight on physical and economic flow accounting. This approach enables physical and monetary information on water to be linked to the System of National Accounts (SNA) and allows environmental and economic policy issues to be analysed together.

Within the aegis of SEEA-2003, a System of Environmental and Economic Accounting for Water (SEEA-W) was prepared by the London Group on Environmental Accounting, and its sub-group on water accounting. SEEA-WATER was designed to provide a systematic framework for organising water information in order to study the interaction between the economy and the environment quantitatively and produce results under the standard nomenclature (ECOSOC, 2007). This framework distinguishes various elements: environmental assets, physical flow accounts, economic flow accounts and the economy's impact on the environment.

A different, more constrained framework is economy-wide material flow accounting, which is restricted to the material exchanges across the boundary between the environment and the economy and the material inputs and outputs connected to international trade. In contrast, SEEA uses input-output tables and the physical supply-and-use tables to address flows within the economy in addition to the exchanges with the environment (Pedersen and de Haan, 2006).

To categorise the origin and destination of flows, SEEA distinguishes between the economy and the environment. It divides the economy into three components: producers classified according to the ISIC sectoral classifications, households, and capital.

SEEA structures the physical flows into supply (origin) and use (destination) tables. The system boundary between the economy and the environment defines the extent to which economic entities can influence environmental materials. For water, the use tables show extraction by industries, households and 'the rest of the world'. The last category captures a variety of physical interactions, including pollution transfers such as acid rain or by rivers, and cross-border movement of solid wastes and residuals via international transport and tourism.

The accounting identities that structure the physical accounts and the categories of flows are based on the material (mass) balance principle, i.e. supply must be equal to use, on an appropriate time scale (use plus change in storage). When ecosystem goods and services are introduced, they must also adhere to this principle. One of the key strengths of accounts is that this definitional consistency enables information to be generated and used at various levels. Researchers can obtain detailed data sets while policy-makers can derive accounting aggregates for policy evaluation.

Combining selected parts of the physical and monetary flow accounts requires a hybrid-flow accounting approach known as the National Accounting Matrix including Environmental Accounts (NAMEA). The physical flow accounts focus mainly on material transfers to and from the natural environment. The monetary side can include movement of products between industries, taxes and value added.

The formal structure of the water accounts comprises the following elements, expressed also in Figure 4.1:

- **Environmental assets (upper part of the figure)**: the stocks and flows that make up the hydrological cycle. This includes monthly data on water flows (rainfall, evapotranspiration, soil water, run-off, supplies and returns by category of users). For stocks, it takes into account reservoirs, lakes and ice (snow and ice as short-term reserves), but groundwater is still poorly considered.

- **Physical flow accounts (exchange between the upper and the lower part)**: flows between the environment and the economy, expressed in physical terms (e.g. m^3/year). The flows are modelled at the monthly level but are quite heavily aggregated because much of the relevant data is still missing. As yet, there are no plans to detail flows internal to the economy (e.g. the amount exchanged between domestic abstraction and industry).

- **SNA flow accounts (lower part of the figure)**: those elements of the existing SNA that are relevant to good environmental management. This category is purely economic and shows how environment-related transactions can be made more explicit.

- **Valuation and environmental adjustments**: ways that the existing SNA could be adjusted to account for the economy's impact on the environment.

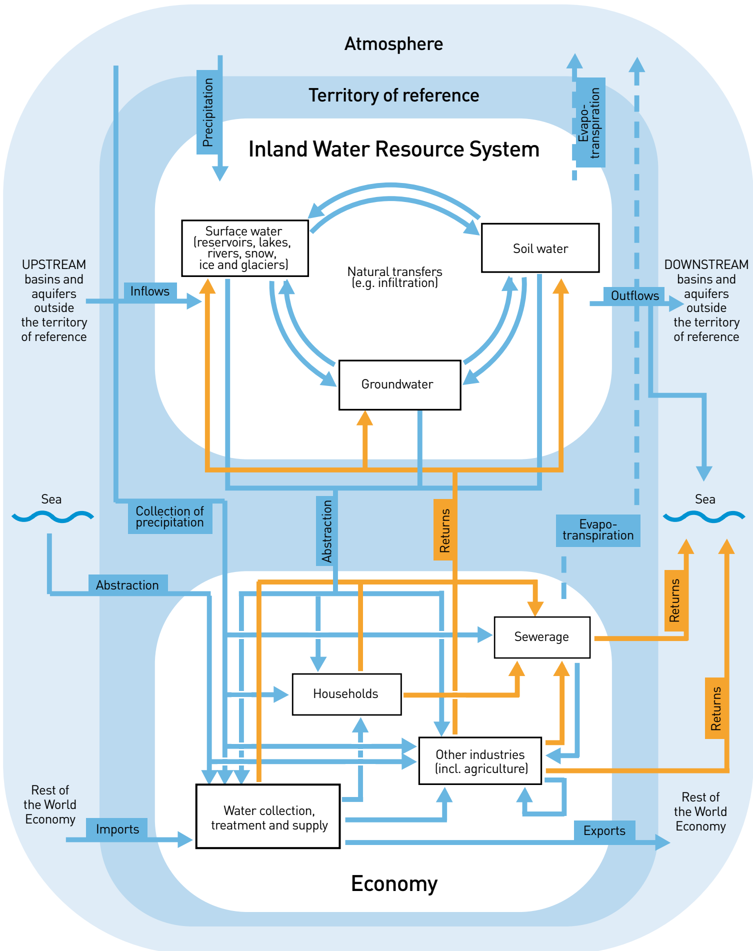
Practical difficulties arise in implementing SEEA and, by extension, water accounts. First, the accounting identities can only be applied when the underlying statistics are sufficiently well developed and cover both the input and the output sides. In practice there is simply insufficient national data in many regions for any solid water-balance calculation. Second, the efforts to integrate ecosystem goods and services into the accounts will increase the imbalance between data needs and availability.

4.2.2 Approach to water in ecosystem capital accounts (SEEA vol.2)

As noted above, the second volume of SEEA-WATER will feature ecosystem capital accounts, focusing on the water provisioning service,

Figure 4.1

Main flows within the inland water resource system and the economy



Source: UNSD (2003)

security of access, and water-use impacts on other ecosystem services and environmental infrastructure.

The ecosystem capital accounts will approach water as a component of a broad range of hugely valuable ecosystem services: direct provisioning services for people and key economic sectors such as agriculture and hydroelectricity. They also, in particular, provide services of regulating and maintaining ecosystems and cultural services, both being functionally essential to ensure all the provisioning services (first 'theme' groups in Table 4.1). The ecosystem accounts will link water resources to other aspects of natural infrastructure such as biomass production and landscape integrity, which are covered by land-use accounts.

The main ecosystem services involving water can be listed using the common international classification of ecosystem services (CICES) under discussion in the context of the SEEA revision. All the services addressed in SEEA-WATER so far (UNSD, 2007) are 'provisioning services'. They are completely covered by respective groups in the CICES Table 4.1 (water-relevant groups covered by SEEA-WATER 2007, outlined in blue). There are also many important regulatory and cultural services supported by the water cycle (outlined in red) which are so far not fully covered in SEEA-WATER 2007.

4.2.3 Ecosystem Capital Water Accounts

As an extension of SEEA-W, Ecosystem Capital Water Accounts (ECWA) record the same basic flows but in a different way. Whereas ECWA reports for inland ecosystems, SEEA-WATER reports for economic sectors. In principle, the same flow will be recorded in both accounts, which balance each other.

Ecosystem capital accounts aim to measure the capacity or potential of an ecosystem to deliver provisioning, regulatory and cultural services and the impacts of over-use or misuse which degrades natural capital. Quantifying and comparing stocks and flows (supply and use) is not sufficient to identify impacts on and degradation of ecosystem assets (EEA 2012). Because water is the socio-ecological system's vital fluid, ecosystem capital accounts must address a variety of questions, including:

- Is enough water of the appropriate quality available at the right place when needed?
- Are human uses (abstraction, management, transfers, pollution, irrigation) compatible with expected risks of drought periods? Are the human uses safe enough?
- Is current water use compatible with the social objectives of river quality and related services?

4.2.4 Accounting methodology

ECWA will organise the accounting balance around the concept of 'accessible water'. As

Table 4.1

Water and ecosystem services in the draft common international classification of ecosystem services (CICES)

<table>
<tr><th>THEME</th><th>CLASS</th><th>GROUP</th></tr>
<tr><td rowspan="8">Provisioning</td><td rowspan="4">Nutrition</td><td>Terrestrial and animal foodstuffs</td></tr>
<tr><td>Freshwater plant and animal foodstuffs</td></tr>
<tr><td>Marine plant and animal foodstuffs</td></tr>
<tr><td>Potable water</td></tr>
<tr><td rowspan="2">Materials</td><td>Biotic materials</td></tr>
<tr><td>Abiotic materials</td></tr>
<tr><td rowspan="2">Energy</td><td>Renewable biofuels</td></tr>
<tr><td>Renewable abiotic energy sources</td></tr>
<tr><td rowspan="11">Regulation and maintenance</td><td rowspan="2">Regulation of wastes</td><td>Bioremediation</td></tr>
<tr><td>Dilution and sequestration</td></tr>
<tr><td rowspan="3">Flow regulation</td><td>Air flow regulation</td></tr>
<tr><td>Water flow regulation</td></tr>
<tr><td>Mass flow regulation</td></tr>
<tr><td rowspan="3">Regulation of physical environment</td><td>Atmospheric regulation</td></tr>
<tr><td>Water quality regulation</td></tr>
<tr><td>Pedogenesis and soil quality regulation</td></tr>
<tr><td rowspan="3">Regulation of biotic environment</td><td>Lifecycle maintenance and habitat protection</td></tr>
<tr><td>Pest and desease control</td></tr>
<tr><td>Gene pool protection</td></tr>
<tr><td rowspan="4">Cultural</td><td rowspan="2">Symbolic</td><td>Aesthetic, heritage</td></tr>
<tr><td>Religious and spiritual</td></tr>
<tr><td rowspan="2">Intellectual and experimental</td><td>Recreation and community activities</td></tr>
<tr><td>Information and knowledge</td></tr>
</table>

Source: EEA (2010)

outlined above this refers to the overall available water minus the amount to be reserved for environmental requirements. The term is used following the approach of 'Human Appropriation of Renewable Fresh Water approach' (HARFW).[1] However, accounts differ from that approach in several respects, in particular because they record returns of water and water stored in dams as accessible although it has been 'appropriated'.

Ecosystem capital accounts are based on physical statistical units (e.g. hydrological units, land-cover units) and not on economic units defined from their institutional status (e.g. enterprises, governments or households). In the case of terrestrial systems, they are basic land-cover units (e.g. forests, cropland areas, urban areas) which are in a second step combined into socio-ecological landscape units. For water, they are hydrological units (rivers, lakes, aquifers...). Rivers are considered as basic reaches re-combined into hydrological networks. River basins and sub-basin limits are considered explicitly in mapping terrestrial and hydrological statistical units.

4.2.5 Key accounting variables in ECWA

In addition to SEEA-W, the key accounting variables in ECWA relate to accessible water:

- accessible freshwater stocks in aquifers (i.e. not including stocks that are inaccessible due to physical constraints, salinity, costs, etc.);
- accessible freshwater stocks in lakes, dams and reservoirs (reservoirs increase accessibility by storing water and decrease it by generating additional evaporation);
- actual evapotranspiration (ETA), including the use of water by rain-fed agriculture and managed forests, which is a measure of rain water accessed in situ;
- accessible ecosystem water flow, which is the available hydrological effective rainfall net of the water which is inaccessible because of the water regime (most of the flood water in temperate countries), pollution (river runoff needed to dilute pollution to acceptable levels and/or to maintain life in rivers), additional ETA induced by irrigation, and other uses.

4.2.6 Aggregated accounting balances in ECWA

The first aggregate is Total Ecosystem Accessible Water (TEAW), which summarises the various positive and negative changes in the water resource: flows and changes in stocks. This indicator can be computed by ecosystem units and river sub-basins and basins and aggregated at the level of administrative regions and countries, as well as according to any geographical or climatic zoning.

TEAW will vary according to factors such as precipitation (positive or negative impacts); spontaneous evapotranspiration by crops or tree plantation (negative); additional evapotranspiration by irrigation (negative); storage in reservoirs (positive) and additional evaporation from reservoirs (negative); salinisation of groundwater (negative); pollution of rivers (negative); and transfers of water received (positive) or supplied (negative).

The TEAW aggregate is not sufficient to assess the availability of water completely. The temporal variability of the meteorological conditions also needs to be taken into account, including a succession of wet and dry periods and the possible temporary severe stress that may result for people, agriculture and nature.

ECWA could capture this risk by using a stress coefficient based on the number of days when plants cannot access any water in their growing season, recently calculated by EEA. Net Ecosystem Accessible Water is obtained by multiplying TEAW by the water stress coefficient. On that basis, a headline indicator derived from ECWA is Ecosystem Accessible Water Surplus, which compares withdrawals of water (abstraction, diversion to electricity

1 Human Appropriation of Renewable Fresh Water (HARFW) is defined in Vitousek et al. (1986). An estimation of HARFW was undertaken by Postel et al. (1996).

turbines, net storage in reservoirs) to Net Ecosystem Accessible Water.

4.2.7 Water and river ecosystems

Rivers are more than a freshwater resource and wastewater sink. The rivers network connects various ecosystems within the river basin and this interaction in turn influences the ecological potential of the rivers themselves. In addition to water stocks and flow accounts presented in ECWA, so-called 'Green Infrastructure Accounts' propose the calculation of Rivers Ecosystem Potential (REP) as a supplement to the Landscape Ecosystem Potential (LEP) based on terrestrial features. The measurement unit for REP is not m^3 of water but the standard-river-kilometre (srkm) which equals 1 km*m^3*$second^{-1}$. This unit allows comparison and adding up of rivers of different sizes in a meaningful way. It is proposed in SEEA-WATER 2007 for water quality accounts.

In ECWA, water quantity will therefore appear three times: in the water stock account (in m^3, mostly aquifers) to calculate the accessible freshwater in stocks (e.g. net of non-usable saline water), in flow accounts (in m^3) to estimate the accessible water flow net of the water requested for diluting waste water pollution, and finally as a component of REP (in srkm).

The Rivers Ecosystem Potential records (in srkm) amounts of large, medium and small rivers as well as brooks and streams. The stocks (in srkm) are weighted in a second step with a river integrity composite index which combines water quality, fragmentation and an index of the naturalness of river ecotones (the zones between two major ecological communities). The River Ecosystem Potential is correlated with water accessibility over space, in particular regarding terrestrial nature (srkm/km^2) as well as with most of the regulating and socio-cultural services described in table 4.1 (outlined in red).

4.3 Water scarcity indicators

Many indices exist to evaluate water resource availability quantitatively. This report considers only models and approaches on a wider pan-regional scale. These provide initial guidance which may be followed up by more in-depth analysis of the local or regional situation.

The major types of indicator considered relate water availability to human requirements or the amounts withdrawn to the renewable water supply. A third group aims to assess the status of water ecosystems and their management against a variety of criteria.

4.3.1 Indices focusing on human water requirements

The Falkenmark water stress indicator (Falkenmark, 1989) relates water availability to human population. Falkenmark proposed 1 700 m^3 of renewable water resource per capita per year as the threshold, based on estimates of water requirements in the household, agricultural and energy sectors, and the needs of the environment.

Falkenmark defined three levels of scarcity: availability of less than 500 m^3 per capita is designated as 'absolute scarcity', 500–1 000 m^3 per capita as 'water scarcity' and 1 000–1 700 m^3 per capita as 'water stress', with 'no stress' above 1 700 m^3.

The Falkenmark indicator is widely used since the data are readily available and the meaning is intuitive and easy to understand. However, it has important disadvantages. Annual national averages hide important scarcity information at smaller scales and the cut-off points 1 000 and 1 700 m^3 per capita are not well founded on physical/ecological evidence. In addition, the indicator does not take into account the availability of infrastructure that modifies the availability of water to users and it has to be specified whether the figures included or exclude green water. In general, indicators based on availability per capita fail to identify problems in areas such as the Murray-Darling basin in Australia, where concerns were based on over-exploitation of the resource not linked to population.

Other indicators of human water requirements include Gleick (1996) who proposed 50 litres of water per day as the 'basic human water requirement' (for drinking, sanitation, bathing and food preparation) and estimated the percentage of individuals in each country who fell short of this threshold.

Ohlsson (2000) built on the Falkenmark indicator by integrating a society's 'adaptive capacity': its ability to alter overall freshwater availability using economic, technological or other means. The United Nations Development Programme's Human Development Index is used to weight the Falkenmark index and Ohlsson (2000) called this a 'Social Water Stress Index'.

4.3.2 Water resource vulnerability indices

Shiklomanov (1991) led the first attempts to consider the ratio of demand to availability. He compared national water demand in the industrial, agricultural and domestic sectors to national annual water availability.

Raskin et al. (1997) built on this work, replacing water demand with water withdrawal, and defining the 'Water Resources Vulnerability Index' as total annual withdrawals as a percentage of available water resources. Water withdrawals are defined as the amount of water taken out of rivers, streams or aquifers to satisfy human needs for water. The authors suggest that a country is scarce if annual withdrawals are between 20 per cent and 40 per cent of annual supply, and severely water-scarce if the figure exceeds 40 per cent.

Alcamo et al. (2000) also use this definition for their 'criticality ratios': the ratio of water withdrawals for human use to total renewable water resources. Alcamo et al. apply the ratios using their global model WaterGap.

Vorosmarty et al. (2005) used a similar approach, introducing indices for local relative water use and water reuse and applying them using geospatial tools at 8 km resolution. Water use was represented by local demand: the sum of domestic, industrial and agricultural water withdrawals. Dividing local demand by the river corridor discharge entering from upstream cells yields an index of local relative water use. A high degree of stress is indicated when this ratio exceeds 0.4. Total water use from all cells divided by the river corridor discharge gives the water reuse index, which represents the extent to which runoff is recycled or reused as it accumulates and flows toward the basin mouth.

Pfister et al. (2009) proposed a water scarcity index, which is often used as a characterisation factor for water consumption in life-cycle impact assessment (LCIA). Using the withdrawal-to-availability ratio calculated for each river basin, a weighting factor is applied for each river basin to account for variation in monthly or annual flows. Finally, a logistic transformation of the transformed withdrawal-to-availability values gives a water scarcity index.

The water exploitation index (WEI), based on data collected via a joint OECD–Eurostat questionnaire, also uses the ratio of annual total water abstraction to available long-term freshwater resources. A WEI above 20 per cent implies that a water resource is under stress, and more than 40 per cent indicates severe stress and clearly unsustainable use of the resource (Raskin et al., 1997).

Most withdrawal-to-availability indicators are based on average volumes per year, which do not reveal sensitive seasonal effects and periods when availability and demand differ. For example, many of the systems cited above would not indicate as stressed or sensitive those areas with high winter rainfall but low water 'storage capacity' (e.g. calcareous soils in the Mediterranean). Pfister et al. (2009) include monthly variability, and for European applications the European Environment Agency is currently developing an application of the WEI that disaggregates the information at the monthly and river-basin levels (EEA, 2012).

Concern can be expressed that withdrawal-to-availability indicators:

- do not express absolute availability, a ratio of 1:10 or 10:100 or 100:1 000 would always result in 0.1;
- do not consider sensitivity to additional water use - adding 1 unit of use to a 1:10 situation would double the withdrawal-to-availability to 0.2, but leave it essentially unchanged if the ratio were 100:1 000;
- consist of two dimensions: use and availability. As a result, countries in, for example, the arid Sahel region are not regarded as critical because if withdrawal is zero, the withdrawal-to-availability will also be zero.

Rijbersman (2006) has argued that the criticality ratio and similar indicators are flawed in that:

- data on water resource availability do not take into account how much could be made available for human use;
- water withdrawal data do not take into account how much is used consumptively (or evapotranspired) and how much could be available for recycling, through return flows;
- the indicators do not take into account a society's capacity to adapt to cope with stress.

The International Water Management Institute (IWMI) attempted to overcome all three problems. Its analysis takes into account the share of the renewable water resource available for human needs (accounting for existing water infrastructure) - the primary water supply. The analysis of demand is based on consumptive use (including evapotranspiration) and the remainder of water withdrawn is accounted for as return flows. The future adaptive capacity of each country was assessed for the period 2000–2025, considering potential development of infrastructure and an increase in irrigation efficiency through improved water-management policies. Countries that will not be able to meet the estimated water demands in 2025, even after accounting for future adaptive capacity, are described as 'physically water-scarce'. Countries that have sufficient renewable resources but would need to make very significant investments in water infrastructure to make these resources available are defined as 'economically water-scarce'.

This model is appealing; it makes some allowance for infrastructure so is more realistic than assessing physical scarcity alone, and the resulting map is widely referenced. However, a disadvantage is its complexity, as it is not intuitive, and hence relatively inaccessible to the wider public. The method also relies on considerable expert judgement because data are not available to assess all components of the indicators. While the IWMI water scarcity map is frequently cited, the more complex definitions of scarcity are not used by other authors or in other analyses. Furthermore, it does not provide an indication of water resource vulnerability (environmental impacts) but focuses on water stress for humans.

4.3.3 Indices incorporating environmental water requirements

Sullivan's water poverty index (2003) aims to convey both the physical availability of water and the degree to which that water serves humans and maintains ecological integrity. The index clusters components in five dimensions: access to water; water quantity, quality and variability; water uses for domestic, food and productive purposes; capacity for water management; and environmental aspects.

An advantage of this indicator is its comprehensiveness. Disadvantages are its complexity, its difficulty to grasp intuitively and the fact that it is not available at a high, more detailed, spatial resolution. The indicator represents an average of many different elements so that counties that would be expected to differ significantly can have a similar water poverty index. The relative weighting of respective variables also strongly influences the index values.

The Smakhtin water stress index (WSI) (Smakhtin, 2004) is applied using the WaterGAP model and represents a modification of Alcamo's earlier index to incorporate environmental flows. Alcamo considered the ratio of withdrawal to mean annual runoff and Smakhtin developed this by subtracting from the annual runoff (in the denominator) the environmental water requirements, expressed as a percentage of long-term mean annual river runoff that should be reserved for environmental purposes. A water stress index over 1 is categorised as 'overexploited', 0.6–1 is 'heavily exploited' and 0.3–0.6 is 'moderately exploited'. The EEA is currently developing this indicator further to enable monthly and river basin-level disaggregation and include return flows.

Chaves and Alipaz (2007) have proposed a broad 'river-basin sustainability index'. The model is river basin-specific (up to 2 500 km^2) and is the average of four indicators based on hydrology (both quantity and quality), environment, life and policy, each having pressure, state and response parameters. Stakeholders agree by consensus on scores of 0, 0.25, 0.5, 0.75 or 1 for each parameter. A challenge for the model is the availability of the required information at the river-basin level.

The Water Footprint Assessment Manual (Hoekstra et al., 2011) (see below) proposes a water-scarcity indicator that improves on predecessors by:

- looking at water consumption rather than water withdrawal;
- comparing water consumption to natural rather than actual runoff;
- subtracting environmental flow requirements ;

- comparing water use and availability on a monthly rather than an annual basis.

4.4 Water Footprints and Life Cycle Assessment

4.4.1 Water Footprints

The water footprint (WF) was introduced in 2002 as an indicator of freshwater use that looks at both direct and indirect water use of a consumer or producer (Hoekstra, 2003). The Water Footprint Network (WFN) has since further developed the concept and related definitions (Hoekstra et al., 2011).

The water footprint of an individual, community or business is defined as the total volume of freshwater used to produce the goods and services consumed by the individual or community or produced by the business. The water footprint is a temporally and geographically explicit indicator, showing not only the volumes of water consumed and polluted but also when and where the water is consumed. The three WF components are defined as:

- blue water footprint: consumption of blue water resources (surface and groundwater);
- green water footprint: consumption of green water resources (rainwater insofar as it does not become run-off) (Falkenmark, 2003);
- grey water footprint: volume of freshwater that is required to dilute and thus reach a certain assimilation of the load of pollutants given natural background concentrations and existing ambient water quality standards (see 5.7).

Water Footprint Assessment (WFA) refers to the full range of activities involved in designing and delivering an assessment of water footprints and formulating a response:

- setting goals and defining the scope of the assessment;
- quantifying and locating the water footprint of a process, product, producer or consumer, or quantifying in space and time the water footprint in a specified geographic area;
- assessing the environmental, social and economic sustainability of this water footprint;
- formulating a response strategy.

Broadly speaking, the goal of assessing water footprints is to comprehensively quantify total and actual water consumption at a specific time and place and to assess the sustainability of the water consumption. The information gained through these two steps can then be used to identify and prioritise appropriate response strategies.

4.4.2 Production and consumption perspectives

The water footprint can be used to understand the water consumption related to the production of goods and services and their consumption. Production water footprint accounts show the allocation of water in a river basin, nation or a business to different goods or services. The water footprint of production is temporally and geographically based on the time and location of the production. The water footprint of consumption relates to all the water used in the production of the goods and services consumed by an individual or a group of individuals. The water footprint of consumption is related to the location of the consumer which may or may not be in the same location as the production of these goods or services. The water footprint of consumption links the consumer, through the water embedded in non-local products consumed, to the water footprint of production in river basins around the world. In both the water footprint of production and consumption, the focus is not limited to promoting water-use efficiency at field level but extended to wise water governance in supply chains as a

Box 4.2 Added value of the water footprint: new dimensions for better water management

Consumers: When considering water management, consumers usually focus on their direct water footprint (i.e. home water use). However, a consumer's indirect water footprint is generally much larger and should therefore be the focus of analysis (Hoekstra et al., 2011). Consumers can reduce their footprints by changing their consumption patterns or selecting products that have a relatively low water footprint and small impacts. This requires, however, that they have the information to make that choice. Since such information is generally unavailable, it is important that consumers demand transparency from businesses and regulation from governments.

Companies: Companies have traditionally focused on water use in their operations, not in their supply chain. The water footprint takes an integrated approach, revealing that most companies have a supply chain water footprint that is much larger than their operational water footprint. As a result, companies may conclude that it is more cost-effective to shift investments from efforts to reduce their operational water use to efforts to reduce their supply chain water footprint and the associated risks (Hoekstra et al., 2011). Water footprint thinking encourages businesses to incorporate a consumptive water-use perspective in parallel with conventional water withdrawal indicators. It also shifts the focus from meeting emission or discharge standards to managing the grey water footprint using ambient water quality standards from the ecosystem standpoint.

Investors: A business's failure to manage its water footprint and formulate appropriate responses may translate into various forms of business risk (Levinson et al., 2008; Pegram et al., 2009; Morrison et al., 2009; Morrison and Schulte 2010; Barton, 2010): physical, reputational, regulatory and financial. Risk can actually turn into opportunity for companies that proactively respond to the challenge of global freshwater scarcity. Furthermore, addressing the issues of freshwater scarcity and pollution should be seen as part of corporate social responsibility.

Governments: Traditionally, countries formulate national water plans by evaluating how best to satisfy water users. Although countries consider options both to reduce water demand and to increase supply, they generally do not include the global dimension of water management. They therefore seldom consider explicitly options to save water by importing water-intensive products. In addition, by focusing on domestic water use, most governments are unaware of the sustainability of national consumption. Many countries have significantly externalised their water footprint without determining whether imported products are the cause of water depletion or pollution in the producing countries. Governments can and should engage with consumers and businesses to work towards sustainable consumer products. National water footprint accounting should be a standard component of national water statistics, supporting the formulation of national water and river basin plans that are coherent with national policies on, for example, the environment, agriculture, industry, energy, trade, foreign affairs and international cooperation. Water footprint and virtual water trade accounts are a relevant input into various governmental policy areas, such as national, state, river-basin or local water policy; environment; agriculture; industry/economic policy; energy; trade; foreign policy and development cooperation (Hoekstra et al., 2011).

whole (Kuiper et al., 2011). By integrating the water footprint of production and consumption in water resource management, the true potential for using water more efficiently and meeting new challenges and opportunities that globalisation creates for water management, can be assessed.

4.4.3 Sustainability assessment in water footprinting

The three components of the water footprint – green, blue and grey – need to be assessed for environmental, social and economic sustainability. The aim of the assessment is to identify where water consumption and pollution violate sustainability boundaries. In the case of the blue water footprint, the environmental flows can be subtracted from natural runoff to get blue water availability. The blue water footprint can then be compared to the blue water availability. The analysis should be done monthly to accurately address intra-annual variability of river flows and water consumption. If the blue water footprint exceeds water availability at any time in the catchment, the water footprint is not sustainable at that time. In this case, action would need to be taken to reduce the blue water footprint to bring it within sustainability boundaries. The green water footprint can also be compared to green water availability, as outlined in the WFA handbook (Hoekstra et al., 2011), although this analysis has yet to be done in case studies. The total grey water footprint for a specific pollutant in a catchment can be compared to the total runoff to determine whether the full assimilation capacity of the river has been used or exceeded. If the total grey water footprint is less than the total runoff, the footprint is sustainable. If environmental flows or water quality standards are violated, it would be expected that the secondary impacts on ecosystem services, biodiversity, human health and other uses of water would begin to occur.

Analysis of water scarcity and water pollution levels addresses the environmental aspects of sustainability. However additional criteria must be developed to assess economic and social sustainability. Integration of these three aspects of sustainability will need to be considered to ensure that the trade-offs are accurately understood and perverse outcomes are avoided.

Box 4.3 Water footprint and virtual water trade in China

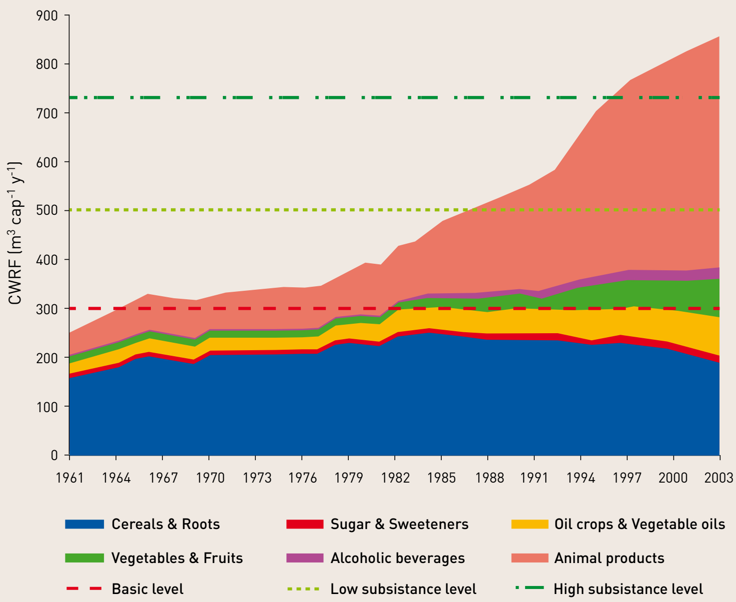
There has been a strong increase in per capita water footprint in China in recent decades, from 255 m^3 $cap^{-1}yr^{-1}$ in 1961 to 860 m^3 cap^{-1} yr^{-1} in 2003 (Liu and Savenije, 2008) (Fig. 4.2). This was caused mainly by a shift of food-consumption patterns towards protein-rich Western diets. Meat used to be luxury food in China, and its consumption remained at low levels (< 13 kg cap^{-1} yr^{-1}) prior to 1980. However, meat consumption has risen rapidly, by a factor of 3.7 from 1980 to 2003, mainly as a result of a rapid increase in per capita income, urbanisation, and market expansion.

In contrast, the consumption of cereals has not changed much, and the consumption of the two staple food, rice and wheat, peaked in the late 1990s and has declined slightly since then. In China, it takes 2 400–12 600 litres of water to produce a kilogram of meat, whereas a kilogram of cereal needs only 800–1 300 litres (Liu et al., 2007). The recent rise in meat consumption has pushed China's annual water footprint for food production up by a factor of 3.4. Compared with China's population growth by a factor of 1.9 over the same period, this suggests that dietary change is making a high demand on water resources.

Changing food-consumption patterns are the main cause of worsening water scarcity in China (Liu et al., 2008). Trends indicate that the future per capita water footprint will increase further in the next few decades, which will doubtless create high pressures on the limited water resources of China, particularly in the north.

Figure 4.2

Per capita water footprint (CWRF) for food consumption in China from 1961 to 2003



The spatial distribution of water resources in China is highly uneven. The North China Plain constitutes roughly the three river basins, Huanghe, Huaihe and Haihe (the HHH region). Its water resource availability is extremely low. Yet the region is the major bread basket of the country, especially for wheat and corn. Various measures have been implemented to deal with the water scarcity problem. One of them is to transfer water from the Yangtze River to the north, the so-called South-North Water Transfer (SNWT) project.

On the other hand, the north region is currently a net exporter of virtual water through food trade to the south. Each year, a huge amount of virtual water (52 billion m^3/yr) flows from northern to southern China in the form of agricultural commodities (Ma et al., 2006). This volume of virtual water is 20 per cent more than the total volume of water from the SNWT project, or 43 billion m^3/yr. A question that has been debated in the political arena and scientific community is the rationale of the transfers of real water and virtual water between the south and the north. Such transfers have often been criticised for not following the virtual water strategy. The far-reaching impact of the current patterns of real water and virtual water transfers on China's ecosystems has also been a major concern.

In reality, however, water is only one of the factors among many that influence decisions on trade. In Southern China, arable land is a scarce resource relative to the north, and the rapid development in urban sectors has led to an increase in the opportunity costs of inputs, particularly land and labour. Meanwhile, the dominant sub-tropical climate in the south is not favourable for wheat and corn. Hence, water endowments alone cannot be the sole criterion to judge the rationale of the transfer patterns. A more comprehensive analysis is needed to take natural conditions and socio-economic factors into account. Nevertheless, a quantification of virtual water embedded in the food transfers from north to south provides useful information for a comprehensive assessment of trade-offs of the real and virtual water transfers.

4.4.4 Life Cycle Assessment and Weighted Water Footprint

Life Cycle Assessment is an ISO-standardised (ISO 14040/14044) tool that evaluates the environmental performance of products and services along their life cycle (ISO, 2006). It assesses the various environmental impacts by quantifying all inputs (e.g. extraction and consumption of resources) and outputs (e.g. waste and emissions), and then evaluates the contribution of these inputs and outputs to the impact categories, e.g. climate change, eco-toxicity and ozone depletion.

As shown in Figure 4.3, the full 'cradle-to-grave' life cycle of a product or service comprises numerous stages: extracting materials from the earth; processing, production and assembly procedures required to create the finished products or services; transportation; consumer use; and ultimately disposal of the products or waste materials (UNEP, 2002). The cycle is driven by the societal needs and uses which in today's globalised world in most cases involve many places and actors around the world and leave specific environmental impacts at each stage and in each location.

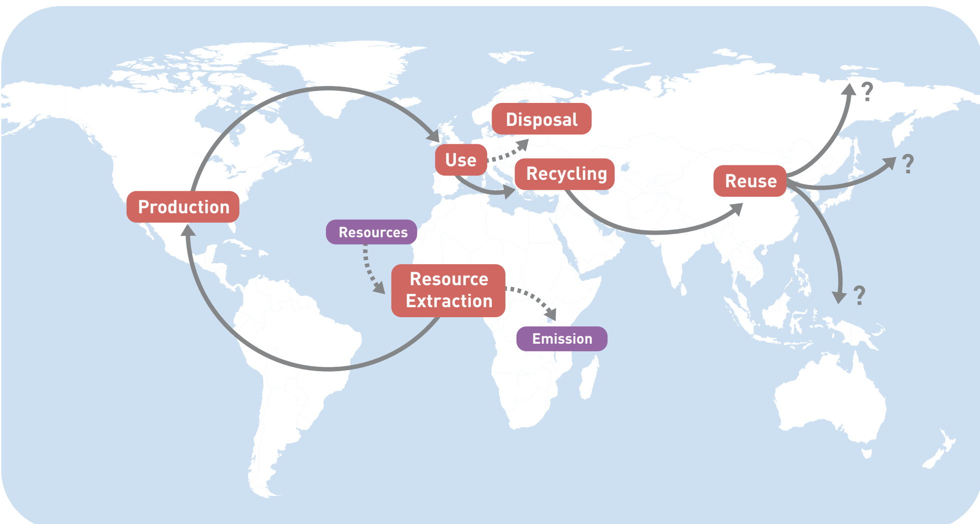
According to ISO, LCA is structured into four phases. The first phase, 'goal and scope definition', defines the purpose and scope of the LCA study, outlining the level of detail that will be required. It states the functional unit, i.e. the quantitative reference for the study, and describes the data requirements for both the second and third phases.

The second phase, 'inventory analysis', is the stage where all data is collected for the unit processes, and mathematical relations are used to relate the data to the functional unit of the study, a process called 'normalisation'. The result is a Life Cycle Inventory (LCI) table. Other procedures may also be performed, such as allocation in instances where there are multiple outputs, and data evaluation (for example sensitivity analysis).

In the case of quantitative water assessments, input-output balances, based on the hydrology and water uses by the different (economic) stakeholders, are set up during the inventory analysis phase, which are similar to the ones

Figure 4.3

Life Cycle Assessment - Life cycle of an aluminium product, e.g. can for soft drinks



Source: UNEP (2002)

Box 4.4 Water consumption throughout a car's life cycle (Warsen et al., 2011)

Volkswagen has been analysing the environmental effects of its cars and components by means of LCA for many years. However, due to lack of data and appropriate impact assessment models, the consumption of freshwater has not been considered. Volkswagen therefore started a study to analyse the freshwater consumption of three specific models Polo, Golf and Passat along their product life cycles on both inventory and impact assessment levels.

The freshwater consumption throughout a car's life cycle is determined using the GaBi 4.3 software and internal LCA databases (Volkswagen, 2011) comprising several thousand datasets for materials and production steps.

In order to obtain a regionalised water inventory, which is a prerequisite for a meaningful impact assessment, the total water consumption is allocated to different car material groups as a first step. The water consumption in these groups is then assigned top-down to the corresponding countries on the basis of import mixes, location of suppliers, production sites, etc. Based on this, country- and watershed-specific characterisation factors are calculated and selected impact assessment methods for water consumption (Frischknecht et al., 2009; Motoshita et al., 2011; Pfister et al., 2009) are applied to estimate the environmental consequences. In this water footprint study only freshwater consumption was considered. It is complemented by a regular LCA which considers impact categories like eutrophication, acidification, human- and eco-toxicity.

At the inventory level, the water consumption along the life cycles of the three cars was:

- Polo 1.4 TDI: 51.7 m^3
- Golf 1.6 TDI: 62.4 m^3
- Passat 2.0 TDI: 82.9 m^3

For all three cars, more than 90 per cent of the water was consumed in the production phase.

Water consumption takes place in 43 countries, with less than 10 per cent of the total consumed directly at the production site in Wolfsburg, Germany, mainly from painting and evaporation of cooling water. More than 70 per cent of the total relates to steel and iron materials and polymers and 20 per cent to special metals (gold, silver, and platinum group metals (PGM).

The study shows that impact assessment results can lead to different conclusions from purely volumetric water footprints. However, water use and consumption figures are not complete in current LCA databases and regionalisation of inventory data, which is a necessary and inevitable step, still has to be based on assumptions such as the manual disaggregation of import mixes. We therefore recommend improving the quality of water data and establishing spatially differentiated water flows as it is already common practice for fossil energy carriers.

used in the water register and water accounting approaches (see sections 4.1 and 4.2).

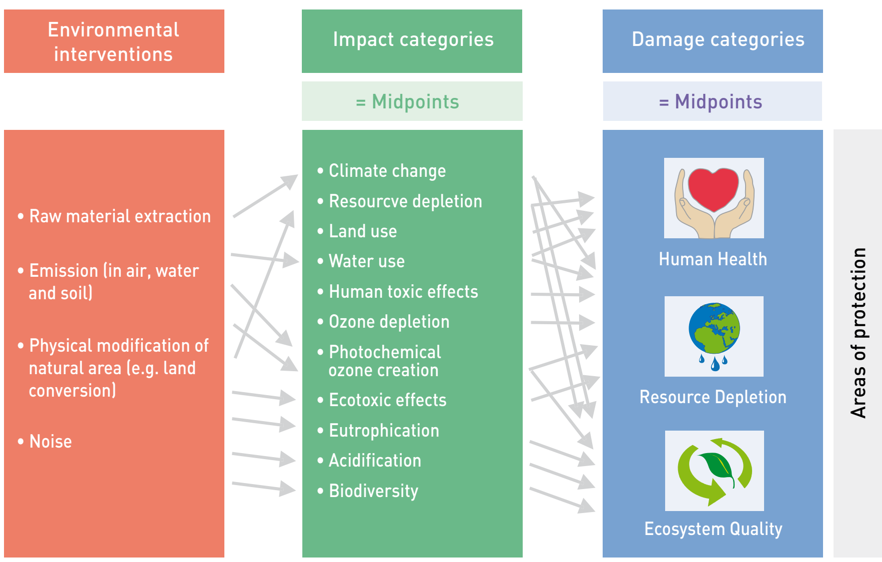
The third phase, 'impact assessment', aims to evaluate the LCI table with regard to environmental impacts. Categories of environmental impacts are selected, for example climate change, human and eco-toxicity, and acidification. The inventory analysis results must then be assigned to the different impact categories - a process termed 'classification'. Characterisation factors are then used to transform the LCI results into common units, which are aggregated to obtain a single number for each impact category - the indicator result. This 'characterisation' step leads to the environmental profile of the product system.

The fourth and final phase, 'interpretation', evaluates and interprets the results from the inventory analysis phase or the impact assessment phase or both. The first step involves identifying the most significant results and evaluating them. The reliability of the results can be assessed through a completeness check, sensitivity analysis, uncertainty analysis and a consistency check. In the final step the conclusions and recommendations are reported.

LCA users include industry, governments, consumers and consumer organisations. LCA and life cycle thinking are very important because it is only by considering each stage in a product's or service's life cycle that all impacts can be identified and improvements made, while avoiding any 'burden shifting' (between the life cycle stages, the impact categories or geographic regions).

As LCA only assesses the environmental performance of a product or service, however, it needs to be used in conjunction with other assessment tools that can evaluate other impacts, including economic and social ones. UNEP has developed guidelines for assessing the social aspects in the life cycle of products (UNEP, 2009).

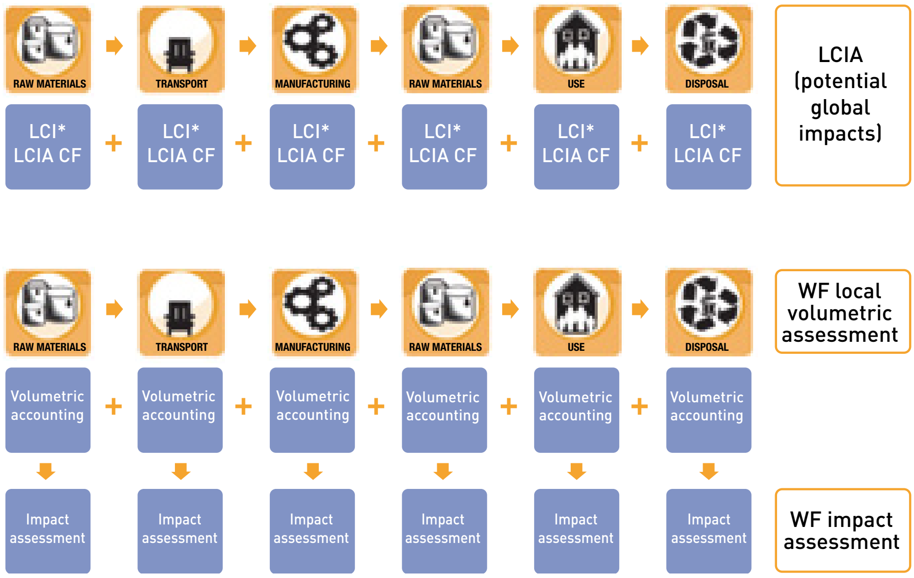
Figure 4.4
Modelling steps in Life Cycle Assessment



Source: adapted from Pfister et al. (2011)

Figure 4.5

LCA and WFA using different ways to include impact assessments in their calculations



Individual impact categories of LCA have been identified as footprints, e.g. the carbon footprint[2] (equivalent to midpoint category 'global warming potential') or the water footprint (in this report referred to as the weighted water footprint).

4.4.5 Impact assessment in water-quality oriented LCA

LCA analyses material-resource considerations and their impacts, in particular pollution of water. As outlined in several publications, the quantitative aspects of water resource use have not ben well covered in LCA methodologies until recent years (Koehler, 2008).

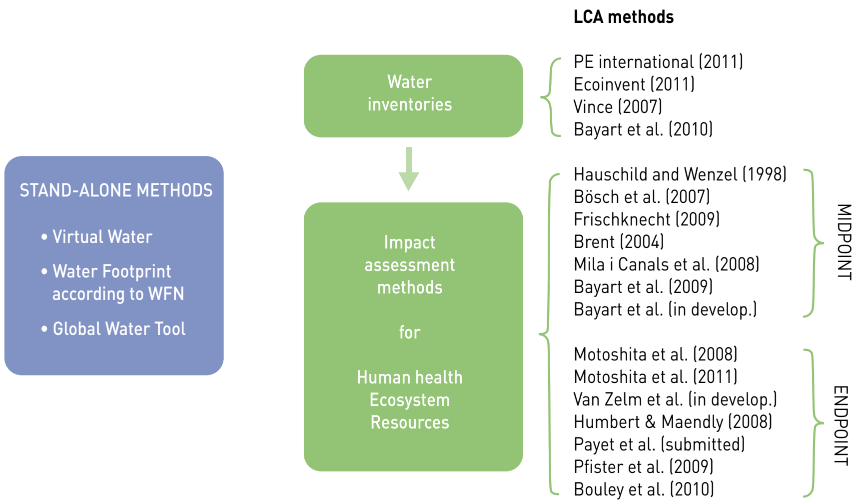
Figure 4.4 illustrates the modelling steps in LCA. Environmental interventions (physical inputs and outputs) are covered in the inventory phase (LCI). These are characterised in the impact assessment phase (LCIA) within impact categories (midpoints) and/or damage categories (endpoints). Midpoint methods characterise impacts in terms of a common unit within their category based on modelled effects (e.g. radiative forcing as CO2-equivalents for climate change). Endpoint methods characterise potential damage of the areas of protection (e.g. ecosystem quality and human health damage caused by the radiative forcing of greenhouse gas emissions).

LCA assesses individual environmental flows (which are to be understood as exchanges between economic sectors and nature, for example emissions or consumption of resources). Mila I Canals et al. (2009) and Pfister et al. (2009) suggest therefore that *water-related impacts* in volumetric assessments can be captured by consumption of water resources (loss of water from the freshwater system), which usually convey the environmental impact of 'blue water' and 'change in green water' (the difference between the 'green water' consumption of an activity compared to the natural situation). This would be captured as a

2 Another rationale behind the LCA methodology for choosing impact coefficients would be to seek consistency with the carbon footprint. However, in the case of water this would be difficult since the effects of carbon emissions are global and reduction and allocation of permits are easily open for global trade, while water can be only dealt with in a very spatially concrete manner and requires more complex consideration.

Figure 4.6

Impact assessment methods in LCA (Berger and Finkbeiner, 2010)



Source: Berger and Finkbeiner (2010)

midpoint assessment as shown in Figure 4.4. How the LCIA places the impact assessment in comparison with Water Footprint Assessment (WFA) is shown in Figure 4.5.

Emissions to water are addressed individually and summarised within impact categories (such as eco-toxicity and eutrophication) or combined as impacts on ecosystem quality. In relation to the water footprint terminology, these approaches can be understood as an advanced 'grey water' measure, as the impact assessment is based on complex cause-effect chains. Bayart et al. (2010) identify some additional impacts of degradative use.

LCA methods vary in their coverage of emissions, but in total hundreds of substances are addressed. In order to avoid double counting, water accounting schemes applied in an LCA context should only account for water consumption since freshwater pollution is covered by other impact categories. There are specific methods developed to describe impacts in the field of eutrophication, acidification, human- and eco-toxicity using different model for cause-effect relationships and indices (Goedkoop et al., 2009; Garnier-Laplace et al., 2008; Struijs et al., 2011; Itsubo et al., 2008).

Early LCA methods, such as the Swiss eco-scarcity method (updated by Frischknecht et al., 2008), related impacts mainly to emission targets. The cause-effect relations now used to assess environmental impacts are more sophisticated, however, and are improving rapidly. Examples include the current EU-funded project 'LC-Impact'. For all methods, spatial distinction is crucial for improving the reliability and usefulness of the results.

Developments to improve the quantitative consideration in the LCA analysis have therefore started to integrate WFA into the LCA analysis.

However, a purely volume-oriented approach like WFA would not be consistent with the original LCA concept, building on impact factors to reflect the damage that different products do to human health or the environment. Therefore the LCA community has taken up the water footprint concept in a slightly modified way in order to address the recognised deficit of quantitative volume-oriented water resource assessments, whilst maintaining consistency with the wider LCA concept.

As shown in Figure 4.6 there are many impact

Box 4.5 Comparing LCA and WFA

Comparing the two alternative definitions of water footprint – WFA- (Hoekstra et al., 2011) and LCA-related (Pfister and Hellweg, 2009; Ridoutt and Pfister, 2010) – reveals quite significant differences.

A detailed water footprint study applying both concepts analysed two products 'Dolmio pasta sauce' and 'Peanut M&M's' (Ridoutt and Pfister, 2010; Ridout et al., 2009). The 'volumetric water footprint' includes unweighted green, blue and grey water, while the 'stress-weighted water footprint' presents the same values but weighted by the water stress (factor of 0-1.5) in the location of water use, as presented in the table (adopted from Ridout and Pfister, 2010). Green water has a stress factor of zero, as green water is considered part of a 'land footprint' in LCA (Ridout and Pfister, 2010).

ingredient	Volumetric water footprint [1]	Stress-weighted water footprint [1]
Dolmio® pasta sauce		
Tomato products	149.9	133.9
Sugar	22.9	< 0.1
Onion	12.0	1.8
Garlic	5.9	0.1
Minor ingredients	3.3	1.9
Peanut M&M's®		
Cocoa derivates	690.1	4.1
Peanuts	140.2	1.1
Sugar	135.1	0.9
Milk derivates	133.6	5.3
Palm oil derivates	27.3	< 0.1
Minor ingredients	17.8	0.2
Tapioca starch	7.9	0.5

The results clearly show the relevant differences: while Peanut M&M's have much higher volumetric water footprints than Dolmio pasta sauce, the related potential environmental impact is much lower (stress-weighted water footprint). This reflects the fact that ingredients with relatively high water consumption (e.g. cocoa derivatives or peanuts) are mainly rain-fed and, if irrigated, found mainly in humid areas of low water scarcity, while, for example, for Australian tomatoes, irrigation water consumption adds significantly to water stress. It therefore guides the focus of the analysis of product supply chains towards the most important issues. The method therefore offers a simple yet meaningful way of making quantitative comparisons between products regarding their potential to contribute to water scarcity.

The approach is helpful in pointing to hotspots that should be investigated in greater detail, using tools like integrated water resource management. Also, it includes part of the high spatial resolution results on water consumption and related scarcity in the aggregated number, providing a good interpretation potential for customers, as is the case for carbon footprints, where the potential impacts on global warming are aggregated to a single number (e.g. CO2-equivalents). The stress-weighted water footprint is therefore based on high-quality crop water consumption data of the highest resolution currently available (5arc-minutes), (Pfister et al., 2011; Pfister at al., 2009) and weighted by the corresponding water scarcity factors.

The same comparison was done with the results presented in a case study on the water footprint of bioenergy, where, for example, maize becomes favourable over sugar beet when applying the stress-weighted water footprint. Again this illustrates the different conclusions taken from different water footprint definitions and the need for synchronisation.

As a result of these comparisons one can conclude that both approaches should be used in combination, reporting blue and green water as well as the stress-weighted water footprint in order to have a transparent yet informative result, as is done for proper carbon footprint assessment in LCAs, where different emissions (e.g. CH4 and CO2) are reported separately but finally aggregated in a weighted number).

assessment methods in LCA. They all model different cause-effect-chains to assess the consequences of water consumption (or use) on human health, ecosystems, and resources instead of focusing on the aggregation of volumes only. A review of methods can be found in Berger and Finkbeiner (2010). An on-going ISO process has been set up to discuss, in a wider community, the possibilities of integrating WF definitions into the conceptual structure of LCA and translating the original WF into LCA calculations by adding a weighting factor.

However, expanding the original water footprint concept from just water quantitative management into a combination of quantitative and qualitative assessment provides a more complex picture, but loses the simplicity of the awareness-raising tool, which the original WFA method set out to be.

This process and the widening of the concept is reflected in a recent update of the Water Footprint Assessment Manual (Hoekstra et al., 2011).

4.4.6 Water Footprint Assessment and Life Cycle Assessment: commonalities and differences

Water Footprint Assessment (WFA) and quantitative water aspects of Life Cycle Assessment (LCA) cover similar ground and are, from the accounting side, built on the same basic hydrological balance calculations. However, they come from different methodological context and origin and have different purposes.

LCA, coming from traditional material balances, is an ISO standard tool for assessing the environmental impacts of different products and services. WFA uses a volumetric approach and, as a consumption-based indicator, is meant to provide information on single products, or at the corporate level, in the context of sustainable, equitable and efficient water management and allocation. It can be used at various levels: river basin, global, product or corporate.

Because of the different traditions and purposes, the two methodologies have developed slightly different solutions for assessing impacts. Intense efforts are currently under way to collaborate and define a common approach with widely-accepted definitions and procedures.

Table 4.2 shows that WFA and LCA both comprise four basic stages. The inventory phases of the WFA and LCA methodologies are very similar and also closely match the approach used in water accounting. In LCA, the inventory phase involves calculating and quantifying water-use inputs and outputs across a product's life cycle. In the WFA

Table 4.2

Stages in LCA and WFA

Stages	LCA	WFA
Preparation	Goals and scope of study	Setting goals and scope
Inventory	Life cycle inventory (LCI)	Water footprint accounting
Impact assessment	Life cycle impact assessment (LCIA)	Water footprint sustainability assessment
Results	Interpretation	Water footprint response formulation

Note: the LCA stages are as defined in ISO 14044; the WFA stages are as defined in the WFA Manual (Hoekstra et al., 2011).

accounting phase, blue and green water is quantified separately for each step of the supply chain. The green and blue figures then can be aggregated to generate a final footprint value.

Life Cycle Impact Assessment (LCIA) compiles and evaluates the inputs and potential environmental impacts of a product system throughout its life cycle. In WFA, the water scarcity impact category is assessed by calculating the blue water volume with the characterisation factor for each region, source and, if available, timing. The sustainability assessment is also conducted in this phase of WFA. It involves evaluating the water footprint of each step of the supply chain individually from the environmental, social and economic perspectives in the affected water basin.

In the final phase of the LCA, the global impacts of water use across the life cycle are calculated by aggregating the impacts of all the stages. In WFA, the response options, strategies or policies are formulated.

The key difference between LCA and WFA is that whereas LCA focuses on impact-weighted water consumption volumes without physical interpretation at every stage of the life cycle (Pfister et al., 2009; Ridoutt et al., 2009), WFA first considers water consumption in terms of volume and then assesses the sustainability of consumption from both local and global perspectives (Hoekstra et al., 2011). Both LCA and WFA analyse sustainability by evaluating impacts on hydrology (primary impacts) and on society, economics and ecosystems (secondary impacts). The difference between the two approaches is in their scope. LCA includes all the supply chain and provides a generalised picture, while WFA looks at single cases after identifying hotspots on a volumetric basis. In that way WFA also looks at the sustainability of water allocation from sustainability, equity and efficiency perspectives at the river-basin level and beyond.

4.5 Virtual water

In general, water is not transported over long distances in the same way as, for example, crude oil because it is currently not profitable to do so. Nevertheless, a significant amount of water is implicitly transferred in goods that contain water or, even more important, require water for their production. The concept of 'virtual water' presents a way of understanding the transfers of water implicit in global trade flows (Allan, 2003).

The water footprint is an expression of water intensity (efficiency) as it is expressed as the amount of water consumed per unit of product. Calculating the water footprint therefore provides the information needed to examine the virtual water flows that occur through trade.

Through calculating the water footprint of economic activities in different regions of the

Box 4.6 Examples of Virtual Water Assessments

Virtual water trading has been recognized by Chile for some time (GWP, 2006b). In the mid-1970s Chile chose to pursue a development model which involved exporting products for which the country had a comparative advantage, such as copper, fresh fruit, wood pulp, lumber, salmon, and wine, all of which use water in their production processes. However, the sharp rise in demand occurred in relatively water-poor river basins, where it was driven by market forces or the availability of other inputs or resources, and not by the areas' water endowments. Most of Chile's copper, for example, is mined and processed in the Atacama Desert.

This led to growing competition for water in some river basins. The result is that export needs are now competing with in-country needs for drinking water and farming for the domestic market, water is rising in value, and exports are resulting in the 'virtual transfer' of water out of the country. The amounts lost can be substantial: around 1 900 million cubic meters per year in the case of Chile's copper and fruit exports alone. This is 1.4 times the amount of potable water produced per year in the country. One of the key policy recommendations is to calculate the 'hidden' water transfers in exports and allow for these in both development planning and water resource management.

An analysis of the virtual water in exported and imported crops undertaken for Andalusia (Velázquez, 2007) also showed that Andalusia uses large amounts of water in its exports of potatoes, vegetables and citrus fruit, whilst importing cereals and arable crops with lower water requirements. The main conclusion is that the agricultural sector will need to greatly modify its use of water if it is to achieve significant water savings and an environmentally sustainability path.

The UK's Royal Academy of Engineering concurs with this in its report on global water security (RAE, 2010) in which it states that developed nations are in a position to meet some of their water needs by importing 'virtual' water in the form of goods and services from other countries. One of its main recommendations is that the water footprints and virtual water content of globally-traded goods and agricultural products need to be taken into account in trade negotiations to protect communities suffering from water stress.

The Victorian Department of Primary Industries was more critical of the use of virtual water (Frontier Economics, 2008). The report documents how the concept was used initially to illustrate the advantages to water-scarce nations of trade with other nations rather than use of local resources, but was then extended to argue against the production or export of commodities with high embodied water content.

The review lists the key shortcomings of virtual water: the assumption that all sources of water are of equal value; that water released from an intense water-use activity is necessarily available for a less intensive use; that it fails as an indicator of environmental harm or of whether water is being used within sustainable extraction limits and thus offers no guidance for policy makers to ensure environmental objectives are being met. The report concluded that these shortcomings render the virtual water concept meaningless and cast serious doubts on the wisdom of applying the concept to guide policy conclusions, such as proposals to restrict the production and/or export of commodities that have high 'virtual water' content. The report also states that it would be of no benefit to environmental outcomes to develop virtual water labelling standards on food.

Australia's National Water Commission came to a similar conclusion but from a different perspective (NWC, 2008). In their view the measurement of virtual or embodied water does not provide a useful or reliable benchmark for allocating the nation's scarce water resources. In practice, it is the opportunity cost which is seen as the most practical measure; this captures the value given up when one application is given preference over another.

world, it is possible to identify those regions that have a comparative advantage in water efficiency for a specific product. To maximise water resource efficiency on the global scale, one ideal would be to move production to the regions that have the highest comparative advantage. Obviously, this would have significant social consequences, but as new economic activities are encouraged in specific locations, the water footprint could be used to help analyse the water efficiency of an activity in a specific location as well as to provide comparisons with water efficiencies in other regions. This comparative information could inform economic development policy and help increase resource efficiency.

To encourage the decoupling of water consumption from economic growth, the water footprint can also be used to identify the relative economic value of each unit of water used (the footprint's inverse, expressed as water productivity [economic value per unit water consumed]). This can be considered in the development of economic sectors so that sectors with the lowest water footprint are selected. In this case, regions or countries would focus production on high-value goods and would trade for low-value goods (high or low value per unit of water consumed).

Water scarcity and the environmental impacts of water consumption can also be addressed through assessing virtual water flows. In this instance, water-scarce areas would rely on imports of water-intensive goods to reduce the local demand for water. Through trade, the most water-scarce regions or nations could import water-intensive products and develop products or services that require less water (water-extensive products), thereby relieving pressure on domestic resources (Yang et al., 2006).Conversely, for water-abundant countries there are economic grounds for exporting virtual water to fulfil needs in water-scarce areas. International 'virtual water flows' could enable economic development with lower aggregate environmental impacts.

However, as reflected in Box 4.6, the virtual water concept does not sufficiently consider the different opportunity costs of blue, green or grey water, which are always highest for blue water. The concept is therefore clearly a good tool for planning purposes and awareness-raising, but may not be directly applicable to water allocation between particular river basins.

4.6 Water stewardship – quantification in corporate monitoring

Virtually every industry and commercial activity, from agriculture and manufacturing to commerce and tourism, requires a stable and consistent supply of water. Water scarcity, pollution, and other water-related challenges pose problems and risks that affect the short- and long-term viability businesses. These risks are often categorised into three overarching types:

- physical risks, which stem from having too little water (scarcity); too much water (flooding); or water that is unfit for use (pollution). They can be caused by drought or long-term water scarcity, over-allocation among users, flooding, or pollution that renders water unfit for use;

- regulatory risks, which occur because of changing, ineffective, poorly implemented, or inconsistent water policies. Stricter regulatory requirements often result from water scarcity, conflict among various users, or excessive pollution. Ineffective policies can create a less inviting or stable business environment or degraded catchment conditions because of incoherent policy design or inconsistent application and enforcement;

- reputational risks, which stem from changes in how stakeholders view companies' real or perceived negative impacts on the quantity and quality of water resources and the health and well-being of workers, aquatic ecosystems, and communities. Reputational concerns can lead to decreased brand value or consumer loyalty or changes in regulatory posture, and can ultimately threaten a company's legal and social license to operate.

Corporate water accounting and Water Footprint Assessment is a key component in companies' water stewardship and water risk management. During the accounting process, companies collect many different types of information, including:

- relative water use and water-use efficiency of their different products, manufacturing processes, suppliers, and value-chain segments;

- location and nature of their various sources of water;

- relative water stress (based on the local hydrologic, ecological, socio-economic, and governance conditions in the catchments in which they operate).

Considering these pieces of information together can help companies identify risk 'hot-spots' by better understanding which water-intensive facilities are located in regions with high water stress. This information provides a basis with which companies can:

- drive operational efficiency and more sustainable product design in a strategic manner;

- assess and manage environmental and social impacts associated with their water use and wastewater discharge;

- assess and manage risks associated with their water performance and catchment conditions;

- disclose relevant information about their water policies and practices to stakeholders.

Companies use a wide range tools and methodologies to facilitate their water accounting processes. While many companies develop their own proprietary tools to measure and monitor their water performance, many use publicly-available methods, namely Water Footprint Assessment (as developed by the Water Footprint Network), Life Cycle Assessment, and the World Business Council for Sustainable Development's (WBCSD) Global Water Tool. WFA and LCA are typically used to understand how a company uses water internally, as well as the social and environmental impacts associated with that water use and wastewater discharge. The WBCSD Global Water Tool attempts to identify which facilities might be more prone to water risks based on local water scarcity.

The European water stewardship scheme (EWS), developed for Europe by the European Water Partnership (EWP), addresses operational performance evaluation in terms of sustainable water management, including local river-basin impact, integrated response solutions and risk management of responsible water users.

The EWS defines efficient and implementable sustainable water management response strategies for water users, including industry and farmers, in Europe and on a river-basin scale. The EWS includes a guideline/standard and checklists for private water users to help them in changing practices towards sustainable water use, management and governance. It is highly complementary to water accounting tools. It also aims at rewarding for sustainable practices, takes into account the context of EU policies, and promotes a take-up of the EU legislative requirements in the Water Framework Directive.

The EWS is an initiative of the global Alliance for Water Stewardship (AWS). It provides a powerful water-efficiency tool to help achieve sustainable water management on-site; to implement good management practices and to complement legal measures which together contribute towards sustainable water management at the river-basin scale. The strength of voluntary environmental schemes lies in collecting and serving multiple interests to benefit from more flexible regulation, lower administrative burdens, and superior environmental performance. A generic 'global Water Stewardship standard' that has been set up within a global multi-stakeholder process coordinated by the AWS, will ensure a harmonised implementation of the integrated Stewardship approach world-wide.

The Alliance for Water Stewardship is currently developing a global certification standard that encourages and incentivises improved corporate water management and provides environmental, social, and economic benefits at the river-basin level. This standard will apply at the facility and river-basin level and will target agriculture, industry, and water service providers. In addition to the certification standard, AWS is developing a verification process to ensure that company claims are credible and beneficial. It will also include a tool that helps companies identify a suitable risk response strategy. The methodologies that AWS will use to assess corporate water stewardship are still under development.

5 Summary and Conclusions

5.1 Water connects

This report provides a link between the reality of the serious and concerning status of our water resources due to increasing pressures of all kinds and the measures that are feasible and under development in many parts of the world, but that need implementation. It is one in a series of three reports by the UN International Resource Panel (IRP) dealing with water resources in the context of global change and scarcer resources that call for a major transformation in the global economy.

Water in the development of a Green Economy is vital in three ways: it is an asset essential for life and a common good for human well-being, it is a production factor and economic asset essential for economic prosperity, and, integrating these two, it is a vital environmental asset essential for the maintenance and regulation of the ecosystem services that ensure the long-term sustainable provision of the economic and social goods and services on which prosperity depends.

This gives sustainable water management a key role in **integrated actions and activities** to structure a new, green economy and can thus provide a pilot for a paradigm shift towards the integration of economic, social and environmental principles.

Water connects. It connects air with land. It connects regions, cultures, opinions and different (economic) interests.

The missing link between the need for change and action to implement this change is **information and knowledge** of the exact scope, character and location of the problem to inform all actors, offering possible measures, justifying target setting and balancing actions and policy options in the most effective way. Many examples of good or difficult water management around the world show that objective and targeted information can unblock the stakeholder dialogue on which the cross-sectoral understanding of efficient water management so much depends.

5.2 Quantifying water use in the local and global perspective for cross-sectoral sustainable water management

Water as a resource differs strikingly from resources like metals, oil or coal, dealt with in previous UNEP reports (UNEP, 2011a). Water management is a mix of local, continental and global matters, but most water management is driven by local conditions in local catchments and ruled by **regional or local governance** structures, which involve governmental policy actions as well as private sector activities and behaviour of the different stakeholders (civil society, farmers, industries enterprises, utilities, etc.).

All regional and local management is of course to be seen in a pan-regional and even global context. Some aspects of water management are directly dependent on agreements and cooperation in transboundary river basins (e.g. Rhine or Danube in Europe), are related to water transfers between adjacent river basins (e.g. Singapore/Malaysia), or are 'virtual' via the water needed for goods and products, depending on international agreements, trade and political developments (trade, pricing, subsidies).

As the case studies and methodological details show, particular for Water Footprint Analysis and Life Cycle Assessments, issues of water management, consumption and production are highly relevant to international trade between developed and developing countries, as well as within a country with differentiated issues of scarcity and economic development, as exemplified by the case studies in the report.

As water is a resource that is tightly bound to and dependent on local climatic and ecological conditions, the impacts of water use in any kind of production chain always have to be analysed at the local level and in the catchment where the abstraction for the particular step in the supply chain takes place. In many cases, and often for agricultural products, these are in developing countries.

But water management per se does not have a global dimension in the way that air does (greenhouse gases, climate change, etc.) or other physical commodities such as ores and fossil fuels which are physically transported and traded. The global context of water management is more subtle. In this perspective it is very important to understand that all the quantification approaches discussed in this report need to carefully consider the physical impacts of water use and possible overexploitation and pollution in the catchment of original production of any goods in the global and trading context.

The most relevant actions and measures to be taken for sustainable water management are either driven by national or regional governments and are thus on a macro-economic level, or require management decisions at a sectoral and corporate level (e.g. agriculture or industries). Both levels are of course highly interrelated and also related to international and inter-regional trade and policies. However they serve different purposes.

There has to be a distinction between wider awareness-raising, large-scale policy planning processes (e.g. at the national or pan-regional level) and operational planning at the local level in the river basin. The information for politicians, stakeholders and the public needs to be concrete and targeted at all these levels.

Water and interest in water and its use connect all stakeholders in these and between these different levels. Those involved include politicians and administrators at the different governmental levels and from the very different sectors, as well as private and public actors. The range is from actors in the agriculture and food industry, transport and energy suppliers, water utilities, manufacturing industries and enterprises of all sizes, to actors for the public interests (consumer, social and environmental NGOs). The art of water management between these different actors is one of integration and balancing powers for the common interest of further welfare and growth.

The report provides methodologies to inform the knowledge base at all these levels and to help ensure that these are applied in the right combination to link them together in a coherent decision process, improving the overall governance of water and including all relevant actors.

5.3 Decoupling

In this area, spanning economic growth and human welfare, and ecological integrity to support both, there is ample evidence that economic growth is often coupled with **unsustainable depletion of natural resources** which impairs the environmental foundations of our life. While providing short-term prosperity to certain parts of the population, other parts and future generations are not benefiting in the same way or are worse off, due to environmental impacts and deterioration of the natural capital vital for economic growth and human prosperity. The principle of decoupling as described in recent UNEP reports shows an alternative to this development.

Decoupling at its simplest is reducing the amount of resources such as water or fossil fuels used to produce economic growth and de-linking economic development from environmental deterioration (UNEP, 2011a). The idea of decoupling can thus be a guiding principle for implementing sustainable water management.

The most significant argument for decoupling arises from the logic that all environmental impacts, including their social consequences, can jeopardise sustainable economic development and human well-being, as stated, for example, in the World Water Assessment Programme.

The case studies on water balances, water productivity and environmental impacts in this report provide some evidence of the need for and feasibility of decoupling. A future water report of the resource panel will go into more detail on the possibilities and opportunities of decoupling from a practical perspective.

5.4 Risk and knowledge management, the role of information for policy options in a new governance for sustainable water management

For sustainable water management at the local level in the catchments where water abstraction or consumption takes place, the quantification approaches discussed in this report can provide the relevant knowledge base to feed the governance structures that foster sustainability and the protection of environmental resources for the **benefit of social equity**. As stated in previous UNEP and OECD reports, a green economy aims to 'improve human well-being and social equity, while significantly reducing environmental risks and ecological scarcities'.

Proper quantification of water assets helps to ensure that investments in maintaining and restoring ecosystems are made at an early stage so that ecosystems can provide benefits, including social benefits, more reliably and enduringly. Such investments can avoid unnecessary restoration costs and secondary investments in medical and health care in areas where people suffer from polluted drinking water and insufficient sanitation.

Accounting approaches such as registers and water accounting (UNSD, 2007) start at the macro-economic level to inform allocations at the national and river-basin level (national, regional or transboundary), whereas Life Cycle Analysis and Water Footprint Analysis focuses on products/commodities.

Where an integrated view of the **corporate and macroeconomic level of water management** is implemented it can develop into a tool for water stewardship and corporate risk assessment. Sustainable water management in the private sector, and in particular in large international corporations, is driven by the need to minimise business risks. The most important concerns for private stakeholders include physical water risks like scarcity/floods, pollution and the related reputational risks, climate change impacts, and unstable governance structures and unreliable regulatory frameworks (CEO Water Mandate, 2011; UNEP, 2011c).

It is thus evident that using the same transparent and agreed information base for national and corporate risk assessments connects governments, civil society and the private sector for a new, transparent and participatory approach to sustainable water management. It is a precondition for a common understanding of the correct effective measures needed to ensure sustainable resource use.

Policymakers have a variety of tools at their disposal to achieve this goal. Political will is needed to respect the inherent resilience and sustainable limits of ecosystems and ensure that the environment has the volumes and quality of water it needs to provide ecosystem goods and services. This requires norm setting and clear and efficient but effective legislation based on quantitative evidence. In order to implement measures to fully achieve the targets, a wider range of policy options needs to be used to encourage the most cost-effective and innovative developments, using an active, multi-stakeholder approach, again underpinned by quantitative assessments.

Policy options that could result in improved water management (or improved environmental management in general) can be categorised into four areas:

- public participation and awareness to prepare the ground and provide wide agreement throughout society and between all stakeholders (politicians, economic and social leaders, the public) on common values for future sustainable development;

- flexible and cooperative governance, including and enabling effective regulations, and institutional arrangements to implement them, to improve sustainability and resource efficiency;

- technological innovation, to use resources more efficiently and protect society and the environment from harmful effects;

- economic instruments and investments to enable technological innovations, social equity and sustainable development in a growing economy.

Three key elements are needed to support this array of policy options and decision-making on water management and related economic and social implications:

- sufficient knowledge, data and information about how much water is available, the uses for which it is needed (including environmental needs), the identity of users and the relevant time and space scales;

- clear, easy to use and harmonised international methodologies to assess this knowledge, information and data and to make well-founded allocation decisions that are widely accepted;

- political decisions about water allocation that ensure that all relevant ecosystem services are maintained for current and future generations, and to secure further technological development and innovations to enhance water efficiency and productivity (as described in further work by the IRP).

A proper, objective, reliable and inarguable information base helps to provide groundtruth for competing arguments and to prioritise policy options in a balanced stakeholder dialogue.

5.5 Methodologies for quantifying water-resource management

To support these assessments and improve governance as outline above, the report lists and evaluates different methodologies, sources of data, information and related definitions. A number of key messages emerge.

Summarising the details given on each of the methodologies, the Resource Panel would not give priority to one approach over the other, but it needs to be emphasised that they each have their respective value and area of application.

Two basically different but related issues have to be distinguished: corporate water management is concerned with products/commodities; and the macroeconomic regional or national management level is concerned with accounting-based spatial/hydrological issues. Some of the methodologies are relevant to both, but only with certain limitations.

- In many parts of the world, the development of **water registers,** which describe the availability of water and identify who is entitled to access it in a region, is in its infancy. The same is true of systems that enable efficient management of allocations during times of scarcity. Rather than developing these registers and systems in isolation from more general water accounting arrangements, it is possible to develop them so that they become the primary source of information used to document how, where and when water may be and is used.

- Systems built in this manner typically begin by partitioning a water resource into a number of 'pools' of differing allocation priorities. Entitlements to access water allocated to each pool are then distributed amongst users or user groups. As the volume of water within the pools is likely to change from season to season, each entitlement is defined as a share of any water allocated to the pool. Sustainable diversion limits are set for each pool in a manner that ensures enough water is set aside for conveyance, maintaining the environment and meeting other needs.

- The water for maintaining the environment will ensure that ecosystem services are delivered as an indirect benefit of water use, in addition to its use by agriculture, industry and human settlements.

- **Water accounting** is crucial to allow those responsible for water registers to undertake this prioritisation. Without adequate data and sources of information on water availability, use and productivity, these decisions cannot be made on a rational basis.

- In more and more parts of the world that are increasingly water stressed, water accounting has therefore become a key statistical activity for governments, similar to accounting for the carbon intensity of GDP. Together with investments in green sectors, these indicators are becoming the starting point for managing the transition to a green economy.

- However, a current shortcoming of traditional water accounting (UNSD, 2007) is the lack of direct consideration of environmental impacts and, often due to data restrictions, the lack of disaggregation to more meaningful hydrological units and temporal information. Further national efforts are needed to generate such data, while on the international level further work is needed on the revision of SEEA-W to fully integrate ecosystem services and natural capital into accounts.

- An **integrated approach to water management across media and sectors** is needed, as there are potential trade-offs between land and water use, ecosystems, GHG emissions, soil degradation, etc.

- **Water scarcity indicators** provide an overview and guidance at the pan-regional level and can be used to inform the international coherence of more detailed regional or local assessments, but by themselves do not provide detailed enough information to guide policy decisions.

- A **life cycle perspective** is needed in order to account for water use and its related impacts along the entire production chain, from feedstock production to conversion and final use of both agricultural and industrial products. While it is important to take a holistic approach and a long-term perspective, cooperation needs to occur at the river-basin level.

- It has become clear that there are basic philosophical differences between existing accounting methods for water use over the life cycle of products and systems. The **Water Footprint Network** (WFN) — and with it the virtual water concept — understands water as a global resource. According to this approach water is limited only at the global level. Allocating more water to an industrial product means less water going to food, the environment or other uses. Therefore water volumes are the main concern. For a meaningful water-efficiency assessment, providing tools for regional and local water management, the Water Footprint Assessment needs to specify the seasonal and spatial aspect of the analysis more clearly. Furthermore additional criteria must be developed to assess economic and social sustainability and assess the possible opportunity costs of different possible water uses.

- In contrast, for the **Life Cycle Assessment** (LCA) community, the environmental impacts of water use are the main concern. In LCA the local impacts are aggregated to a functional system level. An increasing number of stakeholders support the further development of regionalised tools to overcome the shortcomings of the aggregation of factors.

- Life cycle impact assessment and water footprint according to the WFN are inadequate without **the differentiation of localised impacts and consideration of seasonal effects**. This information is needed to calculate the ecosystem service sustainability index. Only such an index allows the quantification of decoupling economic growth from both water use and impacts on ecosystems, needed to track progress with water productivity.

- **Capacity-building** for water accounting is needed worldwide but particularly in developing countries where existing data gaps also need to be filled. One of the main constraints on water management is a lack of updated data. Some monitoring needs to be carried out on a regular basis to comply with regulations and with sustainable production.

- Many business corporations are developing water management and stewardship schemes. There needs to be a parallel improvement in the way that local, regional and global governmental institutions manage and monitor water resources and productivity.

Combining the above points, it is important to note that only a **combination** of the different approaches can fully help and support sound policy decisions. From a social and economic perspective it is vital that the sources of water (blue, green, grey) is identified in all accounting systems, and to find ways of incorporating the differential opportunity costs when adding up their values. The report further emphasises the need for **impact and sustainability assessments** to support the maintenance of all ecosystem services and for a paradigm shift in future policies in order to fully address decoupling and impact assessments at all levels.

In many (particularly developing) countries, the limiting factor for full application of the appropriate quantification is **data availability**. In these cases regional adaptions and preliminary analysis with easy to use indicators might be appropriate. These '*Water Accounts Light*' could use available state indicators of water bodies like the state of the groundwater table, the status of water level in lakes and reservoirs, and eutrophication.

Further future development of all these approaches and their testing in common and comparable studies is recommended to provide the best and most applicable instruments for policy decisions and to enable the tracking of performance on measures for more efficient water management and decoupling.

5.6 The way forward

This report takes its starting point the clear need to assess water resource use and management against ecosystem resilience and limits of sustainability when developing policy options in order to **balance the competing needs** of water users.

The **environment's water needs** must be treated as a vital priority in order to ensure the steady supply of the basic regulatory ecosystem services that underpin the delivery of social and economically-valuable provisioning services. In essence, the water ecosystems must function properly and make clean and sufficient water available to ensure food production (crops, husbandry and fish), drinking water supply, energy and cultural values.

Effective and targeted assessments depend on **open data access** and optimal data availability to function in a transparent and equitable dialogue of relevant stakeholders.

The methodologies applied for the assessment of resource use and allocation as well as for the assessment and tracking of pollution loads need to be **transparent and comparable** between regions up and downstream of the connecting water bodies and scalable between the local and regional or pan-regional scales. Further effort are needed to provide this comparability and the link between different scales, as shown by the differences between the accounting methodologies, LCA and Footprint assessments.

Application of the different methodologies and approaches needs to be **suitable and tailored** for the relevant purpose and the right scale in management, time and location. Only that can provide an equitable, knowledge-guided **allocation of water resources** including to meet environmental needs.

Using the conceptual and methodological analysis set out in the report, the International Resource Panel with its Water Efficiency Working Group will publish two other assessments, an overview of the scope of the water management problem around the world and an analysis of the economic and social elements of water productivity and efficiency together with aspects of governance and institutional arrangements.

This modular approach aims to provide a comprehensive overview of the policy options to implement sustainable water management in a green economy that recognises water as vital natural capital while continuing to develop a healthy and productive water sector within the economy that cares for and enables social equity.

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About the International Resource Panel

The International Resource Panel (IRP) was established to provide decision makers and other interested parties with independent and authoritative policy-relevant scientific assessments on the sustainable use of natural resources and, in particular, on their environmental impacts over their full life cycles. It aims to contribute to a better understanding of how to decouple economic growth from environmental degradation. This report is the second in a series of reports of the IRP on Sustainable Water Management, providing methodologies and strategies for measuring water use in a green economy, with the ultimate objective of ensuring that water – an essential resource for all life – is managed to the highest levels of efficiency and productivity.

Working Group on Sustainable Water Management

The objectives of the International Resource Panel are to:

a. provide independent, coherent and authoritative scientific assessments of policy relevance on the sustainable use of natural resources and in particular their environmental impacts over the full life cycle; and

b. contribute to a better understanding of how to decouple economic growth from environmental degradation.

The rationale and overall objective of the Working Group (WG) relate to both bullet points and the core strategic basis for the work of the International Resource Panel.

The first report in the series drew on existing literature and conceptual frameworks developed by the IRP in other research, to provide a conceptual and analytical basis for decoupling policy and decision making in water resource management. In particular, it focuses on how decoupling can enable maximize water efficiency and productivity, reduce water pollution in all the major water sectors (i.e. agriculture, industry, domestic, and environmental flows), and at the same time support sustained growth and human wellbeing.

This second report analyses the different ways for quantifying and accounting for water flows and productivity within the economy (including environmental needs). Based on data from the literature, the report provides the current state of knowledge of the different indicators and tools for quantifying water productivity and highlights why this is important for developing robust allocation and management systems that preserve the natural capital. It is therefore an important piece of work to inform the discussions on decoupling economic growth from water use and impacts and the debate on resource productivity indicators going beyond GDP and carbon that underpin a green economy.

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

- sustainable consumption and production,
- the efficient use of renewable energy,
- adequate management of chemicals,
- the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

- **The International Environmental Technology Centre** – IETC (Osaka), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information, see www.unep.fr

Water is an essential resource for virtually all aspects of human enterprise, from agriculture via urbanization to energy and industrial production. Equally, the many uses for water create pressures on the natural systems. In this context, enhanced water productivity and management is a major challenge not only for direct water users, water managers and policy makers but also for businesses and final consumers. In most parts of the world, however, the development of consistent water accounting systems both from the production and consumption perspective is in its infancy.

This report analyses the different ways for quantifying and accounting for water flows and productivity within the economy (including environmental needs). Based on data from the literature, the report provides the current state of knowledge of the different indicators and tools for quantifying water productivity and highlights why this is important for developing robust allocation and management systems that preserve the natural capital. It is therefore an important piece of work to inform the discussions on decoupling economic growth from water use and impacts and the debate on resource productivity indicators going beyond GDP and carbon that underpin a green economy.

The report focuses on two main elements: 1) the conceptual background and knowledge on how water use puts pressure on the environment; 2) methodologies to quantify water availability and use and how this influences ecosystems.

www.unep.org
United Nations Environment Programme
P.O. Box 30552 Nairobi, 00100 Kenya
Tel: (254 20) 7621234
Fax: (254 20) 7623927
E-mail: uneppub@unep.org
web: www.unep.org

UNEP

For more information, contact:
UNEP DTIE
Sustainable, Consumption and Production Branch
15 rue de Milan
75441 Paris CEDEX 09
France
Tel: +33 1 4437 1450
Fax: +33 1 4437 1474
E-mail: unep.tie@unep.org
www.unep.fr/scp

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