Statistics Netherlands

Memo

Sustainable Development Goals for water - SDG 6.4 - Three step approach for monitoring

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project number 301620
ENR - Arbeid, Milieurekeningen en Regio & SLO - Milieu
05 December 2016

remarks The views expressed in this paper are those of the author(s) and do not necessarily reflect the policies of Statistics Netherlands.

Preface

This memo has been produced by Statistics Netherlands (CBS), Deltares and eLEAF with the support of the support of the Ministry of Infrastructure and Environment and the Ministry of Foreign Affairs, being the two key stakeholders to the SDG Target 6.4. It is part of the Dutch effort as a Proof of Concept country for SDG 6.

We considered the use of the ladder approach for the Netherlands in order to add detail to the monitoring system already in place via existing national statistics. By means of remote sensing information is incorporated in these statistics already, but can be extended, and modelling could be able to add more detail.

We also looked in what way the used approach in the Netherlands can be of use in other countries including the use of other sources, in order to support the procedures that can be applied in countries to monitor and report on their targets of SDG 6.4.

We show the available data sources that can be used to monitor SDG 6.4 for the Netherlands. Although available data sources for the Netherlands are discussed and examples of the calculated indicators are given, reporting on SDG 6.4 is not the scope of this memo. This information can be found in other documents compiled by Statistics Netherlands from their existing water statistics & SEEA-Water Accounts.

Table of Contents

1. Introduction and Objective

In September 2015, heads of state from all around the world adopted the 2030 Agenda for Sustainable Development consisting of 17 Sustainable Development Goals (SDGs) and 169 targets. The 2030 Agenda includes a dedicated goal on water and sanitation (SDG 6) that sets out to 'ensure availability and sustainable management of water and sanitation for all'. The indicators under target 6.4 comprise SDG 6.4.1 – change in water use efficiency over time – and SDG 6.4.2 – Level of water stress that relates water withdrawal ('abstraction') to available freshwater resources. Six Proof of Concept countries, including the Netherlands, were invited to test the methodologies developed by UN organizations and to collect data for the indicators linked to SDGs 6.3 to 6.6. Chapter 2 gives a short overview of the background of the SDGs.

As a result of the Proof of Concept process, Statistics Netherlands (CBS), Deltares and eLEAF began a limited project aiming to show what can be compiled for the indicators under SDG 6.4 for the Netherlands and what could be compiled to support other countries in the process of evaluating the 6.4 SDGs. A short summary of the indicators is presented in Chapter 3. More information on this can be found on the official publications on the SDGs: http://www.unwater.org/publications/publications-detail/en/c/434399/.

This memo considers the available data for and compilation of SDG 6.4, taking a three step ladder approach on the available data sources that can be used to compile the indicators. The existing national statistics enriched with additional data sources, can ensure that basic data for monitoring water use efficiency and water stress will be available for the Netherlands.

The core line of development of the methods is the so-called ladder approach, a three - step approach in which data combinations for compilation of the indictors are described, from either:

i) existing data available from National Accounts, water statistics (following IRWS[1]) & SEEA – type Water Accounts[2];
ii) supplementary data from satellites and models;
iii) An integrated approach with full consistency between the statistical data, model data and satellite data.

These three types of data sources are described in Chapter 4 in a concise manner. More information on these data sources can be found in the annexes, as well as in the report 'GEMI proof of concept report' (Ministry of Infrastructure and Environment, 2016), the report sent to UN-Water by the Netherlands.

In Chapter 5, first an example of the data for calculation of indicator 6.4.1 is given, showing that this indicator can entirely be calculated using available statistical data. Secondly, the ladder approach for indicator 6.4.2 is assessed for the Netherlands as it is currently in use by Statistics Netherlands for reporting on established and standardized water statistics and SEEA – type Water Accounts to Eurostat (Graveland and Baas, 2012). It serves as a good example of the value of the ladder approach, even for countries that already have detailed national statistics

[1] International Recommendations for Water Statistics (UN, 2012c).
[2] Following 'International statistical standard', the SEEA – Central Framework and SEEA Water Accounts as published by United Nations Statistical division (UNSD), (UN et al., 2012a; UN et al., 2012b).

combined from their National Accounts, waters statistics and SEEA – Water Accounts, such as the Netherlands. Chapter 6 elaborates further on the advantages of the ladder approach, building on what has already been done in the Netherlands. This is done in a qualitative manner through examples of more temporal and spatial resolution of the components underlying the indicator.

Although the methods for compiling SDG 6.4 indicators are near completion, critical comments on these proposed methods (meta-documents) have been made, where deemed necessary, including informed suggestions for further improvement in the final stages. These observations are listed in Chapter 7.

The final chapter (8) contains conclusions, as well as recommendations for further developing the ladder approach.

2. Background

Sustainable Development Goals

In September 2015, heads of state from all around the world gathered in New York City to adopt the 2030 Agenda for Sustainable Development, an ambitious 'plan of action for people, planet and prosperity', comprised of 17 SDGs and 169 targets, aiming to do nothing less than 'transform our world'.

The 2030 Agenda includes a dedicated goal on water and sanitation (SDG 6) that sets out to 'ensure availability and sustainable management of water and sanitation for all'. SDG 6 expands the Millennium Development Goal focus on drinking water and sanitation to the entire water cycle, including the management of water, wastewater and ecosystem resources. With water at the very core of sustainable development, SDG 6 does not only have strong linkages to all of the other SDGs, it also underpins them; meeting SDG 6 would go a long way towards achieving much of the 2030 Agenda.

GEMI

Progress towards the SDGs needs to be monitored. UN-Water is currently trying to integrate UN-monitoring initiatives for SDG 6. For SDGs 6.3 to 6.6, GEMI (the Integrated Monitoring initiative) was created as a partnership of UNEP, UN-Habitat, UNICEF, FAO, UNESCO, WMO, and WHO, and resides under the UN-Water umbrella. GEMI is the UN-sponsored initiative aiming at establishing and managing a coherent monitoring framework for the implementation of SDG 6 for water and sanitation.

Six Proof of Concept countries, including the Netherlands, were invited to test the methodologies developed by UN-Water and collect data for the indicators linked to SDGs 6.3 to 6.6. The results of the Proof of Concept Phase for the Netherlands were recently reported to UN-Water (Ministry of Infrastructure and Environment (IenM) (2016)). That report gives insight in the many meetings, workshops and discussions organized to gain an understanding of the different indicators included in SDGs 6.3 to 6.6, as well as to gain and share experiences and solutions for providing data for the compilation of the indicators.

National setting on monitoring of the SDGs

Statistics Netherlands (CBS) represents the Netherlands in the Inter-agency and Expert Group on SDG indicators (IAEG-SDGs), and discusses the different aspects of the SDGs in this international setting. In the Netherlands, the relevant stakeholders are preparing for the sound and functional monitoring of the full range of SDGs. Therefore, different Ministries, Statistics Netherlands, research institutes, academia and consultants have evaluated their responsibilities with respect to this, and provided relevant information related to the content of the indicators, concepts, methodologies, required data and reporting. For the full range of SDGs, a first assessment on the monitoring for the country has recently been published (Statistics Netherlands, 2016a).

The indicators have been re-assessed on their feasibility, suitability, measurability, and relevance during the IAEG-SDGs meetings and exchanges since autumn 2015. It is expected that the IAEG-SDGs will provide a flexible framework for the development of the indicators and their monitoring, in order to allow for rephrasing of the indicators when needed and the addition of new indicators or more detail when technological developments permit this.

Towards integrating monitoring capabilities

During an expert meeting at the Ministry of Foreign Affairs on 24 August 2016, SDG 6.4 was considered in a broader context. Two concerns were raised which led to the initiation of this small project. The first concern was the availability of reliable data to monitor SDG 6.4 beyond the Netherlands. The second concern was the loss of information when indicators are reported on a national level only. These concerns were based on a number of observations:

- The Netherlands' long history of living with water has prompted the collection of a large amount of data on water use, water supply, emissions to water, the related economics, and water resources, as well as its rivers and hydrological systems. Moreover, the statistical data in National Accounts, SEEA Water Accounts and water statistics, compiled at a national level for the Netherlands, is included in the international statistical data systems and is collected by international bodies such as the UN (UNSD), World Bank, OECD, FAO, Eurostat, EEA. As such, it is possible to make international comparison of indicators compiled in a consistent manner following international standards as is IRWS and SEEA – Water Accounts. This type of data becomes available for other countries too, as an increasing number of countries develop water statistics and SEEA water accounts.
- Technological innovations make new ways of monitoring possible. Advances in remote sensing and modeling are offering additional ways to add detail and quality to the existing assessment of the physical part of water use efficiency and water stress indicator compilation, extending opportunities for use in proper water management at different scales.
- The combination of statistical data, remote sensing and modelling can offer more temporal and spatial detail, adding valuable input to attempts to improve water management, which is aimed at enhancing water use efficiency and reducing water stress at the different scales in the country.

Concluding that monitoring of ***water use efficiency*** and ***water stress*** can be done in a more integrated way, an intensified cooperation and integration (applying the 'ladder approach') of the available data and evaluation of its strengths were proposed during the meeting. This memo is the result of this proposal.

3. Definition of SDG 6.4

3.1 Introduction

In this chapter, we briefly explain the definitions of the indicators. It will be a concise description, as more information on this is readily available in other documents. However, the details of the indicator descriptions were assessed during the preparation of this memo. This resulted in a number of observations about the application of the methodology in the Netherlands. These observations can be found in Chapter 7.

SDG 6 is defined to: 'Ensure availability and sustainable management of water and sanitation for all.' It consists of six main targets with two additional targets on cooperation and capacity building.

Target 6.4 focuses on water use efficiency and water scarcity, defined to: 'By 2030, substantially increase water use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.'

Indicator 6.4.1 is related to water use efficiency, defined as: 'Change in water-use efficiency over time.'

Indicator 6.4.2 considers water scarcity, defined as: 'Level of water stress: freshwater withdrawal in percentage of available freshwater resources'

3.2 Indicator 6.4.1 on water use efficiency

The proposed indicator would provide information on the efficiency of the economic usage of water resources, particularly on the value added (VA) generated by water use in the three aggregated sectors of the economy, and the distribution network losses.[3] Indicator 6.4.1 is not just about the absolute level, but it monitors the change in '**water use efficiency**' over time. It is defined in the proposed indicator as the volume of water withdrawn divided by the VA over time of a given major sector (showing the trend in water use efficiency). Following International Standard Industrial Classification (ISIC) 4 coding (See: Annex II, United Nations (2008)), the aggregated sectors are defined as:

1. Agriculture, forestry and fishing (ISIC A);
2. Mining and quarrying, manufacturing, constructions and energy (ISIC B, C, D, F); and
3. All of the service sectors (ISIC 36-39 and ISIC 45-99), which include Water collection, treatment and supply industry (ISIC 36).

The following terminology can be used (following note of UN Water):

- Water use: general non-specific term that describes any action through which water provides a service; and
- Water withdrawal [4]: water abstracted from a river, lake, reservoir or aquifer (V).

[3] The distribution efficiency of water systems is explicitly considered only for the municipal sector as a separate indicator, but it is nonetheless implicit within the calculations for the other sectors, and could be made explicit if needed and where data are available.

[4] SEEA-Water normally uses term '***abstraction***' when it is subtracting the groundwater or surface water from the environment.

The indicator is supposed to be computed as the sum of the aggregated sectors of the nations' economy, weighted according to the proportion of water withdrawn by each sector over the total withdrawals, such that:

$$WUE = A_{we} \times P_A + I_{we} \times P_I + S_{we} \times P_S$$

Where:

- WUE = Water use efficiency (USD/m^3, or EUR/m^3);
- A_{we} = Irrigated agriculture water use efficiency (USD/m^3 or EUR/m^3);
- I_{we} = Industrial water use efficiency (USD/m^3 or EUR/m^3);
- S_{we} = Services water use efficiency (USD/m^3 or EUR/m^3);
- P_A = Proportion of water withdrawn by the agricultural sector over the total withdrawals;
- P_I = Proportion of water withdrawn by the industry sector over the total withdrawals; and
- P_S = Proportion of water withdrawn by the service sector over the total withdrawals.

The computing of each of the three sectors is described extensively in Annex III.

For this calculation, details about the required data and underlying data sources are explained in the next paragraphs following the three approaches. Also, the detail chosen in the dimensions of the calculation that are subject to this exercise, depending on the available data, will be shown and discussed in the next paragraphs. Issues such as rationale and interpretation, disaggregation, data sources and collection, comments and limitations, current data availability and indicator tier, responsibility, etc. and references will be discussed there.

3.3 Indicator 6.4.2 on water stress

This indicator provides an estimate of pressure by all sectors on the country's renewable freshwater resources. A low level of water stress indicates a situation where the combined withdrawal by all sectors is marginal in relation to the resources, and has therefore little potential impact on the sustainability of the resources or on the potential competition between users. A high level of water stress indicates a situation where the combined withdrawal by all sectors represents a substantial share of the total renewable freshwater resources, with potentially larger impacts on the sustainability of the resources and potential situations of conflicts and competition between users.

This indicator is defined as the ratio between total freshwater withdrawn by all economic sectors and total renewable freshwater resources, after having taken into account environmental water requirements. Main sectors, as defined by ISIC standards, can include, for example: agriculture; forestry and fishing; manufacturing; energy sector; and municipalities. This indicator is also known as water withdrawal intensity. Moreover it closely relates to the Water exploitation index (WEI), calculated and published by Eurostat. The data on freshwater withdrawal are also used for the calculation of indicator 6.4.1 on water use efficiency, and the data on environmental water requirements feeds into indicator 6.6.1 on water-related ecosystems.

The indicator is calculated with the following formula:

$$\text{Stress (\%)} = TWW / (TRWR - Env.) * 100$$

Where:

TWW = Total freshwater withdrawn, where year to which it refers will be provided;
TRWR = Total renewable freshwater resources, calculated as:

Internal Renewable Water Resources + External Renewable Water Resources; and

Env = Environmental water requirements.

The three components of the indicator are described below:

1) **Total renewable freshwater resources (TRWR)** are expressed as the sum of (a) internal renewable water resources and (b) external renewable water resources. The term "water resources" is understood here as freshwater resources.

a) **Internal renewable water resources (IRWR)** are defined as the long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation (resources produced within the territory), taking into consideration the overlap between them;

b) **External renewable water resources (ERWR)** are defined as the part of the country's renewable water resources that is not generated within the country. The ERWR include inflows from upstream countries (groundwater and surface water), and part of the water of border lakes or rivers.

2) **Total freshwater withdrawal (TWW)** is the volume of freshwater extracted from its source (rivers, lakes, aquifers) and is estimated at the country level for the following three main sectors: agriculture, municipalities (including domestic water withdrawal) and industries (including cooling of thermoelectric plants).
TWW is in general calculated as being: [the sum of total water withdrawal by sector] minus [direct use of wastewater, direct use of agricultural drainage water and use of desalinated water]. In formula:

$TWW = \sum ww_s - \sum du_u$

Where:

- TWW = Total freshwater withdrawal;
- ww_s = Water withdrawal for sector "s". s = agriculture, industry, energy, etc.; and
- du_u = Direct water use from source "u". u = direct use of wastewater, direct use of agricultural drainage water and use of desalinated water.

3) **Environmental water requirements (Env.)** are the quantities of water required to sustain freshwater and estuarine ecosystems. Water quality and the resulting ecosystem services are excluded from this formulation, since it is confined to water volumes. This does not imply that quality and the support to societies which are dependent on environmental flows are not important and should not be taken care of. Methods of computation of Env. are extremely variable and range from global estimates to comprehensive assessments for river reaches. For the purpose of the SDG indicator, water volumes can be expressed in the same units as the TWW, and then as percentages of the available water resources.

The indicator on water stress is built upon a variety of data, from statistical data on water withdrawals by companies, to measured flow data in rivers and streams, to meteorological data on precipitation (P) and evapotranspiration (ET). In the next paragraph, it is described which data sources are used, with specifications of availability, possibilities of temporal and spatial disaggregation, alternative and/or complementary data sources.

4. Data sources for monitoring SDG 6.4

4.1 Introduction

In this chapter we describe the data sources that can be used for the ladder approach. The first paragraph gives information on national statistics as compiled by countries' National Statistical Institutes (NSI's) based upon internationally agreed statistical standards (Annex I). The second paragraph considers remote sensing-based data sources. The third paragraph focuses on model-based data sources. The latter two descriptions are described more general in relation to the area of application, focusing both on the Netherlands and beyond. At the end of each paragraph, a brief list of pros and cons in relation to monitoring of SDG 6.4 is presented. More detailed information on each of the data sources and how the information is obtained is presented in the annexes.

4.2 Data from SEEA-Water and Water Statistics

4.2.1 Statistical data for indicator 6.4.1

The available data from Statistics Netherlands allow for complete calculation of the proposed Water Use Efficiency (WUE), using the international standards of System of National Accounts (SNA), European System of Accounts (ESA), the System of Environmental Economic Accounting (SEEA) Water Accounts, and Water Statistics along with the official ISIC categories in detail (See: Annex I and II). The following section describes the statistical data compiled within Statistics Netherlands needed for the different compilations steps of indicator 6.4.1. This data allows for the calculation of the underlying three separate indicators, as described in Chapter 3.

Water withdrawals per economic activity

Statistics Netherlands has a long-lasting experience in compilation of statistics on water withdrawal and water use by combination of a variety of data sources. This data is compiled for use within the SEEA-Water Accounts as well as for international questionnaires, such as the OECD-Eurostat Joint Questionnaire and the EEA State of the Environment. The statistical data include yearly abstracted volumes of fresh groundwater, fresh surface water and marine water (Statistics Netherlands, 2016c; 2016d) and for some years soil water.[5] Comparable yearly statistical data are available from 2001 onwards; for 2008, 2010 and 2012, the data are disaggregated to detailed level of economic activity, according to ISIC. For several years, data per sub-river basin have also been constructed. Until now, only annual data are compiled, so there is no monthly or seasonal resolution.

For calculation of the proportion of water withdrawn by the agricultural sector for irrigation, the total agricultural area and the area under irrigation is needed. This data comes from either the spatial land statistics (group) or from SEEA – type land accounts for total area. For area under irrigation, data is obtained from LEI as enlarged figures on irrigation data from their sample among the farming population (LEI, 2014).

[5] Direct use of non-conventional water, i.e. direct use of treated wastewater, direct use of agricultural drainage water and desalinated water is excluded. Soil water here relates to the large volumes of water that either via evaporation (E, from surface) and transpiration (T, from plants, together ET, Evapotranspiration. These data are based upon remote sensing data (processed satellite data) and already obtained from eLEAF.

Industrial withdrawals include those of the manufacturing industry, energy sector and environmental services and are based on annual environmental reports, the National Groundwater Register, as well as additional estimates.

Data on withdrawals of groundwater and surface water by the public water supply companies stem from the VEWIN Statistics and are readily available on a yearly basis. Table 4.1 provides an example of available data on water withdrawals. More background information can be found in Annex IV.

Table 4.1: Example of statistical data on fresh water withdrawals.

Million m3	2008	2010	2012
Withdrawal of fresh surface water, total	**9,430**	**9,926.7**	**9,783.8**
of which by			
Agriculture (ISIC 01-03)	21.0	26.3	6.4
Mining, manufacturing industry (ISIC 06-33)	2,762.4	2,741.1	2,836.3
Energy sector (ISIC 35)	5,724.3	6,136.0	5,956.8
Water companies (ISIC 36)	489.8	456.3	463.7
Environmental services (ISIC 37-38)	432.3	566.9	520.6
Other sectors (ISIC 41-97)	0	0	0
Withdrawal of fresh groundwater, total	**1,075.4**	**1,066.1**	**999.5**
of which by			
Agriculture (ISIC 01-03)	51.2	97.4	54.3
Mining, manufacturing industry (ISIC 06-33)	168.3	130.9	126.7
Energy sector (ISIC 35)	1.7	5.1	4.9
Water companies (ISIC 36)	762.2	760.8	753.6
Environmental services (ISIC 37-38)	1.4	2.2	1.3
Other sectors (ISIC 41-97)	90.7	70.0	58.8
Total freshwater withdrawal TWW	**10,505.4**	**10,992.8**	**10,783.3**
of which by			
Agriculture (ISIC 01-03)	72.2	123.7	60.7
Mining, manufacturing industry (ISIC 06-33)	2,930.7	2,872.0	2,963.0
Energy sector (ISIC 35)	5,726.0	6,141.1	5,961.7
Water companies (ISIC 36)	1,252.0	1,217.1	1,217.3
Environmental services (ISIC 37-38)	433.7	569.1	521.9
Other sectors (ISIC 41-97)	90.7	70.0	58.8

Source: Statistics Netherlands, 2016d.

Economic data

The required monetary data for the three aggregated sectors (agriculture, industry, public water supply and other services) is readily available from the National Accounts (NA) department within Statistics Netherlands. It produces the Dutch NAs and monitors in detail the country's economic performance, such as the combined income (GDP), upon officially agreed ***international standards*** (the System of National Accounts 2008, SNA–2008; UN et al., 2009). In

the NA, detailed economic data like on VA next to production and intermediary use are provided on both a yearly and quarterly basis. The NA data is published in CBS - StatLine for GDP, the electronic database of the institute, and in yearly or quarterly publications (such as Statistics Netherlands (CBS) (2013a, 2014a; 2016e). Data is compiled with large detail following the ISIC-4 categories (see Annex II). Also a regional disaggregation is available in the Regional Economic Accounts. See Annex IV for more detail on the economic statistical data.
To these NAs, a number of so-called satellite accounts are connected, like Regional Economic Accounts, Agricultural Accounts, Growth (productivity) Accounts, Environmental Accounts (EA) and ecosystem accounts (also referred to as Natural Capital Accounts, NCAs).
This data is compiled in accordance of international formats and via the international questionnaires among others send to Eurostat, European Central Bank, OECD, IMF and United Nations.

The available data on water withdrawal ('abstraction') in physical terms, together with the economic data from National Accounts currently available from Statistics Netherlands, allow for complete calculation of the proposed WUE – indicator.

Example
The publication 'Environmental Accounts of the Netherlands' (see: Statistics Netherlands (CBS) (2012, 2013b & 2013c and 2014c & 2015b) often includes the calculation of water intensity, that is, the inverse of the calculated WUE (or alternatively described as 'water productivity') here. Water use intensity for an industry can be defined as the use or abstraction of water in litres divided by its VA, expressed in euros. This can be done for each type of water (either groundwater or surface water abstraction as well as for tap or drinking water use. Moreover statistics are available by detailed ISIC industry which allows the WUE indicator to be calculated for each industry supporting analysis across detailed industries. Figure 4.1 shows the groundwater use intensity for a variety of economic sectors.

In 2012, livestock breeding, manufacturing of basic metals, followed by the manufacturing of paper and paper products, manufacture of food products, beverages and tobacco products and 'other agriculture' showed the highest groundwater, i.e. the lowest water productivity or WUE. The industries with the highest use intensity rates used up to over ten times more water to earn a euro of VA compared to the average calculated for the overall Dutch economy in 2012.

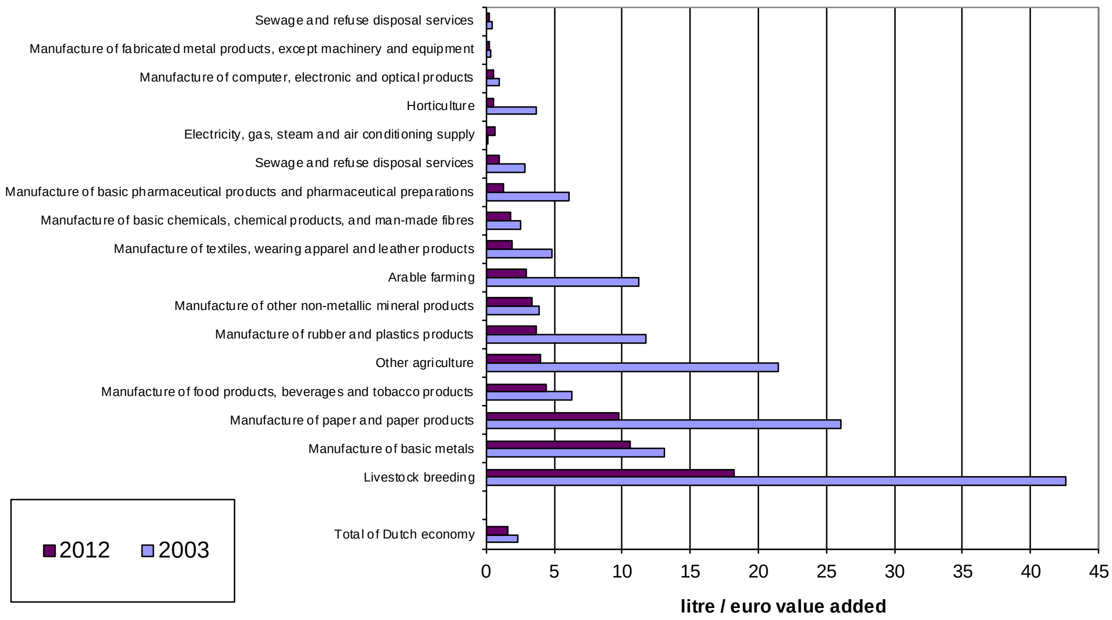


Figure 4.1 Groundwater use intensities for a selection of industries with highest groundwater intensities within the Dutch economy. Data from: Statistics Netherlands (CBS) (2016f), with some processing.

4.2.2 Statistical data for indicator 6.4.2

The statistical data available within Statistics Netherlands can basically quantify at least three of the four components of the water stress indicator.

1a) Internal renewable freshwater resources (IRWR)

Within the international standards for water statistics (OECD/Eurostat, 2012), a parameter is defined that is strongly related to IRWR: Internal Flow. Internal Flow is defined as: 'the total volume of river runoff and groundwater generated, in natural conditions, exclusively by P into a territory. The internal flow is equal to P less actual evapotranspiration (AET) and can be calculated or measured.'

Basic data:

P data from 300+ stations are available from the KNMI, for each year and per station. Evapotranspiration data is available for 30+ stations from KNMI, but this only reflects the so-called reference crop evaporation, which basically can be interpreted as potential ET.

Advanced data

Data on actual ET is currently available for 2 years, namely 2009 and 2014. P data interpolated to a more spatial resolution as well as in greater temporal detail is also available from eLEAF. This data were constructed by eLEAF for Statistics Netherlands in the framework of projects for Eurostat, financed by Eurostat grants.

See paragraph 4.3 for elaborate background and method on these two items compiled by eLEAF.

1b) External renewable water resources

Statistics Netherlands only compiles data on inflow of surface water from Belgium and Germany to the Dutch territory. Information on groundwater flows are not calculated or estimated. Data on surface water inflow are compiled for international questionnaires providing harmonized data to Eurostat, OECD, EEA, and UNSD. For major stream flows like the Rhine and the Meuse, a long time series exists. For 2009 and 2014, Statistics Netherlands holds daily flow data of all large and small rivers, brooks and canals entering the Dutch territory from Germany and Belgium. This data was compiled in the framework of projects for Eurostat, financed by Eurostat grants (Graveland & Baas, 2012)
This data is inventoried from the National Water Authority (Rijkswaterstaat) and the Dutch regional Water boards, basically structured as average daily flow (m3/day) at the gauging stations situated at or near the border.

2) **Total freshwater withdrawal (TWW)** is the volume of freshwater extracted from its source (rivers, lakes, aquifers) for agriculture, industries and municipalities. The data availability is already described concisely in section 4.2.1. Annex IV provides more in-depth information.

3) **Environmental water requirements (Env.)** are the quantities of water required to sustain freshwater and estuarine ecosystems.
Currently, Statistics Netherlands has no data for this component.

4.2.3 Pros and cons of using national statistical data

The use of statistical data for indicators under 6.4 has a number of advantages:

- The available data from Statistics Netherlands allows for complete calculation of the proposed Water Use Efficiency (WUE) (indicator 6.4.1), using the international standards of SNA, SEEA-W, Water Statistics and in line with the official ISIC categories.
- Economic data is available with high detail regarding industrial classification and is compiled along the National Accounting Standards used by statistical offices all over the world. This results in an unprecedented comparability of data across countries.
- Water withdrawal data is also defined by and compiled along the framework of the SEEA-Water and international standards for water statistics, using the framework of the harmonized OECD, Eurostat, EEA and UNSD questionnaires. At least in the countries in the European and OECD areas, comparable values for indicators can be constructed.
- Economic data, as well as data on water withdrawals, can be compiled on a sub-national scale, for instance per river basin.
- Several projects conducted within Statistics Netherlands have already lead to successful use of remote sensing data, combined with register data on flows and statistical data on withdrawals.
- The statistical data is mostly available in long time series, more than the demanded 20 years. This largely suffices to comply with the required LTAA of the indicators.
- To compile the item External Inflow in the water statistics / water accounts, detailed and very accurate data is obtained from the water management authorities in the Netherlands.
- With support by World Bank and United Nations Statistical Division (UNSD), as well as with regional initiatives and support, countries increasingly establish and develop water statistics and SEEA Water Accounts, both flow accounts (with Water supply & Use tables) and Water Asset Accounts in compliance with international statistical standards, that allow for compilation of the physical water part of both indicators, 6.4.1 and 6.4.2. For the economic part of indicator 6.4.1, compilers can easily rely upon data from the

National Accounts of practically all countries globally. Using the international standards allows for comparison among countries in a standardised and equal manner.

The disadvantages consist of:

- Not all parameters are available in statistical data. Data on Actual Evapotranspiration is already added from satellite data. Trans boundary groundwater flow needs to be added to complete the external renewable resources in indicator 6.4.2. Water Stress, 'Environmental water requirements' (indicator 6.4.2) is not accounted for yet. This can be added, although there is still a substantial debate about the way it should be compiled. This is demonstrated In paragraph 4.4.3, where a few hydrological methods for calculating Environmental Flow are discussed.

4.3 Remote Sensing-Based Data

4.3.1 Introduction

Remote sensing can be a valuable additional source of data for monitoring indicators 6.4.1 and 6.4.2. The number of Earth Observation (EO) satellites has been growing steadily over the past decades, offering increasingly detailed and reliable data on atmospheric and land surface conditions. Based on this data, the actual evapotranspiration (AET) can be derived. AET is the sum of evaporation and plant transpiration from the Earth's surface to the atmosphere. It is an important component of the hydrological cycle and therefore for calculating the IRWR. In the Netherlands, AET amounts to more the 60% of the annual rainfall. It is also a good indicator for the volume of water used by the agricultural sector.

A number of algorithms have been developed to calculate the AET based on remote sensing data. eLEAF has developed the SEBAL and ETLook algorithms, which have been used extensively to calculate AET around the world. For other algorithms, Karimi and Bastiaanssen (2015) have made an overview of existing algorithms and compared the result in more detail. Currently, eLEAF produces AET data, among others, for the Dutch water boards and the FAO. The former covers the whole of the Netherlands; the latter covers the whole of Africa and the Middle East. eLEAF has also made AET data for Statistics Netherlands. This data was used to calculate the internal flows of 2009 and 2014. It was incorporated by Statistics Netherlands to improve their internal flow calculations, compared to the traditionally used data sources. This is discussed in Chapter 5, where we consider the ladder approach for SDG 6.4.2.

4.3.2 Remote sensing data for indicators 6.4.1-2

Much remote sensing data is freely available, such as MODIS, Landsat, Proba-V and Sentinel 2. In additional, a number of AET datasets based on this data are already available, such as NASA's MOD16 and LSA SAF. In 2017, FAO's freely available Water

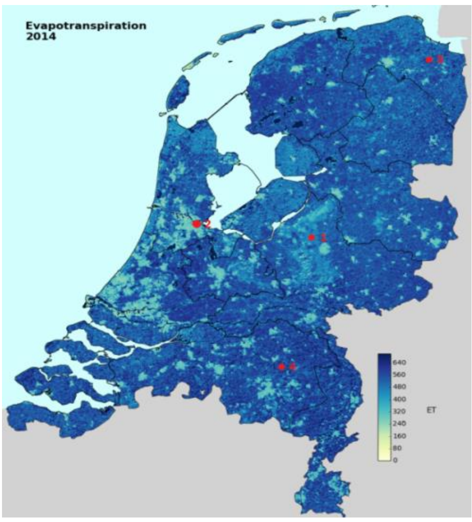


Figure 4.2: Actual evapotranspiration (mm) for the Netherlands at a 250m resolution.

Productivity database[6], referred to above, will also become available.
Although satellite-based data can only cover the agricultural sector in SDG 6.4.1, it is a valuable addition, offering a spatial and temporal resolution that is difficult to match with surveyed data. Figure 4.2 gives an example of satellite-based AET for the Netherlands. This was produced by eLEAF for Statistics Netherlands for their internal flow calculation of 2014. The urban areas in the western part of the Netherlands clearly stand out due to their low AET (point 2 is located in Amsterdam).

In Figure 4.3 the time series of AET for 2014 is shown for the four points in Figure 4.2. Point 1 is located in a forested area, point 2 in and urban area and points 3 and 4 in agricultural area. As expected for the Netherlands, there is a large difference in AET between the winter and summer period.

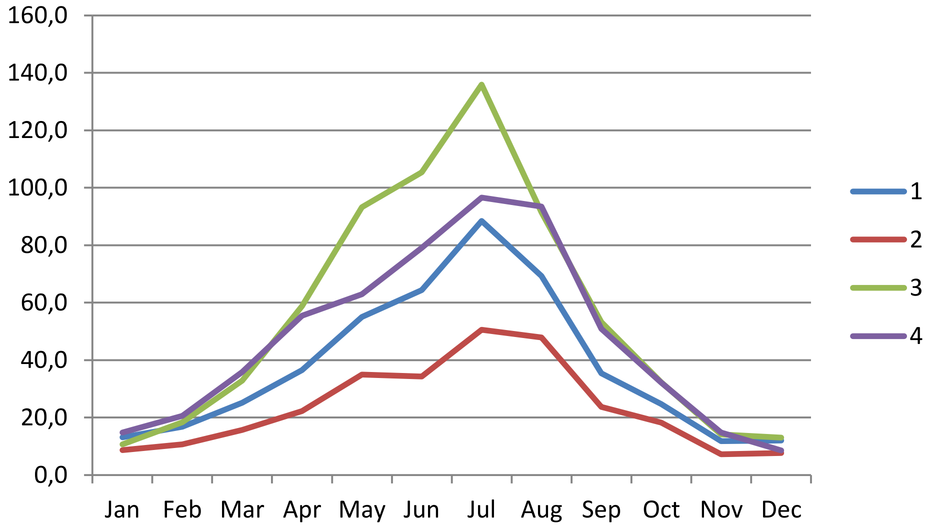


Figure 4.3: Monthly AET (mm) for the four points in Figure 4.2.

In Chapter 5 is described how remote sensing based AET data is used to improve the internal flow calculation for the Netherlands (part indicator 6.4.2). For water use efficiency in the agricultural sector conversion steps are required to derive irrigation withdrawal from AET data. This is explained in annex V with some additional information on calculating AET.

4.3.3 Pros and cons of using remote sensing data

The use of remote sensing-based data has a number of advantages:

- Agricultural water use derived from remote sensing, which is actual ET can be made for each country relatively easily;
- A number of AET data sources are already publicly available;
- Historical archives make it possible to assess the trend in water use efficiency, even when no prior information has been collected;
- The methodology can be consistently implemented in each country, making cross-country comparison for AET possible; and
- It has a high level of spatial and temporal resolution, which will enable more targeted policies to improve agricultural water use efficiency.

[6] www.fao.org/in-action/remote-sensing-for-water-productivity/en/

Its disadvantages consist of:

- It can only cover water use for crop growth in the agricultural sector. Nevertheless this is one of the biggest categories of water abstraction from the environment;
- Additional steps are necessary to convert AET (crop water consumption) to irrigation water withdrawal.

4.4 Model-Based Data

4.4.1 Introduction

For the particular objective of assessing indicators 6.4.1 and 6.4.2, models can be used to provide information at several spatial and temporal scales. The two models that provide the required data are the Netherlands Hydrological Instrument (NHI) (De Lange et al., 2014, www.nhi.nu) and PCR-GLOBWB (Wada et al., 2014), coupled to a global scale groundwater model (De Graaf et al., 2015) for the entire world. The models are developed by Deltares, Wageningen Environmental Research and Utrecht University, in cooperation with other organizations. The required data for the indicator can either be the result of the model outcome or processed data that is used as model input.

In the following paragraphs, we present a brief summary of the models and of the data available to compile the indicators. An extensive description of the models and data can be found in Annex VI.

National Scale: the Netherlands Hydrological Instrument (NHI)

The NHI model is a detailed hydrological model for the Netherlands. It calculates water balances of soil, vegetation, surface waters and the subsurface of the Netherlands, on a spatially distributed 250 m horizontal resolution. Calculation results are available on a daily basis for the period from 1911 to 2015. The results can be analysed on different scales, for example on a grid with a cell size of 250 m and on regional districts. Therefore, a variety of datasets and measurements are used as input and calibration or validation data (Hoogewoud et al, 2015, Kroon et al, 2015).

The NHI model only provides water-related data. The output of the NHI model can be used as input for effects models, for instance, for the economic values of crop production in the agricultural sector (model Agricom) and ecological effects in surface waters and natural areas.

Global scale: PCR-GLOBWB and global MODFLOW

The PCR-GLOBWB model generates water balances for subsurface and surface waters on a global scale. Water availability and water demand calculations are integrated to dynamically simulate water use at a daily time step and to account for the interactions between human water use and terrestrial water fluxes. The main goal of this integrated modelling framework is to estimate actual water use (i.e., withdrawal and consumption) rather than potential water demand (independent of available water). It does not include any information related to crop production and therefore it can only provide information related to the water system, such as water balances for the surface water and larger groundwater aquifers in the world. Data is available on a daily basis for the period of 1958 to 2010, for each cell of 5 by 5 arcminutes (approximately 10km at the Equator). To calculate the transboundary flow of groundwater, the model is combined with the global groundwater model using MODFLOW (de Graaf et al., 2015).

4.4.2 Model data for indicator 6.4.1

For indicator 6.4.1, NHI can provide:

1) The modelled water withdrawal per sector and per source (surface or groundwater) at a national level (more detailed if desired);

2) The proportion of rain-fed agriculture at a national level as an input to calculate the proportion of agricultural gross VA produced by rain-fed agriculture; and

3) The total calculated gross VA by agriculture per crop species separately (in combination with the effect model Agricom. This is calculated, based on calculated evaporation deficits in NHI and price information from LEI.

Data is available on a daily basis for the period 1911 to 2015, on different scales (from cell size 250 m to regional districts) (see Annex VI for more details). Examples of calculation results are shown in figure 4.4.

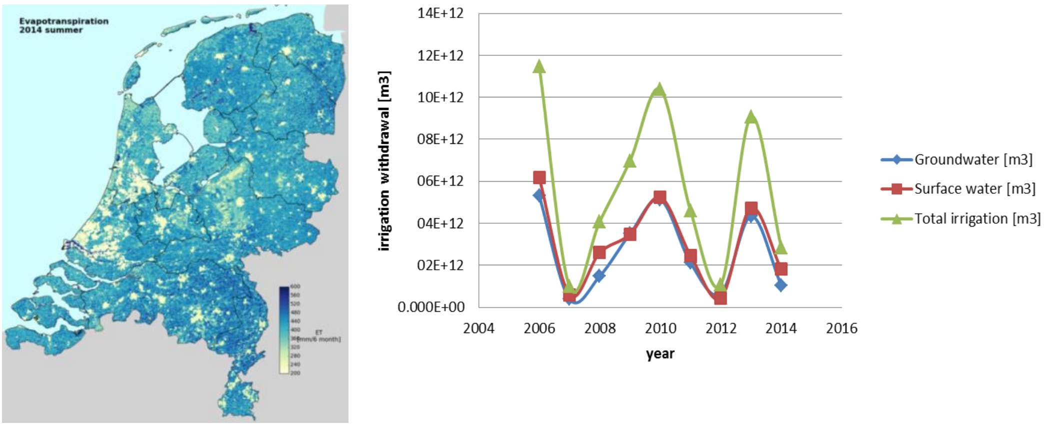


Figure 4.4: Actual evapotranspiration (mm) for the Netherlands, for the summer half year (May-October)(left) and trends in irrigation demand during several years (m3/year) (right), as calculated by NHI.

On a global scale, PCR-GLOBWB provides the following data for indicator 6.4.1:

1) The water withdrawal per sector and per source (surface/ groundwater) at a global level; and

2) The proportion of rain-fed agriculture at a global level as an input to calculate the proportion of agricultural gross VA produced by rain-fed agriculture.

4.4.3 Model data for indicator 6.4.2

In addition to the data mentioned for indicator 6.4.1, NHI can provide following data (1911-2015) for the total renewable freshwater resources:

- Average annual flow and discharges of rivers (internal and external);
- Total discharge of the river and stream systems (internal and external);
- Recharge of aquifers as spatially distributed grids (internal); and
- Groundwater discharge over the country borders (inflow – outflow).

Characteristics are available in input data of NHI to estimate the amount of water needed to sustain freshwater ecosystems. This environmental flow can be calculated using several methods as illustrated by the paper of Pastor et al. 2014, for example from the flow curves of the most important rivers (figure 4.5).

One of the hydrological methods that is most used for national or global assessments is the so-called Q90. With this method, the flow that exceeds 90% of the period of record is accounted as the flow needed to maintain the ecosystems. Another method estimates that between 20 and 40% of the total renewable resources is needed for the ecosystems (30% is considered here as a practical approach). Both methods can be used to assess the term Environmental Water Requirements of the indicator Water Stress. However there are some limitations in using these methods. The most important limitation is related to the fact that both methods compile an average value for the year and do not take into account the variability of the flow within the year. Besides, for some ecosystems, maybe a Q50 or a Q80 would be sufficient, but this method, and also the one related to the total renewable resources, do not take into account the requirement of specific ecosystems. An alternative approach is to consider the estimates of the ecological needs as described by the water authorities Rijkswaterstaat and the Water Boards.

Some input data related to vulnerable aquatic ecosystems is available, and labelled in NHI as environmental flow (e.g. de Grensmaas, Haringvlietsluizen and Vecht). In addition, there is data on vulnerable terrestrial natural areas and peaty areas (to prevent soil subsidence), which might also be considered. The cumulated demands in dry periods for those categories are considered as alternative approach with local estimation.

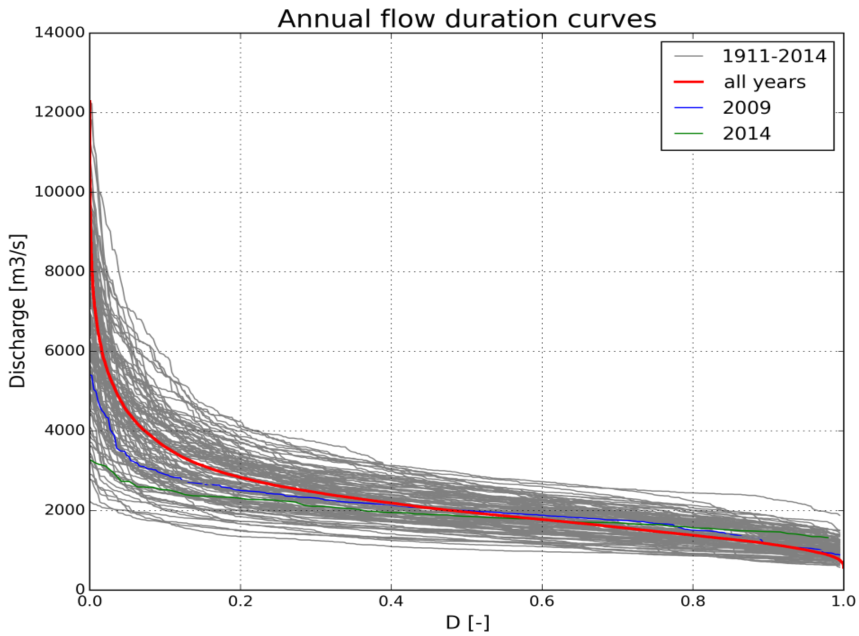


Figure 4.5: Example of annual flow duration curves of the river Rhine at Lobith

On a global scale, PCR-GLOBWB provides in addition to the data mentioned for indicator 6.4.1, the following information for total renewable freshwater resources:

- Total runoff calculated per cell; this includes direct runoff, interflow, base flow and groundwater recharge (internal);
- Transboundary flow; cells following the country borders should be selected, the direction of the flow determined, and the flow added up (calculated by a combination of PCR-GLOBWB and the global MODFLOW model).

An example for internal renewable resources is shown in figure 4.6.

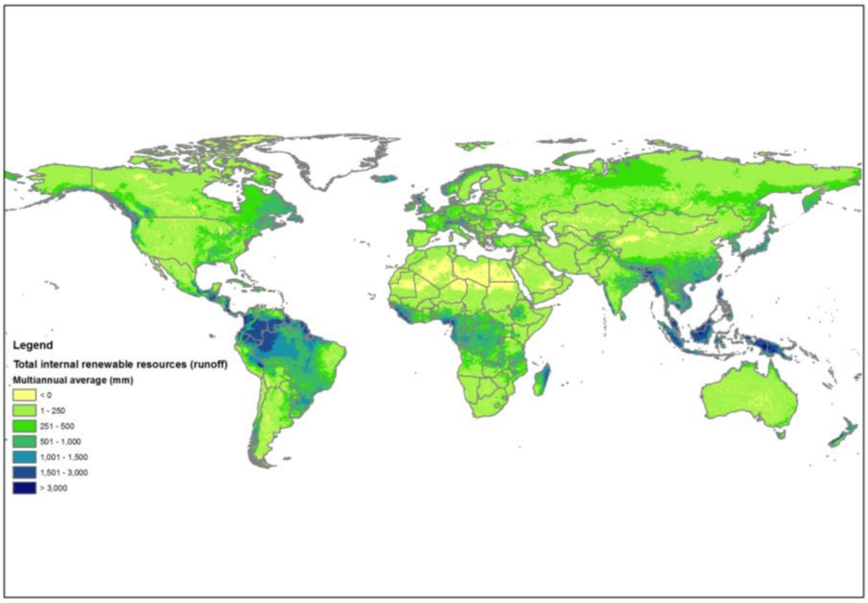


Figure 4.6: Multiannual average (1958-2010) showing the total annual internal renewable water resources at 5 by 5 arcminutes resolution from PCR-GLOBWB (Wada et al., 2014).

4.4.4 Pros and cons of using model data

The use of model data for calculating the water use efficiency indicator has some advantages:

- Hydrological data completely cover the areas of interest on high spatial resolution and daily temporal scale.
- Modelling results are available for long time series, which allows analysis of yearly values as well as long term annuals, as needed for the official method.
- Hydrological processes are completely modelled. This provides a coherent framework for analysis, including extra information from detailed processes. For instance, the total amount of consumed water by crops is distinguished from the water demand and allocation for irrigation, since all terms are explicitly modelled. Recharge of the aquifer not only results from precipitation and AET, but also from runoff, return flows from irrigation, etc.
- In general, model data is continuous in time, without any lack of data. The needed information can therefore be computed for every desired time period and moment in time; and
- The results of PCR-GLOBWB cover areas where hardly any data is known or available.

Besides some advantages, the disadvantages of using model data consist of:

- Setting up the models requires large datasets and sufficient hydrological expertise to set up and complete the model schematisations. Data has to be regularly updated and models have to be calibrated, to reflect reality.
- Although a lot of parameters are based on the same water data as used in the statistic data sets (for The Netherlands e.g. withdrawals from drinking water companies and industries, irrigation data obtained from LEI, precipitation from KNMI), consistency with the data in Water Accounts & statistics within Statistics Netherlands is not assured yet. Hopefully the input data for the models can be aligned with the available National Statistics and/or with data sources used for the compilation of the statistics & Accounts

explained in previous sections. This would further enhance consistency between the national statistics and the models and would enable further analysis.

- Difference also occur between the additional data sources, for example the modelling approach (NHI) to calculate AET is different from the modelling approach that uses satellite data (eLEAF).
- Not all indicator variables are computed directly; post-processing of large datasets is often needed to derive the required variables.

5. The Ladder Approach for the Netherlands

5.1 Introduction

This memo shows how the indicators can be compiled using three different approaches, which in part are complementary approaches. Two approaches will be explained and their respective features regarding data, method, quality and consistency, treated in detail. The third approach is recommended, as a result of the two approaches:

1. Compile the indicators based on statistical data, according to international standards, such as IRWS and SEEA-type Water Accounts;
2. Further improve, by adding available data calculated on the basis of remote sensing and hydrological models.
3. An integrated approach with full consistency between the statistical data, model data and satellite data.

In paragraph 5.2 we give an example of the calculation of the Water Use Efficiency indicator 6.4.1 for one year (2012) based on available statistical data from the water statistics, SEEA type of water accounts and the National Accounts. This example illustrates that the indicator 6.4.1 can be calculated entirely with data from Statistics Netherlands.

In paragraph 5.3, we will elaborate the steps of the ladder approach for indicator 6.4.2. The ladder approach we propose is not a new concept for the Netherlands. In previous work, Statistics Netherlands has elaborated the use of additional data from both remote sensing and models. Actually the remote sensing data have been used already. We are convinced that applying and further integration will be valuable for adding information and detail compilation of the SDGs indicators in the Netherlands and equally important to contribute with information to adequate water management at the extended temporal and spatial scales in the Netherlands. This may equally benefit other countries too. In Chapter 6, this is elaborated further with examples of the effects of using a higher resolution in the data for the components of the water stress indicator.

5.2 Indicator 6.4.1 calculated with statistical data

Table 5.1 show how the official statistical data available within Statistics Netherlands can be used for the calculation of indicator 6.4.1, both the water withdrawals (water abstractions), water use and Value Added for the three main sectors. From this a value for water use efficiency (WUE) can be calculated following the current format of the indicator. For VA the data from National Accounts within Statistics Netherlands is used, for water abstractions data from the published SEEA – type of water accounts by Statistics Netherlands are used; data for 2014 will be published in beginning of 2017.

Table 5.1 Input data for proposed Water efficiency indicator (WUE) from available statistical data

Component		2012 [1)]
Gross value added by sector (M Euro)	GVA	
GVA by agriculture, excl. fish & forestry (ISIC 01)	GVA_a	10,210
GVA by agriculture, fish & forestry (ISIC 02-03) [2)]		336
GVA by industry, incl. energy (ISIC 06-35)	GVA_i	91,393
GVA by services (ISIC 41-43) [2)]		28,323

GVA by services (ISIC 36-39 and ISIC 45-99)	GVA_s	448,792
GVA total Netherlands	*GVA*	*579,054*
Volume water withdrawn by sector (unit: Mm^3)[3)]	V_x	
Withdrawal by the agricultural sector (ISIC 01-03)	V_a (freshwater TWW)	60.7
Withdrawal by the industries (ISIC 06-35)	V_i (freshwater TWW)	8,924.7
Withdrawn by the service sector (ISIC 36)	V_s (freshwater TWW)	1,217.3
Withdrawn by service sector (ISIC 37-97)[4)]	(freshwater TWW)	580.7
Withdrawal total Netherlands		10,783,4
Area land (ha)		
Total agricultural land used [5)]	Area	1,841,698.5
Total arable land used	Area 'arable'	520,802.9
Total land for horticulture in the open [6)]	Area	86,421.0
Total land for forage plants [7)]	Area	237,989.3
Irrigated agricultural land [8)]	Area	53,865.0
Irrigated arable land [6)]	Area 'arable'	15,027.5
Irrigated horticulture land [6)]	Area	10,105.6
Underlying indices needed for the calculation		
A_i prop. irrigated land on total arable land (ratio)	15,027.5 / 520,802.9 =	0.0289
C_r Agricultural GVA by rain fed agriculture (ratio)	1/(1+(0.0289/((1–0.0289)*0.375)))	0.9265

Source: Statistics Netherlands (CBS), 2016c t/m 2016h.

1) Chosen 2012, other years can be compiled too.

2) GVA by these industries are excluded, because not part of the proposed indicator by UN-Water.

3) For data, see table 4.1. This includes abstraction of groundwater and surface water as determined by proposed indicator by UN-Water.

4) Withdrawal in these industries are excluded from the calculation sector, because not part of the proposed indicator by UN-Water.

5) Utilised agricultural area (UAA).

6) Horticulture, in the open: Refers to the growing of crops in the open, usually directly for the market.

7) Forage plants: area green fodder usually serves as fresh forage.

8) Area at least irrigated once this year.

Table 5.2 show how the calculation of the 6.4.1 indicator WUE, by use and processing of the statistical data available (table 5.1). This is done for the three main sectors and based upon the current and preliminary format of the 6.4.1 indicator WUE as proposed by Un-Water.

Table 5.2 Proposed WUE – indicator, calculated with available statistical data, example

Component		2012 [1)]
Sectoral water use Efficiency calculation: A_{we}; I_{we}; S_{we};		
A_i prop. irrigated land on total arable land (ratio)	= 15,027.5 / 520,802.9 =	0.0289
C_r Agricultural GVA by rain fed agriculture (ratio) [2)]	= 1/(1+(0.0289/((1–0.0289)*0.375)))	0.9265

A_{we} Irrigated agricultural WUE (€/m^3)	$= (GVA_a * (1 - C_r)) / V_a$ = 10,210 * (1-0,9265) / 60.7 = = 750.7 / 60.7 =	12.4
I_{we} Industrial WUE (€/m^3)	$= GVA_i \ / \ V_i$ = 91,393 / 8,924.7 =	10.2
S_{we} Services WUE (€/m^3)	$= GVA_s \ / \ V_s$ = 448,792 / 1,217.3 =	368.7
P_X Proportion of water withdrawn by the sector X, over the total withdrawals		
P_S Proportion of water withdrawn by the agricultural sector		0.0059
P_I Proportion of water withdrawn by the industry sector		0.8747
P_S Proportion of water withdrawn by the service sector		0.1193
Computation of 6.4.1: WUE		
$WUE = A_{we} \times P_A + I_{we} \times P_I + S_{we} \times P_S =$	= 12.4 * 0.0059 + 10.2 * 0.8747 + 368.7 * 0.1193 = = 0.0732 + 8.9212 + 43.9859 = = 0.073 + 8.921 + 43.986 = = ***52.981*** ***(53.0 €/m^3)***	

1) Data refer to 2012 withdrawals. Data on 2014 are compiled.

2) A_i and C_r are based upon irrigated 'arable land'. Once land used for horticulture and land for forage plants are included this figure on Agricultural GVA by rain fed agriculture versus by irrigated agriculture will change.

The variables shown in the previous table are computed as follows:

- The available statistical data like on: GVA by industry (ISIC) from NA, water abstractions data (withdrawal) by industry (ISIC) from SEEA - water accounts, utilized agricultural area by agricultural subsector, area irrigated by agricultural subsector are compiled along the methods described in paragraph 4.2.1.
- Data on water withdrawals are compiled by Statistics Netherlands in the framework of SEEA-Water Accounts and water statistics, in line with international standards. The 2012 data are applied to show the way the statistical data is used in compilation of the indicator.
- Only the annual data are used in this example of the indicator compilation.

For agriculture water use efficiency (A_{we}) the irrigated 'arable land' is used as this is suggested in the proposed (preliminary) indicator by UN-Water. An alternative would be to also include land used by horticulture and land for forage plants, this will increase this figure. Due to the relative small proportion of agriculture in total volume of abstractions of ground- and surface water in the country this will only have limited impact on the overall WUE for the country. Several options exists to further improve the indicator, like adding own abstractions by the service industries and adding rain fed agriculture, adding soil water, distributing abstracted water by ISIC 36 over all ISIC industries (See also recommendations in chapter 7 and chapter 8). A simple straightforward option would be to combine the statistical data from National Accounts and SEEA – type Water Accounts for the three industries and calculate the WUE ('water productivity') indicator for the economy as a whole, possibly even per water type, groundwater, surface water, and soil water.

5.3 Indicator 6.4.2 calculated with statistical data

Table 5.3 gives an example of the official statistical data available within Statistics Netherlands that can be used for the calculation of the total renewable water resources and water withdrawals. From this, a basic, first value for water stress can be calculated. For P and ET, data from KNMI is used. Data from 2009 have already been published (Graveland & Baas, 2012); data from 2014 will be published in Q1 of 2017.

Table 5.3 Water stress indicator calculated with statistical data

Component (unit: M m^3)		2009	2014[1)]
Internal Renewable Water Res. (**IRWR**)	P	27,568	31,950
	Potential ET	23,270	23,036
	Internal flow = P – pot ET	4,298	8,914
External Renewable Water Res. (**ERWR**)	Fresh surface water inflow	67,962	70,644
	Fresh groundwater inflow	N/A	N/A
Total Renewable Water Res.[2)] **(TRWR)**	= IRWR+ERWR	72,260	79,558
Total Withdrawals (**TWW)** all sectors	Fresh Surface water	10,654	9,784[3)]
	Fresh Groundwater	1,011	1,000[3)]
	TWW	11,665	10,783[3)]
Environmental Water req. (**Env.**)		N/A	N/A
Water Stress %	=TWW / (TRWR-Env.)*100	16 %	14 %[2)]

1) Preliminary data

2) Excluding groundwater inflow

3) Data refer to 2012 withdrawals. Data on 2014 are under construction.

The variables shown in the previous table are computed as follows:

- Basic statistical data on P, ET and Inflow are compiled along the methods described in paragraph 4.2.2. The concept of Internal Flow is also described there.
- Data on water withdrawals are compiled by Statistics Netherlands in the framework of SEEA-Water Accounts and water statistics, in line with international standards. The 2014 data are not yet available; for this example, data from 2012 is used as a preliminary estimate for 2014.
- For total IRWR, the data reflect actual yearly values, and not the Long Term Annual Average (LTAA) as defined by the official method.

The calculation of water stress (%) in Table 5.3 does not account for external groundwater inflow or for environmental water requirements, as this information is not available in Statistics Netherlands. Moreover, it uses a simplified calculation for total P and ET. If groundwater inflow data is available from models, TRWR will be higher, resulting in a higher denominator and lower water stress values. On the other hand, the incorporation of data on environmental water requirements will lead to a smaller denominator and significantly higher shares of water stress.

5.4 Indicator 6.4.2 calculated with enriched statistical data, satellite data and model results

In Table 5.4, a more advanced calculation of water stress is presented. The calculation differs from that in Table 5.3 in the following areas:

- P data presented here are delivered to Statistics Netherlands by eLEAF and are calculated with the values from 300+ KNMI measuring stations, but are interpolated over the country's surface using P radar measurements; and
- Instead of potential ET, AET is used. This is calculated on the basis of remote sensing (see paragraph 4.3) by eLEAF on request of Statistics Netherlands; and
- A value for external inflow of groundwater is used. This value is calculated with the NHI model by Deltares (see paragraph 4.4); and
- 'Environmental Water Requirements' are taken into account. An estimate for the range of Environmental Flow Requirements is provided by Deltares based on different approaches (a,b,c) as explained in paragraph 4.4 and in table 5.2.
- In this example the total IRWR still reflects actual yearly values, and not the Long Term Annual Average (LTAA) as defined by the official method.

Table 5.4 Water stress indicator calculated with enriched statistical data

Component (unit: M m^3)		**2009**	**2014** [1)]
Internal Renewable Water Res. (**IRWR**)	P [2)]	28,294	31,644
	Actual ET [2)]	17,022	20,005
	Internal flow = P – AET	11,273	11,639
External Renewable Water Res. (**ERWR**)	Fresh surface water inflow	67,962	70,644
	Fresh groundwater inflow[4)]	540	508
	ERWR	68,502	71,152
Total Renewable Water Res. **(TRWR)**	= IRWR+ERWR	79,775	82,791
Total Withdrawals (**TWW)** all sectors	Fresh Surface water	10,654	9,784[3)]
	Fresh Groundwater	1,011	1,000[3)]
	TWW	11,665	10,783
Environmental Water req. (**Env.**)[4)]	a) Method Q90	37,010	42,650
	b) Method 20-40% (30%) TRWR	23,933	24,837
	c) Method model input data	8,011	8,442
Water Stress %	=TWW / (TRWR-Env.)*100		
	a) Env. Method Q90	27%	27%
	b) Env. 30% TRWR	21%	19%
	c) Method model input data	16%	15%

1) Preliminary data

2) Source: WaterWatch (2011), ,eLEAF(2016)

3) Data refer to 2012 withdrawals. Data on 2014 are under construction.

4) Source: Deltares

The following conclusions for the Netherlands can be made, comparing table 5.3 and 5.4:

1. Enriching Statistical data with satellite data and modelling results, results in different outcome.
2. There is a large difference in the values for IRWR, as a result of using AET instead of potential ET, at least in the example using yearly values. The AET is a more realistic approach (especially in drier years), because it considers the availability of water that can be evaporated or transpired.
3. The contribution of the fresh groundwater inflow (i.e. trans boundary flow) as calculated by the hydrological model, is relatively small for the Netherlands. Additional analyses show limited variation (< 20%) in the calculated inflow within 30 years.
4. The different approaches for the Environmental Water Requirements result in a large range of estimated values, which affects the calculated value of water stress. More guidance on the approach is needed, if water stress values of different countries are to be compared.

Combining the statistical data, the satellite-based data and the model-based data for compiling indicator 6.4.2, has proven to be a very useful exercise. Further combining of these data is expected to improve future compilation of the indicators, and might benefit other projects, where statistical data, satellite data and modelling data are involved as well. From this experience we have the following findings and expectations:

- Enhancing consistency between the different approaches is expected to lead to further improvement and refinement of compiling the indicators for the Netherlands and for the support of the countries' actual water management and decisions. This may also apply to other countries.
- Using satellite data has proven to enrich statistical datasets.
- Using hydrological modelling data will further complete and improve statistical datasets, for example information about trans boundary groundwater flow and environmental water requirements, and extending datasets with long time series. At the same time use of existing statistical datasets is expected to further improve the input of the hydrological models, e.g. temporal datasets of withdrawals of surface water and groundwater and use and abstraction by industries outside agriculture and by households.
- Satellite data and hydrological modelling data show different outcome of calculated AET. It should be realized that both are modelling approaches. Further use of satellite data in the hydrological modelling, as validation data, calibration data or input for the models is an on-going process and expected to improve the hydrological modelling. At the same time valuable feedback will become available for future processing of satellite data.

Based on the experiences mentioned above, we recommend a third approach in the ladder approach, for future compilation of the SDG indicators:

- An integrated approach with full consistency between the statistical data, model data and satellite data (see also Annex VII about water accounting+).

In the next chapter we will elaborate further on the advantages of using combined approaches for the compilation of SDGs 6.4.2, with emphasis on the use of data with higher spatial and temporal resolutions.

6. Advantage of the Ladder Approach

6.1 Compilation of indicator 6.4.2 with higher spatial and temporal resolution

As already identified in country-wide discussions on indicator 6.4.2, a yearly and country value for water stress (%) in itself does not tell the whole story about water stress situations that can occur in certain regions or in certain months of the year. More resolution can provide more insight and is necessary for a country such as the Netherlands to detect and monitor water stress at a regional or local level in context of proper water management. More in general, it might not be sufficient to calculate the indicator at a year or country level, because issues at a regional level and that occur within a year are masked. In this chapter, we illustrate this consideration by showing some examples of the variation in the components of the indicator with increased temporal or spatial resolution, or with a breakdown in sectors and or type of water.

Spatial resolution of water withdrawals

Water withdrawals of groundwater and/or surface water can vary between the regions in the country. Activities that require large volumes of water for their production processes, such as for cooling in power plants, are often situated in regions with a large availability of surface water, for instance at the borders of large rivers or lakes. Groundwater abstraction for agricultural production mainly occurs in the higher sandy grounds in the eastern part of the country, where surface water is not always available. Table 6.1 shows the water withdrawal data for 2009 (Graveland & Baas, 2012), with a breakdown into sub-river basins and main economic sectors, separated for groundwater and surface water.

Table 6.1: Water withdrawals (Million m3) per river basin and per economic main sector, 2009

River Basin	Total	Agriculture	Industrial activities [1]	Water supply companies
	Million m3			
Groundwater withdrawals				
Rhine[2]	614.4	36.8	123.4	454.2
Ems	41.9	0.5	4.3	37.2
Meuse	334.0	38.9	53.4	241.7
Scheldt	23.9	0.9	4.2	18.7
Total	**1,011.2**	**73.9**	**185.3**	**751.9**
Fresh surface water withdrawals				
Rhine	6,249	11	5,963	274
Ems	49	1	41	7
Meuse	3,901	4	3,695	202
Scheldt	453	0	452	-
Total	**10,654**	**19**	**10,152**	**483**

Source: Graveland & Baas, (Statistics Netherlands) 2012.

[1] Mining, manufacturing industry, energy sector, environmental services, building sector

[2] Data can also be provided for the four national sub-river basins of the Rhine basin.

Temporal and spatial resolution of external inflow of surface water (ERWR)

Figures 6.1.and 6.2. show the average and the monthly external inflow of surface water from Germany and Belgium into the Netherlands territory via large and small rivers and canals, for the Rhine River basin (6.1) and the Meuse River basin (6.2).

Figure 6.1: Monthly external inflow of surface water versus monthly average inflow Rhine River Basin, 2014.

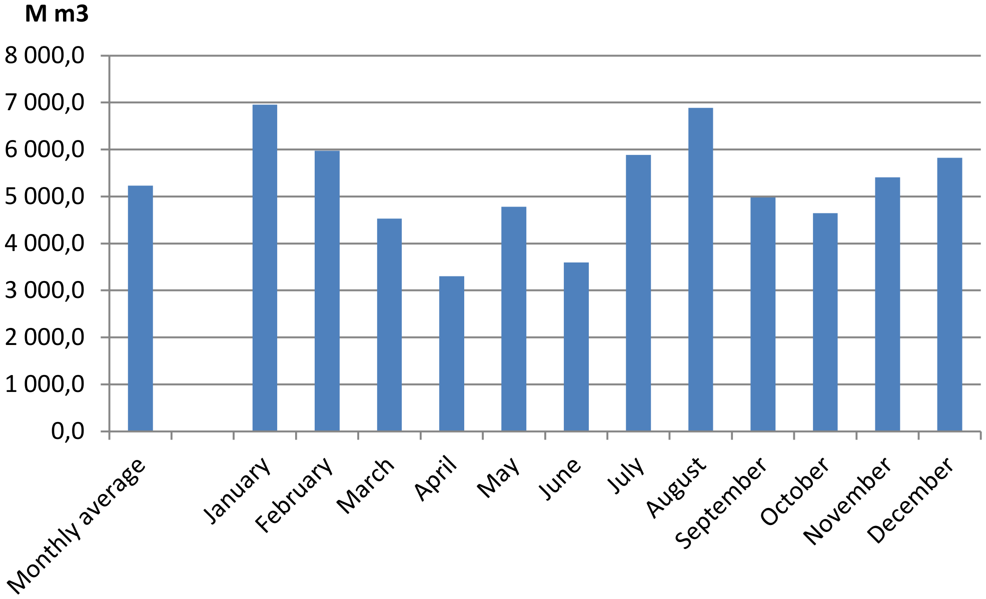
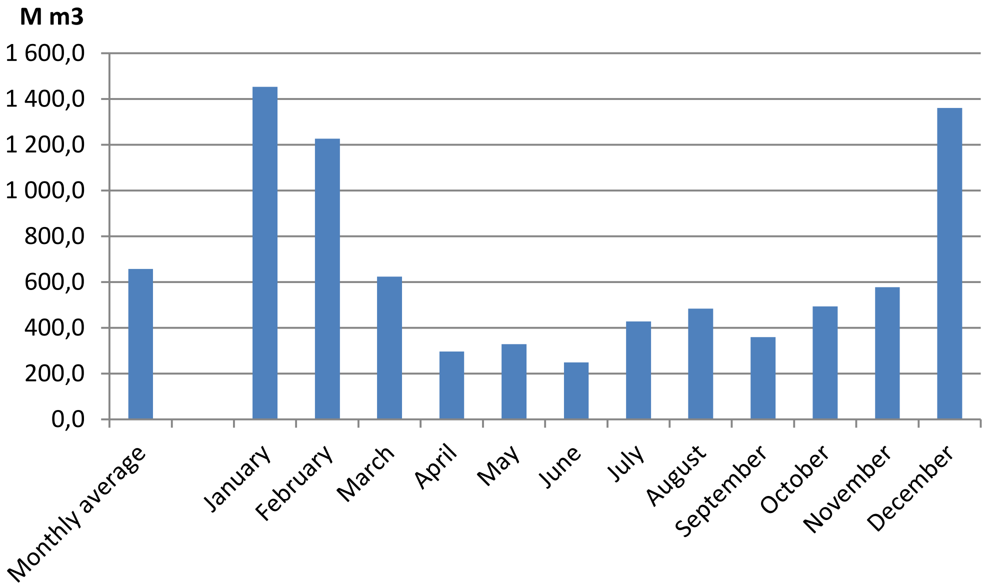


Figure 6.2: Monthly external inflow of surface water versus monthly average inflow, Meuse River Basin, 2014.



These figures show that there is a large variation in the monthly inflow when compared to the average inflow. Also, the pattern of monthly inflow differs between the two river basins, as the

River Rhine is fed by both rainfall and glaciers, while the flow in the Meuse River is more rain-dependent and more regulated by dams and sluices.
After several months with low external inflow combined with increased withdrawals, the monthly or seasonal calculated results of indicator 6.4.2 indicates water stress situations. But this is not detected when the indicator is calculated using yearly values of inflow (monthly average * 12). However, it could be discussed if even a monthly or seasonal calculated water stress is reflecting the real actual water stress. This all depends on the regional and national water management as well as the available soil and groundwater reserves. These two factors can reduce the actual or 'experienced' water stress.

Temporal and spatial resolution of Actual Evapotranspiration

The advantage of AET data as an additional source for monitoring SDG 6.4 is the high temporal and spatial resolution that it offers and its ability to map large areas quickly and consistently. Below are some illustrative examples.

Water stress has a strong temporal and spatial component that is easily lost in national annual values. This is reflected on satellite based images. Figure 6.3 shows the shortage of water in the soil, expressed as ET deficit, for the Netherlands in 2013. Although some droughts are reflected in the annual figures, water stress generally has a seasonal element.

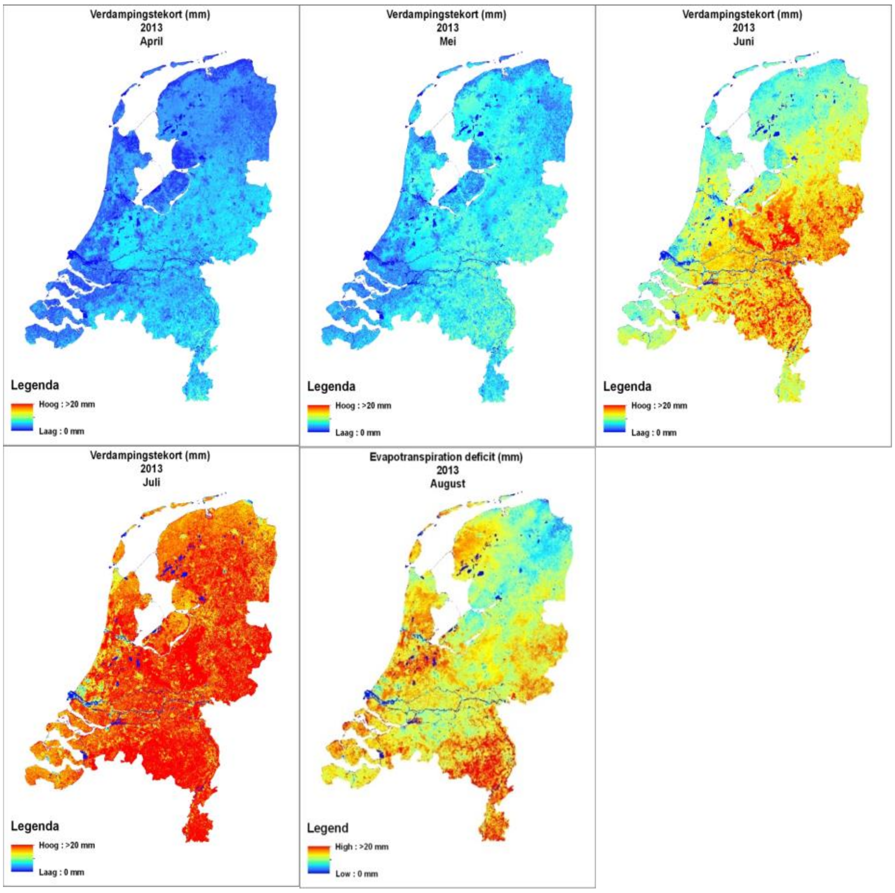


Figure 6.3: Monthly evapotranspiration deficit (Potential ET – Actual ET) in the Netherlands. The deficit indicates the reduced evapotranspiration due to water shortage in the soil (blue indicates a low deficit; red a high deficit.

The relatively dry period (for Dutch standards) around July does not persist the whole year, making it less pronounced when using the annual total value to calculate water stress for this SDG. The figure also shows the regional difference in water shortage, with the southeast of the Netherlands experiencing a more severe and longer drought period. This regional aspect will be missed in a national indicator. This is particularly relevant for large countries that cover multiple climate and ecological zones.

Figure 6.4 is an example of the power of satellite-based data. It shows the 2015 annual AET for Africa and the Middle East at a resolution of 250m, based on 10 daily averages. Satellites have the ability to map large areas quickly and consistently. This can be a valuable addition for monitoring SDG 6.4 in areas where agricultural (irrigation) water use data is sparse or not available.

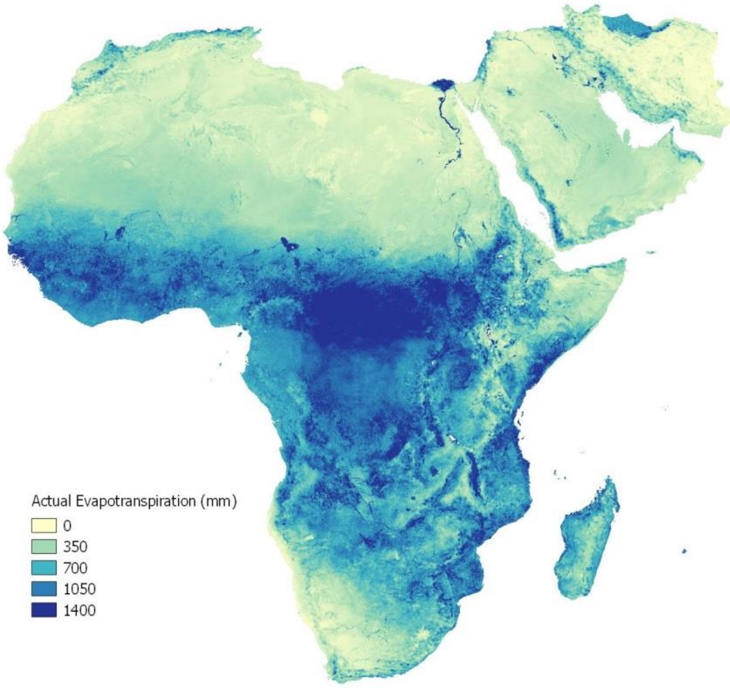


Figure** 6.4: **2015 Annual Actual Evapotranspiration, taken from FAO Water Productivity (test data).

Temporal and spatial resolution of the Irrigation Water Demand
The demand of irrigation water is highly dependent on the crop type, the precipitation regime, and the soil properties. Therefore, the demand is not constant throughout the year and also not homogeneously distributed in space.

In terms of temporal variation, especially in regions in the world where the precipitation regime is bi-modal, with a dry and a wet season, the irrigation water demand can be very high in the dry season and inexistent in the wet season. When calculating water stress, irrigation water demand is an important contributor to the total water abstractions, particularly for some countries where agriculture is the main water consumer. If the irrigation water demand is averaged per year to calculate water stress, it might seem that water stress is inexistent or minimal when in reality during the dry season water stress is a relevant issue in the region. At the same time referring to TRWR as the denominator in the stress indicator 6.4.2, the replenishment of the water resources during the wet seasons will enlarge TRWR. This will reduce the water stress situation in the dry season, compared to a situation with constant droughts. The soil also functions as a buffer to overcome certain temporal periods of droughts. This is also the challenge for water management.

An example of irrigation water demand variation is illustrated by the following two graphs for the Netherlands (top graph; information extracted from NHI) and for Bangladesh (bottom graph; information extracted from PCR-GLOBWB):

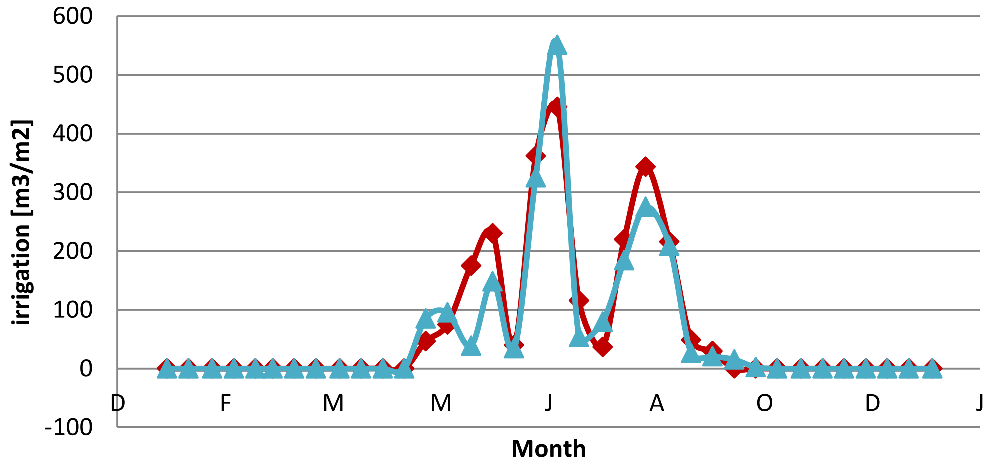


Figure 6.5: Total areal amount of irrigation in m3/m2 for the year 2009 separated for groundwater fed (red) and surface water fed (blue) irrigation withdrawal, as calculated by NHI.

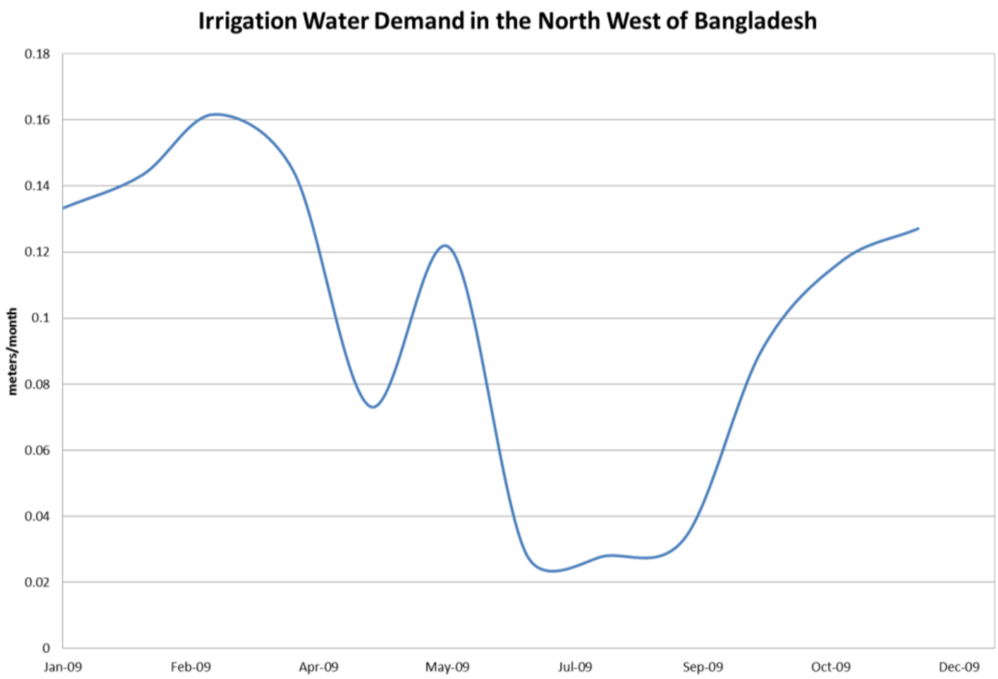


Figure 6-6 Example of a time series extracted from PCR-GLOBWB with monthly irrigation water demand for a random point in the northwest of Bangladesh for the year 2009. The data is presented in metres/month.

In terms of spatial variation, irrigation water demand can also differ a lot from region to region. An illustration of this variation for the Netherlands can be seen in the following maps.

a. Groundwater for irrigation in agriculture – 2009

b. Surface water for irrigation in agriculture – 2009

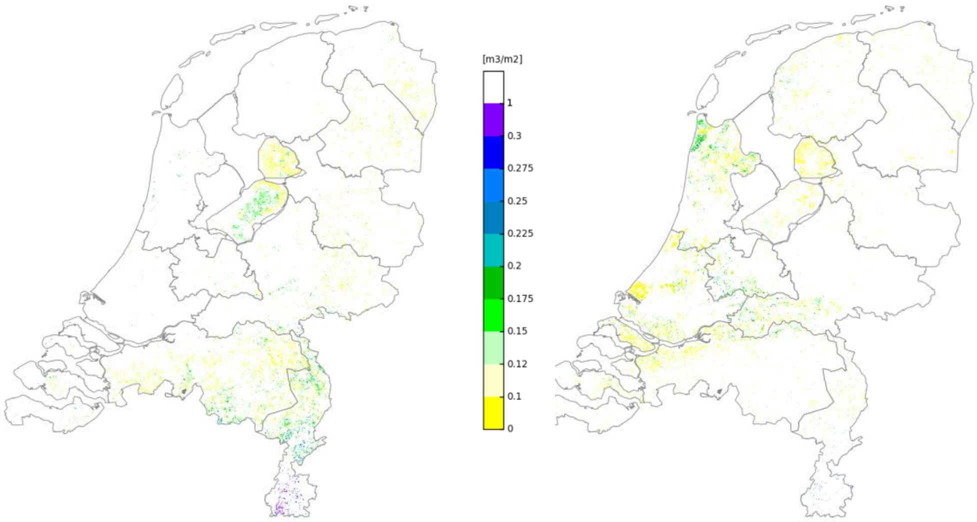


Fig 6-7: Yearly sum of the total water withdrawal per NHI model cell (250x250 m) for irrigation purposes. A distinction is made between surface water and ground water extractions for irrigation purposes. Shown is the year 2009; maps for the 1911-2014 period are available.

The maps and graphs shown above demonstrate the risk of underestimating water stress if the indicator is calculated as an average for the year or an average for a region. These figures also show the advantage of using information with a higher temporal and spatial resolution to identify the months in the year and the regions within the country, most prone to suffer from water stress.

With this information, the pertinent authorities can decide on how to evaluate water stress for a specific country. In some cases, it might be more correct to calculate water stress for the dry season, or use weighted averages per region, in order to reflect the real water stress situation of a country.

These figures also show that model results can fill the information gaps at high temporal and spatial resolution.

7. General observation and recommendations on Methodology

Here we report on some observations on applying proposed SDG 6.4.1 - indicator compilation, method and data.

Experience from compilation WUE – indicator:

A. The WUE indicator can easily be compiled from the existing water statistics and SEEA-type Water Accounts in the country. The economic information from NA and the water information from Water statistics / Water Accounts within Statistics Netherlands (CBS) could be linked and the proposed indicator calculated;

B. A preferred improvement of the currently proposed indicator would be to extend the current indicator, now focusing on groundwater and surface water, with ‘soil water’. For soil water (green water), the same compilation procedure can be applied, starting from the SEEA Water Accounts data; it is conceptually parallel with the other, but currently the data is available for only 2 reporting years (2009 and 2014);

C. In the proposed indicator *rain-fed agriculture* - largely relaying upon precipitation or better *soil water* - is excluded from the WUE concept and calculation. This causes an incomplete assessment and insight in the relation between water provision services to agriculture and Value Added from agriculture. This demands for an adjustment to the proposed method for calculation of the 6.4.1 indicator;

D. Moreover, the indicator suggests that agricultural land is either irrigated or rain fed; however, in many regions and countries that is not the case, as it is often combined on the same land or parcel, contributing or adding to each other;

E. The service water supply efficiency in the indicator calculation carry some strange features, as it relates the water supplied to *all* industries and households with the economic output (VA) of only a limited set of industries, namely the service industries. It means that the VA generated in industries (agriculture, mining and manufacturing) that also rely upon distributed water is not part of this indicator. This is understandable; otherwise, the VA from these industries would be accounted for twice, which would also be confusing and not completely correct. How to solve this needs to be discussed further. One solution would be to add the water abstracted (both ground- and surface water) from the environment by the water supply companies for tap water production and take the share of it that become ‘distributed’ water (item in the PSUT) and end up in either agriculture and industry. Take these two volumes and add them to the volume abstracted via ‘own abstractions’ of ground- and surface water by agriculture and by industry respectively;

F. Disaggregation to detailed industry based upon NA and EA water data could easily be done as the underlying data is readily available in a consistent manner within CBS in the Netherlands. Other countries may want to do that in an similar attempt to make more detailed comparisons across all sectors. This would improve monitoring and enhanced targeting of particular industries, according to complete list of ISIC categories. Subsequently, it enables production of quite detailed water productivity figures across all sectors by combining the physical data on water (possibly per water type) based upon SEEA Water Accounts, with data on economic output or performance (in terms of VA (or GDP) per ISIC industry from National Accounts);

G. Several options for further improvement of the indicator exist as is, adding own abstractions by the service industries, adding rain fed agriculture bot in VA and in Water abstractions (not limit the compilation of WUE to solely agriculture), distribute abstracted water by ISIC 36 over all ISIC industries (not just service industries), and incorporate soil water;

H. A simple straightforward option would be to combine the statistical data from National Accounts and SEEA - Water Accounts for the three industries and calculate the WUE ('water productivity') indicator for the economy as a whole, or possibly even per water type, groundwater, surface water, and soil water;. The scarcity aspects or WUE per show strong differences among the water types as well as options of substitution between the water types;

I. Disaggregation to water type, for example to groundwater or surface water, can easily be done, adding the opportunity to derive more valuable data and information from the indicator; and

J. The frequency that the indicator can be compiled at, is on a biennial basis. With some extra capacity, this can be done on an annual basis. It is simply a matter of repeating the existing work more frequently.

Conceptual / methodological issues of Water Statistics / SEEA - Water Accounts:

K. Statistics Netherlands (CBS), in its Water Statistics / Water Accounts, deal with five main flows of data on a yearly (or biennial) basis to capture all sectors and industries. They compile UN-SEEA – Water Accounts-type data, which distinguishes the supply and use of five types of water: groundwater, surface water (fresh and salt/brackish/marine), soil water, drinking water, and industry water. This is based upon water statistics data and other sources;

L. This information is available in supply and use format for a wide range of industries, following ISIC and in the internationally comparable format following SEEA;

M. The UN-SEEA – Water Accounts are already used in many countries and are further implemented worldwide with help of UNSD and the World Bank;

N. Regarding terminology, it is important to align the terminology, concepts and definitions with the international agreed-upon standard for environmental accounting, the SEEA, or as a minimum, to build bridging within the terminology. For example, it is not always clear whether withdrawal can be interpreted as abstraction, which is water taken from the environment or to be used. That water is used as input in production and consumption processes, including reused water and distributed water; and

O. 'Raw water' versus 'used water' requires some more guidance for the proper compilation of the WUE indicator.

Recommendations after assessing the proposed WUE – indicator compilation:

P. As agriculture in many countries combines rain-fed with irrigation practice, there is reason to try to include the category *rain-fed agriculture*, for both its water use or needs and its VA. Otherwise, part of the economic VA of a country remains outside the indicator, while large part of the VA generated relied upon water (taken from the environment, from the inland water system). This is an omission in the current indicator;

Q. Although important in many countries, irrigation in agriculture, on the other hand, has only limited coverage. In many other countries, there is still a lot to gain in terms of proper water management to serve the economy with rain-fed agriculture globally. Regarding rain-fed agriculture, the role of soil water (together with groundwater) needs to be addressed in the WUE - indicator. A large part of rain-fed agriculture relies upon water provision from the environment via soil water. It is a tremendous resource, or 'natural asset', for agriculture. Often, its value is captured by the asset value of the land. Provision of water to crop production and grass and then to animal feed is one of the main provisioning ecosystem services in many countries or regions. Therefore, it should be considered;

R. Although suggested as causing a bias, once one includes VA from rain-fed agriculture in the indicator calculation, it has therefore been adjusted to solely irrigated agriculture, which causes a limitation of the coverage and relevance of the proposed indicator. Therefore, a suggestion is to link the total volume of water abstracted from the environment by agriculture to its total VA. A country able to generate more VA with similar or less water abstracted performs well in terms of WUE. For example, phasing out uneconomic irrigation by better water management will be covered by such an adjusted indicator. At least, total VA of agriculture comes into the scope of the indicator; and

S. The proposed calculation of proportion of agricultural GVA produced by rain-fed agriculture, in order to calculate the agricultural GVA produced by irrigation, is very stylized. It uses a generic default ratio (fixed) between rain-fed and irrigated yields of 0.375. This is very theoretical, and will vary extremely between regions, crops and climate zones. In addition, it does not relate kg yields to monetary yields. It makes the calculation easy and straightforward to implement, but does not tell the complete story. In many situations, VA generated relies upon the combination of rain-fed and (partly) irrigated water. It is often not possible to distinguish between the two. Often, irrigation is done solely during planting or sowing and sometimes at the end of the season, thus not throughout the complete growing season. Often, irrigation is done in order to enhance the quality of the crop and product and or to guarantee the harvest to some degree. This cannot fully be captured by this indicator.

Issues for debate:

T. It is questionable to aggregate WUE from abstracted water, since abstracted water from the environment within the WUE differs from the abstracted water meant for distribution and supply to all industries and households. Efficiencies between personally abstracted water and distributed water for use are not the same and cannot be compared. One difference is that it has different quality (purified or not) and has totally different value (price);

U. Disaggregation to water type between groundwater and surface water can easily be done from Water Accounts, adding opportunity to derive more valuable data and information from the indicator. This is highly recommended as the impact from groundwater is much different and often more severe, leading to water stress situations (refer to chapter on indicator 6.4.2). That is, water taken from the rivers in an in-stream situation often causes less problems to the water environment and to water resource management than abstractions of fresh groundwater does;

V. Moreover, since the concepts of 'soil water', 'green water', and 'rain-fed agriculture' and its water use have barely any or no role yet in the indicator, they are important to consider. It is therefore suggested to consider the valuable resource of soil water (relating to 'green water') and its major role in mainly rain-fed agriculture and resulting production and VA. In the existing proposal, one can circumvent this for the moment by including the VA from rain-fed agriculture (not just the VA of irrigated agriculture, as it is now). Also, in rain-fed agriculture, much is to be gained with regards to proper water management and WUE; and

W. Objectives other than just generating VA from water might be relevant to consider in the WUE indicator. This could include either water needed for environmental requirements or for *water table management* with a multitude of objectives (foundation piles, prevention of salinization, survival or particular vegetation). Presumably, this can be linked to use or abstraction by a particular industry (ISIC), for example, by government or recreational use.

Indicator 6.4.2

X. According to the definitions in the 'GEMI step-by-step monitoring methodology for 6.4.2', withdrawals by the agricultural sector only include 'annual quantity of self-supplied water withdrawn for irrigation, livestock and aquaculture purposes'. In the typical Dutch water system, the water boards ensure a certain water level in the polders in a large part of the country. This water level management ensures, among other objectives, the availability of water for agriculture. As such, it has to be discussed whether and to which extent the large volumes of water for surface water level management must be taken into account in the volume of TWW. On the other hand, water level management in polders is also necessary simply to 'keep the feet dry', to prevent from salinization of freshwater, to prevent the setting of peat soils and to prevent the deterioration of wooden pile foundations in urban areas. Last but not least, it is aimed to improve or to guarantee the water quality;

Y. The component IRWR has to be calculated as a LTAA. The GEMI methodology does not define how many years have to be taken into account in calculating this LTAA. Moreover, for ERWR actual yearly values have to be calculated. It would be better to use this for IRWR also, so that extreme values of P and AET, in combination with extreme river flow conditions, are reflected in the water stress value. The methodology should give more guidance on these issues; and

Z. The calculation of the component environmental water requirements (Env.) is established with the aim of protecting the basic environmental services of freshwater ecosystems. It is not completely clear whether this focuses only on the water-based ecosystems or also on the terrestrial ecosystem which rely largely upon the availability of sufficient freshwater throughout the year. This should be included in the indicator.

8. Conclusions and recommendations

For this memo, we made a qualitative assessment of the ladder approach for SDG 6.4. The ladder approach uses data from different sources to support the monitoring and reporting on water use efficiency and water stress. In this assessment, we focused on the Netherlands, one of the Proof of Concept countries. Three data sources were included: national statistics, remote sensing-based data and model-based data. National statistics were considered the primary source of information for monitoring. The other two data sources were considered as additional, completing and improving the national statistics, if possible. Based on this assessment, we conclude that for SDG 6.4.1:

- It is possible to generate the required data from existing national statistics for the water use efficiency calculation. Adequate information is available in the National Accounts and Water Statistics / SEEA - Water Accounts;
- As agriculture in many countries combines rain-fed with irrigation practice, there is reason to try to include the category rain-fed agriculture, for both its water abstraction from the environment and its VA. Otherwise, both part of the economic VA of a country remains outside the indicator, while large part of the VA generated relied upon water (taken from the environment, from the inland water system) and also part of the water uptake by crops/plants and transfer to the atmosphere would not be covered by the 6.4.1 indicator. This is an omission in the current indicator;
- More disaggregated data can be provided from existing statistics and National Accounts and SEEA Water accounts, through industry disaggregation (ISIC-4 letter level), regional disaggregation (on (Sub-)River basins or catchments) and coverage, for the different water types, as well on the economic data for detailed industries;
- Further disaggregation, spatial and temporal, is possible when adding remote sensing- and model-based data. For that purpose the model-based data should be aligned with the existing statistical data; and
- Actions to improve water use efficiency will benefit from disaggregated data.

Clear proof of the value of the ladder approach comes from Netherlands Statistics' current practice of reporting the internal flow, which is comparable with the IRWR. To improve the internal flow calculation, remote sensing-based ET data and in/outflow data from models are used. For SDG 6.4.2, we also conclude that:

- Most required data is available from the Water Statistics and water supply, use and assets tables from SEEA - Water Accounts in the Netherlands.
- Fresh groundwater inflow and Environmental Water Requirement has to be added from model based data to complete the indicator.
- Enriching Statistical data with satellite data and modelling results, results in different outcome.
- Using Actual ET (from satellite data) instead of potential ET (from observation data) is a more realistic approach, because it takes the availability of water into account.
- The different approaches for the Environmental Water Requirements result in a large range of estimated values, which affects the calculated value of water stress. More guidance on the approach is needed, if water stress values of different countries are to be compared.
- Further disaggregation in space and time is possible with remote sensing- and model-based data as well as with statistical data; and

- Water stress has a strong spatial and temporal component. This may be lost in annual country level data and reports.

Next to the primary goal of compiling the 6.4 indicators, the indicators could also be used in water policies and management as it provide valuable information to the acting water governing bodies and managers. This even more holds for the further disaggregated indicators, allowing to make better informed decisions. Combining the statistical data, the satellite-based data and the model-based data, has proven to be a useful exercise. Further combining of these data is expected to improve future compilation of the indicators, as well as other projects where statistical data, satellite data and modelling data are involved. Based on this experience we recommend a third approach in the ladder approach, with full consistency between the statistical data, model data and satellite data.

Although our focus was on the Netherlands, we did consider the availability of the additional data sources for the ladder approach outside the Netherlands. We conclude that remote sensing-based data is available in many parts of the world with the same quality as in the Netherlands. Model data is also globally available, though detail and quality may vary depending on the available input data.

We based our assessment on the current proposal by UN-Water for indicators 6.4.1 and 6.4.2. By considering their implementation for the Netherlands, we came across several issues with regards to their practical application. Therefore, we also have some suggestions for practical improvements.

This assessment was only qualitative in nature, given the scope of the project. Especially for 6.4.1 we did not apply the ladder approach, just showed the quantification of the proposed and actual indicator with available statistical data for a single year. For 6.4.2. a first attempt was done to quantify water stress, just to show the potential of available data. We recommend application of the ladder approach for SDG 6.4 in some of the Proof of Concept countries to test the merit of this approach.
If desired the ladder approach can get further developed, for example by directly combining remote sensing data and models. Furthermore, the ladder approach may benefit from the inclusion of other reporting methods, such as Water Accounting. The ladder approach could add detail to the indicators, which allows to generate information that can be used for national and regional water policies.

Sources

0. General, methodologies, classifications, standards:

UN-Water (2016a). *DRAFT Step-by-step monitoring methodology for SDG indicator 6.4.1 on water use efficiency*. http://www.unwater.org/publications/publications-detail/en/c/428723/.

UN-Water (2016b). *DRAFT Step-by-step monitoring methodology for SDG indicator 6.4.2 on water stress*. http://www.unwater.org/publications/publications-detail/en/c/428727/.

Ministry of Infrastructure and Environment (IenM) (2016). *GEMI proof of concept report, The Netherlands. Pilot testing of the draft monitoring methodologies for SDG 6 global indicators (CONCEPT).* Version: 1 November 2016. Netherlands Ministry of Infrastructure and Environment, supported by the Netherlands IHP-HWRP Committee.

1. Statistical data, methodologies, classifications, standards:

AQUASTAT: FAO's global water information system (2016).
http://www.fao.org/nr/water/aquastat/main/index.stm.

Baas, K. and Graveland C. (2011). *Water abstraction and use at the river basin level, Final Report on EU Water Statistics Grant*. Discussion paper (201113), ISSN: 1572–0314, Statistics Netherlands (CBS), Heerlen/The Hague.

Baas, K. and C. Graveland (2014). *Exploring the National Groundwater Register and improving data on industrial water use*. Final report Eurostat Water Statistics Grant 2012. Statistics Netherlands (CBS), The Hague/Heerlen, 2014.

CREEA, *Compiling and Refining Environmental and Economic Accounts* (2013). ETH Zurich, CBS, TUT, SERI. Report Work Package 3 – Task 1: Refine and test SEEAW and relevant water accounting parts of SEEA2012. http://isiarticles.com/bundles/Article/pre/pdf/44471.pdf.

Edens B, and Graveland C, (2014). *Experimental valuation of Dutch water resources according to SNA and SEEA*. doi:10.1016/j.wre.2014.10.003.

eLEAF (2016). *Water Accounting Nederland. De waterhuishouding van 2014 in kaart gebracht* (‘Assessment of the 2009 Watermanagement’). i.o. van CBS. Maurits Voogt, Rutger Kassies. Wageningen, oktober 2016.

Eurostat (2016A). *Database – Eurostat – Environment and energy. Data: Environment (env) – Water (env_wat) – Water statistics on national level (env_nwat) - Renewable freshwater resources (env_wat_res) OR: - Annual freshwater abstraction by source and sector (env_wat_abs)* OR: Water made available for use (env_wat_use) OR: Water use by supply category and economical sector (env_wat_cat) OR: Water use in the manufacturing industry by activity and supply category (env_wat_ind) ETC. This is data from the OECD - Eurostat Joint Questionnaire on Inland Waters (JQ-IW). http://ec.europa.eu/eurostat/data/database.

Eurostat (2016B). *Database – Eurostat – Sustainable Development indicators. Data: Natural Resources (sd_tr) – Fresh water resources (sd_nr_wat)* - Water exploitation index (WEI). http://ec.europa.eu/eurostat/data/database.

Graveland, C. and Baas, K. (2012). *Improvement of the national water balance; Water stocks; feasibility of water balances per river basin, Final report on Eurostat Water Statistics Grant*. Grant Agreement NO. 50303.2010.001–2010.564, Heerlen/The Hague.

Graveland, C. (2006). *Dutch Water flow Accounts, with preliminary results for 2003 and 2004. Voorburg*. Centraal Bureau voor de Statistiek.

Lodder, B.J.H., A.T. van den Berg en C. Graveland (2014). Waterrekeningen naar bedrijfstakken, tijdreeksen-1976-2011. Centraal Bureau voor de Statistiek). Den Haag /Heerlen.

Meer, R. van der (2013a). *Water use in agriculture 2009–2010, at river basin level in The Netherlands (in Dutch)*, nota 13–043, Project code 2275000520, LEI (Agricultural Economics Institute foundation), Wageningen UR, The Hague.

Meer, R. van der (2013b). *Water use in agriculture 2011 and update 2001–2008, at river basin level;* dataset, LEI (Agricultural Economics Institute foundation), The Hague.

Meer, R. van der (2014). *Water use in agriculture 2012, at river basin level; dataset. (in Dutch: Watergebruik in de agrarische sector 2012*), Landbouw-Economisch Instituut (LEI), Den Haag. July 2014.

Meer, R. van der (2016). *Water use in agriculture 2013 and 2014, at river basin level in The Netherlands (in Dutch)*. Wageningen Economic Research, Wageningen. Rapport 2016-081. 24 blz.; 1 fig.; 11 tab.; 5 ref.

OECD/Eurostat (2012). OECD / Eurostat - Joint Questionnaire Inland Waters. OECD – Environment Directorate; Eurostat – Directorate E: Sectoral and regional statistics. Data available at: 〈 http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database 〉, 2012 (accessed November 2016).

SEEA, System of Environmental-Economic Accounting (SEEA)
SEEA: http://unstats.un.org/unsd/envaccounting/seea.asp
SEEA – IRWS: http://unstats.un.org/unsd/envaccounting/irws/

Statistics Netherlands (CBS) (2004). *Waterverbruik; nijverheid, kerncijfers, 1962 - 2001 [Dataset]*. Geraadpleegd op 4 maart 2015 van:
http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=37124&D1=0-9&D2=0&D3=(l-11)-l&VW=T.

Statistics Netherlands (CBS) (2011a). *Environmental accounts of the Netherlands 2010*. Heerlen/The Hague.

Statistics Netherlands (CBS) (2011b). *Living with water: not without Water Statistics*. Baas, Kees and Graveland, Cor. The Hague, Netherlands. Int. Statistical Inst.: Proc. 58th World Statistical Congress, 2011, Dublin (Session IPS094). http://2011.isiproceedings.org/papers/450236.pdf.

Statistics Netherlands(CBS) (2011c). *Water abstraction and use at the river basin level, Final Report on EU Water Statistics Grant*. Heerlen/The Hague.
Statistics Netherlands (CBS) (2012). *Environmental accounts of the Netherlands 2011*. Heerlen/The Hague.

Statistics Netherlands (2012 and earlier). *Environmental accounts of the Netherlands*. Statistics Netherlands (Centraal Bureau voor de Statistiek), The Hague/Heerlen.

Statistics Netherlands (CBS) (2013a). *National Accounts of the Netherlands 2012*. Heerlen/The Hague.

Statistics Netherlands (CBS) (2013b). *Environmental accounts of the Netherlands 2012*. Heerlen/The Hague.

Statistics Netherlands (CBS) (2013c). Green growth in the Netherlands 2012, Heerlen/The Hague.

Statistics Netherlands (CBS) (2014a). *National Accounts of the Netherlands 2013*. Heerlen/The Hague.

Statistics Netherlands (CBS) (2014b). *Watergebruik bedrijven en particuliere huishoudens; Nationale rekeningen [Dataset]*. Geraadpleegd op 21 mei 2015 van: http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=82883NED&D1=a&D2=a&D3=a&VW=T. 2014, 18 november.

Statistics Netherlands (2014c). *Environmental accounts of the Netherlands 2013*. Heerlen/The Hague.

Statistics Netherlands (2015a), *Sustainability Monitor of the Netherlands: Indicator report*. Heerlen/The Hague.

Statistics Netherlands (CBS) (2015b). *Green growth in the Netherlands 2015*, Heerlen/The Hague.

Statistics Netherlands (CBS) (2015c). S*DGs: Overview, water monitoring Nederland by Statistics Netherlands (CBS)*. To: Secretariat, Netherlands National IHP-HWRP Committee, UNESCO – IHE. Cor Graveland and Kees Baas, Statistical Research, water statistics / SEEA - water accounts. Environmental Accounts / Environmental statistics. 13 November 2015.

Statistics Netherlands (CBS) (2016a). *Sustainable Development Goals: een eerste beeld voor Nederland*. 4 November 2016. CBS, Den Haag.

Statistics Netherlands (CBS) (2016b). *Meten van SDGs: een eerste beeld voor Nederland*. 7 September 2016. CBS, Den Haag.

Statistics Netherlands (CBS) (2016c). *Waterstromen in de Nederlandse economie. Korte resultatenbeschrijving en samenvattende tabellen set. Rapport*. Stephan Verschuren, Bart

Staats, Cor Graveland, Kathleen Geertjes, Kees Baas, Remco Kaashoek. Statistics Netherlands, The Hague.

Statistics Netherlands (CBS) (2016d). *Fysieke Aanbod- en Gebruik tabel Water, 2008, 2010, 2012. (Physical Supply- and Use table for Water (SEEA-Water)*. https://www.cbs.nl/-/media/_excel/2016/00/160222_psut_tabellen.xls. Heerlen/The Hague.

Statistics Netherlands (CBS) (2016e). *National Accounts of the Netherlands 2015*. Heerlen/The Hague.

Statistics Netherlands (CBS) (2016f). *Methodebeschrijving Uitbreiding Materiaalmonitor met Water*. Stephan Verschuren, Cor Graveland, Kathleen Geertjes, Kees Baas, Remco Kaashoek. Centraal Bureau voor de statistiek. Den Haag / Heerlen.

Statistics Netherlands (CBS) (2016g). *Methodological description of extending the Materials Monitor with Water Accounts*. Stephan Verschuren, Cor Graveland, Kathleen Geertjes, Kees Baas, Remco Kaashoek. https://www.cbs.nl/en-gb/background/2016/16/extending-the-materials-monitor-with-water. Statistics Netherlands, The Hague / Heerlen.

Statistics Netherlands (CBS) (2016h). *Material flow Monitor - a time series. Report*. Roel Delahaye, Krista Keller, Cor Graveland, Albert Pieters and Joram Vuik. https://www.cbs.nl/nl-nl/publicatie/2016/05/material-flow-monitor-a-time-series. Statistics Netherlands, The Hague.

United Nations, 2008. *International Standard Industrial Classification of All Economic Activities, Revision 4 (ISIC Rev.4)*. Statistical papers Series M No. 4/Rev.4. Department of Economic and Social Affairs, Statistics Division. United Nations, New York.

UN (United Nations), EC (European Commission), IMF (International Monetary Fund), OECD (Organisation for Economic Co-operation and Development) and World Bank (2009), System of National Accounts 2008, SNA-2008, , New York.

UN (United Nations), EC (European Commission), FAO (Food and Agriculture Organisation), IMF (International Monetary Fund), OECD (Organisation for economic Co-operation and Development) and World Bank (2012a*), System of Environmental-Economic Accounting, Central Framework (SEEA-CF)*, New York. SEEA: http://unstats.un.org/unsd/envaccounting/seearev/

UN (United Nations) (2012b), *System of Environmental-Economic Accounting for Water (SEEA-W)*, ST/ESA/STAT/SER.F/100, Department of Economic and Social Affairs, Statistics Division, UN, New York. SEEA-Water: http://unstats.un.org/unsd/envaccounting/water.asp

UN (United Nations) (2012c). *International Recommendations for Water Statistics (IRWS)*, Department of Economic and Social Affairs, Statistics Division, UN, New York. http://unstats.un.org/unsd/envaccounting/irws/irwswebversion.pdf

VEWIN (2010). *Drinkwaterstatistieken 2008*. Vereniging van Waterbedrijven Nederland (VEWIN). Rijswijk. Vereniging van Waterbedrijven in Nederland (VEWIN). Rijswijk. www.vewin.nl

VEWIN (2011). *Kerngegevens drinkwater 2011*. Vereniging van Waterbedrijven Nederland (VEWIN). Rijswijk. Vereniging van Waterbedrijven in Nederland (VEWIN). Rijswijk.

VEWIN (2015). *Kerngegevens drinkwater 2014*. Vereniging van Waterbedrijven Nederland (VEWIN). Rijswijk. Vereniging van Waterbedrijven in Nederland (VEWIN). Rijswijk. www.vewin.nl

WaterWatch (2011). *Water Accounting Nederland. De waterhuishouding van 2009 in kaart gebracht ('Assessment of the 2009 Watermanagement')*. Maurits Voogt, Steven Wilmink, Wim Bastiaanssen. Wageningen, november 2011.

WISE: The Water Information System for Europe: http://water.europa.eu/.

2. Additional satellite-based data, methodologies, classifications, standards:

Bastiaanssen, W.G.M., Pelgrum, H., Wang, J., Ma, Y., Moreno, J., Roerink, G.J., and van der Wal, T. (1998), *A remote sensing surface energy balance algorithm for land (SEBAL): 2 Validation*. J. Of Hydr. 212-213:213-229

Bastiaanssen, W.G.M., M. J. M. Cheema, W. W. Immerzeel, I.J. Miltenburg, and H. Pelgrum (2012), *Surface energy balance and actual evapotranspiration of the trans boundary Indus Basin estimated from satellite measurement and the ETLook model*, Water Resource. Res., 48, W11512, doi:10.1029/2011WR010482.

Karimi, P., W.G.M. Bastiaanssen (2015), *Spatial evaporation, rainfall and land use data in water accounting – Part 1: Review of the accuracy of the remote sensing data*, Hydrol. Earth Syst. Sci, 19, 507-532.

3. Additional modelling data, methodologies, classifications, standards:

De Graaf, I.E.M., Sutanudjaja, E.H., van Beek, L.P.H., Bierkens, M.F.P.: *A high-resolution global-scale groundwater model*. Hydrol. Earth Syst. Sci., 19, 823–837, 2015

De Lange, W.J. G. Prinsen, J. C. Hoogewoud, A. Veldhuizen, J. Verkaik, G.H.P. Oude Essink, P.E.V. van Walsum, J. R. Delsman, J.C. Hunink, H. Th.L. Massop en T. Kroon. *An operational, multi-scale, multi-model system for consensus-based, integrated water management and policy analysis: The Netherlands Hydrological Instrument*. Environmental Modelling & Software 59 (2014): 98-108.

Food and Agriculture Organization of the United Nations (FAO): *Gridded livestock of the world 2007*, edited by: Wint, G. R. W. and Robinson, T. P., FAO, Rome, p. 131, 2007.

Gleeson, T., Wada, Y., Bierkens, M. F., and van Beek, L. P.: *Water balance of global aquifers revealed by groundwater footprint*, Nature, 488, 197–200, 2012.

Hoogewoud, J.C., G. Prinsen, J.C. Hunink, F.J.E. van der Bolt, T. Kroon and P.E.V. van Walsum. *Veranderingsrapportage NHI 3.02; beschrijving van de veranderingen in NHI 3.02*. Report 1209264, Deltares, 2014.

Klein Goldewijk, K. and van Drecht, G.*: Integrated modelling of global environmental change: An overview of IMAGE 2.4, chap. HYDE 3: Current and historical population and land cover*, MNP – Netherlands Environmental Assessment Agency, Bilthoven, the Netherlands, 93–112, 2006.

Kroon, T, G. Prinsen, J. Hunink, M. Visser, H. van den Boogaard (2015). *100 jaar reeks LHM en LSM*; beschrijving van de invoer.

Leunk, I., W.J. Zaadnoordijk, P. Stuyfzand, G. van den Berg (2012). *Verzamelen gegevens grondwateronttrekkingen Nederland* (No. 2012.050). KWR, Nieuwegein.

Massop, H. T. L., Schuiling, C., & Veldhuizen, A. a. (2012). *Potentiele beregeningkaart 2012* (No. 2382). Alterra Wageningen UR, Wageningen.

Pastor, A.V., Ludwig, F., Biemans, H., Hoff, H., and Kabat, P.: *Accounting for environmental flow requirements in global water assessments*. Hydrol. Earth Syst. Sci., 18, 5041–5059, 2014

Portmann, F., Siebert, S., and Döll, P.: *MIRCA2000 – Global monthly irrigated and rainfed crop areas around the year 2000: a new high-resolution data set for agricultural and hydrological modelling*, Global Biogeochem. Cyc., 24, GB1011, doi:10.1029/2008GB003435, 2010.

Sarhadi, A., & Soltani, S. (2013). *Determination of water requirements of the Gavkhuni wetland, Iran: A hydrological approach*. Journal of arid environments, 98, 27-40.

Shiklomanov, I. A.: *Assessment of water resources and water availability in the world*, omprehensive assessment of the freshwater resources of the world, World Meteorological Organization and the Stockholm Environment Institute, Stockholm, Sweden, 1997

Vörösmarty, C. J., Leveque, C., and Revenga, C.: *Millennium Ecosystem Assessment Volume 1: Conditions and Trends, chap. 7: Freshwater ecosystems*, Island Press, Washington DC, USA, 165–207, 2005.

Wada, Y., van Beek, L. P. H., and Bierkens, M. F. P.: *Modelling global water stress of the recent past: on the relative importance of trends in water demand and climate variability*. Hydrol. Earth Syst. Sci., 15, 3785–3808, doi:10.5194/hess-15-3785-2011, 2011a.

Wada, Y., van Beek, L. P. H., Viviroli, D., Dürr, H. H.,Weingartner, R., and Bierkens, M. F. P.: *Global monthly water stress: II.Water demand and severity of water*, Water Resour. Res., 47, W07518, doi:10.1029/2010WR009792, 2011b.

Wada, Y., van Beek, L. P. H., Wanders, N., and Bierkens, M. F. P.: *Human water consumption intensifies hydrological drought worldwide*, Environ. Res. Lett., 8, 034036, doi:10.1088/1748-9326/8/3/034036, 2013.

Wada, y., Wisser, W., Bierkens, M.F.P.: *Global modelling of withdrawal, allocation and consumptive use of surface water and groundwater resources*. Earth Syst. Dynam., 5, 15–40, 2014.

World Resources Institute (WRI):World Resources: *A Guide to the Global Environment 1998–99*, World Resources Institute, Washington DC, USA, 1998.

Annexes

Annex I SEEA Central Framework for Water Accounts

This Annex provides information about the on-going work on SEEA based water accounts and the contribution of the SEEA to SDG monitoring for goal 6.

Method description

The SEEA Central Framework (2012) was adopted as an international statistical standard for measuring the environment and its relationship with the economy in 2012. The SEEA Water (2007) provides a more complete description of accounting for water using the SEEA Standard.

At the heart of SEEA water is an accounting approach that records, as completely as possible, the stocks and flows of water within and between the economy and the environment. The water accounts support an integrated approach to water management. Together the various accounts build a system of information to study the inland water resources system (assets) and its relationship with the economy by determining supply and use of water, where the economy is delineated by the boundaries set in the System of National Accounts. There are three main accounts for water that capture various aspects of this system:

- The Physical Supply and Use Tables (PSUT) measure, in physical (volume) terms; 1) the flows of water entering the economy, which are either abstracted from the environment or imported; 2) the flows of water and wastewater between different economic units within the economy, and; 3) the return flows of water from the economy to the environment (directly or via sewerage treatment plants);
- The Monetary Supply and Use Tables measure the monetary flows associated with water related products;
- The Asset Account describes the inland water resources system in terms of stocks and flows, providing information on the stocks of water resources at the beginning of the accounting period, the corresponding changes in those stocks due to economic activity and natural processes, and the closing stocks of water at the end of the accounting period. This can be thought of as a hydrological water balance.

The concepts and definitions that comprise the SEEA standard for water are designed to be applicable across all countries, irrespective of their state of economic development and variations in water sources and uses.

Application to monitoring SDG 6

The information contained in the SEEA Central Framework Water Accounts (specifically the PSUT and emission accounts) support measurement of the SDG goals 6.3 and 6.4 in particular. It is therefore recommended that the definitions and classifications associated with the SEEA are adopted, as this represents the international standard.

- Wastewater flows from different industries (according to ISIC) and their destination (treatment plants, direct to environment, sent for reuse, etc.) are captured in the SEEA Water Emission Accounts, which can be used in the measurement of indicator 6.3.1.

Water withdrawal (‘abstraction’), use, and consumption are all captured by the SEEA Water accounts and recorded by sector according to ISIC. This allows for the calculation of a water productivity indicator (incorporating GDP or value added ($)), based on definitions encompassed in the international statistical standard (SEEA) and disaggregated by sector according to ISIC.

Annex II Broad ISIC structure (Rev.-4)

The 1-99 ISIC Divisions (2-digit) represent 86 individual main categories of ISIC. These have been aggregated into the following 21 sections.

Section	Divisions	Description
A	01–03	Agriculture, forestry and fishing
B	05–09	Mining and quarrying
C	10–33	Manufacturing
D	35	Electricity, gas, steam and air conditioning supply
E	36–39	Water supply; sewerage, waste management and remediation activities
F	41–43	Construction
G	45–47	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	49–53	Transportation and storage
I	55–56	Accommodation and food service activities
J	58–63	Information and communication
K	64–66	Financial and insurance activities
L	68	Real estate activities
M	69–75	Professional, scientific and technical activities
N	77–82	Administrative and support service activities
O	84	Public administration and defence; compulsory social security
P	85	Education
Q	86–88	Human health and social work activities
R	90–93	Arts, entertainment and recreation
S	94–96	Other service activities
T	97–98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	99	Activities of extraterritorial organizations and bodies

Source: United Nations, 2008. International Standard Industrial Classification of All Economic Activities, Revision 4 (ISIC Rev.4);

Annex III Detailed description of computation of indicator 6.4.1

The definition of the indicator is explained in Chapter 3. This Annex describes the computation for the three sectors mentioned in the indicator.

Concept Indicator 6.4.1

The indicator provides information on the efficiency of the economic usage of water resources, particularly on the VA generated by water use in the three sectors of the economy, and distribution network losses.[7] This indicator, 6.4.1, is not just about the absolute level, it monitors the change in '***water use efficiency***' over time. This divides VA by the water withdrawn over time of a given sector, showing: VA ($ or €) / water withdrawal (m^3).

This indicator is also referred to as '***water productivity***', a term more familiar to certain audiences[8]. One will strive for increase in 'water use efficiency', or 'water productivity' over time for this indicator. Since it relates to economic output in terms of production or VA (Euro) per unit of water (m^3), this can separately be applied to volumes of groundwater, fresh surface water, or soil water. Sometimes, the term 'water intensity' is used by swapping the numerator with the denominator; in that case, one will strive for less water per unit of economic output.

The proposed WUE indicator specifically addresses the target component 'substantially increase water-use efficiency across all sectors' by measuring the economic output per unit of water from productive uses of water withdrawn (abstracted) from the environment, as well as losses in municipal water use. Together, the three sectoral efficiencies are supposed to provide a measure of overall water efficiency in economic activity of a country. The indicator provides incentives to improve water use efficiency through all sectors, highlighting those sectors where water use efficiency is lagging behind.

Other indicators, specifically those for Targets 1.1, 1.2, 2.1, 2.2, 5.4, 5.a, 6.1, 6.2, 6.3, and 6.5, are supposed to complement the information provided by this indicator. In particular, the indicator needs to be combined with water stress indicator 6.4.2 to provide adequate follow-up of the target formulation.

Computation

The indicator is supposed to be computed as the sum of the three main sectors in the economy, weighted according to the proportion of water withdrawn by each sector over the total withdrawals:

$$WUE = A_{we} \text{ x } P_A + I_{we} \text{ x } P_I + S_{we} \text{ x } P_s$$

Where:

- WUE = Water use efficiency (USD/m^3 or EUR/m^3);

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[7] The distribution efficiency of water systems is explicitly considered only for the municipal sector as a separate indicator, but it is nonetheless implicit within the calculations also for the other sectors, and could be made explicit if needed and where data are available.

[8] SEEA-Water in §9.19 refers to WP as Water productivity is the most widely used indicator from the water accounts for cross-sector comparisons. It furnishes a first approximation of the potential gains and losses from a reallocation of water.

- A_{we} = Irrigated agriculture water use efficiency (USD/m^3);
- I_{we} = Industrial water use efficiency (USD/m^3);
- S_{we} = Services water use efficiency (USD/m^3);
- P_A = Proportion of water withdrawn by the agricultural sector over the total withdrawals;
- P_I = Proportion of water withdrawn by the industry sector over the total withdrawals; and
- P_S = Proportion of water withdrawn by the service sector over the total withdrawals.

The calculations for the three main sectors (ISIC-industry aggregates) have their own dynamics and characteristics. For example, the indicator for water use efficiency (principally abstraction efficiency) in agriculture focuses just on the part of *Irrigated agriculture* (EUR/m^3). The water efficiency indicator for industry (principally 'manufacturing', and including power production) is straightforward as it combines industrial VA per unit of industrial water withdrawn, expressed in USD/m^3 (or EUR/m^3). Finally, the services sector water supply efficiency is calculated as the service sector VA, but just for ISIC 36-39 and ISIC 45-99 (see Annex I), divided by the water volume withdrawn for distribution by the water collection, treatment and supply industry (ISIC 36), expressed in USD/m^3, thus excluding the part of the distributed water that flows to the industries in ISIC 1 – 35 and 40 – 43.

The computing of each of the three sectors is described below.

Water use efficiency in irrigated agriculture is calculated as the agricultural VA per agricultural water withdrawn, expressed in USD/m3:

$$A_{we} = (GVA_a * (1 - C_r)) / V_a$$

Where:

A_{we} = Irrigated agriculture water use efficiency [USD/m^3];
GVA_a = Gross VA by agriculture (excluding river and marine fisheries and forestry) [USD];
C_r = Proportion of agricultural GVA produced by rain-fed agriculture; and
V_a = Volume of water withdrawn by the agricultural sector (including irrigation, livestock and aquaculture) [m^3].

C_r can be calculated from the proportion of irrigated land on the total arable land, as follows:

$$C_r = 1 / (1 + (A_i / ((1 - A_i) * 0.375)))$$

Where:

A_i = proportion of irrigated land on the total arable land, in decimals; and
0.375 = generic default ratio between rain-fed and irrigated yields. More detailed estimations are however possible and encouraged at a country level.

Water efficiency of industry **(**including power production) is the industrial VA per unit of industrial water withdrawn, expressed in USD/m3:

$$I_{we} = GVA_i / V_i$$

Where:

I_{we} = *Industrial water use efficiency [EUR/m^3];*
GVA_i = Gross VA by industry (including energy) [EUR]; and
V_i = Volume of water abstracted by the industries (including energy) [m^3].

Water supply efficiency calculation of the Service Sectors, requires the service sector VA (ISIC 36-39 and ISIC 45-99, excluding construction) divided by water abstracted for distribution by the water collection, treatment and supply industry (ISIC 36), expressed in EUR/m^3:

$$S_{we} = GVA_s / V_s$$

Where:

S_{we} = *Services water use efficiency [EUR/m^3];*

GVA_s = Gross VA by services [EUR]; and

V_s = Volume of water withdrawn by the service sector [m^3].

Annex IV Details on statistical data

Available data from statistics:

Statistics Netherlands has a long-lasting experience in compiling statistics and accounts on water abstractions and water use. This data is compiled for use within the SEEA Water Accounts as well as for international questionnaires, like for OECD-Eurostat Joint Questionnaire on inland waters and EEA – SOER (State of the Environment Report). Comparable data are available from 2001 onwards; for 2008, 2010 and 2012, the data are more disaggregated to detailed level of economic activity according ISIC. This includes withdrawal of fresh groundwater, fresh surface water and marine water (Statistics Netherlands, 2016c, 2016d).[9]

In order to calculate the proportion of water withdrawn by the agricultural sector for irrigation, the total agricultural area and the area under irrigation are needed. This data comes from either the spatial land statistics (group) or from land accounts for total area. Data about area under irrigation comes from LEI, Agricultural Economic Research Institute as enlarged figures which are produced from their sample of the farmers' population (van der Meer, 2016).

Data available from National Accounts and Water Accounts & Statistics

For the required economic data, this is readily available from the National Accounts department within Statistics Netherlands. It produces the Dutch National Accounts (NA) and monitors the country's economic performance in detail, such as the combined income (GDP), based on agreed-upon international standards, the System of National Accounts (SNA) 2008 (SNA–2008; UN et al., 2009). In NA on both a yearly and quarterly basis, detailed economic data on production, intermediary use, VA and gross domestic product (GDP) are produced. The NA data is published in CBS - StatLine, the electronic database of the institute, in yearly or quarterly publications (e.g., Statistics Netherlands (CBS) (2013a, 2014a, 2016e)).

A number of so-called satellite accounts are connected to these NA. Examples are regional economic accounts, growth accounts (with productivity analysis), labour accounts, Environmental Accounts (EA), and ecosystem accounts (also referred to as Natural Capital Accounts, NCA). These SEEA - Environmental Accounts (SEEA-EA) are constituted of a list of EA modules, such as Energy Accounts, Water Accounts, Subsoil Accounts (Mineral), and Air Emission Accounts, often with both physical and monetary tables. Moreover, SEEA-EA has several modules which are primarily monetary, such as environmental tax accounts, environmental expenditure accounts (EPEA) and Resource Management Expenditure Accounts (ReMEA).

For the calculation of indicator 6.4.1, these components of detailed data are needed and available:

- Detailed economic data on production, intermediary use, VA, and employment:
    - Available within Statistics Netherlands (CBS);
    - Compiled in the NA department;
    - From the Dutch NAs;
    - According to international standards of SNA & ESA2010;
    - Available at macro- and meso-levels;
    - Industry – classification follows international ISIC-4 (and NACE-Rev.2);
    - By detailed industry (ISIC-4 categories) (see Annex-II: Broad ISIC structure, Rev.-4);

[9] Direct use of non-conventional water, i.e. direct use of treated wastewater, direct use of agricultural drainage water and desalinated water is excluded.

  - Available on yearly basis, if needed at quarterly basis;
  - Data is ready and publicly available at website Statistics Netherlands www.cbs.nl and from www.cbs.statline.nl
  - Data compiled at regional disaggregation's in Regional Economic Accounts;
  - Long time series; and
  - Data on employment (number of employees) by industry from Labor Accounts.

- Detailed data available on physical water abstractions (V) and water uses:
  - Available within Statistics Netherlands (CBS),
  - Compiled by the Environmental Statistics department & Environmental Accounts Group (part of the NA department);
  - From the Dutch Water Statistics & Water Accounts (by SEEA-Water);
  - Physical supply & use tables for water (Water-PSUT);
  - Distinction between abstraction of fresh groundwater, fresh surface water, and brackish or marine surface water, by industry (breakdown to detailed ISIC-Rev.4 level);
  - Distinction between uses of drinking water and of industrial water (also called 'other water');
  - Distinction between 'water for own use' and water via distribution networks obtained from (or supplied to) another sector or industry;
  - Available at the macro- and meso-levels;
  - Industry classification follows international ISIC-4 (&NACE-Rev.2);
  - Available at a yearly (or biennial) basis. Due to budget cuts, part of the water data is only compiled every two years;
  - Data is ready and publicly available at website statistics Netherlands: www.cbs.nl and partly from www.cbs.statline.nl;
  - The water data is partly available for the 7 sub river basins (catchments) in the country; and
  - Data available partly from 2001 onwards and with maximum detail in SEEA – Water Accounts (PSUT) format, for recent years (for reporting year 2008 onwards).

- Additional data sources available and used for the calculation of indicator 6.4.1 are:
  - Data from irrigated area (irrigated once a year) and the area irrigated in total, combining area with frequency on that area per reporting year) by agricultural subsector (5*);
  - Frequency of irrigation on this area per reporting year, per agricultural subsector (5*);
  - Volume of water abstracted, per agricultural subsector (5*);
  - Volume of fresh groundwater abstracted, distinct from abstracted fresh surface water;
  - Data also available about dedicated irrigation (gietwater) in horticulture;
  - Besides irrigation water, abstraction of ground- or surface water for animal drinking, per agricultural subsector;
  - Use of drinking water (from the tap), per agricultural subsector, as well as for all other purposes (except for irrigation);
  - Data available in consistent manner since 2003; and
  - Data obtained from and aligned with LEI-business information network ('Bedrijven-Informatienet', BIN).

Origin of the data used for compilation of statistics:

The data in the economic accounts, the NA, are in large part collected by different groups within the Bureau of Statistics Netherlands; for example, the micro data collected via the so-called production statistics. The statistical business register (ABR) is also important as it is the backbone for connecting more than 1.5 million businesses in the country with the several statistical datasets at the micro level that actually generate statistical output, like the production statistics. To large extent, pre-existing data is collected from external registers, such as data within ministries, other governmental bodies, for example from the tax authorities. All of this data is collected, digitally stored and processed, and integrated into the Dutch NA. As a result, the required economic data in terms of VA per detailed industry (according to ISIC) is readily available from the NAs, Regional Accounts, or else within Statistics Netherlands.

The main sources of data for compiling the statistics / accounts on water withdrawals are:

- LEI: the Agriculture Economics Institute of Wageningen University (LEI) uses a sample of farm enterprises from BIN ('Bedrijven-Informatienet') who produce figures and time series on the quantities of groundwater and surface water withdrawals, the use of tap water, and irrigation water for the various subsectors in agriculture and horticulture. BIN uses a limited sample survey of over 1,000 holdings in agriculture and horticulture that is tracked intensively for several years in a row. The sample survey is in line with European formats through the Farm Accountancy Data Network (FADN). The sample is drawn from the population of agricultural holdings that are included in the agricultural census (see van der Meer, 2013a, 2013b, 2016).
- Electronic annual environmental reports (e-AER; in Dutch: e-MJV): through the e-AERs returned by companies, Statistics Netherlands gathers data about the withdrawal of surface water and groundwater, as well as the use of tap water. That data is made available from the key companies in the industrial sector. Statistics Netherlands extrapolates the individual water data of this selection of companies to the total population and to the populations per category of the International Standard Industrial Classification (NACE or ISIC) by using the data per company and per ISIC class. Not all NACE classes in manufacturing are sufficiently covered by the data from the e-AER. In those cases, Statistics Netherlands makes estimates based on other sources, including old figures from the National Water Survey on water use by industry (see National Water Survey on water use by industry, NWS below).
- VEWIN: VEWIN is the Association of Dutch Water Companies. VEWIN statistics are a key source for the figures on the total withdrawals from groundwater and surface water by the public water supply sector (ISIC 36) as well as total tap water supply, e.g. for household use (see VEWIN 2011, 2010, 2015).
- National Groundwater Register ('Landelijk Grondwater Register', LGR): the National Groundwater Register contains data on:
  - All withdrawals for which registration or notification is obligatory;
  - All permits for withdrawing groundwater and/or infiltrating water;
  - Administrative data, including the purpose for which water is extracted;
  - Technical information, including water quantities abstracted; and
  - Geographical information.

  The National Groundwater Register is still being developed.

For a more detailed methodological description and data sources used, see Statistics Netherlands (2016f) (2016g).

Description of statistics and account compilation practice

Statistics Netherlands (CBS) produces the water statistics and physical water flow accounts on an annual basis. This data represents the relevant part of the physical supply and use tables (PSUT) following international SEEA standards. CBS also has data on freshwater balances, or in other words on the physical water asset accounts for the country. This represents the freshwater flows (resources) that enter the country via rivers from neighboring countries and via precipitation (P) at the Dutch territory and the water that leaves the country via Evapotranspiration (ET) and discharge to the North Sea. Together, this data allows for the calculation of the indicator that shows the water stress situation for the country via indicator 6.4.1: Water Stress (see also: Statistics Netherlands, 2015c).

With the data compiled on an annual (or biennial basis), on physical water flows, this allows for comparison with the economic data at the macro- and meso-scale levels (industry-level; see Annex-II). This data is produced annually and quarterly in the standardized NAs. The Dutch NA applies the International statistical standard of the System of National Accounts (SNA). For that purpose, CBS also uses the implementation guidance provided by Eurostat, the European statistical office in Luxembourg, via its European System of Accounts (ESA2010). These are official, internationally agreed upon statistical standards to which the Netherlands wants to comply. Together, indicator 6.4.2 on Water Productivity can be calculated or derived both at the macro- and at the meso-level (see also: Statistics Netherlands, 2016e).

Computation of 6.4.1

The WUE indicator is computed as the sum of the three indicators for the different sectors discussed in the calculation framework before. Therefore, they should be weighed according to the proportion of water withdrawn by each sector over the total withdrawals from ground and surface water for the country. Moreover, the indicators are about the change over time; thus, historical data for a substantial number of years is required to assess the change of the indicator::

$$WUE = A_{we} \times P_A + I_{we} \times P_I + S_{we} \times P_s$$

Where:

WUE = Water Use Efficiency

Where:

- WUE = Water use efficiency (USD/m^3; either EUR/m^3)
- A_{we} = Irrigated agriculture water use efficiency (EUR/m^3)
- I_{we} = Industrial water use efficiency (EUR/m^3)
- S_{we} = Services water use efficiency (EUR/m^3)
- P_A = Proportion of water withdrawn by the agricultural sector over the total withdrawals
- P_I = Proportion of water withdrawn by the industry sector over the total withdrawals
- P_S = Proportion of water withdrawn by the service sector over the total withdrawals

For this calculation, these components of detailed data are needed:

- Detailed economic data on *production, intermediary use and VA, employment*.
- Detailed data on *physical water abstractions (V) and water uses*.
- *Additional date sources* needed for calculation.

As explained these three datasets required are available at Statistics Netherlands.

Together, these three datasets allow for the calculation of the proposed WUE indicator.
Since the proposed indicator consists of three parts, the compilations needs for each of them is shown.

A. Water use efficiency calculation in ***irrigated agriculture*** requires the agricultural VA per agricultural water abstracted, expressed in EUR/m^3::

$$A_{we} = (GVA_a * (1 - C_r)) / V_a$$

Where:

A_{we} = *Irrigated agriculture water use efficiency [EUR/m^3];*

GVA_a = Gross VA by agriculture (excluding river and marine fisheries and forestry) [EUR] → Taken directly from NAs, available per subsector;

C_r = Proportion of agricultural GVA produced by rainfed agriculture → ratio C_r, $C_r = 1 / (1 + (A_a / ((1 - A_i) * 0.375)))$;$V_a$ = Volume of water abstracted by the agricultural sector (including irrigation, livestock and aquaculture) [m^3] → Per agricultural subsector and by type of water, either groundwater or surface water;A_i = Proportion of irrigated land on the total arable land, in decimals; and

0.375 = Generic default ratio between rain fed and irrigated yields. → based upon area, can be derived from available data on irrigated land (land irrigated at least once per season).
More detailed estimations are possible and encouraged at a country level (for example, by the agricultural sector), such as dairy farming, arable farming, horticulture, etc.

B. Water efficiency calculation of ***industry*** (including power production) requires the industrial VA per unit of industrial water withdrawn, expressed in EUR/m^3:

$$I_{we} = GVA_i / V_i$$

Where:

I_{we} = *Industrial water use efficiency [EUR/m_3];*

GVA_i = Gross VA by industry (including energy) [EUR] → Taken directly from NAs, available per detailed industry (ISIC - industry). Data is in constant prices (deflated) to the required baseline year (2015); and

V_i = Volume of water abstracted by the industries (including energy) [m^3] → this be provided per 'industrial' or per 'manufacturing' industry (ISIC) and by type of water, either groundwater or surface water.

Industrial water withdrawal (V) is collected at a country level through national records (as previously is described) and reported in questionnaires, for example to Eurostat, OECD, UN, FAO, or EEA, in units of m^3/year.

C. Water supply efficiency calculation of the ***service sectors*** requires the service sector VA (ISIC 36-39 and ISIC 45-99, excluding construction as it is part of 'industry') divided by water abstracted for distribution by the water collection, treatment and supply industry (ISIC 36), expressed in EUR/m^3:

$$S_{we} = GVA_s / V_s$$

Where:

S_{we} = *Services water use efficiency [EUR/m_3];*

GVA_s = Gross VA by services [EUR] → Taken directly from NAs, available per services industry. Data is in constant prices (deflated) to the required baseline year (2015).

V_s = Volume of water withdrawn by the service sector [m^3] → per group of 'industrial' or 'manufacturing' industry (ISIC) and by type of water, either groundwater or surface water.

Data on volumes of abstracted and distributed water are collected at a country level by the Dutch Association of water supply companies (10*) in the Netherlands (VEWIN), and obtained by Statistics Netherlands. Data is in units of m^3 / year or million m^3/year.

Once the three underlying indicators are calculated with the available statistics and accounts data accordingly, we combine them applying the correct ratio of each.
The proportion of water abstracted or abstracted, distributed and used (in the case of the service sectors) can be calculated by combining the abstraction by each of the three industry clusters, agriculture, industry and services separately over the total abstractions for the country. This can be done by using the described data on water volumes abstracted per industry. This can also be detailed by distinguishing groundwater from surface water.

The finding is that the proposed WUE indicator can be calculated on an annual (or biennial basis). This is because the underlying calculations can be executed completely and combined with the application of the correct shares of the three before mentioned sectors in abstraction.

In addition, more detailed information can be derived from the available data, statistics, NAs and SEEA Water Accounts. For example, indicators by detailed industry can be compiled. Statistics Netherlands collects the required data on a regular basis and compiles the relevant tables both for the economics and environmental and resource statistics accounts. The results are published in recurring annual publications, such as 'National Accounts of the Netherlands' (CBS, 2012 – 2016), 'Environmental Accounts of the Netherlands' (CBS, 2010 – 2015), 'Green growth of the Netherlands' (CBS, 2011 – 2015), 'The Dutch economy', and monitor sustainability of the Netherlands.

Potential for disaggregation of data
Disaggregation is possible in several dimensions:

1. The economic data in NA is available on an annual basis, on a quarterly basis, and in consistent time series (after ESA 2010 revision);
2. The economic data from NA monetary Supply and Use tables can get disaggregated to ISIC-industry level for a total of 60 – 70 industries (publication levelshable);
3. The same holds for the physical water data in the form of PSUT-Water, and disaggregated to 60 – 70 industries (publication level);
4. For both the economic and physical water variables in the WUE, the equation can even be disaggregated per industry, allowing for much more detailed WUE – computation by industry. Once combined, WUE indicators for detailed each industry and water type can be compiled;
5. Economic data in NAs can be disaggregated to either regional or provincial levels (12*), by COROP-area or COROP-region (40*);
6. Part of the water data can be disaggregated to the 7 (Sub-) river basins; and
7. The current practice of updating part of the water data once every two years (due to budget limitations) could potentially be increased and intensified to annual compilation practice again.

Results, some examples
The publication 'Environmental Accounts of the Netherlands' (see: Statistics Netherlands (CBS) (2013c & 2013b and 2014c & 2015b) often includes the calculation of water intensity, which is the inverse of the calculated WAU (or so-called 'water productivity'). Water use intensity for an industry can be defined as the use or abstraction of water in litres divided by its VA in euros,

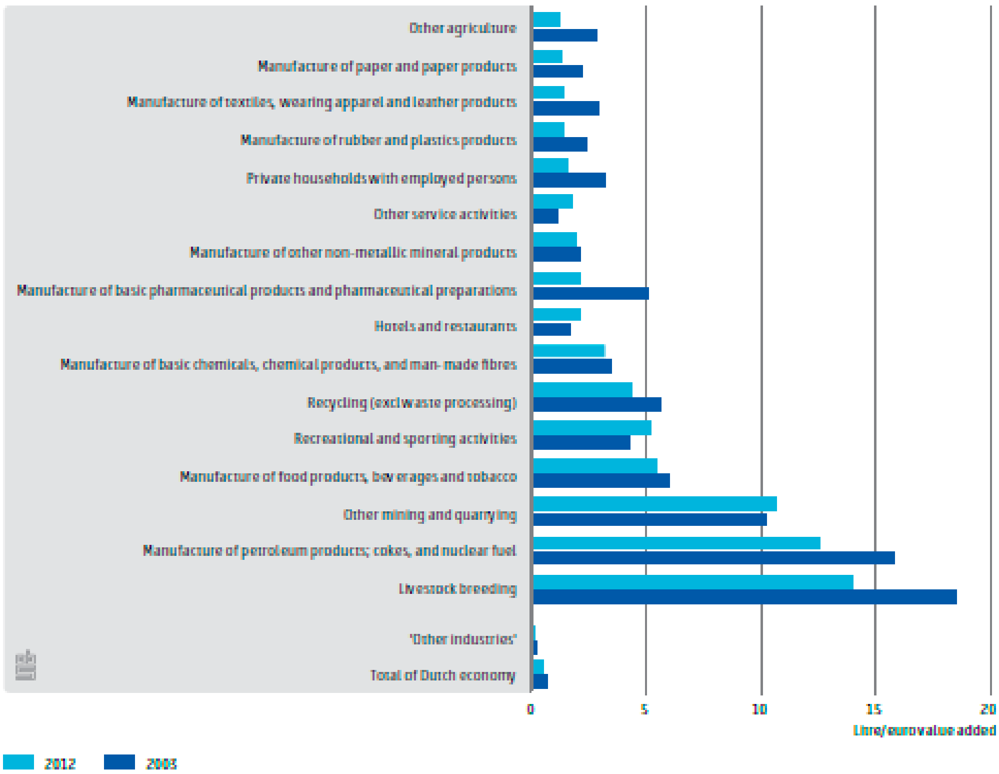
together resulting in a litre/Euro ratio. This can be done for each type of water either groundwater or surface water abstraction and for tap or drinking water and by detailed ISIC industry or for the drinking water intensity as supplied to each industry. The two figures show the results for the reporting year 2012.

Water use intensity

From the data in the above-mentioned publications, one can see that water use intensities in the Netherlands are on a downward trend. Whereas the size of the country's economy in VA grew by 15 percent between 2003 and 2012, tap water use was reduced by almost 10 percent over the same period. Over this nine-year period, the tap water use intensity of the production activities in the Dutch economy were reduced by 21 percent, implying an average annual reduction of over 2.5 percent. Almost all industries reduced their tap water use intensities for the 2003–2012 period (Statistics Netherlands (CBS) (2014c), Ch.3.1 Water use, Fig. 2.3.4).

Between 2003 and 2012, an average of 0.55 litres of tap water (drinking water) was used per euro of VA generated by the Dutch economy (Figure III.1). In 2012, this was reduced to 0.50 litres per euro, significantly less than the 0.63 litres in 2003. Livestock breeding, the manufacture of petroleum products, fuel coke, nuclear fuel and other mining and quarrying showed the highest water use intensity rates, followed by the manufacture of food products, beverages and tobacco, recreational and sporting activities, and recycling (excl. waste processing). In 2012, the 16 industries with the highest water use intensity rates (Figure IV.1) used up to eight times more water 'to earn a euro' than average for the Dutch economy.

Figure IV.1 Industries with the highest tap water use intensities, 2012



This figure refers exclusively to tap water of drinking water quality.

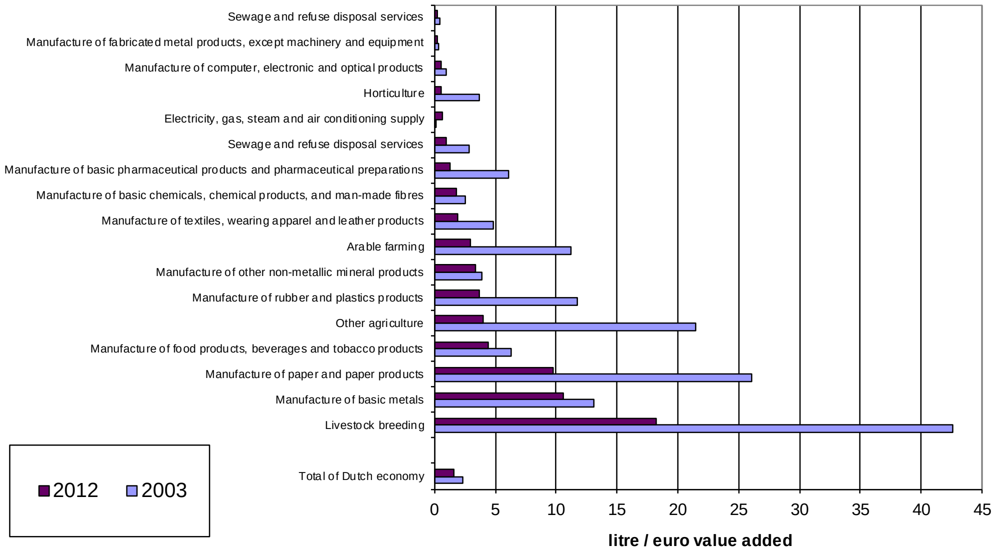
Source: Statistics Netherlands (CBS) (2014c), Ch.3.1 Water use, fig 2.3.4;

Groundwater intensity

Groundwater in the Netherlands is predominantly abstracted and used by the water supply industry, which dominates the groundwater abstraction in all river basins. This water is, however, largely be distributed to the other industries and households. Therefore, the water supply industry is excluded from the overview in figure III.2.

Figure IV.2 shows groundwater intensity across a selection of industries with higher groundwater intensities (and therefore lower water productivities) over two reporting years. On average, between 2003 and 2012, two litres of groundwater were abstracted for every euro of VA generated by the Dutch economy. In 2012, this was only 1.63 litres per euro, which is substantially less than the 2.32 litres in 2003[10]. In 2012, livestock breeding and manufacturing of basic metals, followed by the manufacturing of paper and paper products, food products, beverages, tobacco products, and other agriculture showed the highest groundwater use intensity rates. The industries with the highest use intensity rates used up to over ten times more water to earn one euro of VA compared to the average calculated for the Dutch economy overall in 2012.

Figure IV.2 Industries with the highest use intensities for groundwater, 2012*



Source: Statistics Netherlands (CBS) (2013b, 3.1 Water use & 2014c, Ch.3.1 Water use & 2015b, Ch.2.9 Groundwater abstraction; Statistics Netherlands (CBS) (2016c; Data from: Statistics Netherlands (CBS) (2016d), with some processing.

* This graph shows groundwater use intensities, which are opposite to groundwater productivity.

In analysing longer time series data for water intensities, it can be seen that the size of the economy in terms of VA has more than doubled since 1976, while tap water use and water abstractions from the environment have hardly grown and even contracted. As a result, the water intensity of the Dutch economy has been halved for tap water use and groundwater abstractions and close to halved for surface water abstractions. Generally, each subsequent year, economic performance improved while the water use and abstraction from water resources diminished or remained constant (Statistics Netherlands (CBS) (2013b, §3.1 Water use).

[10] Value Added in calculation for the two years was expressed in 2010 constant prices.

Table IV.1 provides an example of the data for two reporting years that can be used for the calculation of the Total Renewable Water Resources (TRWR) in indicator 6.4.2. Data from 2009 have already been published (Graveland & Baas, 2012); data from 2014 will be published in Q1 of 2017. Table IV.2 gives an example of available data on total water withdrawal for the years 2008, 2010 and 2012. Figure IV.3 shows a time series of the total freshwater withdrawals with a distinction between withdrawals of groundwater and surface water.

Table IV.1 Available data on Total Renewable Water Resources

Component (unit: M m3)		2009	2014[2)]
Internal Renewable Water Res. (IRWR)	Precipitation (P) [1)]	28,294	31,644
	Actual ET (Act ET) [1)]	17,022	20,005
	Internal flow = P – Act ET	11,273	11,638
External Renewable Water Res. (ERWR)	Surface water	67,962	70,644
	Groundwater	N/A	N/A
Total Renewable Water Res.[3)] (TRWR)		79,235	82,282

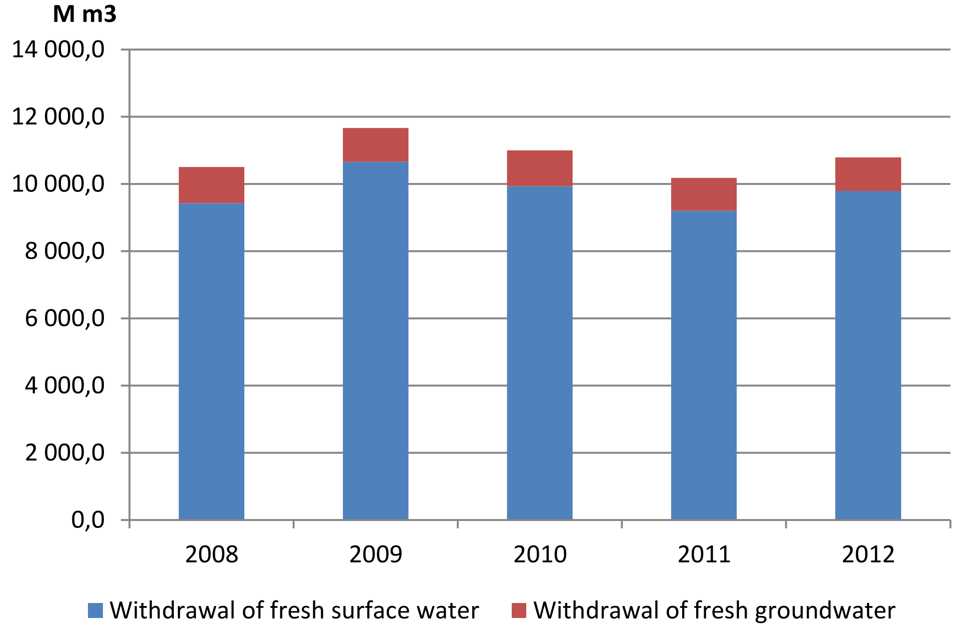
1) Source: eLEAF (see also paragraph 4.3).
2) Preliminary data.
3) Not taking into account the external flows of groundwater.

Table IV.2 Freshwater withdrawal per main economic sector (Statistics Netherlands, 2016)

Million m^3	2008	2010	2012
Withdrawal of fresh surface water, total	**9,430**	**9,926.7**	**9,783.8**
of which by			
Agriculture (ISIC 01-03)	21.0	26.3	6.4
Mining, manufacturing industry (ISIC 06-33)	2,762.4	2,741.1	2,836.3
Energy sector (ISIC 35)	5,724.3	6,136.0	5,956.8
Water companies (ISIC 36)	489.8	456.3	463.7
Environmental services (ISIC 37-38)	432.3	566.9	520.6
Other sectors (ISIC 41-97)	0	0	0
Withdrawal of fresh groundwater, total	**1,075.4**	**1,066.1**	**999.5**
of which by			
Agriculture (ISIC 01-03)	51.2	97.4	54.3
Mining, Manufacturing industry (ISIC 06-33)	168.3	130.9	126.7
Energy sector (ISIC 35)	1.7	5.1	4.9
Water companies (ISIC 36)	762.2	760.8	753.6
Environmental Services (ISIC 37-38)	1.4	2.2	1.3
Other sectors (ISIC 41-97)	90.7	70.0	58.8
Total freshwater withdrawal TWW	**10,505.4**	**10,992.8**	**10,783.3**
of which by			
Agriculture (ISIC 01-03)	72.2	123.7	60.7
Mining, manufacturing industry (ISIC 06-33)	2,930.7	2,872.0	2,963.0

Energy sector (ISIC 35)	5,726.0	6,141.1	5,961.7
Water companies (ISIC 36)	1,252.0	1,217.1	1,217.3
Environmental services (ISIC 37-38)	433.7	569.1	521.9
Other sectors (ISIC 41-97)	90.7	70.0	58.8

Figure IV.3: Withdrawals of freshwater, 2008-2012 (CBS, several reports)



Sources: Statistics Netherlands, 2016c; 2016d; 2014b; 2014c).

Potential for disaggregation of data for indicator 6.4.2

Table IV.3 provides an overview of the available years for the four components of the indicator, as well as the spatial and temporal disaggregation possibilities of currently available data for future datasets.

Table IV.3 Spatial and temporal disaggregation of data from Statistics Netherlands

Component	Dataset	Spatial disaggregation	Temporal disaggregation
Precipitation (P) [1)]	2009, 2014	Grid 250 m x 250 m	Monthly
	Future years	Grid 250 m x 250 m	At least monthly
Actual ET (Act ET) [1)]	2009, 2014	Grid 250 m x 250 m	Monthly
	Future years	Grid 250 m x 250 m	At least monthly
External inflow	2009; 2014	River Basin, gauging station	Daily stream flow
Total Withdrawal	2001-2014	River Basin	Yearly
Environmental flow	No statistics	-	-

1) Available via eLEAF (see also paragraph 4.3)

The spatial GIS-based data will facilitate the aggregation to each administrative unit or water policy-relevant area, such as a river basin.

Annex V Remote sensing based data for SDG 6.4

Calculating AET

AET is driven by the available solar energy, weather conditions (air temperature, humidity and wind speed), and the moisture content in the soil. Over the past decades, several algorithms have been developed to calculate the ET with remote sensing data. These algorithms use the surface energy balance, which is based on the principle that the incoming radiation, if not reflected, heats the ground, the air, or is used for ET. Figure IV.1 shows a schematic diagram of the surface energy balance, with the arrows indicating the different energy fluxes. Remote sensing data is used to solve the energy balance. The algorithms behind these calculations are not explained here; additional information on SEBAL and ETLook can be found in Bastiaanssen et al. (1998, 2012).

SDG 6.4.1: AET to irrigation water use

The basic AET data based on remote sensing consists of raster maps that depict the amount of ET in mm for each pixel. The raster maps represent a specific period, which generally varies from daily to yearly. In the latter case, the data has been aggregated from smaller time units, as yearly average values cannot be used to calculate AET. The best results are obtained when calculation takes place on a daily basis.

AET has to be converted to match the reporting format of SDG 6.4.2. This requires a number of steps:

Agricultural land selection: Satellite remote sensing-based data is generated for the whole area under observation, including forests, urban areas, etc. All non-agricultural land has to be excluded from the dataset. Land cover maps can be used to identify the agricultural areas within a country. Other sources can also be used to identify the agricultural area, such as cadastral data on field boundaries. For the Netherlands, 'Basisregistratie Gewassen' contains the exact field boundaries, as well as annually updated information on the crops grown in the field. When crop type information is available, water use efficiency can also be disaggregated to the crop level.

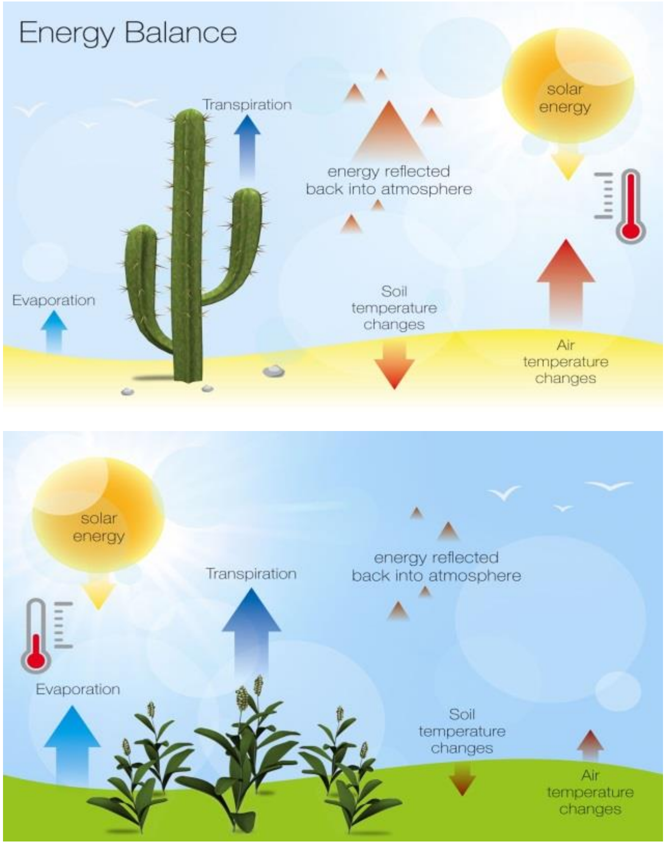


Figure V.1: Energy balance over a desert area and an irrigated field.

Temporal aggregation: AET is only relevant during the growing season when considering crop water use. Therefore, the start and end of the season have to be identified. This data is often available at the national level, based on long year-average crop phenology. Some global datasets are also available, based on satellite data. These have the advantage of a better incorporation of annual variability, but often have information on a limited number of crops.

Irrigation withdrawal conversion: SDG 6.4.2 focuses on irrigated water use. This cannot be derived directly with satellite data, as the source of the water (rainfall or irrigation) cannot be distinguished. Some methods exist to estimate this with AET and P data. In areas where irrigation is the main source of water supply, these methods work well. Where rainfall is the dominant water source, additional field information may be required to get a good estimate. The latter can also come from modelled data, as described in Chapter 4.4.
Furthermore, SDG 6.4.2 focuses on water withdrawal, not on water consumption by the agricultural sector. AET is comparable to the crop water consumption; hence, a correction with the irrigation efficiency is required to get the irrigation water withdrawal.

Spatial aggregation: The raster data is aggregated to the required administrative unit, such as country level. Obviously, much spatial information on water use is lost when aggregating to country level. Although not required for SDG reporting, countries may want to use the higher level of spatial detail for their own targeted actions to improve water use efficiency.

Annex VI-1 Model based data for SDG 6.4 (NHI)

General

Related to the summary given in the main text of paragraph 4.4, this annex contains the extended description of the NHI model and the available components and parameters needed for compiling the indicators.

Brief description of NHI

The Netherlands Hydrological Instrument (NHI) is built with the best available data and top-of-the-line software, and developed through collaboration between water management and engineering companies and national research institutes. The NHI is currently applicable on national and regional levels and different temporal scales; it contains a number of coupled model concepts and software related to:

1. The saturated zone (groundwater),;
2. The unsaturated zone;
3. Regional surface water; and
4. National surface water.

Refer to Figure V-1 for a schematic overview. The national application of NHI is mainly targeting water movement under average and dry circumstances and is used for policy analysis (e.g. the national Delta Programme), different research topics on water management, as well as real-time drought monitoring. In addition, the NHI also aims at regional applications with a focus on a regional analysis of ground and surface water systems, for example in looking at water stress and water safety (De Lange, et al., 2014).

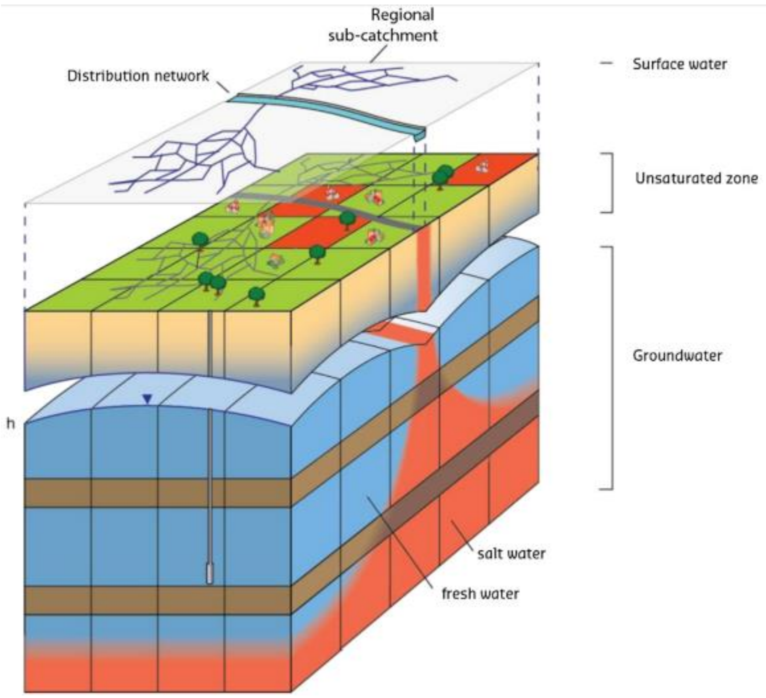


Figure VI-I: Schematic overview - the water domains covered by the hydrological models in NHI

NHI calculates the daily water withdrawal based on water demand and water availability. Water withdrawals are divided into surface water, unsaturated and saturated groundwater, and are interactively calculated by the different NHI components. A subdivision is made between withdrawal for agricultural purposes and industrial and services supply extractions. The water demand for irrigation can be specified in time and space, and distinguished between groundwater and surface water and will be explained in more detail. This is visualized in Figure V-2. The proportion of rain-fed agriculture for the Netherlands can be calculated with this map as well.

The total arable area with irrigation is determined from the “landbouwtellingen”, and by estimating it is known how much of the total area is irrigated with surface water (50%) and by groundwater-fed irrigation (50%). Additionally, for larger regions, the total amount of irrigational area (in ha) is known per land use type. Rules of thumb (considering, among others, the specific soil characteristic parameters and drainage characteristics) are used to provide detailed model input for irrigation per 250 m cell (Massop et al., 2012). The model calculates the irrigation needed depending on the available moisture storage in the root zone. An example of the total yearly irrigation flux for both groundwater and surface water-fed irrigation calculated with the NHI model is shown in Figure V-3.

The total water demand of the industrial sector and the water supply for households is available in the NHI as point measurements at specific locations. With the modelling approach, abstraction effects can be analyzed and visualized spatially. For industry, only large extractions are included, but in case of drinking water extractions all known withdrawal locations and amounts are included. Extraction rates are given in m^3/day and serve as input data for NHI. The total extraction (or infiltration) rates per day are based upon the most recent information (Leunk et al., 2012) and the total permitted amount per year; if needed, these are divided over several soil layers and model cells (distributed spatially). Yearly variations of the extracted discharges are not taken into account. The total national well flux for a specific modelled time period is available as an output variable in the calculated water balances. Related economic effect models to calculate the gross VA by the industrial and services supply sectors at a national scale are not yet available to be coupled to the NHI.

Besides water demand for agriculture, industries and public supply, other water demands can be also analysed, such as the water demand in natural areas. With the NHI, water demand and water stress for vulnerable and non-vulnerable natural areas are calculated for decision-making regarding water supply during dry periods (see Figure V-4). Water management of the vulnerable natural areas receives in practice as well as in the model higher priority. The use of this kind of model information may complete the monitoring of the efficiency of water use.

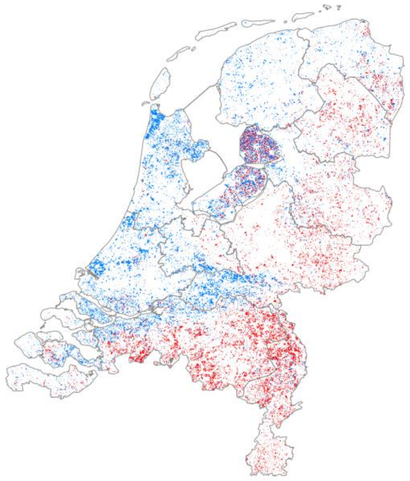


Figure VI-1: Potential irrigation locations in the Netherlands from groundwater (red), from surface water (blue) and without irrigation (white), on a 250 m horizontal resolution grid to provide input for NHI.

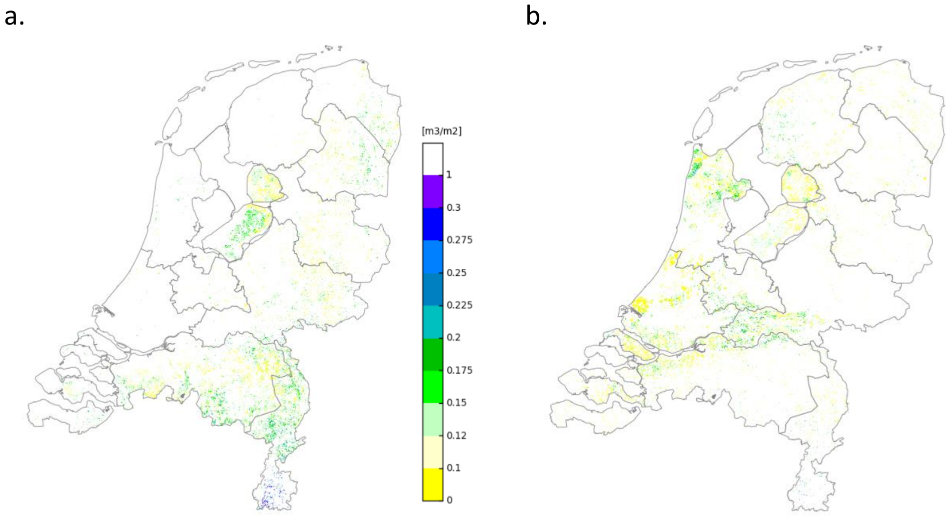


Figure VI.2: MetaSWAP yearly irrigation flux (m^3/m^2) calculated for the year of 2010 from groundwater (a) and from surface water (b)

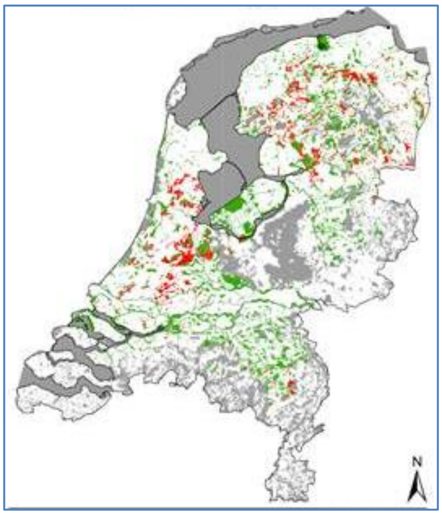


Figure VI-4 Overview of the Dutch nature areas split by vulnerable nature areas (red) and non-vulnerable nature areas (green) to calculate water demand for vulnerable natural areas

Table VI-1 overview of the data availability in the NHI model per component of the 6.4.1

Parameter	Sub-parameter	Related NHI parameter(s) description	Resolution
A_{we}	C_r	Irrigation maps: • Total arable land + land use map • Irrigated arable land Nearly 20% of agricultural area is irrigated	MetaSWAP output: Spatial: 250x250 m Temporal: daily
	GVA_a	Available through the Agricom coupling	Agricom output Spatial: 250x250 m Temporal: yearly and 10 day timesteps
	V_a	Flux grids with volume per area (m^3/m^2): • ground water extraction (qspgw) • sprinkling precipitation P (from groundwater: Psgw) • sprinkling precipitation P (from surface water: Pssw) Total area of agricultural sector is 367105 ha	MetaSWAP, MODFLOW, and MOZART output Spatial: 250x250 m Temporal: daily
I_{we}	GVA_i	Not available	
	V_i	Well fluxes in m^3/day (combined with drinking water supply extractions)	MODFLOW output (groundwater) and MOZART/DM output (surface water) Spatial: point measurements and grid based (250x250 m) Temporal: daily and yearly
S_{we}	GVA_s	Not available	
	V_s	Well fluxes in m^3/day (combined with industrial extractions)	MODFLOW output (groundwater) and MOZART/DM output (surface water) Spatial: point measurements and grid based (250x250 m) Temporal: daily and yearly

Table V-2 overview of the data availability in the NHI model per component of the 6.4.2, in addition to Indicator 6.4.1

Parameter	**Sub-parameter**	**Related NHI parameter(s) description**	**NHI model concept**
$TRWR$	$IRWR$	River fluxes in m^3/day Recharge fluxes in m^3/m^2: • precipitation flux (Pm) • evaporation fluxes (Esp, Eic, Epd, Ebs)	DM/Mozart output Spatial: point measurements Temporal: daily or 10 day time step MetaSWAP-MODFLOW output grid based (250x250 m) Temporal: daily
	$ERWR$	Transboundary fluxes River discharges at country borders (m^3/s)	MODFLOW output grid based (250x250 m) Temporal: daily DM/Mozart input Spatial: point measurements Temporal: daily or 10 day time step
AWW	WW Irrigation	Flux grids with volume per area (m^3/m^2): • ground water extraction	MetaSWAP output grid based (250x250 m) Temporal: daily
	WW Livestock	Not available	
	$WW\ Aquaculture$	Not available	
IWW	-	Well fluxes in m^3/day (combined with drinking water supply extractions)	MODFLOW input grid based (250x250 m) Temporal: monthly And DM input Spatial: districts Temporal: yearly
MWW	-	Well fluxes in m^3/day (combined with industrial extractions)	MODFLOW input grid based (250x250 m) Temporal: monthly And DM input Spatial: districts Temporal: yearly

Annex VI-2 Model based data for SDG 6.4 (PCR-GLOBWB)

General

Related to the summary given in the main text of paragraph 4.4, this annex contains the extended description of the global model PCR-GLOBWB and the available components and parameters needed for compiling the indicators.

Brief description of PCR-GLOBWB

PCR-GLOBWB is a calibrated and validated hydrological model intended for global to regional studies. This model has been developed at the Department of Physical Geography of Utrecht University (the Netherlands) and has been applied in several studies regarding global and regional water assessments. PCR-GLOBWB has also been coupled to water quality models, groundwater models, and water distribution models. PCR-GLOBWB is constantly being reassessed through the different applications in several projects.

PCR-GLOBWB is a grid-based model with a cell size of 5 by 5 arcminutes (approximately 10km at the Equator) that represents terrestrial hydrology on a daily basis. It calculates a daily water balance between buckets representing different parts of the hydrological system. The model runs for the period of 1970 to 2010, and is currently being extended to cover more recent years.

The calculations are done on a cell-by-cell basis. For each grid cell, PCR-GLOBWB uses process-based equations to compute moisture storage in two vertically stacked soil layers. It also computes the water exchange between the soil and the atmosphere and the underlying groundwater reservoir. Exchange to the atmosphere is comprised of precipitation, evapotranspiration, snow accumulation and melt, all of which are modified by the presence of the canopy and snow cover. The exchange with the underlying groundwater reservoir comprises deep percolation, capillary rise, and vertical fluxes. All fluxes in PCR-GLOBWB are shown in Figure V-5.

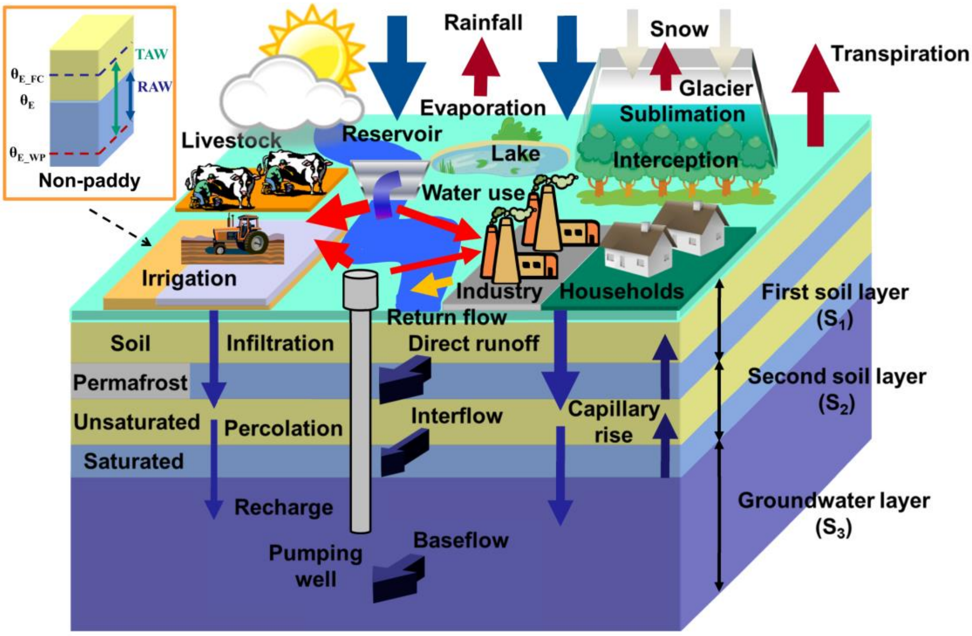


Figure VI-3 Schematisation of PCR-GLOBWB (Wada et al., 2013)

Water availability and water demand calculation is integrated to dynamically simulate water use at a daily time step and to account for the interactions between human water use and terrestrial water fluxes. The main goal of this integrated modelling framework is to estimate actual water use (i.e., withdrawal and consumption) rather than potential water demand (independent of available water).

Water withdrawal at a global level

PCR-GLOBWB calculates the daily water withdrawal based on water demand and water availability. Water withdrawal is divided into surface water and groundwater by means of an allocation scheme that assesses the available water in both systems. It is also divided into withdrawal for irrigation, livestock, industry and domestic use. The data has a cell size of 5 by 5 arcminutes and is available at daily time steps for the period 1970-2010. This allows for several temporal and spatial aggregations.

The separation between groundwater and surface water withdrawals is calculated based on surface water availability, including local and upstream reservoirs and available groundwater reserves. The amount of groundwater extracted is calculated as a fraction of the total water demand. The fraction used is the simulated daily baseflow against the long-term average river discharge. This fraction is considered the readily available amount of renewable groundwater reserves for a given day.

The irrigation water withdrawal is calculated based on an irrigation scheme dynamically linked with the daily available surface and soil water. The link between irrigation, surface water and soil balance changes the amount of soil moisture and therefore also the irrigation requirements. In this way, the daily state of the soil moisture can be better estimated and the evaporation and crop transpiration of irrigated areas as well. Moreover, the model separates paddy and non-paddy crops. The paddy crops are schematized as crops irrigated with flooding, while the non-paddy have other types of irrigation. A crop-specific calendar and the growing seasons are used to calculate the crop per cell, and crop coefficients per crop development stage are assigned to them. Irrigation applied is such to ensure an optimal crop growth. The irrigation scheme also includes dams and reservoir information. For a complete description of the irrigation water withdrawal, we refer to Wada et al., 2014.

Industrial water demand is also an input for PCR-GLOBWB. The calculation is based on gridded industrial demand for the year 2000 obtained from Shiklomanov (1997), WRI (1998), and Vörösmarty et al. (2005). Industrial water demand is constant over the year as seasonal data is not globally available. In order to extrapolate the industrial water demand to the other years, the water demand for the year 2000 was multiplied by water use intensities calculated based on country-specific economic development. The development is based on gross domestic product, electricity production, energy consumption and household consumption. The algorithm used to estimate the development can be found in Wada et al. (2011a).

Livestock: livestock water withdrawals are an input for the model and are calculated based on livestock water demand. In the model, the number of livestock in a cell is multiplied by the corresponding daily drinking water requirement, which is a function of daily air temperature (Wada et al., 2011b). The data on livestock density is obtained from FAOSTAT (FAOSTAT; http://faostat.fao.org/) and downscaled to each cell size using the FAO (2007) data for the year 2000.

Note that withdrawals for the aquaculture sector are not considered in PCR-GLOBWB.

Water withdrawal for the households are considered in PRC-GLOBWB, not the entire services sector. Population density per cell multiplied by the domestic water withdrawal was used to estimate the water withdrawal per cell. This dataset is also an input for PCR-GLOBWB. Daily water demand was estimated using air temperature data. Per capita water withdrawals per country for the year 2000 were obtained from the FAO AQUASTAT database. To extrapolate the data for the other years, water use intensity based on economic and technological development was used (same as for the industrial water demand). The global population maps per decade from Klein Goldewijk and van Drecht (2006) were used to downscale the FAOSTAT yearly population data to create gridded maps for each year.

Table V-III gives an overview of the data availability in the PCR-GLOBWB model per component of the 6.4.1 indicator.

In addition to the data mentioned for indicator 6.4.1, PCR-GLOBWB provides, on a global scale, the following information for total renewable freshwater resources:

- Total runoff calculated per cell; this includes direct runoff, interflow, base flow and groundwater recharge (internal);
- Sum of the river discharges at country borders (related cells); and
- Transboundary flow

Transboundary flow is calculated by a combination of PCR-GLOBWB and the global MODFLOW model (De Graaf et al, 2015). The global-scale groundwater model was built using the USGS code MODFLOW. It is a 3D groundwater numerical model with a cell size of 5 by 5 arcminutes, just like PCR-GLOBWB. The model consists of 2 model layers simulating a top layer, often partly impermeable or otherwise simulating a shallow aquifer, and a deep layer, simulating a deep aquifer. The model is available for the period 1960-2010 with monthly time steps. This groundwater model has been dynamically coupled with PCR-GLOBWB, meaning that there is an exchange of information between them. Specifically, PCR-GLOBWB produces groundwater recharge data, surface water levels, and information on groundwater abstractions. With this input and other information, the groundwater model calculates groundwater heads and a groundwater balance. The heads are sent back to PCR-GLOBWB to be used in the soil-water balance to calculate the groundwater recharge. A full description of the model can be found in de Graaf et al., 2015. To determine the transboundary flow, the cells following the country borders should be selected, the direction of the flow determined, and the flow added up (calculated).

Examples of calculations with the global models are shown in Figure V-6 – V-12 .

Table VI-III: overview of indicator components available in the PCR-GLOBWB model

Parameter	Sub-parameter	Related PCR-GLOBWB parameter(s) description	Resolution
A_{we}	C_r	Maps of global irrigated areas	Spatial: 5'x5' Temporal: yearly
	GVA_a	Not available	-
	V_a	Grid based maps are available. Irrigation water withdrawal (mm) calculation: • paddy (flood irrigation) and non-paddy crops (other irrigation types) • crop per cell (crop-specific calendar + growing season) • crop coefficients per development stage Livestock water withdrawal: • model input grids • calculated based on livestock water demand: o daily drinking water need o livestock density: FOASTAT Aquaculture: Not available	Spatial: 5'x5' Temporal: daily
I_{we}	GVA_i	Indirectly available via country-specific economic development estimation, based on: • gross domestic product • electricity production • energy consumption • household consumption	Spatial: 5'x5' Temporal: yearly
	V_i	Industrial water demand: • model input grids • total water demand 2000 • year constant value • water use intensities	Spatial: 5'x5' Temporal: daily
S_{we}	GVA_s	Indirectly available via country-specific economic development estimation, based on: • gross domestic product • electricity production • energy consumption • household consumption	Spatial: 5'x5' Temporal: yearly
	V_s	Water withdrawal per cell: • population density • domestic water withdrawal • FAO AQUASTAT database	Spatial: 5'x5' Temporal: daily

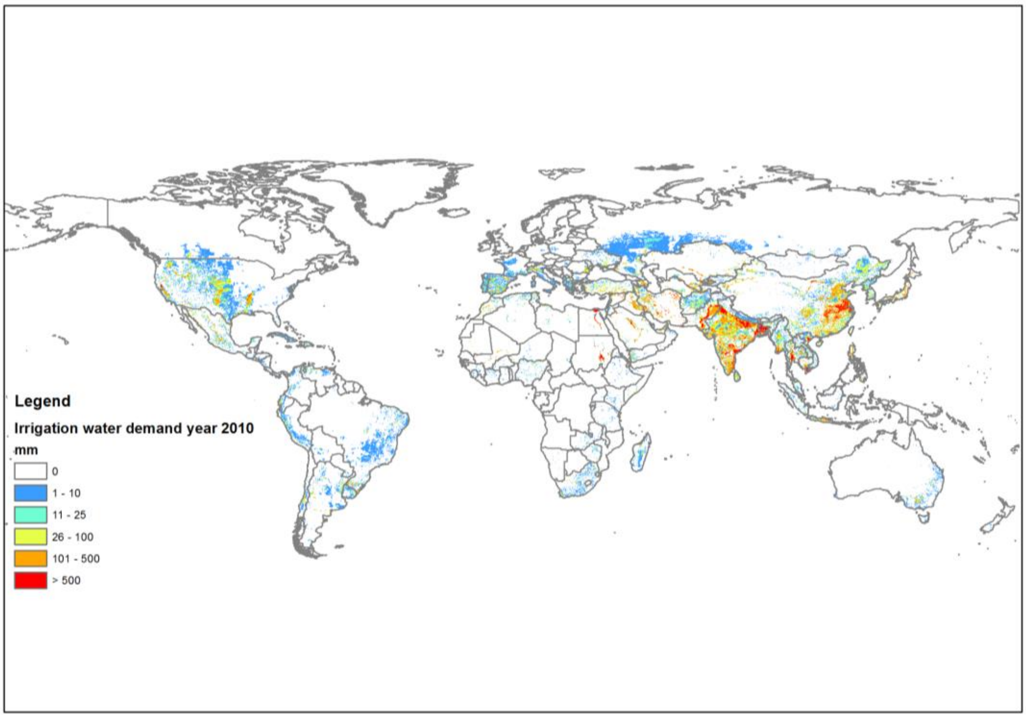


Figure VI-6 Total irrigation water demand for the year 2010 as calculated by PCR-GLOBWB

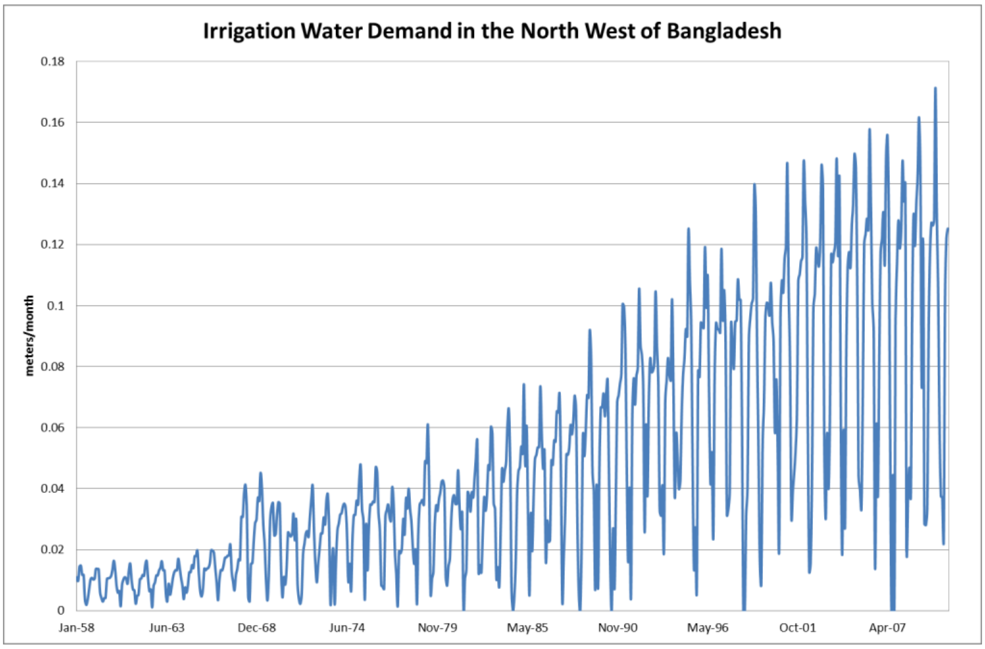


Figure VI-7 Example of a time series extracted from PCR-GLOBWB with monthly irrigation water demand for a random point in the northwest of Bangladesh. The data is presented in metres/month

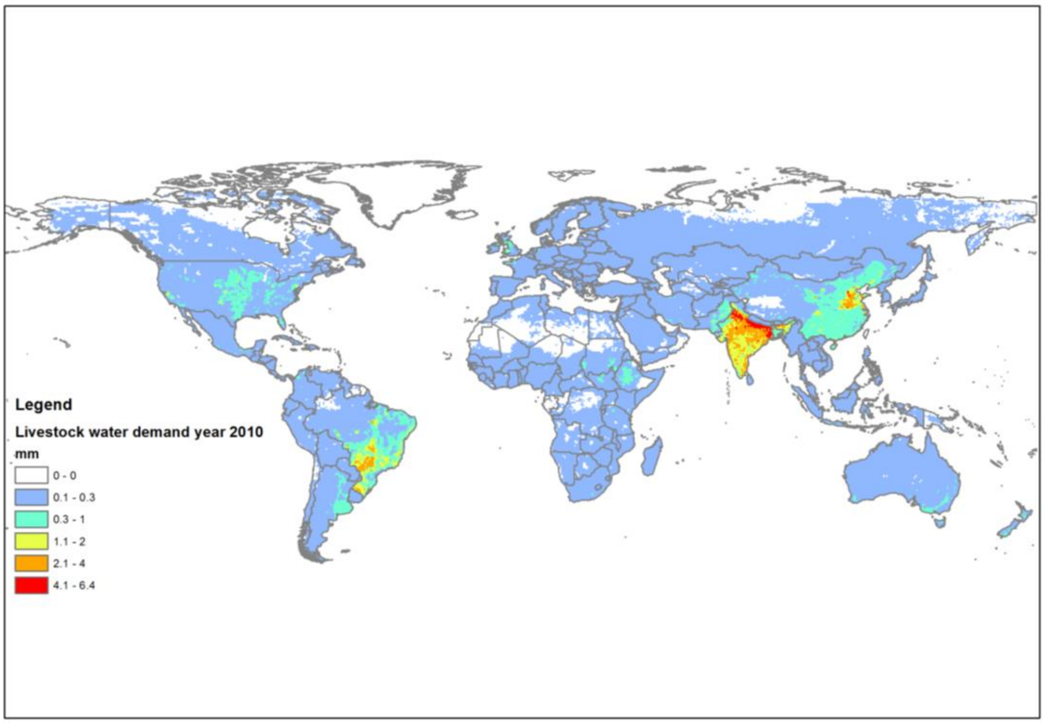


Figure VI-8 Total livestock water demand for the year 2010 as calculated to use as input in PCR-GLOBWB

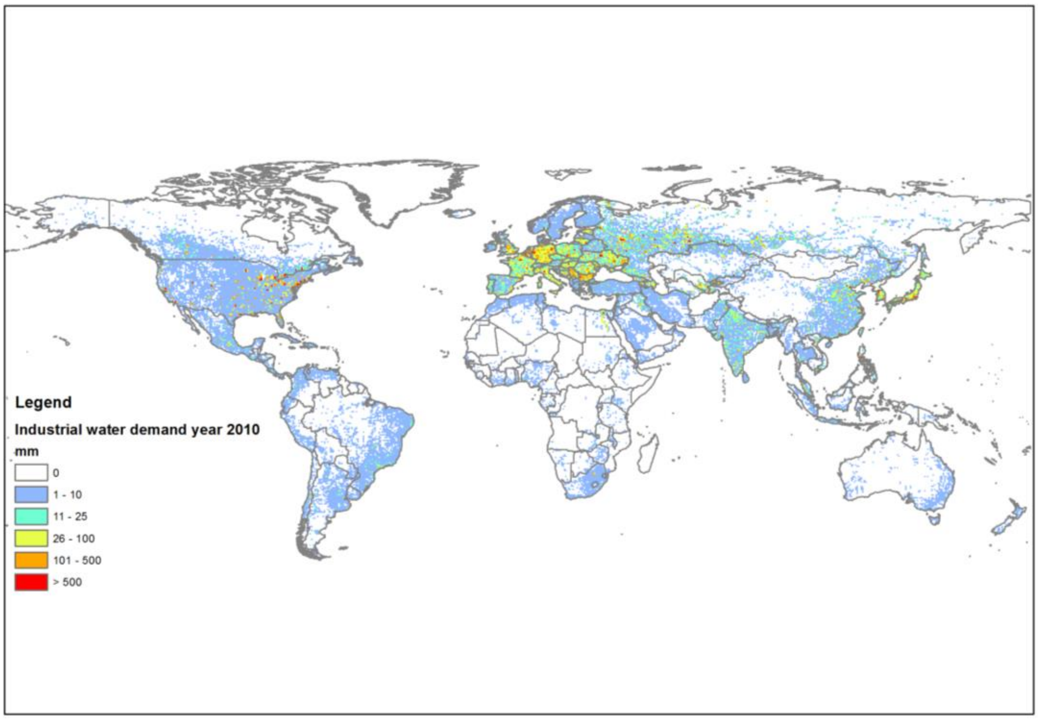


Figure VI-9 Total industry water demand for the year 2010 as calculated to be used as input for PCR-GLOBWB

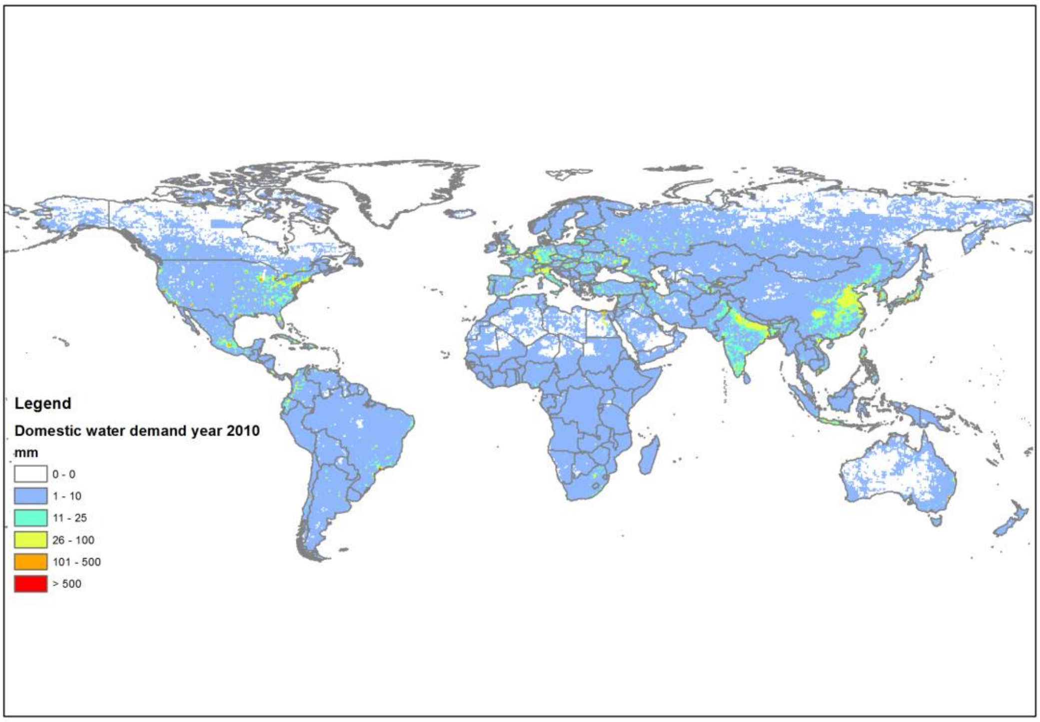


Figure VI-11 Total domestic water demand for the year 2010 as calculated to be used as input for PCR-GLOBWB

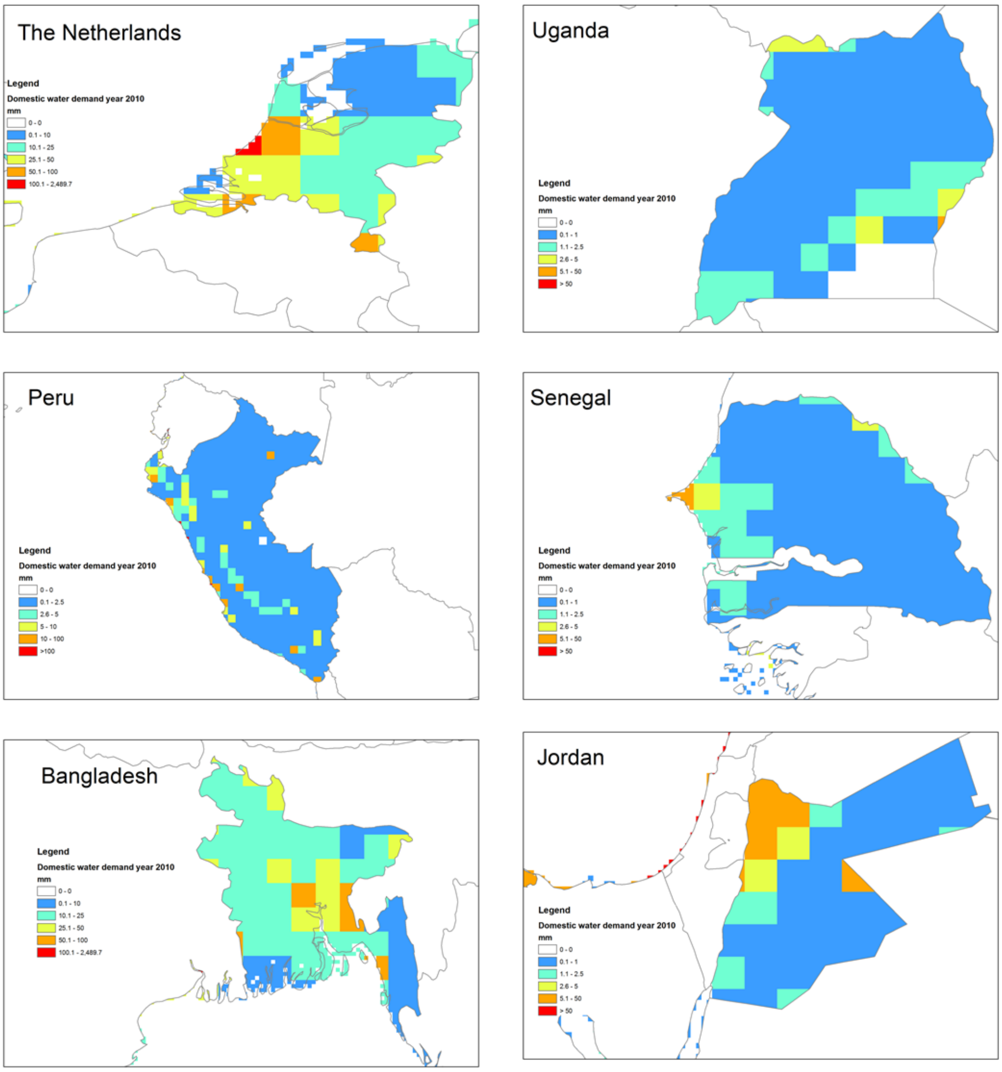


Figure VI-12 Detail for the 6 proof-of-concept countries of the water demand for domestic use averaged for the year 2010. Note: the legend is different per country and it is given in mm. In order to convert it to m^3, it needs to be multiplied by the area of the cell. The cell area is 5 by 5 arcminutes; the equivalent in metres is different per country depending on its latitude.

Annex VII Water Accounting +

Water Accounting + & ladder approach

This Annex provides information about the on-going work in the WA+ group at UNESCO-IHE, and the contribution the WA+ approach can give to the ladder approach of the SDG monitoring. It specifically discusses contributions to SDG target 6.4 which aims at ‘ensuring sustainable withdrawals and supply of freshwater to address water scarcity’. It also contributes to SDG 6.6 aiming at ‘protecting and restoring water-related ecosystems’.

Method description

Water Accounting Plus (WA+) is a newly developed reporting system on the total water resources conditions in river basins. The UNESCO Chair for Global Water Accounting is supported by DGIS. Partners for Water Accounting are FAO, CGIAR, UNESCO-IHE, UN Water. WA+ is meant to facilitate the longer-term planning of land use and water use practices and the benefits and services water consumption has for society. WA+ emerged from the need to have a rapid assessment for ungauged river basins. Global water scarcity analysis can be prepared only if an open access and standard approach on water flows and stocks exists. Then it can be brought under the attention of policy makers and NGO’s. WA+ reports with sheets, tables, and maps and is largely based on earth observations and global hydrological models. If untapped data is available through ground measurements (i.e. higher up the ‘ladder’) results can be more refined.

Data products

The sheets include thematic information on: resource base, beneficial and non-beneficial consumptive use, agricultural services, utilized flow, surface water flow, groundwater, ecosystems services (which is most relevant for SDG 6.6), and sustainability indicators. The sheet on utilized flow describes withdrawals, return flows and committed water flows (to environment and other sources). The sheet on sustainability can give insight in a trend of groundwater over abstraction or exploitation of surface water.

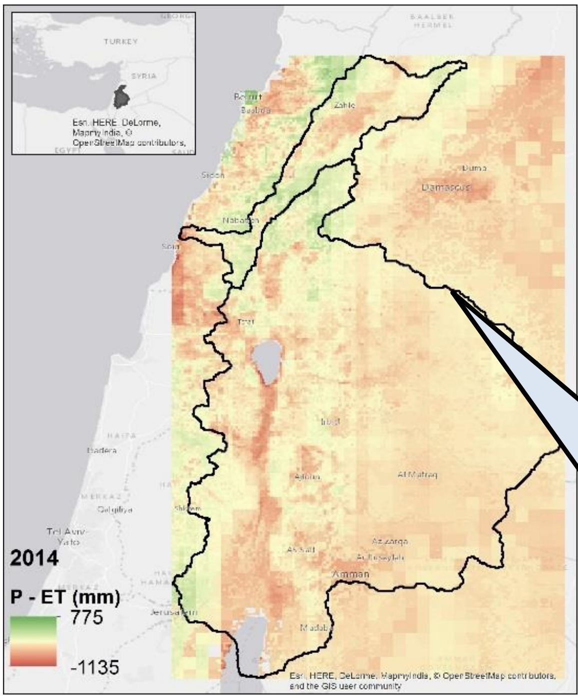


Figure VII.1 Water withdrawals

Show case:
Water withdrawals in the Near-East

Spatial datasets of precipitation (rainfall) and evapotranspiration (ET) are generated through remote sensing. This shows spatially which areas use more water than rainfall (negative P-ET coloured in red). If a trend of several years show the same pattern, it can indicate a potentially unsustainable situation for surface and groundwater resources.

Crop Water Productivity at Different Spatial Aggregation Levels

This Annex provides information about the on-going work in the WA+ group at UNESCO-IHE, and the contribution their methodology can give to the ladder approach of the SDG monitoring. It specifically discusses contributions to SDG target 6.4 which aims at 'substantially increasing water use efficiency across all sectors'.

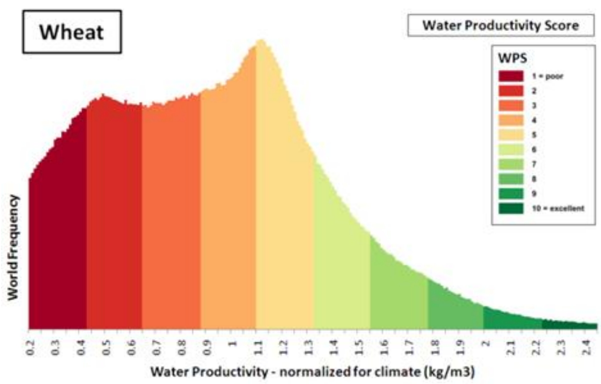
Progressive monitoring – providing the baseline
The idea of the ladder approach is that a baseline can be established for monitoring the agricultural water management conditions for each country. Two aspects are of importance for the baseline methodology. Firstly, monitoring should be possible independent of the country's economic situation, data availability, or political issues. Secondly, the baseline should provide trustworthy, accurate, and objective results. Remote sensing data provides an ideal dataset to fulfil both requirements for a baseline. It is objective, globally available, oftentimes for free, and provided at regular intervals.

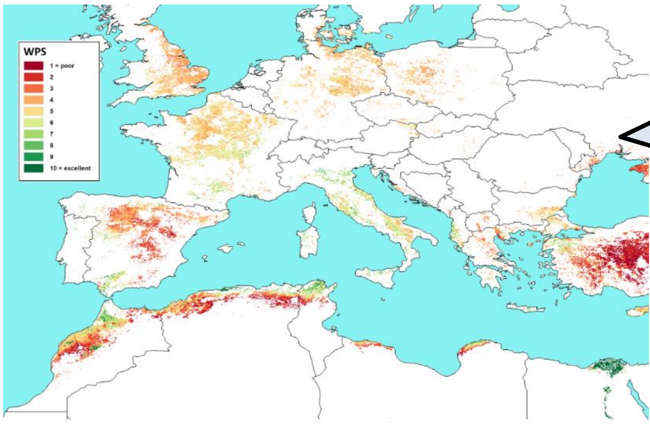
Method description
Following international standards laid down by CGIAR, certain UN organisations, and the Water for Food Institute, crop water productivity is defined as:

CWP = biomass or crop yield [kg] / volume water consumed [m^3]

Consumed water describes the amount of water involved to produce a certain crop, which is no longer available to downstream users in the river basin context. Both components (biomass and water consumed) can be computed from advanced remote sensing algorithms. Soon the FAO will provide water productivity data at different spatial scales, starting at the African continent at 250m resolution. UNESCO-IHE has developed pySEBAL (automated in Python coding language) to compute crop water productivity for all other cases not spatially covered by the standard FAO database at the proper spatial resolution.

Water Productivity Score
The SDG 6.4 specifically aims at increasing water use efficiency, however determining the target values for each country or region is a challenge. Also a standard reporting for different crops grown under different climatic regimes is not self-evident. Our suggestion is to use the Water Productivity Score (WPS), which gives scores relative to the range of water productivity values in given agro-ecological zones and production potentials. WPS is jointly developed between UNESCO-IHE and FAO and can help policy makers to set targets and monitor them.





Show case: Wheat WPS in the Mediterranean

The spatial distribution of WPS across the Mediterranean, indicates which areas perform relatively poorly. It also indicates that within a country there are areas with an excellent WPS, and other areas with poor WPS. Using this spatial information is more useful for managers, than using a country average, because areas for potential increase can be better identified.

Figure VII.1 Wheat WPS in Mediterranean