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Recommendation for Life Cycle Inventory Analysis for Water Use and Consumption

Working Paper

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1 Abstract

1.1 Purpose

Water stress and environmental impacts related to water consumption are an emerging issue to be considered in life cycle assessment (LCA). Different life cycle impact assessment (LCIA) methods are available for the evaluation of water use and consumption. These methods require distinct information and therefore lead to different approaches on how to inventory, model and represent the water flows within the life cycle inventory analysis (LCI). Clear guidelines are thus necessary.

1.2 Methods

First we evaluate different LCIA methods and the terminologies used therein. Then an LCI method is proposed that allows a straightforward quantification of water flows and that can be used with different LCIA methods. It is furthermore harmonized with existing databases such as ecoinvent or the ESU data-on-demand.

1.3 Results

It is found that existing LCIA methods assess in most cases the blue water consumption and use. This requires a definition and implementation of new water flows in the inventories. Furthermore, the impacts of water use and consumption strongly depend on the region and its hydrological conditions. Therefore it is necessary to inventory water on a regional level. Country-specific and archetypical elementary flows are proposed. The application of the resulting LCI with two selected LCIA methods is shown with the example of bioethanol produced in different countries and from various feedstock.

1.4 Conclusions

The approach makes it feasible to assess water use and consumption. It can be used also in combination with existing databases such as ecoinvent as well as with different LCIA methods. It is recommended to investigate the water flows in the foreground system as far as possible with data differentiated according to the method proposed here.

1 Introduction

Water footprint is an emerging issue to be considered in life cycle assessment (LCA). Different life cycle impact assessment (LCIA) methods are available for the assessment of water use and consumption (e.g. Boulay et al. 2011; Frischknecht et al. 2009a; Goedkoop et al. 2009; Hoekstra et al. 2011; Milà i Canals et al. 2009; Pfister et al. 2009). These methods require different ways how to inventory the water flows within the life cycle inventory analysis (LCI). So far water flows are mainly characterised by the source (e.g. river, groundwater) or type of use (e.g. cooling, turbination) in existing LCI (de Beaufort-Langeveld et al. 2003; Hischier et al. 2001). This is the starting point for this paper. The key question addressed is:

How can we inventory the consumption of water in such a (practical) way that the LCI can be used with different LCIA methods investigating the "water footprint" of a product?

After evaluating the different LCIA methods and the definitions used therein we develop an LCI method that allows a straightforward identification and quantification of water flows and that can be applied by different LCIA methods in the impact assessment. It is furthermore harmonized with existing databases such as ecoinvent or the ESU data-on-demand (ecoinvent Centre 2010; Jungbluth et al. 2012).

An LCA study about bioethanol from different feedstock and regions serves as an example how to apply and use the LCI method proposed in this paper (Flury & Jungbluth 2012; Muñoz et al. 2012). The ecoinvent data v2.2 is used as background database and calculations are done with the LCA software SimaPro. The LCI method developed here is also applicable with other databases or software.

1.1 Definitions

A range of different terms is used in the context of water use and water consumption. There is no standard definition of them yet. As a base for the following, methodical discussions, some basic terms are listed and their definition is harmonised in Table 1.

The distinction between water consumption and water use is essential. While the water use covers nearly the whole off-stream water input and all types of water utilisation (e.g. cooling, irrigation etc.), the water consumption describes only the amount of water that is lost to a watershed as a result of the off-stream activities considered. Water consumption is sometimes also called "net water use" or "net water withdrawal". Three categories of water consumption are often distinguished: blue water extracted from surface- and groundwater, green water representing rain water stored as soil moisture and grey water.

The grey water is a virtual water flow representing the total amount of water needed to dilute polluted water so that background concentrations are reached again. It is an indicator for the pollution or the water quality, respectively. The particular definition of these types of water can vary slightly among the different studies and according to their scope and system boundaries. Table 1 shows a harmonised definition.

The analysis of the water consumption concentrates mainly on the quantity of the water. The degradation of the water quality is often assessed in separate impact categories (e.g. ecotoxicity or eutrophication).

Table 1 Definition of different terms concerning the water use and water consumption (based on Hoekstra et al. 2011; Milà i Canals et al. 2009; Pfister et al. 2009).

Water use	All types of water use; in industrial and agricultural processes, households; **not** including in-stream processes (e.g. turbinated water in hydropower).
	=
→ Water degradation	Part of the water use that is released back into the same water shed but with a changed water quality (chemically or physically), e.g. from agricultural fields or cooling
	+
→ Water consumption	Part of the water use that is not released into the same water shed due to evaporation, evapotranspiration, product incorporation, discharge into another watershed. The water is "lost" to the watershed, i.e. it is no more available to ecosystems and humans or only in a changed quality.
	=
→ Blue water consumption	Part of the consumed water that derives from surface water and groundwater. It is available to ecosystems and humans.
	+
→ Green water consumption	Part of the consumed water. Rain water that is stored as soil moisture and lost by the evaporation through the soil and the uptake through the plants.
	+
→ Grey water consumption	If not counted separately as water degradation, part of the consumed water. It describes the amount of water needed to dilute the load of pollutants to reach natural background concentrations. This is virtual water consumption.
→ Water borrowing	Part of the water use that is released back into the same water shed without a change in water quality. E.g. turbinated water. The water is unrestrictedly available for further use. Within our approach we do not consider this to be part of the water use.

1.2 Impact assessment methods

In this section we provide an overview of the published LCIA methods for the assessment of water consumption and use. For further details we also recommend the summaries provided by Kounina et al (in submission), Jeswani and Azapagic (2011) as well as Berger and Finkbeiner (2010). Bayart et al. (2010) provide not only an overview of the latest developments in this topic but they also discuss the most important aspects of water consumption as well as water quality issues.

The **ReCiPe method** (Goedkoop et al. 2009) adds up the m^3 of water used on a mid-point level but it is not considered in the end-point indicators. No weighting, characterisation nor regionalisation is implemented. The category indicator of the water depletion (WD) includes the water use from lakes, rivers, wells and unspecific natural origin.

The **Water Footprint** (Hoekstra et al. 2011) is a widely known and applied method to quantify the water consumption. The Water Footprint quantifies the blue, green and grey water of the direct (foreground system) and indirect (background system) water consumption. The Water Footprint does not measure or assess the related environmental impacts of the water consumption. The blue and green water consumption is defined by the crop water use (m^3/ha) and the yield. The grey water consumption is calculated from the chemical application rate to the field (kg/ha), the leaching-run-off fraction as well as the maximum acceptable and the natural concentration for the most important pollutant, i.e. the pollutant that yields the highest grey water volume. This approach cannot be applied in the usual life cycle assessment methodology because it requires unit process specific calculations instead of generic characterisation factors that can be applied on cumulative LCI results.

The approach of **Milà I Canals et al.** (2009) focuses on two impact pathways of freshwater consumption: the freshwater ecosystem impact (FEI) and the freshwater depletion (FD). The FEI describes the effects on the ecosystem quality due to changes in the freshwater availability as well as in the water cycles as a result of land use changes. For the FEI, a water stress index ($WSI_{Milà}$) for different river basins is defined. It is the ratio of the water withdrawal to the water available for human use after subtracting the needed amount of water for ecosystems (Smakhtin et al. 2004). The method of Milà I Canals et al. considers blue and indirectly green water consumption. Concerning the latter, Milà I Canals et al. (2009) argue that it does not have a direct impact on the environment and as a consequence it should not be considered in the LCIA. It is rather the change in land use that should be assessed as it affects the infiltration and the evapotranspiration and consequently the availability of freshwater to other users. The reduced long-term availability of groundwater due to its use is described by the FD. The baseline method for abiotic resources depletion in the CML 2001 guidelines (Guinée et al. 2001) is adapted for the development of FD characterisation factors.

In the approach of **Pfister et al.** (2009) characterisation factors are provided for the assessment of the environmental impact of water consumption. The method is adapted to the Eco-indicator-99 impact assessment method (EI’99, Goedkoop & Spriensma 2000). The focus lies on three areas of protection: human health, ecosystem quality and resources. The effects of water consumption on human health is characterised by the lack of water for irrigation, which consequently leads to malnutrition. The reduced availability of freshwater in ecosystems eventually leads to a diminished vegetation and biodiversity, and consequently to a reduced ecosystem quality. The damages to resources described by Pfister et al. (2009) follow the concept of the abiotic resource depletion applied in EI’99 (Goedkoop & Spriensma 2000), where the “surplus energy” (MJ) needed to make the resource available in the future is used as indicator. The approach of Pfister et al. (2009) considers the consumption of blue water. Green water is not included directly but it is mentioned that with the lack of blue water the availability of green water might eventually be reduced too. A water stress index ($WSI_{Pfister}$) relates the water consumption to the water availability and serves as mid-point characterisation factor.

Boulay et al. (2011) provide a regionalised approach for the assessment of the direct impacts of freshwater use on human health. They do not only differentiate between human users (e.g. domestic, agricultural, fishery) but also between water categories taking into account the water quality. The mid-point level quantifies the amount of water withhold from other users as consequence of water use. The water stress, the vulnerability to changes in the water availability of different users, their ability to adapt to these changes and the impacts on human health form the characterisation factor. This is combined with the volume of water consumed, which results in the potential impacts of human health due to the water consumption.

The **Ecological Scarcity Method** (Frischknecht et al. 2009a; Frischknecht et al. 2009b) is based on the availability and the scarcity, respectively, of the resource water. The scarcity of freshwater is defined according to the water stress index of OECD (2004): Share of water withdrawal to the available water resource (precipitation + inflows – evaporation). Based on national or watershed based levels of water consumption and the acceptable water stress index as suggested by the OECD (2004), eco-factors are defined. The eco-factors are applicable to all types of either water use or consumption except for the in-stream water use in hydroelectric power plants. If fossil (non-renewable) water is consumed, the eco-factors of the most severe water stress category are to be applied. The European research institute DG-JRC in Ispra recommends the Ecological Scarcity approach for the assessment of water use and consumption as a mid-point indicator in LCIA (Hauschild et al. 2011). In order to facilitate the comparison of the results using Ecological Scarcity 2006 with midpoint indicator results applying Pfister et al. (2011), the regionalised eco-factors are related to the average eco-factor of all OECD countries and quantified in m^3 OECD water equivalents per m^3.

There are no requirements and guidelines for the assessment and reporting of water footprints published by the **International Organization for Standardization (ISO)**[1] yet.

In Table 2 the main characteristics of the presented methods are summarized.

While the Water Footprint and the ReCiPe method simply summarize the water consumption and the water use, respectively, and do not assess its environmental impact, the other three specified methods include a characterisation step. The Water Footprint may serve as a good guideline in the data collection but not as LCIA method. Pfister et al. (2011), Frischknecht et al. (2009a) as well as Boulay et al. (2011) have developed methods which assess the impact of the consumption of water resources. While Frischknecht et al. (2009a) account for the resource availability and may additionally serve as a proxy indicator for environmental impacts caused by water stress, the method of Pfister et al. (2011) explicitly includes environmental impacts on resources, ecosystems and humans. The approach of Boulay et al. (2011) however does only consider the impacts on human health, omitting the impacts on ecosystem quality and the water resources. The water use is an integral part of the Ecological Scarcity Method (Frischknecht et al. 2009a). The method of Pfister et al. (2011) is easily combinable with the Eco-Indicator 99 (Goedkoop & Spriensma 2000). Both methods allow for the comparison of products and services on an endpoint level.

[1] http://www.iso.org/iso/home.html

Table 2 Overview of different approaches to quantify and assess the impacts of water use and consumption.

				Mode of calculation			**Water consumption categories**				**ecoinvent water flows considered**				
Method	**Indicator**	Water use	Water consumption	Summation of flows	Impact assessment	**Impact pathways**	Blue	Grey	Green	Regionalised approach	Water, river/lake	Water, unspec. nat. origin	Water, cooling	Water, turbine use	Water, well in ground
ReCiPe (Goedkoop et al. 2009)	Water depletion (m^3)	x		x		Water depletion (resources)				no	x	x			x
Water Footprint (Hoekstra et al. 2011)	Water consumption (m^3)		x	x		-	x	x	x	no					
Milà I Canals et al. (Milà i Canals et al. 2009)	Ecosystem-equivalent water (m^3) Abiotic depletion potential (kg Sb eq)		x		x	Freshwater ecosystem impact Freshwater depletion	x		(x)	no					
Enhanced Eco-indicator 99 (Pfister et al. 2009)	Characterisation by Water Stress Index (WSI). Midpoint: Impact on human health (DALY), ecosystem quality (PDF*m^2a) &resources (MJ surplus). Endpoint: EI99HA points		x		x	Human health Ecosystem quality Resources	x			yes	x	x			x
Human health impacts (Boulay et al. 2011)	Human health impacts (DALY)		x		x	Human health	x	(x)		x					
Ecological scarcity method 2006 (Frischknecht et al. 2006; Frischknecht et al. 2009a)	Eco-points (UBP)	x	x		x	Water scarcity (resources)	x			yes	x	x			x

2 Method

2.1 Inventory of the water flows

Water consumption is an emerging issue and most impact assessment methods do not consider the consumption of freshwater yet (Jeswani & Azapagic 2011). Furthermore, water consumption is not recorded in most life cycle inventory databases and the current list of elementary flows is incomplete. The water elementary flows in LCI databases such as the ecoinvent database cover only the water input to a product system. The water output so far was neither completely qualified nor quantified completely.

In Figure 1 all water flows to and from one unit process are illustrated. The elementary flows from surface water and ground water are shown on the left hand side. Ecoinvent distinguishes them according to the water sources (e.g. rivers, lakes, and ocean[2]) (Frischknecht et al. 2007). Rain water is an additional water flow into a system. It is not reported in ecoinvent so far. The water flows from a unit process are differentiated between water released back to the watershed where it was withdrawn from (surface runoff to rivers and lakes and into the soil), water that is directed to a treatment process and the water that is lost to the watershed. The latter includes water that is evaporated either through plants or due to industrial processes (e.g. evaporative cooling) and water that is embodied in products so that it is not available to the ecosystem anymore.

For the description of the complete set of water flows, additional elementary flows are needed and consequently implemented. They are provided with the respective country and archetypical codes that allows a specific assessment of the water consumption. The archetypes distinguished are based on the extended categories of water scarcity defined by the OECD (2004): low, moderate, medium, high, very high, and extreme water stress. On the input side, the water flow "water, unspecified natural origin, country XY" is implemented. It describes all the blue water input into a system, independent of the water source (lake, river, and ground). It stands for and replaces all the other, existing fresh water input flows of ecoinvent.

The turbinated water is still inventoried separately. The evaporation from hydropower reservoirs is directly modelled in updated inventories of hydroelectricity (Flury & Frischknecht 2012). Water evaporated is quantified as airborne emission "water, country XY". The elementary flow "water, embodied in product, country XY" represents the water embodied in the products. This is not exactly an elementary flow as the water is not released to nature but stays within the technosphere and thus it is a property of the reference product. Water embodied in a product which enters a new process is considered as water input too. The input of embodied water is inventoried as negative value and the output as positive value.

The evaporated and embodied water flows cannot be larger than the blue water input to the process as, in line with some approaches described above, we do not account for rain water and the evaporation, embodiment and outflows of rain water in the LCIA. However, it is recommended to consider the rain water inflow in the inventory for the sake of completeness. The flows "water, soil", "water, river" and "water, lake" describe the runoff into the soil and to surface water. They are not to be confused with the waste water flow: While the elementary flows describe the direct release of the water to nature, the waste water is first treated in the sewage plant before its release to nature. The "waste water, to treatment" is a process flow rather than an elementary flow. The sum of all water inputs equals the sum of the outputs. The water consumption is defined as the sum of the water evaporated and the water embodied in the product.

[2] Sea water is usually not considered in the water consumption. It is only mentioned for completeness. This applies also to the outflow "water, ocean" in case it is saline.

The water flows considered in the ecoinvent inventories report the water use but not the water consumption. As it is not feasible to complete all existing processes in the ecoinvent database with the new elementary flows, a simplified approach based on the original ecoinvent elementary flows is needed: Instead of changing the quality or quantity of the elementary flows, the modifications are made directly in the LCIA methods: Water consumption factors are introduced expressing the fraction of an existing elementary water flow consumed due to the activities in the product system (Table 3). As the factors only apply to the ecoinvent elementary flows, the newly implemented flows are not concerned. The combination of the factors and the new elementary flows covers the existing databases as well as newly inventoried processes.

Table 3 Consumption factors implemented for existing ecoinvent elementary water flows and for new elementary flows. The factors are applied on the LCIA methods Pfister et al. and Ecological Scarcity

Elementary water flow in ecoinvent and new elementary flows	**Consumption factor**	**Use factor**	**Sources**
Water, cooling, unspecified origin	0.05	1	Muñoz et al. 2010, Rosiek et al. 2010, Jefferies et al. 2011, Gleick 1994, Shaffer 2008, Stiegel & al. 2008, Scown & al. 2011
Water, lake	0.1	1	Shaffer 2008, Statistics Canada 2010
Water, river	0.1	1	
Water, well, in ground	0.1	1	
Water, rain	0	0	
Water, unspecified natural origin	0.1	1	Based on Shaffer 2008, Statistics Canada 2010
Water, turbine use, unspecified natural origin	0 [*])	0	The evaporation from hydropower reservoirs is directly modelled in this paper with updated inventories of hydroelectricity (Flury & Frischknecht 2012)
Water, salt, ocean	0	0	Frischknecht et al. 2009a; Goedkoop et al. 2009; Hoekstra et al. 2011; Milà i Canals et al. 2009; Pfister et al. 2009
Water, salt, sole	0	0	
Water, unspecified natural origin, country XY/archetype WSI [1])	0	1	
Water, country XY/archetype WSI [1])	1	0	
Water, embodied, country XY/archetype WSI [1])	1	0	

[*]) For the use of ecoinvent data v2.2 (Bolliger & Bauer 2007) a rought estimation with a consumption factor of 0.0005 is possible (average global electricity mix investigated by Flury and Frischknecht (2012)).

[1]) archetype WSI: six elementary flows covering low, moderate, medium, high. very high and extreme water stress

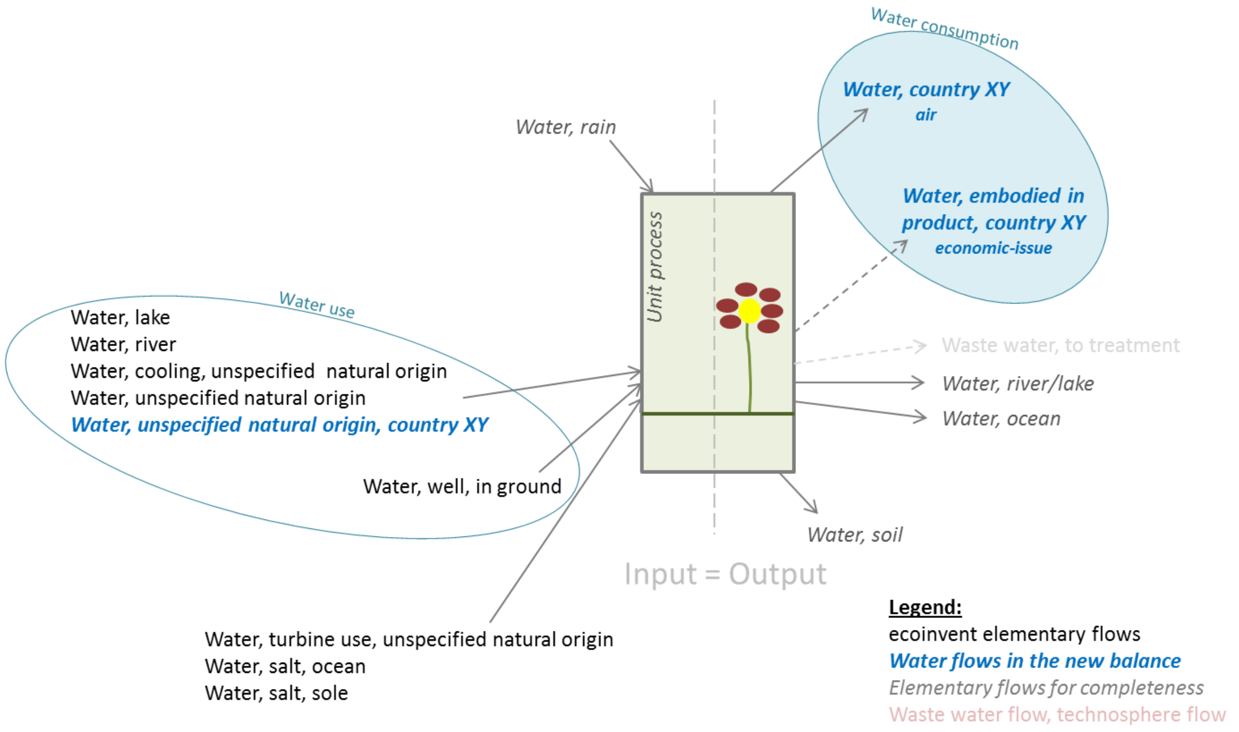

Figure 1 Exemplary water flow diagram of an agricultural unit process and graphical definition of the terms “water use” and “water consumption”.

2.2 Case study: water balance of bioethanol from different feedstock

The approach described above was applied first in a study on the bioethanol production from different feedstock: sugarcane from Brazil, US corn as well as sugar beet and wheat from France (Flury & Jungbluth 2012; Muñoz et al. 2012). The sugarcane cultivation is investigated for the Centre-South and the North-East area in Brazil. The corn cultivation is distinguished between the cultivation where only the grain is harvested and the stover is left on the field and the cultivation where both, grain and stover, are collected. For both commodities the bioethanol production stage is modelled separately.

The water balance of the agricultural stage is modelled based on CROPWAT (FAO 2009). From the precipitation during the cultivation period and the plant water requirement, the irrigation requirement is calculated. Losses are not considered. The water content of the product harvested is described by the “water, embodied, country XY”. As no losses are considered, the water evaporated is determined by the difference between the irrigation and the embodied water. The sugarcane cultivation in Brazil represents a special case. In addition to the rain and the irrigation, the sugarcane fields are also irrigated by the fertilization with vinasse, a nutrient-rich co-product from the bioethanol production. The resulting water flows are presented inTable 4.

The water balance of the bioethanol production is mainly determined by the water input and the waste water output. These flows are well documented in most process specifications. Based on the quantity of feedstock required and on the quality of the final product, bioethanol, the flows of the embodied water are quantified. Sugar beet, for instance, has a water content of 782 g per kilogram beet harvested (see Table 4). From one kilogram of beet 52 g of ethanol is produced. An allocation factor of 88.5 % is applied to the main product ethanol. The rest of the impacts is allocated to the by-product (pulp). This result in 13 kg of embodied water that flows into the ethanol production system per kg of ethanol produced (see Table 5). The water content of bioethanol is 5 %. From the water input, the waste water output and the embodied water flows, the amount of evaporated water is determined so that the water input equals the water output (Table 5). The bioethanol production plants under study have an on-site waste water treatment facility. The treated water is released directly to the environment ("water, to river"). The bioethanol production processes also produce by-products such as Dried Distillers Grains with Solubles (DDGS), electricity and vinasse. The embodied water flows are modelled and allocated based on the actual physical streams. Most of the other environmental burdens are allocated to the different products according to their economic values.

Table 4 Water balance of the feedstock cultivation for the bioethanol production in different countries (Flury & Jungbluth 2012).

		Sugar-cane	**Sugar-cane**	**Maize (whole plant)**	**Maize grain**	**Maize stover**	**Sugar beet**	**Wheat**
	Elementary flow	BR CS	BR NE	US	US	US	FR	FR
	Yield (t/ha)	82.7	57.7	9.7	9.7	4.7	84.6	6.2
Water balance		**kg/kg**	**kg/kg**	**kg/kg**	**kg/kg**	**kg/kg**	**kg/kg**	**kg/kg**
	country XY=	BR	BR	US	US	US	FR	FR
In	Water, unspecified natural origin, country XY	22.7	79.3	326	265	127	2.17	14.1
	Water, rain	183	266	364	296	141	35.1	788
	Water, embodied, country XY *(negative)*	-0.06	-0.06	0	0	0	0	0
Out	Water, country XY (evaporated)	22.1	78.7	326	265	127	1.39	13.9
	Water, embodied, country XY *(positive)*	0.73	0.73	0.16	0.16	0.18	0.78	0.17

Table 5 Water balance of the bioethanol production from different feedstock (Flury & Jungbluth 2012).

		Sugarcane	**Maize grain**	**Maize stover**	**Sugar beet**	**Wheat**
	Elementary flow	BR	US	US	FR	FR
	Yield (kg ethanol/kg feedstock)	0.03	0.34	0.22	0.05	0.29
	Allocation to ethanol	50%	84%	87%	89%	73%
Water balance		**kg/kg**	**kg/kg**	**kg/kg**	**kg/kg**	**kg/kg**
	country XY=	BR	US	US	FR	FR
In	Water, unspecified natural origin, country XY	2.04	1.56	0.0059	7.2	7.3
	Water, embodied, country XY *(negative)*	-11.2	-0.38	-0.68	-13.2	0.43
Out	Water, country XY (evaporated)	5.11	0.08	5.53	19.8	0.74
	Water, embodied, country XY *(positive)*	0.005	0.005	0.005	0.005	0.005
	Water, to river	7.13	1.78	1.07	0.44	6.94

3 Results and discussion

The impacts of water use and consumption of the bioethanol production presented are assessed with the LCIA methods developed by Pfister et al. (2011) and Frischknecht et al. (2009a).

The upper part of Figure 2 shows the illustration of the cumulative water use and consumption. The foreground system, above all the cultivation of the feedstock, causes the most considerable part of the water consumption in the whole production chain (Table 6), which is why the total amount of water used and consumed, respectively, do not differ significantly. The bioethanol production chain of sugarcane in the North-East region of Brazil has the highest demand for water. The water consumption of the production chain in the Centre-South region is considerably lower due to climatic differences. The two French production chains from sugar beet and wheat have the lowest water demands.

The choice of the method for the impact assessment of the water consumption affects the ranking. In the approach of Pfister et al. (2009), the water stress index is highest for the USA. Consequently and in combination with a considerable water demand, the characterised water consumption in the bioethanol production chain from maize products in the USA is the highest (Figure 2). The water consumption of US maize cultivation is also rated the highest if assessed with the Ecological Scarcity method (Frischknecht et al. 2009a). This is mainly due to the amount of water consumed; the characterisation factor itself is slightly lower than the French one. However, as the absolute water consumption in the production chains in France is comparably low, the resulting characterised water consumption is low too.

Even though the bioethanol production chain from sugarcane in Brazil consumes a comparably high amount of water, the water stress caused by these activities is low. This is because of the very low water stress index and characterisation factor of water consumption in Brazil in both assessment methods compared to the other two countries under study. The difference between the Brazilian and French characterisation factors is higher in the Ecological Scarcity method than in the approach of Pfister et al. The resulting characterised water consumption in Brazil is therefore lower than the French one in the first case and slightly higher in the second case.

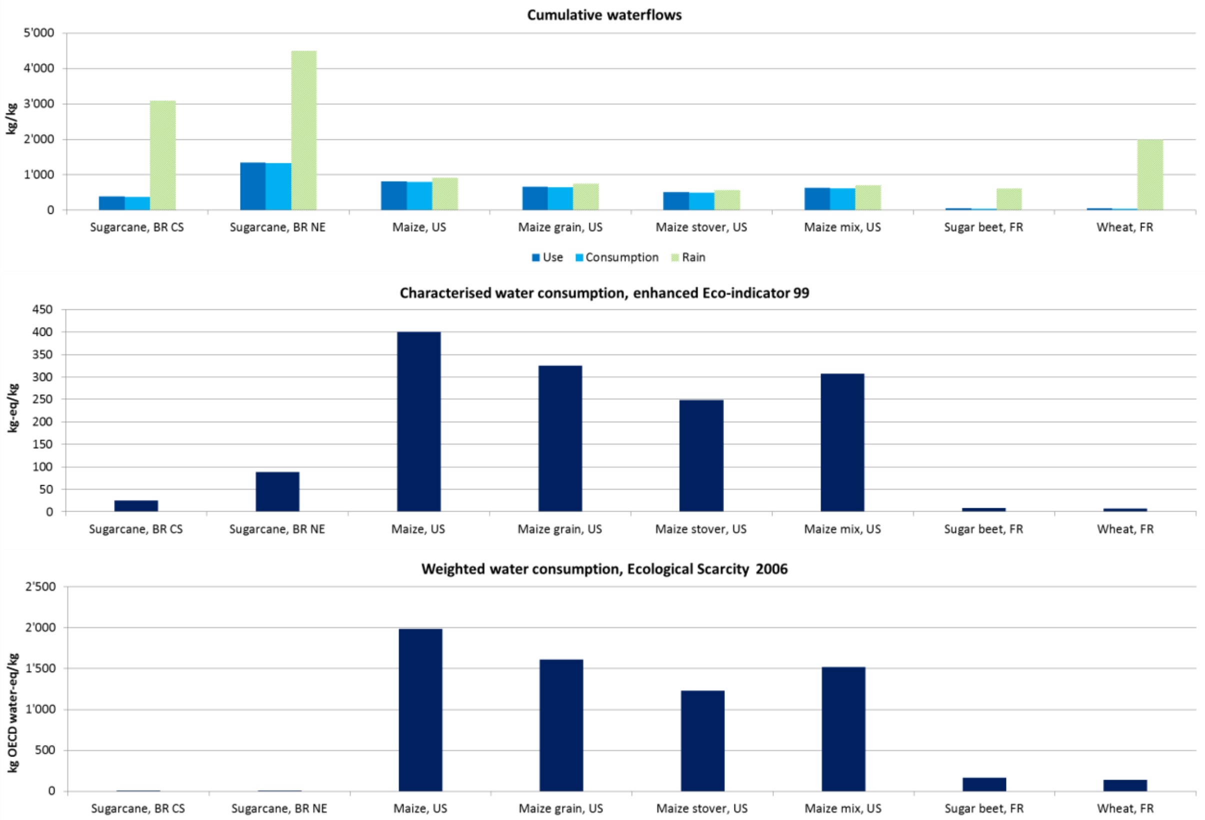

Figure 2 Comparison of the cumulative water use and consumption in the production chains of bioethanol from different feedstock (upper part). Mid-point and weighted results from the assessment of the water consumption based on the Water Stress Index defined by Pfister et al. (2009) and based on the water use indicator of the Ecological Scarcity method 2006 (Frischknecht et al. 2006; Frischknecht et al. 2009a) (lower part).

Table 6 Cumulative water flows, characterisation and impact assessment of the water consumption in the bioethanol production chains based on the enhanced Eco-indicator 99 method of Pfister et al. (2009) and on the Ecological Scarcity method (Frischknecht et al. 2006; Frischknecht et al. 2009a). The foreground system includes the cultivation as well as the bioethanol production.

System / Indicator		Unit/ kg ethanol	Sugarcane BR CS	Sugarcane BR NE	Maize US	Maize grain US	Maize stover US	Maize mix US	Sugar beet FR	Wheat FR
Foreground	Use	kg	386	1'341	803	653	498	616	43.9	42.6
	Consumption	kg	379	1'334	802	652	498	615	43.7	36.0
Background	Use	kg	5.74	5.84	12.3	11.8	18.2	13.3	7.94	7.94
	Consumption	kg	0.446	0.456	0.826	0.785	1.29	0.906	0.634	0.585
Enhanced Eco-indicator 99	Characterisation (WSI)	kg	25.0	87.9	401	326	249	307	8.02	6.62
	Endpoint results	points	3.31E-03	1.14E-02	5.52E-02	4.49E-02	3.44E-02	4.24E-02	1.02E-04	5.53E-04
Ecological Scarcity 2006	Weighted	kg OECD water-eq	2.47	7.38	1'984	1'613	1'231	1'521	166	137
	Endpoint result	eco-points	0.244	0.730	196	160	122	150	16.4	13.5

4 Conclusions

In this paper we describe a methodology for the collection of life cycle inventory data that can be used in the assessment of water consumption and water use. An evaluation of different LCIA methods showed that it is necessary to quantify at least the blue water consumption and use. Furthermore impacts of water use and consumption are different depending on the region. Therefore it is necessary to inventory water flows separately for each region. It is proposed to use country-specific or archetypical elementary flows. In order to make an assessment of both, water use and consumption, feasible it is necessary to quantify the water inputs and outputs of the system. This includes the water input (“unspecified natural origin”), the water evaporated and embodied in the product.

The approach developed can also be used in combination with existing databases such as ecoinvent. Nevertheless it is recommended to investigate the water flows in the foreground system with data differentiated according to the method proposed here. The application of the LCI method has been shown with a case study on bioethanol. It is also successfully used for life cycle inventories of several food products (Jungbluth et al. 2012).

The evaluation of one case study with different LCIA methods shows that there are considerable differences in the characterisation applied to water flows in different regions. Thus, it is recommended to use more than one method in a sensitivity analysis. To enable this further harmonisation seems to be necessary between different LCIA methods concerning the elementary flows that have to be investigated in the LCI.

5 Literature

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