A simple method to better evaluate the freshwater use impact of irrigated crops. The case study of a Mediterranean Basin

Almudena Hospido[1,]*, Montserrat Nuñez[2] and Assumpció Antón [2,3]

[1] University of Santiago de Compostela, Department of Chemical Engineering, 15782 Santiago de Compostela, Spain

[2] Institut de Recerca i Tecnologia Agroalimentàries (IRTA), 08348 Cabrils, Barcelona, Spain

[3] Universitat Rovira Virgili, Department of Chemical Engineering, 43007 Tarragona, Spain

*almudena.hospido@usc.es

Abstract Nowadays, several approaches addressing water in the context of LCA are available. Even when those approaches are quite young and there are already some references available on their application, the general trend in LCA studies is still to ignore the assessment of the freshwater use impact or, in the best case, its inclusion on the life cycle inventory level. In this sense, this paper presents, and validates by means of a case study, a simple method that looks for a more adequate evaluation of the freshwater use impact associated to irrigated crops. The methodology lies on the definition of the irrigation profile or mix of a basin and its consideration in the impact assessment stage, following the Freshwater Ecosystem Impact (FEI) indicator. The method is here tested for the Segura basin (SE Spain) and the preliminary results are presented.

1 Introduction

The consideration of water in Life Cycle Assessment (LCA) studies was very limited till now [1,2]. Its exclusion is justified by [3] on the basis that LCA was initially developed for industrial systems, less water-dependent that agricultural ones. In this sense, and not being the first remarking that, Roy et al. [4] identified agricultural production as the hotspot in the life cycle of food products. Agriculture is also the most water demanding activity worldwide, accounting for about 70% of the whole water withdrawn [5], and therefore water consumption and its related impacts should be included in LCA studies, in order to assist to identify more sustainable paths of performance.

This paper presents a simple method that incorporates information regarding the different sources of freshwater both at the inventory level and the environmental impact assessment level.

2 Materials and methods

The methodology here presented lies on two main elements: the "irrigation mix" concept and the FEI (Freshwater Ecosystem Impact) indicator defined by Milà i Canals et al. [3].

When using water for irrigated crops, several sources can be available depending on the geographical conditions as well as the economic and technological level of development:

1) Surface Water (SW): Water that is extracted from the natural surface sources of the basin for irrigation

2) Ground Water (GW): Water that is extracted from groundwater bodies through wells

3) Runoff Water (RW): Water requirement that is covered by agricultural runoff reclamation and reused again for irrigation

4) Desalinated Water (DW): Water that is desalinated in the basin and used for irrigation

5) WasteWater (WW): Regenerated wastewater that is used for irrigation

6) Transferred Water (TW): Water from natural sources in other basin that is transferred from being used in the basin of interest

All these sources build up what we have named the "irrigation mix" or "irrigation profile", similar to the electricity production mix that characterised the background information associated to the electricity used by a product, a process or a service.

This distribution of freshwater sources was also considered in the impact assessment stage, following the FEI indicator [3], stated as volume of ecosystem-equivalent water per volume of irrigated water and calculated from equation 1, which refers to the volume of water likely to be affecting freshwater ecosystems:

$$FEI = IW \cdot CF \quad (1)$$

Where IW is the amount of irrigated water consumed and CF is the characterisation factor, calculated as follows:

$$CF = \sum_i x_i \cdot CF_i \quad (2)$$

Being xi the fraction of the total irrigated water that is covered by each of the different origins above identified and CFi the individual characterisation factor associated to each water type (eq. 3):

$$CF_i = WSI = WU/(WR\text{-}EWR) \text{ for } i= SW, GW, TW$$
$$CF_i = 0 \text{ for } i= WW, DW, RW \qquad (3)$$

Where WSI is the Water Stress Index coined by Milà i Canals et al. [3] that relates the total annual freshwater extraction for human uses in a specific region (i.e. water use, WU) and the annually available renewable water supply in that region (i.e. water resources, WR), taking into account the environmental water requirements (EWR) of the river basin.

3 Results

3.1 Calculating the parameters of the model

Due to its agricultural water scarcity, a Mediterranean basin (the Segura basin, Fig. 1) was chosen as a case study to test the defined approach. So, the functional unit defined was 1 m3 of water used for irrigation in crops grown in the Segura basin. By doing so, the results obtained can be easily integrated in LCA studies of irrigated crops, or more complex studies with agricultural ingredients, where only information regarding the amount of irrigation water is available.

Fig.1: Spanish basins and the Segura basin (selected for the case study)

Data regarding the irrigation mix (the first term in eq.2) of the Segura Basin, i.e. the different water flows there used for irrigation, were gathered (Table 1) and the individual characterisation factors (the second term in eq.2) were calculated (Table 2).

Tab.1: Irrigation profile of the Segura basin

	IWi (GL/year)	References
Surface Water (SW)	860 *	[6]
Ground Water (GW)	210 *	[6]
Runoff Water (RW)	45	[7]
Desalinated Water (DW)	53	[8, 9]
WasteWater (WW)	65	[10]
Transferred Water (TW)	268	[11]

* Assuming that the total own resources available for use are designated to irrigation.

Tab.2: Characterization factors for the different water sources available in the Segura basin

	CFi	Comments
Surface Water (SW) Ground Water (GW)	1.445	WU = 1,834 GL/year [12] WR = 1,329 GL/year [13] EWR = 60 GL/year [6]
Runoff Water (RW)	0	To avoid double counting, the stream coming for exceeding irrigation does not contribute to the freshwater impact indicator as its associated impact was already calculated when extracted from natural sources for the first time
Desalinated Water (DW)	0	In agreement with Muñoz et al. [14], seawater is considered an unlimited resource and does not contribute to any impact related to water use. However, it can play an important role in other impact categories, such as global warming, due to the high energy requirements of the desalination processes.
WasteWater (WW)	0	As stated by Muñoz et al. [14], water reuse has a beneficial rather than a detrimental effect as it decreases the pressure on freshwater ecosystem
Transferred Water (TW)	0.923	Value directly taken from [3]

3.2 Applying the model

Once the irrigation profile and the individual characterisation factors are calculated, the FEI associated can be obtained: 1.19 m3 ecosytem-equivalent water/m3 irrigation water. The figure is significantly lower that the value obtained if the irrigation mix is ignored and the WSI of the Segura basin is directly applied: 1.44 m3 ecosytem-equivalent water/m3 irrigation water .

The comparison of both values clearly reflects the benefits associated to the use of artificial water sources and provides a quantification of the improvement achieved on the water stress of the Segura basin.

According to the data included in Table 1, the total amount of water used for irrigation (1,501 GL/year) is not enough to totally meet the irrigation demand of the Segura basin: 1,639 GL/year [12]. With the hypothesis that all the irrigation demand should be covered, several alternatives are being defined and assessed according to the method here described, and the results are expected to be available soon [13].

4 Future work

The simple model here described aims to help users to better address water use in LCA studies that includes agricultural irrigated products. So, it will be applied to crops produced Region de Murcia (a province belonging to the Segura basin) [13] as an example of the implications of this method to cross from the inventory level (water use indicator) to the impact assessment level (FEI indicator).

LCA methodology is able to quantify the environmental impact of a product, process or service from a holistic perspective, avoiding so the transfer of pollutants between compartments and between impact categories. So, being aware that, on a global scale, water is not a limited resource and that through technology it can be available everywhere, we suggest complementing the model for the estimation of impact on freshwater resources (by means of the FEI) with another environmental impact category that provides us the probable side effects related to the artificial water sources identified. To do so, the use of energy associated to the different water sources available in the Segura basin will be quantified and evaluated in terms of global warming potential [13].

5 Acknowledgements

Dr. Hospido express thanks to the Xunta de Galicia for financial support during her stay at IRTA and her fellow position at USC (IPP-06-57).

6 References

[1] Berger & Finkbeiner, Review - Water Footprinting: How to Address Water Use in Life Cycle Assessment?, *Sustainability*, Vol. 2, 2010, 919-944.

[2] Kounina, Margni & Humbert, Review of methods addressing water in a life cycle perspective, *Int. J. LCA*, (Manuscript to be submitted).

[3] Milà i Canals, Chenoweth, Chapagain, Orr, Antón & Clift, Assessing freshwater use impacts in LCA: Part I—inventory modelling and characterisation factors for the main impact pathways, *Int. J. LCA*, Vol. 14, 2009, 28-42.

[4] Roy, Nei, Orikasa, Xu, Okadome, Nakamura & Shiina, A review of life cycle assessment (LCA) on some food products, *J. Food Eng.*, Vol. 90, 2009, 1-10.

[5] FAO, *Estimated world water use, 692*, 2010. Available at http://www.fao.org/nr/water/infores_maps.html

[6] <http://www.chsegura.es/chs_en/cuenca/resumendedatosbasicos/recursoshidricos/resumen.html>, (Accessed 09.03.2011)

[7] <http://www.chsegura.es/chs_en/cuenca/resumendedatosbasicos/recursoshidricos/reutilizacion.html>, (Accessed 09.03.2011)

[8] <http://www.chsegura.es/chs_en/cuenca/resumendedatosbasicos/recursoshidricos/desalacion.html>, (Accessed 09.03.2011)

[9] Personal communication <http://www.valdelentisco.es/contactav.as>

[10] <http://servicios2.marm.es/sia/visualizacion/lda/recursos/noconvencionales_reutilizacion.jsp>, (Accessed 09.03.2011) [In Spanish]

[11] <http://www.chsegura.es/chs_en/cuenca/resumendedatosbasicos/recursoshidricos/trasvaseTajoSegura.html>, (Accessed 09.03.2011)

[12] <http://servicios2.marm.es/sia/visualizacion/lda/socioeconomico/demanda.jsp>, (Accessed 24.03.2011) [In Spanish]

[13] Hospido, Núñez & Antón, Irrigation mix: an easy way to better describe and assess the freshwater use impacts associated to crops, *Env. Sci. & Techn.*, (Manuscript to be submitted).

[14] Muñoz, Milà i Canals & Fernández-Alba, Life Cycle Assessment of Water Supply Plans in Mediterranean Spain: The Ebro River Transfer versus the AGUA Programme, *J. Ind. Ecol.*, Vol. 14, No. 6, 2010, 902-918.