Commentary

On the water footprint of energy from biomass: A comment

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1. Introduction

The paper by Gerbens-Leenes et al. (2009) deals with two particularly important preoccupations for the environment: the use of water resources and the environmental impact of bio-energy development. After being a tool for research, the water footprint (WF) is about to become an indicator able to orientate public policies or the strategy of private operators as suggested by studies carried out on this topic by the International Standardization Organization (ISO), under the Preliminary Work Item ISO 14046. That is why we thought it necessary to study this work in detail. First we checked the calculations and input variables. Then we questioned the interpretation of the results and eventually made propositions for a better assessment of agricultural pressure on water resources. The reader is advised to refer to the full article, to be able to fully understand the following considerations, especially for the first section about figures.

2. Are WF Values Relevant?

In their discussion, the authors acknowledged uncertainties for WF estimations, although these were not likely to change WF ranking and magnitudes. However, we believe errors and inaccuracies as well as methodological difficulties cast a doubt on this assertion.

We do not claim to give an exhaustive study, our review being limited to the cases of both rapeseed and sunflower which are essential in our research activities. Moreover, we did not study the pertinence or the use of the model CROPWAT. We checked computations from Gerbens-Leenes et al. (2008), which is a detailed version of Gerbens-Leenes et al. (2009). Considerations on other crops are not the result of an exhaustive analysis, but refer to some obvious elements.

2.1. The Calculations Are Subject to Errors and Inaccuracies

We noticed two mistakes concerning rapeseed as well as strong uncertainties on the estimation of input variables.

The variables Economic Yield (EY), Harvest Index (HI) and Dry Matter (DM) lack coherence. We agree that the HI of 0.32 corresponds to the seed/total dry matter ratio. But this HI is incompatible with the definition of the EY as “inflor + seed” and the DM estimated at 0.74, values which we find incomprehensible, since usually only seeds are harvested at the present time for various purposes (oil for food; cakes for feed; rape methyl ester or pure oil for biofuel). If we refer to the marketing standard of 9% for seed moisture for rapeseed harvested in France, the DM should have been 0.91. Moreover, the rate of 26% of rapeseed mineral constituents announced by Gerbens-Leenes et al. (2009) refers in fact to the unanalyzed fraction obtained by subtraction according to Appendix 3 of Gerbens-Leenes et al. (2008). In reality, the rate of mineral constituents is about 4% (INRA, 2002). New computations carried out after removing the mistakes linked to the DM and the percentage of mineral constituents reduced the WF of rapeseed by 24% in comparison with values indicated in the paper.

The high variability of results between countries for a given crop shows a great sensitivity to agronomic and weather conditions. For example, for corn, the WF varies between 9 and 200 m³/GJ. Because of this sensitivity, the estimation of variables used for these computations appears particularly critical. The authors started from data found in the literature. Gathering references on such a wide subject is difficult, and the comparison between crops requires a certain coherence. We noticed a high heterogeneity of sources relative to different years and geographical situations. For example, the HI of sunflower came from trials carried out on two varieties in Pakistan in 2001 and 2002, and the lowest value (0.31) was kept. Trials carried out on 18 varieties in France in 2008 gave higher values, from 0.33 to 0.45 (Debaeke et al., 2010). Such approximation could be significant: values higher than 0.31 change the rank of the WF of sunflower among the other crops in Brazil. More fundamentally, the HI as a fixed crop descriptor is an erroneous concept, since HI heterogeneity has to be considered among varieties (genetic diversity), in time (genetic progress) and in space (various agro-climatic conditions). The problem is identical for other variables, particularly for yield evaluation, which has to be estimated over several years to avoid any influence of particular weather conditions for a given year. Indeed, the year 2005 chosen as reference by Gerbens-Leenes et al. (2008) was characterized in Zimbabwe by a period of drought linked to economic problems, resulting in low yields for corn (Source: FAOSTAT). The yield appears to be a key variable to explain the variability of WF.
results. The good performances simulated for the Netherlands can be associated to an intensive land use per area unit. This analysis shows that it is necessary to pay more attention to the estimation of variables and to perform sensitivity analysis.

2.2. Some Methodological Points Are Not Explained or Poorly Justified

The authors first calculated the water needed by crops according to the Penman–Monteith equation. This water corresponds to a potential yield without water stress. But in the following step of their method, they took real yields into account. This discrepancy may artificially increase WF in places where crops suffer from water stress in non-irrigated areas.

The authors did not say whether they take the non-productive phase of perennial crops into account. A palm tree, for example, will not be productive before the age of two and a half years (CIRAD and GRET, 2002). Again about the palm tree, the HI of 1 was not explained. Is the water used to produce plant organs, stems and leaves taken out of WF, and a...

Concerning annual crops, the notion of «growing season» mentioned by the authors implies that the water evaporated during the intercropping period is not considered to play a part in production. But this methodological choice seems difficult to justify. How should the water lost by evapotranspiration between two crops be considered? If we take the example of corn in Northern Europe, it is sown from May on, before which a winter covering crop may be mandatory to avoid nitrogen leaching in groundwater (Beaudoin et al., 2005).

After the oilseed rape harvest in July, volunteer plants (i.e. rapeseed growing from seeds fallen on the ground during harvest) can be left in the field during a few months, for the same reason. Assigning all water lost by evapotranspiration over the year would be a better way to take these differences into account, and to valorize practices of water management outside the crop cycle, for example with the dry-farming techniques aiming at keeping the water in the horizon of soil cultivation (Widstoe, 1911).

These considerations show that the criterion of water flow allocation for the calculation of WF is poorly justified: making a difference between a “good” natural evapotranspiration which does not contribute to WF, and a “bad” one linked to production and consumption which does, is irrelevant since intercropping periods and growing seasons are part of coherent cropping systems. This is the same kind of irrelevance when we consider land use. For example, the problem arising from reclaiming a non-cultivated area to settle a rain-fed crop is linked more to the soil use than to insufficient water resources, except in the case of crops which may impact the groundwater recharge. Ridoutt and Pfister (2010) had already criticized the concept of «green water» referring to rain water evapotranspired by crops, as opposed to «blue water», as irrigation water used by farmers. In the study by Gerbens-Leenes et al. (2009), the total evapotranspiration of crops was considered according to the Penman–Monteith equation, and there was no difference between «green» and «blue» water. If we could clarify the hypotheses on water allocation, the results would become more meaningful.

2.3. The Authors Calculated WF by Aggregating Heterogeneous Objects

The authors described what they called «hypothetical crops», which are neither real cases, nor averages values of real cases. It is therefore difficult to estimate what they represent in reality, all the more so that we have no idea of the dispersion of WF values which could be important due to the variability of production conditions. Moreover, it seems questionable to choose the country level to represent the diversity of geographic areas. For example, the diversity of agro-ecological conditions is much more important in the USA than in the Netherlands. The valorization of data bases on weather conditions, yields and oil contents should make it possible to obtain a more realistic modeling of WF distribution for a given crop and geographical area, and to summarize information with appropriate descriptors. This would facilitate the assessment and the adaptation of subsequent measures to local contexts.

The calculation of WF average values for different crops raises the problem of the absence of weighting by areas. Indeed, is it possible to give the same importance to crops occupying very different areas? We shall underline here as an example that sunflower is not cultivated in the Netherlands (source: FAOSTAT) although it is taken into account in the calculation of a national average value.

3. How to Interpret the Results?

Notwithstanding the mistakes and inaccuracies mentioned above, another problem raised by the study concerns result interpretation. For each of the four studied countries, Gerbens-Leenes et al. (2009) presented a list of crops described by only one variable, WF (Table 1). This presentation suggests two types of comparisons: the most performing crop in a given country or the most favorable country for a given crop. Lastly, the authors made a comparison between biomass WF expressed in the form of national average values, and those of primary energy sources (Table 1). The aim is to estimate consequences resulting from an increase in bio-energy consumption. We think this is a misreading of the results. Not only does WF not give complete information on the problem to solve, but the terms of the assessment proposed by the authors lack pertinence.

The WF concept is questionable for the assessment of pressure on water resources. We expressed above our questioning about the «green waters» concept. Moreover, the WF computation only gives part of the necessary information, i.e. the water quantity necessary for the biomass synthesis. The resource scarcity must be taken into account. Such information adds another degree to spatial variability: an identical WF value for a given crop will have a totally different meaning if we are in a region with a strong water deficit or in another which is regularly watered. In fact, this criticism appears in the reference booklet of the WF: «for this purpose the water footprint map can be overlaid with a map showing local water stress. In this way one can identify the hotspots where water footprint reduction is most urgent» (Hoekstra et al., 2009). But this essential point does not appear in the discussion.

To solve this problem, Ridoutt and Pfister (2010) suggested carrying out life cycle assessments (LCA), balancing the WF value with an index of water scarcity defined locally. The unit always remains water m² related to a quantity of product (or energy), but comparisons between products, whose geographical origins are known, become possible. However, if the LCA with this balanced WF could advise consumers and improve the efficiency of processes all along the manufacture chain, it does not allow the checking or forecasting of the real impact of actions carried out to improve the use of water resources.

These questions require an integration of results: the impact does not depend on the crop as such, but on the area covered by this crop or on produced and consumed volumes. Gerbens-Leenes et al. (2009) worked out this integration, ascribing the WF values to energy consumption by inhabitant (m²/capita/year). Thus, there is a misunderstanding about the concept of footprint: the authors mentioned a “WF of biomass” whereas it would be more appropriate to refer to a “WF of an inhabitant using only biomass for energy supply”. There is confusion between the qualification of a product and the qualification of a consumption mode. The idea of a “WF of biomass” hides the true comparison proposed by the authors, i.e. what would happen if primary energies were fully replaced by bio-energies? It seems to us this maximalist scenario is totally unrealistic.

Another way to integrate WF results would be to ascribe them to areas. The evaluation would deal with different scenarios of land use. Carried out in such a way, the comparison made by the authors would be more realistic.
seems impossible: for example, the full shift from primary energies to oilseed rape biomass in the Netherlands would mean cultivating about five times more than the country area!

4. The Three Problems Raised by the Assessment of Agricultural Pressure on Water Resources

The question is legitimate, but the authors’ demonstration is not convincing. The analysis developed above suggests that an assessment of the impact of bio-energy development on water resources, and in a wider sense toward other environmental issues requires the solving of three problems:

1) How is it possible to build meaningful objects (e.g. WF, typical crops, average values by country...), which have to be comparable, considering the heterogeneity of methods and data?

Institutional data bases concern mainly agricultural statistics or references on the composition of products, but they do not say anything on a wide number of parameters and input variables of models and tools used for the evaluation. The use of scientific literature to find this information is very difficult and requires expertise in the concerned disciplinary field. This statement claims for strengthening the dialog and close collaboration between disciplines.

2) How is it possible to integrate results, starting from elementary objects created in the previous step? In the precise case of water quantitative management, the variation in space of consumption and resource is in favor of a spatial integration to make a link between land use and the impact on the resource available for our own use (ground water table, river and tank). From an agronomic point of view, the land use can be linked here to the farming system concept: the crop is not considered in an abstract way independently of its context, but as an element of a coherent system at the field level (crop rotation) and regional level (according to local priorities: agriculture and cattle breeding integration, development of cash crops, landscape management...). The farming system coherence does not mean that a farming system is always desirable or sustainable. It only indicates the existence of functional and historical links between the elements of the system, which explain for example that it is not possible to replace a given crop by another one without modifying the coherence of the system. In other words, the sustainability of a crop rotation is different from the sum of individual crop sustainabilities, and the sustainability of land use in a region is different from the sum of individual crop rotation sustainabilities. At first sight, the authors’ approach centered on the final product does not take this type of consequence into account.

3) Lastly, how do the results of this partial assessment relate to other economic, social and environmental issues? The authors did not really deal with this question apart from a quick reminder of the question of greenhouse gas emissions. We must admit that making different objects like water, carbon, employment, income or biodiversity comparable remains a very difficult problem to solve.

References


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