sigAGROAsesor: A software platform application to extend the use of sustainability indicators into agricultural systems

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ABSTRACT

Food systems will have to provide increasing amounts of products at lower environmental costs. Life Cycle Analysis (LCA) is a methodology that can be used in agricultural systems to quantify input flows, materials and energy, as well as processes needed to obtain a food product. Selection of the appropriate impact categories and use of the corresponding indicators is of upmost importance to promote agricultural sustainability. A key aspect to guarantee the success of the concept and use of environmental impact thinking in agriculture is the involvement of farmers in the calculation of sustainability indicators. The objective of this work is to develop an online GIS-based platform for extensive crops with four decision-support tools (DST): crop varieties, fertilization, irrigation, and risk of plant disease appearance, at the same time that agricultural sustainability indicators can be calculated, in a plot basis. Selected indicators are: a) Carbon footprint, b) Water footprint, and c) Pesticide application pressure, ecotoxicity and human toxicity. Trade-offs among indicators are taken into account by using a per product unit or per area approach to balance out the caused impacts. In this way, we expect that main impacts of agricultural systems will be controlled at the same time that increasing crop productivity is achieved.

Keywords: LCA, GIS, Carbon footprint, Water Footprint, Pesticide toxicity

1. Introduction

At European level food (particularly, meat and dairy products) are among the sectors causing the majority of environmental impacts related to final consumption expenditure (Tukker et al., 2006). The manufacture of fertilizers and pesticides, farm operations, processing and transport of farm products, packaging, refrigeration, cooking, and end of life disposal options depend on natural resources and fossil energy. Most of investigations related to environmental aspects associated with agriculture focus on specific items, such as ammonia volatilization, nitrous oxide emissions, nitrate leaching, phosphorous fixation in soils as well as P losses, etc. However, in order to evaluate and compare the entire environmental burden related to agricultural production systems, it is necessary to consider all environmental impacts at the same time (Brentrup et al., 2001).

Sustainability comprises three pillars: economic, environment and social, and many indicators have been proposed to assess the state of the sustainability of agricultural production systems. Life Cycle Analysis (LCA) is a methodology used to measure the environmental impact of a product, process or system through its entire life cycle. In addition to identifying the impacts and potential improvement options of a product, LCA can aid in the selection of relevant indicators of environmental performance (ISO 14040:2006).

Looking at only one or a few indicators, important aspects of sustainability can be missed, so it is needed to choose a set of indicators that fit properly the system we are evaluating. Several schemes have been proposed in order to account for a balanced set of environmental indicators in agriculture; for example, under the GLOBAL 2000 scheme (Wildenberg, 2012), five field level-based indicators (N-balance, P-balance, humus-balance, pesticide use and energy intensity) and five indicators based on “material input per service unit” (carbon-footprint, biotic and abiotic material input, water input and area used) were chosen. With a focus on the on-farm activities, Agbalance™ Life Cycle Analysis combines environmental, social and economic sustainability indicators, calculates aggregated indices for the three types of indicators, and provides a single overall sustainability index (Schoeneboom et al., 2012).

In recent decades, LCA has been increasingly used for the assessment of agricultural impacts (Anielski Management Inc, 2010; Point, 2008; Renouf and Fujita-Dimas, 2013) due to its utility to inform strategic environmental programs, monitor progress, and most importantly, lead to a minimization of environmental burdens resulting from the provision and use of products and services (Guinée et al., 2002).

The life cycle inventory (LCI) is usually the most time-consuming and complicated stage of an LCA. In agricultural systems, the availability of quality data for the LCI is a challenge because a large amount of information needs to be gathered. The robustness of the indicators to be calculated will greatly depend on the accuracy of the data provided. Usually LCI data collection will involve interviews and surveys to farmers and advisory organizations, as well as looking for process data from LCI databases (Point, 2008). However, in late years the amount of information collected at agricultural systems in Europe is increasing. Common Agricultural Policy (CAP) aims to support farmers' incomes whilst encouraging them to produce high quality products and to adopt more sustainable practices. In order to follow up CAP objectives, a Land Parcel Identification System (LPIS) has been developed and information systems across the EU hold more than 135 million detailed land parcels, annually declared by 8 million farmers (JRC, 2014). At the Spanish level, the geographic information system for the management of CAP is known as SIGPAC. This system can be used to incorporate information about soil, crop, farming operations, etc., which can then be stored at the parcel level, thus providing unique data for different purposes. Moreover, climatic, meteorological, phenological, etc. data can be assigned to each parcel from the network of meteorological stations and from records in agricultural experimental stations. Using this system, Decision Support Tools (DST) can be developed in order to provide farmers with agricultural advice for the main agricultural operations.

Although the opportunity is arising, there are not many examples linking GIS with LCA, and the ones available provide only a partial integration. Falcucci et al. (2012) incorporated climate and agro-ecological zones in explicit GIS layers for elaborating LCA of greenhouse gas emissions from global livestock production. Hercule et al. (2012) studied how to use GIS data layers to standardize and simplify the choice of inventory for agricultural production: pumping energy required for irrigation, fuel inputs for cultivation (largely determined by clay content of the soil), etc.

As already mentioned, farmers need to collect information for different purposes such as to abide European regulations, to apply for CAP aids, etc. At European level a framework for achieving a sustainable use of pesticides has been developed (EC, 2009). Among the mandatory actions to be implemented, record keeping of any use of pesticides is included. Pesticide use, date, product and amount have to be recorded, so this information can be declared if the farmer is required to do so. Besides, the eco-conditionality aids for small farms are becoming more and more important, since the farmers' income is going to depend increasingly on aids, especially with decoupling. All this translates in record-keeping and report elaboration to benefit from these measures. In this sense, farmers will require standardized systems for collecting information and preparing mandatory reports. Besides, another important aspect of European agricultural policies is the recent inclusion of green payments and climate risk management tools proposed for the CAP for the period beyond 2013, which shows the European Commission's willingness to expand this climate component.

In summary, there is an urgent need to develop tools for increasing the efficiencies of food systems at a lower environmental cost. In this sense, precision agriculture at the interplot and intraplot level is gaining consideration for increasing agricultural productivity. The aim of the sigAGROasesor project (LIFE + 11/ENV/ES/000641) is to develop an online tool capable of displaying customised recommendations for extensive agriculture, in real time, and for specific parcels, on the basis of a series of detailed biotic and abiotic variables. Furthermore, it incorporates a set of environmental indicators to make farmers aware of the environmental impacts of their cropping management practices. It is based on GIS methodology to display the cropping units as well as the variables needed to run the DST, which provide agronomic advice to the farmers as well as alerts of disease appearance risks. An additional goal is to develop a DST for calculating environmental indicators to allow farmers and users of the AGROASESOR platform to measure key aspects of sustainable agriculture. It ultimately seeks to help farmers and farm managers to achieve the most efficient and sustainable crop production systems.

2.Methods

2.1. Platform AGROASESOR

The AGROASESOR platform is an on-line services platform, which comprises three pillars on which this expert system and decision-support tool is based: a) the application of modern GIS technologies for the management of geo-referenced information, making use of soil variability, climate and weather information, crop condition, plant health alerts, and biotic and abiotic risks in the decision-making process, b) Web-based Decision

Support Tools (DST) to systematise decision-making at the farm, and c) geo-referenced traceability, as a tool to register and manage historical records of Crop Management Units (CMU). In this way, the system will use all available information associated with each of the parcels of the farm incorporating it into decision making programs. In this way, farmers, advisors and cooperative managers will have an instrument for extensive field crops, which will provide specific advice, with precise handling tips (varieties, fertilization, irrigation, disease risk). With regard to sustainability, a specific area within the platform will allow the calculation of environmental indicators. The information generated by farmers and agricultural advisors and introduced at the CMU level to provide technical recommendations on the DST is the basis for calculating environmental indicators. Furthermore, through maps, algorithms, data tables, etc. we will incorporate the “extra” needed information (Figure 1). Therefore, the AGROASESOR platform will incorporate environmental criteria to guide economic and social farming practices towards more sustainable production models.

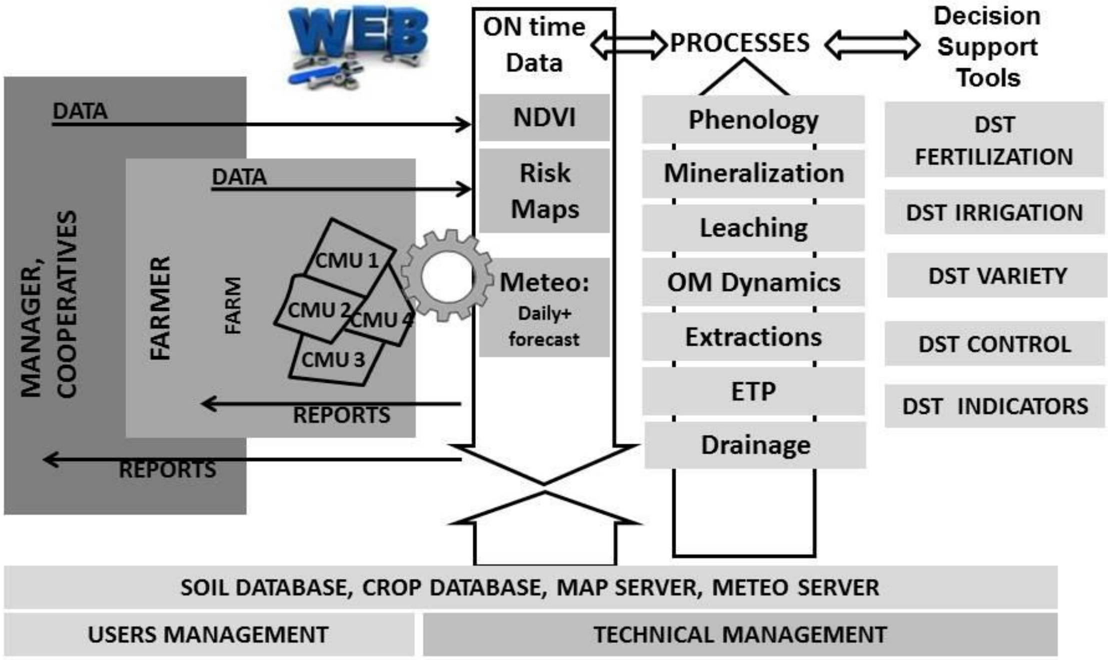


Figure 1. Operating system of the AGROASESOR platform: entities involved in the management of the platform, databases that support Decision Support Tools (DST), general processes performs for obtaining data for the DST. The DST INDICATORS is based on the data of farming operations, including all the inputs involved, as well as outputs in the form of yields from the Crop Management Unit (CMU).

2.2. Development of the environmental indicators at the spatial level

At the AGROASESOR platform, GIS is used to provide information at different levels and scales: a) soil properties (soil depth, texture, SOM, pH, etc.), b) weather variables, climate and meteorological data are assigned to each CMU through an algorithm, which identifies the most representative weather station, c) agricultural inputs and agricultural operations, d) factors needed to calculate the environmental impacts (GHG emission factors related to temperature values, regions with different companies providing electricity, etc.), e) factors needed to assess the environmental impacts, for example, to assess the impact of water consumption in different watersheds.

Besides, we are calculating Gross Margin of the CMU, and we have also selected Soil Organic Matter as an indicator of sustainable land use, which will be followed through time to assess soil quality. In this way we can balance out the different needs that agricultural systems have to take into consideration, maintaining an appropriate balance between economic goals and land maintenance, that is, we simultaneously raise the level of soil organic matter to a certain level and try to maximize benefits from the cropping system.

Carbon footprint calculation is based on a simplified LCA following ISO 14040 standard (ISO 14040:2006) and PAS 2050 (BSI, 2011) methodology; the boundary of the calculation is “cradle to gate”. Upstream processes such as the emissions related to the production of fertilizers and fuel were included, whereas manufacturing and maintenance of machinery and infrastructure were not taken into account within the Scope 3. In relation to the Scope 1, fuel consumption associated to fix and mobile combustion sources, as well as tillage and cultivation practices, were taken into account. Within farming operations the emissions of N_2O from the application of N fertilizers and soil cultivation were calculated using IPCC Tier 1 methodology (IPCC, 2006). Finally, within the Scope 2, electrical consumption was taken into account. Emissions of GHG from the production and distribution of a range of fertilizers, seeds and pesticides were taken from the Ecoinvent database 2.2 (Ecoinvent Centre, 2010). For compost and animal manure, ADEME (2010) and GES´TIM (2010) were used. The average Spanish electricity production mix was selected for calculating the environmental impact of electricity consumption.

Water footprint was calculated following the Water Footprint Network (Hoekstra et al., 2011) and ISO/DIS 14046 (2) methodology, adding its three components: the green, blue and gray water footprint. Although from the LCA standpoint there are some drawbacks in this approach as, for example, not taking into consideration the water footprint associated with the manufacture of raw materials, it has to be mentioned that data from the whole value chain, including all the suppliers, was impossible to get at this stage. Given that,quality changes in different environmental parameters are excluded in the volume based WFN approach and regional aspects are not included in sufficient detail, the Water Scarcity Index (WSI) was calculated as a measure of water use impact. The WSI was calculated based on Pfister et al. (2009), but using the water stress characterization factors values developed for 55 river basins in Spain (Núñez et al., 2013).

Pesticide indicators for pressure (number of applications), ecotoxicity (aquatic and terrestrial) and human toxicity were calculated using the most specific impact values derived for pesticide products. We used 1,4 Dichlorobenzene as an equivalent toxicity unit (Ecoinvent Centre, 2010).

3. Results

The main objective of building the DST INDICATORS at AGROASESOR has been achieved and been tested using a spread datasheet, which was developed previously to incorporate all the required farming operations, data and emission factors. Based on the calculations performed in the spreadsheet, programming was developed to accomplish the needed calculations, while taking into account that a great part of the primary and intermediate data is available in the platform. In this way, users include their management practices, taking into account the tractor, the equipment and the inputs, which are provided in top-down lists; besides, climate, weather, soil characteristics, biotic and abiotic factors are provided. However, the development of such a tool has to find a compromise between simplicity and accuracy, so that results are meaningful for the purpose of the tool and users are not discouraged to use the DST INDICATORS.

3.1. Development of the environmental indicators at the spatial level: assumptions and restrictions

3.1.1. Carbon footprint: Cut-off criteria, assumptions and limitations

The calculator has several sub-systems that decompose overall emissions by greenhouse gas emitted and crop management operations.

3.1.1.1. Fertilization

In the first step the user has to choose the mineral fertilizer, slurry or manure applied from the list that the tool provides. The mineral fertilizers, slurries or manures set out in this list have incorporated specific GHG emission factors from the production and distribution collected from Ecoinvent 2.2 (Ecoinvent Centre, 2010), ADEME (2010), or GES´TIM (2010) databases. Finally, the user has to enter the dose applied at each application. If the applied fertilizer does not appear in the list, the user has to enter the percentage of N, P_2O_5 and K_2O in the fertilizer. In this case, the calculator uses general GHG emissions factors from Ecoinvent 2.2 (Ecoinvent Centre, 2010) database.

Nitrous oxide (N_2O) and nitric oxide (NO) emissions related to fertilizer application were included according to IPCC Tier 1 method (IPCC, 2006), where it is assumed that 1% of applied N as mineral or organic fertilizer is emitted as N_2O. In relation with indirect fertilization-induced soil emissions, leaching is assumed to occur at a rate of 0.3 % of N applied (IPCC, 2006) for a moist climate zone. Although the tool calculates nitrate leaching in the DST fertilization, it is not feasible to use this specific leaching data in the DST INDICATORS in order not to cause an excessive time delay in obtaining the results for the indicators. Emissions of CO_2 from soil resulting from urea application or liming are also accounted for using the IPCC emissions factor (IPCC, 2006) of 0.20 and 0.12, respectively. Finally, the annual amount of N in crops residues (F_{CR}) returned to soil was calculated following IPCC 2006 Tier 1 approach (Eq. 1). The user has to answer the questions of what percentage of the plot is burned and what percentage of the residues is incorporated into the soil. We use the combustion factor (Cf) according to Chapter 2 of IPCC (2006):

$$F_{CR} = \sum_{T} \left\{ \begin{matrix} Crop_{(T)} \bullet \left(Area_{(T)} - Area\,burnt_{(T)} \bullet C_f \right) \bullet Frac_{Renew(T)} \bullet \\ \left[R_{AG(T)} \bullet N_{AG(T)} \bullet \left(1 - Frac_{Remove(T)} \right) + R_{BG(T)} \bullet N_{BG(T)} \right] \end{matrix} \right\} \qquad \text{Eq. 1}$$

where,

$Frac_{Renew\ (T)}$ = Fraction of total area under crop T that is renewed annually equals one, because all the crops included are annuals.

$R_{AG(T)}$ = Ratio of below-ground residues dry matter, for cereals = 1.3, based on Spanish National Inventory of Atmospheric emissions.

$N_{AG(T)}$ = N content of above-ground residues, for cereals = 0.006, based on IPCC (2006)

$Frac_{Remov(T)}$ = Fraction of above-ground residues removed annually. If the answer to the question regarding the incorporation of crop residues into the soil is Yes, then we assumed that the factor equals 0, since residues are not removed. If the answer is No, the tool calculates the percentage of removed residues; in this case, we assumed that residues that are not burned are removed.

3.1.1.2. Pesticides

Although at usual application rates of pesticides the GHG emission from their fabrication and distribution is small, we wanted to give special emphasis to this section due to the importance of the effect of pesticide products on toxicology indicators as explained below. In this case, the tool provides a list of more than 2,000 pesticides based on the list published by the Spanish Ministry of Agriculture, Food and Environment, with all the trade names of the authorized pesticides. We compiled emission factors from Ecoinvent 2.2 (Ecoinvent Centre, 2010) for all the different active ingredients. For each trade name, their active ingredients were compiled and, when available, specific emission factors were incorporated into calculations; otherwise, we used the overall emission factor for insecticide, herbicide or fungicide.

3.1.1.3. Direct energy usage

To estimate the fuel consumption of machinery for farming operations such as tilling, drilling, seeding and harvest, we developed a list with the most common machinery used by farmers and we assigned to each machine fuel consumption (L ha^{-1}) according to the studies of the Spanish Institute for Diversification and Energy Saving (IDAE, 2005). Emissions of CO_2 from fuel consumption are accounted for using Ecoinvent 2.2 (Ecoinvent Centre, 2010) emission factors, of 3.066, 2.660 and 3.339 for diesel, petrol and biodiesel, respectively.

Only electrical consumption in irrigation systems has been considered (Sprinkler, 1.0 kWh; Pivot, 0.5 kWh and Drip, 0.3 kWh). We estimated the electrical consumption for each irrigation system according to Guide des valeurs Dia´terre v. 1.11 (2011). Specific emission factors of electricity were taken from the Spanish electricity production mix.

3.1.2. Pesticide application intensity, ecotoxicity and human toxicity

We build on Ecoinvent 2.2 (Ecoinvent, Centre, 2010) to get 1,4-DCB (kg eq.) factors for all the active ingredients available in this database (Table 1). These factors have been applied to the list of 2,000 authorized pesticides in Spain to calculate freshwater, marine and terrestrial ecotoxicity as well as human toxicity for each commercial pesticide.

Table 1. 1,4-DCB (kg eq.) factors for the different active ingredients available in Ecoinvent 2.2.

Active ingredient	**Freshwater ecotoxicity**	**Seawater ecotoxicity**	**Terrestrial ecotoxicity**	**Human toxicity**
2,4-D	0.058	0.064	0.002	3.747
Alacloro	0.132	0.111	0.005	6.696
Atrazina	0.084	0.074	0.002	4.321
Carbofuran	0.084	0.104	0.004	5.975
Cianacina	0.091	0.079	0.002	4.657
Dicamba	10.672	0.717	0.174	7.745
Diuron	0.106	0.113	0.003	6.376
Glifosato	1.304	0.199	0.026	14.855
Linurón	0.106	0.113	0.003	6.376
Maneb	0.209	0.199	0.001	13.356
MCPA	0.058	0.064	0.002	3.747
Metolacloro	0.397	0.058	0.002	3.112
Paratión	0.505	0.110	0.010	7.275
Propacloro	0.196	0.267	0.023	16.234
Aclonifen	0.101	89.977	0.008	119.040
Captan	0.031	0.036	0.001	2.019
Clorotalonil	0.033	0.042	0.001	2.444
Clorotolurón	0.053	0.072	0.003	4.135
Dimetenamida	0.151	0.152	0.003	8.641
Folpet	0.028	0.034	0.001	1.916
Fosetil-al	0.426	0.076	0.008	4.939
Isoproturón	0.045	0.061	0.002	3.401
Mancozeb	0.209	0.199	0.001	13.296
Mecoprop	0.046	0.051	0.001	2.927
Metaldehído	0.009	0.010	0.000	0.512
Metamitrona	0.064	0.066	0.001	3.865
Napropamida	0.077	1.227	0.146	72.502
Orbencarb	0.086	0.094	0.002	5.660
Pendimetalina	0.017	0.019	0.000	0.945
Prosulfocarb	0.052	0.068	0.002	3.789
Fungicide	0.112	0.091	0.002	5.219
Herbicide	0.132	0.111	0.005	6.696
Insecticide	0.350	0.167	0.006	8.053

Moreover, given the importance of reducing the number of applications, a second indicator is proposed: pesticide pressure defined as number of pesticide applications per plot.

3.1.3. Water Footprint

Taking into account that the purpose of sigAGROasesor is to encourage users to calculate sustainability indicators, in this first step, we have chosen a simplified calculation of water footprint to make it friendlier, as it has been mentioned in the Methods section.

The green water footprint is an indicator of the human use of so-called green water. Green water refers to the precipitation on land that does not run off or recharges the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. The tool calculates the green water footprint according to the following equation (Eq.2):

$$\text{WFgreen} = \Sigma \text{Pe/production} \ (m^3/t) \qquad \text{Eq.2}$$

where, Pe = The sum of the effective precipitation from seeding to harvest. These data are calculated on a daily basis from the meteorological data entered into the platform.

The blue water footprint is an indicator of the consumptive use of so-called blue water, in other words, fresh surface or groundwater. The tool calculates the blue water footprint by dividing the amount of the consumption of irrigation water by the production (m^3/t).

The gray water footprint is defined as the volume of freshwater required to assimilate the load of pollutants, based on natural background concentrations and existing ambient water quality standards. This water footprint is calculated by dividing the pollutant load (L, in mass/time) by the difference between the ambient water quality standard for that pollutant (the maximum acceptable concentration Cmax, in mass/volume) and its natural concentration in the receiving water body (Cnat, in mass/volume) and by the production. We assumed: L = Pollution load as N loss by leaching and runoff multiplied by the excess N. On one hand, we estimated a loss rate of 10 %. On the other hand, we calculated the excess of N as the difference between the nitrogen supplied (organic and mineral fertilization, and N supplied by irrigation water) and extractions. These values are compiled specifically from the DST fertilization.

- Cmax = It has an established legal maximum of 50 mg NO_3 L^{-1}, according to the Water Framework Directive (EC, 1991).
- Cnat = 0, because of natural concentrations are not known precisely but are estimated to be low, and thus for simplicity one may assume Cnat = 0.

Finally, the sum of green, blue and gray footprints is the total water footprint.

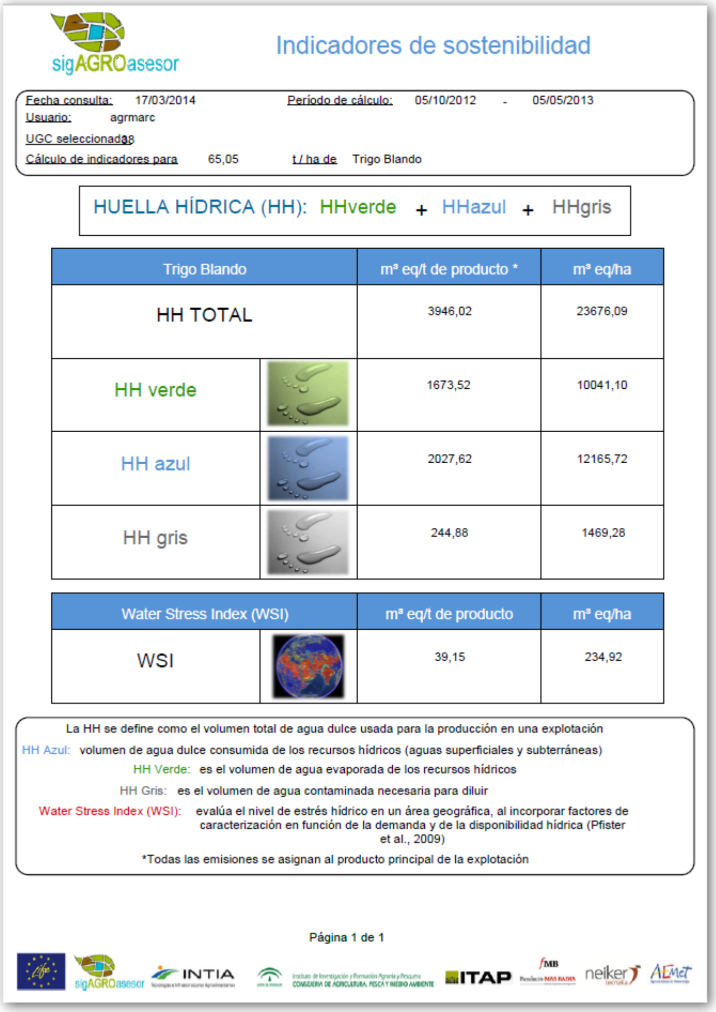
3.1.3.1. Water Stress Index

Water stress is a condition where an imbalance occurs between water demand/need and water availability consumed for meeting the need (UNESCO, 2009). Determination of water stress in an area is calculated using the so called Water Scarcity Index (WSI). We used these values for 55 river basins in Spain as defined by Núñez et al. (2013). The Water Stress Index is calculated by multiplying the water scarcity index for a given area by the water footprint.

3.2. Reporting of the environmental indicators

Once the indicators have been calculated, the tool generates a report with the results for each indicator. As an example, the Water Footprint report is depicted in Figure 2.

In the case of Carbon Footprint, the report indicates total values and the contribution of each of the points to be taken into account (emissions from soil management, emissions from fabrication and distribution of fertilizer and pesticides, emissions from gasoil and electricity). For the Water Footprint, the result is expressed as the sum of the green, blue and gray water footprint and each one separately. In addition, it includes the result of the WSI indicator. Finally, in the case of pesticides, the report expresses the freshwater, marine and terrestrial ecotoxicity as well as the human toxicity and pesticide application intensity.



sigAGROasesor

Indicadores de sostenibilidad

Fecha consulta: 17/03/2014 Período de cálculo: 05/10/2012 - 05/05/2013
Usuario: agrmarc
UGC seleccionada: 38
Cálculo de indicadores para 65,05 t / ha de Trigo Blando

HUELLA HÍDRICA (HH): HHverde + HHazul + HHgris

Trigo Blando		m³ eq/t de producto *	m³ eq/ha
HH TOTAL		3946,02	23676,09
HH verde		1673,52	10041,10
HH azul		2027,62	12165,72
HH gris		244,88	1469,28

Water Stress Index (WSI)		m³ eq/t de producto	m³ eq/ha
WSI		39,15	234,92

La HH se define como el volumen total de agua dulce usada para la producción en una explotación

HH Azul: volumen de agua dulce consumida de los recursos hídricos (aguas superficiales y subterráneas)

HH Verde: es el volumen de agua evaporada de los recursos hídricos

HH Gris: es el volumen de agua contaminada necesaria para diluir

Water Stress Index (WSI): evalúa el nivel de estrés hídrico en un área geográfica, al incorporar factores de caracterización en función de la demanda y de la disponibilidad hídrica (Pfister et al., 2009)

*Todas las emisiones se asignan al producto principal de la explotación

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Figure 2. Water Footprint Report (in Spanish).

4. Discussion

One difficulty in the use of LCA, and corresponding environmental indicators, is the interpretation of the environmental impacts because results encompass different environmental impact categories. Methodologies as environmental footprint, which incorporates four environmental indicators: pesticides, greenhouse gas emissions, eutrophication and acidification, have been proposed (Lillywhite, 2008) to overcome the difficulties in interpreting LCA results; at the same time, aggregated indicators are useful for comparing different agricultural commodities in an easier and more comprehensive way. However, the main aim of the AGROASESOR tool with regard to sustainability is to inform farmers on what agricultural operations are causing the largest environmental impacts. So far, as above mentioned, we have incorporated three main indicators to the AGROASESOR platform: carbon footprint, water footprint, and pesticide ecotoxicity and human toxicity. In this way we account for the main environmental impacts of agricultural production. However, interpretation of the results is needed. Our approach is to place the results obtained in a relative scale, which can be built from literature values, or from the values that result from the use of the AGROASESOR platform by the farmers. In this way, a farmer can know how much impact causes in relation to other farmers in a similar production agroecosystem or in a more general scale. This will be helpful for the farmers to decide in which aspects of their production scheme to make favourable changes for the environment. At the same time, the AGROASESOR platform calculates an economic indicator, gross margin, and the farmer can also decide on the economic impact of the assayed agricultural operations.

In a cradle-to-grave analysis, trade-offs between improvements at one stage and increased impacts at another stage are identified (Cowell, 1999). However, AGROASESOR follows a cradle-to-gate approach, considering yield at the field border (CMU) as the product. This fact is partially overcome by assessing several environmental indicators, not only one as is the case for calculations of carbon footprint to measure the global warming potential, which is the objective of many studies.

We calculate indicators in a per production unit as well as in a per surface unit. We can look at a methodology to balance out these two types of calculations. The use of agricultural inputs, in particular, improved varieties, fertilizers, water, pesticides by increasing production in a synergistic way and at optimum adjusted rates by the AGROASESOR platform will allow increasing yields at the same time that decreasing agricultural inputs. In this way the impact per unit of product is expected to diminish. However, when considering impacts by surface unit, we get additional information on absolute amounts of impacts, regardless of production. Thus, we can choose absolute threshold values we do not wish to surpass, and also check that we abide the legislation regarding to the use of agricultural inputs or operations for a given geographical area. This is another contribution to the sustainability of the different production systems. Among the expected impacts of the project are the increase in yields (5%), fertilizer, water and pesticide product use efficiencies (+5%), while decreasing use in absolute values of irrigation water (-5%) and energy consumption (-5%). As mentioned above, Soil Organic Matter has been chosen as a reliable indicator of soil quality and the inner impact of agricultural production.

One of the advantages of the program with regard to environmental indicators is that when asking for reports, the level of aggregation for each indicator can be chosen: one CMU, a set of CMU, all the CMU with a given crop, all the CMU belonging to a farm, etc. In this way it is very easy to establish comparisons to take into account the interest of the farmer or the advisor. At the same time the administrators of the system can work in an integrated approach to answer more general questions regarding crops, inputs, or agricultural operations. Data variables and results can be exported through “csv” files, so by choosing the adequate parameters we can calculate environmental impacts for the variables we are interested, for example, comparing farmers that apply mineral fertilization with those that use mineral fertilizers combined with organic amendments. In this way, we can identify the effect of specific agricultural practices on whatever of the indicators we are interested in.

5. Conclusion

The AGROASESOR platform will allow the extension of the use of sustainability indicators to farmers. This is so because they will have available a web GIS software, which will facilitate the accomplishment of legal, administrative and technical requirements, at the same time that will provide them with the determination of environmental and economic indicators. As all the information needed for the different DST to work is introduced, calculations for the indicators are made easier, thus providing farmers and their advisors with a tool with multiple uses. Further inclusion of models to account for key processes is needed. Furthermore, it would be important to include more crops and indicators to account at the greatest extent with trade-offs at the agricultural level.

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