Water footprint of soybean production in Argentina

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Abstract In the last decade, the use of biomass for energy purposes has raised high expectations for the production of liquid biofuels in Argentina. This situation involves economical benefits and new opportunities of trade with consumer countries. But on the other hand, impacts as the change in land use, deforestation or water withdrawal may be intensified. The water requirements of biofuel production mainly depend on the type of feedstock and on regional variables, being feedstock cultivation the most water-intensive of biofuel production process. This paper presents the calculation of the water footprint for soybean cultivation in Argentina under irrigated and non-irrigated conditions, using the method proposed by the Water Footprint Network. The result of the assessment carried out provides relevant information for a sustainable water management according to the local conditions useful for local producers.

1 Introduction

Argentina is one of the biggest grain producers in the world, being soybean the one which has attracted more attention in the last years, and also has a leading role as producer and exporter of vegetal oils. In the last decade, the use of biomass for energy purposes has raised high expectations for the production of liquid biofuels in the country. The production of biodiesel in 2010 increased by 37% over the previous year. This situation involves first economical benefits and new opportunities of trade with consumer countries. But on the other hand, environmental impacts such as the change in land use, deforestation or water withdrawal may be intensified. The water requirements of biofuel production mainly depend on the type of feedstock and on regional variables such as climate and geographical characteristics, being feedstock cultivation, the most water-intensive of all biofuel production processes.

In recent years the cultivation of soybean to produce biodiesel has spread to regions of the country in which it is necessary to implement technology to supply irrigation for matching the water requirements of crops. The latter agricultural practice allows crop sowing about 35 – 45 days before than if non-irrigated farming. This is a common practice to reduce the threat of pests in the crop even if it requires extra water because rainfall is lower at that time. The purpose of this study is to compare the water footprint of soybean cultivation when applied artificial irrigation and when the production comes from rainfed agriculture.

2 Material and Methods

The study considers two agricultural systems: rainfed soybean crop and irrigated soybean crop in the province of Córdoba, Argentina.

The operations considered are no-till sowing, fertilization, sprayings and harvest. The irrigation includes a central pivot system with five towers and an overhang, with an energy demand of 40 kWh.

Water Footprint is calculated following the method proposed by the Water Footprint Network [1]. The green evapotranspiration (ET_{green}) and blue evapotranspiration (ET_{blue}) have been calculated using the CROPWAT 8.0 model [2], choosing the irrigation schedule which allows the specification of the provision of real-time irrigation. The outcomes given by the program are: the fraction of water readily usable by the crop (RAM) which indicates the maximum moisture depletion that can be allowed to avoid water stress conditions; the total amount of water available for cultivation (TAM) and the total depletion of soil moisture which represents the amount of water to be applied to bring the soil to field capacity (Depletion).

In the rainfed system the ET_{green} was considered as equivalent to the total evapotranspiration, because the ET_{blue} is zero. To estimate the ET_{green} and ET_{blue} in irrigated agriculture fixed irrigation was selected depth of 25 mm, irrigation at 60% of critical depletion and irrigation efficiency of 90%.

The meteorological data used belong to the Manfredi experimental station located in the province of Cordoba, and correspond to the average historical data for the years 2001-2010. The main data regarding cultivation, sowing, harvesting dates and fertilizers and pesticides application rates were taken from local data published by INTA [3-7]. To calculate the gray component of the water footprint standards for drinking water quality recommended by [8] have been used while the normal concentrations of N in the receiving basin have been measured as 1 mg/L [9]. Natural concentrations of pesticides and herbicides in the receiving water body have been considered to be zero due to lack of data.

Results and Discussion

Figures 1 and 2 show the curves of RAM, TAM and Depletion obtained for both systems studied. The total gross irrigation above field capacity (corresponding to zero) at the beginning of the cycle of irrigated system is not available for cultivation because it cannot be retained in the soil and drains naturally as deep percolation. This portion of water is considered as losses of irrigation.

As can be seen in Figure 1, at any time the depletion curve irrigated system outperforms the RAM curve, indicating that the crop is not under water stress during the growing season. By contrast, in the rainfed system (Figure 2) RAM curve is surpassed by the depletion curve after 60 days into the crop cycle. Water stress in the rainfed cultivation implies a reduction in the productivity of soybean, which represents in this case 14.3% of the maximum achievable under optimum conditions.

The water footprint of the soybean cultivation in Córdoba is 2572.2 m3/ton for the irrigated system and 2440.7 m3/ton for the non-irrigated system (Figure 3). Tables 1 and 2 show that the green component of the Water Footprint is considerably higher for the non-irrigated system, while the grey component is similar in both cases.

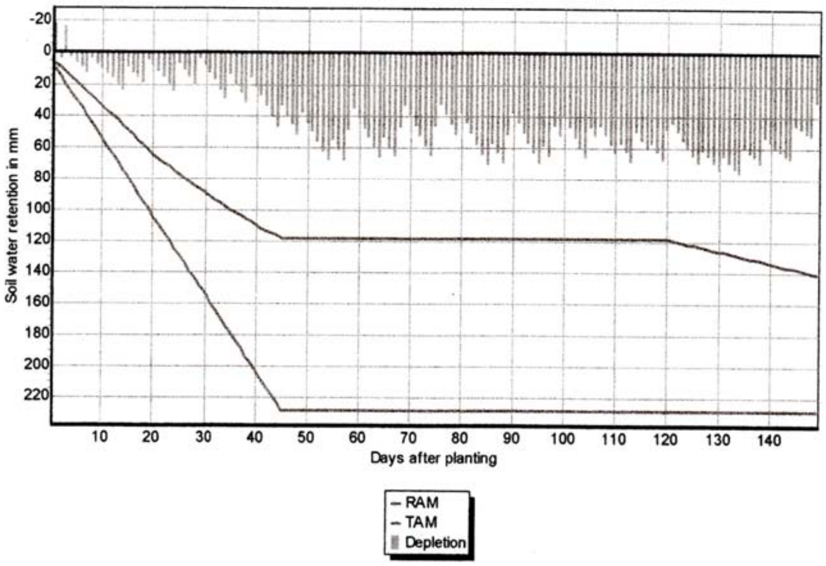

Fig.1: **Calculation of RAM, TAM and Depletion for soybeans in Argentina. Irrigated systems.**

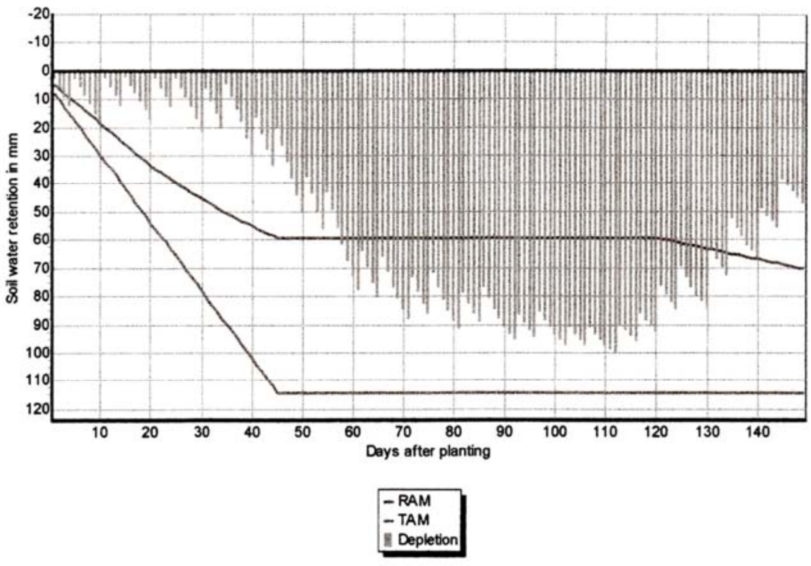

Fig.2: **Calculation of RAM, TAM and Depletion of the soybeans in Argentina for rainfed systems.**

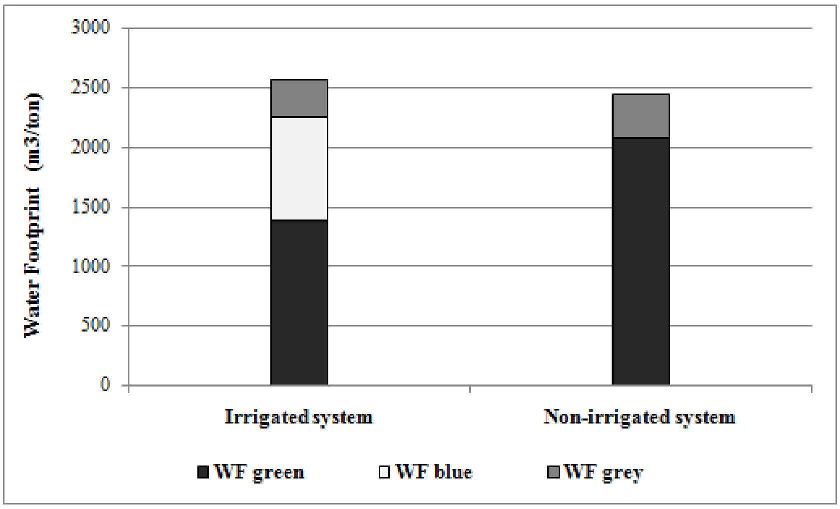

Fig.3: **Water footprint (m3) to produce 1 ton of soybeans in Argentina for different agricultural systems.**

Tab.1: **Green and blue components of the water footprint for soybean, for irrigated and rainfed systems.**

Farming system	CWU $_{green}$ (m^3/ha)	CWU $_{blue}$ (m^3/ha)	Yield (ton/ha)	WF $_{green}$ (m^3/ton)	WF $_{blue}$ (m^3/ton)
Irrigated system	4427.0	2802.0	3.2	1383.3	875.5
Non-irrigated system	5837.0	0.0	2.8	2084.6	0.0

Tab.2: **Grey components of water footprint for soybean, for irrigated and rainfed systems.**

Farming system	Total WF $_{proc, grey}$ (m3/year)	Yield (ton/ha)	WF $_{grey}$ (m^3/ton)
Irrigated system	1002.8	3.2	313.4
Non-irrigated system	997.1	2.8	356.1

3 Conclusions

Irrigation produces an increase in productivity of soybean cultivation under the studied conditions. As expected, irrigation increases the total water footprint, but the difference between both irrigated and non-irrigated cases are not significant.

However, this aspect should be discussed more deeply incorporating others growing areas with different soil characteristics and specific climatic conditions to determine if irrigated systems in soybean cultivation is a sustainable practice in Argentina.

4 References

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