WATER AND ENERGY FOOTPRINT IN A DRIP IRRIGATED AND SPRINKLER FROST PROTECTED BLUEBERRY CROP IN CONCORDIA, ARGENTINA

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ABSTRACT

Yield, Water and Energy footprint was measured in a Snowchaser variety of blueberry (*Vaccinium corymbosum L.*) commercial crop of 30 ha of 10 years old in Concordia , Entre Ríos province, Argentina. The crop is planted in rows separated 3.5 m and the plants at 75 cm. The crop is irrigated by a drip system with two laterals of drip tubes per each line of crop. Drippers are at 30 cm of distance with a flow or 1.1 liter per hour. The system is operated by a submergible pump with an electrical motor of 60 kilowatts, working on well of 60 meters depth. The crop is protected of the effects of frosts by a sprinkler systems, giving 3 mm per hour of precipitation. To protect the crop the system must works beginning before the temperature is below zero degrees Celsius and continuously till all the ice formed during the nights over the plants is liquified. That means a pumping requirement of 900 cubic meters per hour of instant flow, provided by 4 wells with turbines pumps, working simultaneously and moved by diesel engines. The objective is to quantify the fresh fruit harvested, the water footprint and the energy footprint per year from 2010 to 2018. Energy footprint is divided in blue energy footprint and grey energy footprint. The blue energy footprint was measured in watts per kg of fresh fruit produced and the grey energy footprint in centiliters of gasoil per kg of fresh fruit, that´s because irrigation system works with electrical energy and the anti-frost system with diesel engines. Average yield of the crop was from 2010 to 2018, of 11,14; 11,72; 12,60; 11,01; 13,15; 16,41; 13,53; 10,70 and 9,4 ton per ha respectively. Water footprint of the 30 has was 981, 350, 257, 243, 196, 266, 209, 265 and 318 liters of water per kg of fresh fruit from 2010 to 2018 respectively. Blue energy footprint was 37, 23, 11, 12, 12, 18, 22, 29 and 27 watts per kg of fresh fruit from 2010 to 2018 respectively, while Grey Energy footprint was 27, 8, 10, 9, 2, 7, 3, 3 and 3 centiliters of gasoil per kg of fresh fruit.

Keywords: water management, water footprint, energy footprint, blueberry.

1. INTRODUCTION

In 1993, Allan introduced the concept of virtual water, measured the water contained in each product and the water used during that process (Allan, 1998).

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The concept of hydric footprint was proposed by Hoekstra and Hung (2002), dividing the use of water considering the source of it and the pollution associated with the production process. The two concepts respond to the quantification requirements of the water used, however, the concept of water footprint implies the volume of waters used and that of virtual water implies the flow of water used as a net balance of the water used at the level of countries. Chapagain and Hoekstra (2004) estimated the water footprint for various countries during the period 1997-2001. Currently, the water footprint is classified as: Blue water that is used in irrigation from surface and underground water sources (Undurraga*et al*, 2013); Green water is the water used by the cultivation from rainwater and C: grey water is contaminated water during the production process (Falkemark, 2003) andGrey water is difficult to measure because it is not sufficiently studied and measured in the way that blue water and green water are. The differentiation and quantification of the three types of water is crucial because of the environmental implications derived, requiring various regulatory policies to guarantee the sustainability of the water resource (Pérez, 2008)

The knowledge of the water footprint in blueberry cultivation (*Vaccinium Corymbosum L.*) is a crucial factor in the planning of the efficient use of irrigation water, in the improvement in the productivity of the waters and in the sustainability and competitiveness of the production of this Cultivation (Holzapfel and Pannunzio, 2014) (Pannunzio, 2010). The need for Argentina's blueberry crops to produce against season in the months of September, October and November, implies that flowering occurs in periods at risk of frost, which affect its viability in the event of no resort to any method of Protection. The frosts that occur in the area are mostly radioactive, with thermal inversion and less advective or mixed cases.

Frost protection systems require the release of energy that is produced by changing the state the water sprinkles the system that when deposited on the plants goes to the solid state, releasing energy to the floral organs. At the end of the frost and after the thermal investment that occurs after sunrise and to remove the ice that is deposited on the plants, it is necessary to continue watering so that the energy required for the change of state of solid to liquid is provided by the water that is being applied and not from the flowering organs, which would suffer very negative effects if this occurred. For this reason the supply of water to the system must be continuous, safe and without interruption.

The supra-arboreal sprinkler irrigation system ws adopted to avoid the damage caused by these frosts, The water used for this requirement is not consumptive and essential for the production to be viable, therefore it cannot form part of the Blue water, which is used for irrigation and is considered as a member of the Grey Water (Pannunzio *et al*, 2016). Each blueberry variety has its grey footprint according to its flowering date and the evolution of the year's temperatures.

Sprinkler irrigation systems are operated by vertical submersible pumps operated with diesel engines. The option of diesel engines is due to the high cost of the electrical installations and of the electrical energy and especially by the instability of the provision of electrical energy that suffers in Concordia supply cuts, that are not admissible in the use of the technology of Antifreeze irrigation, which requires a continuous application of water during the frost phenomenon. To this it is added that the polynomial with which the monthly turnover is calculated penalizes the users of elevated seasonal consumption, such as the fruit production in general (Pannunzio, 2019).

The Entre Rios province has abundant groundwater and surface water sources. Its main surface water sources are the Paraná River at its west, with an average flow of 15,000 m^3/s. On the east side is the river Uruguay with a flow of 5,000 m^3/s Both tributaries Rio de la Plata, in North are on the northwest the River Gauyquiraró tributary of the Paraná and in the northeast the Mocoretá tributary of Uruguay. Entre Rios Province is included within the area covered by the Guarani aquifer, which includes areas of Brazil, Paraguay, Uruguay and Argentina, with a water reserve estimated at 55,000 cubic km.. Prior to planting, the most suitable areas were selected for the cultivation of blueberries, which required sandy and well-drained soils. This area has soils that contain in surface Pliocensriver sands, suitable for cultivation. Bilberry has very superficial roots and in the first 30 cm of soil there should be no impediments for good drainage. The area has an average slope of 1.7%, reaching values of up to 10%. These slopes associated with sandy textures and high-intensity storm events imply a high risk of erosion (Pannunzio *et al*, 2016).

2. METHODS

2.1 Case study: blueberries in Concordia

The trail was developed in a farm located at Colonia Ayuí, Concordia, Entre Ríos, Argentina, with the following coordinates: 31°11'24"S, 58°02'54"W. There is a commercial farm called Berries del Sol S.A., with 30 ha of Southern High bush Blueberry varieties (*Vaccinium corymbosum*, L.). Rainfall in the area is between 800 and 1700 mm annually well spread around the year. Effective rainfall was calculated with Soil Conservation Service method (SCS) of the United States Agriculture Department (USDA) and adjusted with Dastane proposal.

2.2 Soils of the area

Relation between water potential and water content was determined with Richards method in order to determine the quantity of water to be applied per irrigation. Water potential threshold was established at 30 cb.

2.3 Source of water

Water for irrigation in this area can be obtained from deep wells, these wells can produce usually 300 $m^3 \cdot h^{-1}$. Some farms also built some dams, with storage capacity to provide water considering the requirements of a sprinkler frost protection system, with a precipitation rate of 3.5 $mm \cdot h^{-1}$ or 35 $m^3 \cdot h^{-1}$. Those systems worked in average 10 hours per night and 30 nights during winter and early spring. Irrigation water is measured with flow meters, one with each pumping station.

2.4 Pumping equipment

There is a pump supply by an electric engine for the drip irrigation system, and pumps with diesel engines for the anti frost irrigation system. The electric and diesel consumption were measured to know the energy demand of each system.

2.5 Blueberry yields

Blueberry yield was measured daily after each harvest day during the period between 2010 to 2018, to be used in the water and energy footprint calculations.

3. RESULTS AND DISCUSSION

3.1 Yield of the crop

The yield of the crop during the period between 2010 and 2018 can be seen in figure 1. In some years as 2016-2018 period, less fruit was harvested because of a slide down of market prices caused by huge supply of the production of different countries.

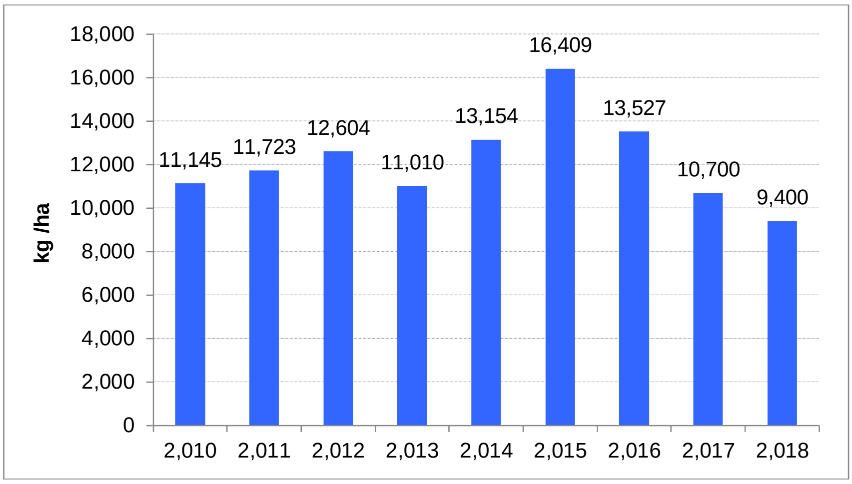

Figure 1: Yield per ha from 2010 to 2018

3.2 Water footprint

Water footprint is detailed in figure 2. It can be seen that at the beginning huge quantities of water were required by plants, due to the fact of the growing and establishing period of plants, and the strong winter of 2010 in which anti frost system operation was required.

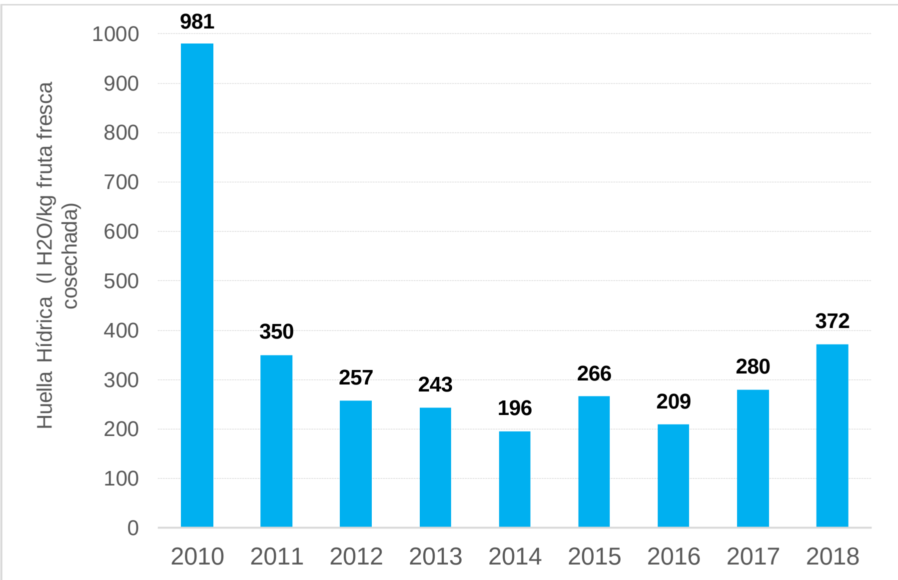

Figure 2. Water footprint of blueberry in Concordia, Entre Rios.

3.3 Blue energy footprint

Blue energy footprint is described as the amount of energy required to meet full irrigation requirements. In the case where electric engines are used to supply energy for irrigation pumps, watts used to produce each kg of fresh fruit, is propose as the unit to describe those requirements. In figure 3, watts/kg of fresh fruit harvested is displayed.

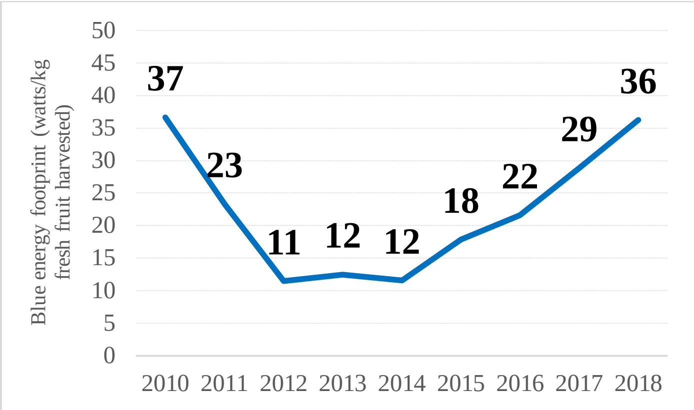

Figure 3: Blue energy footprint, displayed in watts used per fresh fruit harvested

3.4 Grey Energy footprint

Grey energy footprint, is proposed as the energy used by anti frost irrigation systems to avoid damages of frost events during sensitive periods for crops. In this case blueberry crops are blossoming during winter, and early spring, that's why sprinkler irrigation systems operation area required. To avoid the investment in the installation of lines of medium tension, diesel engines are installed to provide energy for pumps to operate sprinkler system. The energy use is measured in this case in centi liters of gas oil used to produce each kg of fresh fruit harvested. Results of the requirements from 2010 to 2018 are detailed in figure 4.

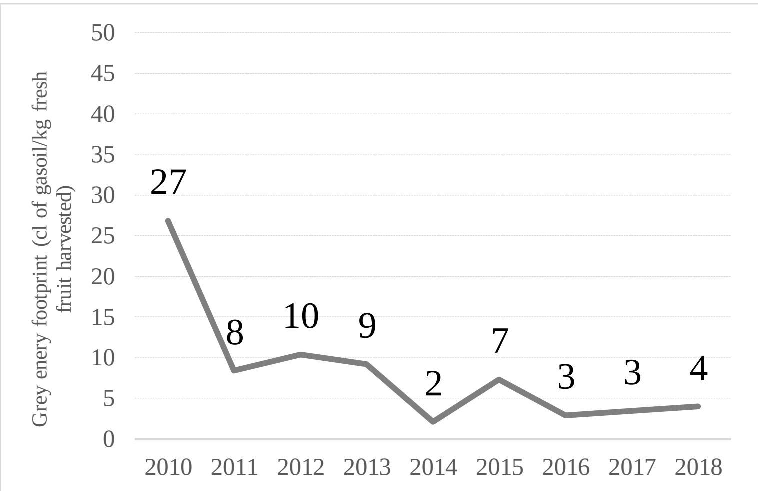

Figure 4: Grey water footprint, displayed in centiliters of gasoil used per kg of fresh fruit harvested.

4. CONCLUSIONS

Energy footprint is divided in blue energy footprint and grey energy footprint. The blue energy footprint was measured in watts per kg of fresh fruit produced and the grey energy footprint in centi liters of gas oil per kg of fresh fruit, that´s because irrigation system works with electrical energy and the anti frost system with diesel engines. Average yield of the crop was from 2010 to 2018, of 11,14; 11,72; 12,60; 11,01; 13,15; 16,41; 13,53; 10,70 and 9,4 ton per ha respectively. Water footprint of the 30 ha was 981, 350, 257, 243, 196, 266, 209, 265 and 318 liters of water per kg of fresh fruit from 2010 to 2018 respectively. Blue energy footprint was 37, 23, 11, 12, 12, 18, 22, 29 and 27 watts per kg of fresh fruit from 2010 to 2018 respectively, while Grey Energy footprint was 27, 8, 10, 9, 2, 7, 3, 3 and 3 centi liters of gas oil per kg of fresh fruit. Is crucial to quantify water and energy requirements in fruit crops to collect all the data during a period of years allowing decision makers to advise what group of crops can be planted in following years considering the availability of water and energy.

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