DESIGN IRRIGATION, MANAGEMENT AND EXTENSION PRACTICES IN BLUE BERRIES (*Vaccinium corymbosum L.)* TO IMPROVE "INSIDE-GATE WATER FOOTPRINT": A CASE STUDY IN CONCORDIA, ARGENTINA

A. Pannunzio[1], E. A. Holzapfel[2], P. Texeira[3] and F. Bologna[4]

ABSTRACT

Proper design, management and extensive practices to irrigation workers, are tools to improve water use efficiency, relevant agent to give solutions to the increasing demand of food, sustainability and productivity of irrigated crops. All the water used in the farm, including the water used in packing facilities to clean tools and machinery, fresh water used and all other uses inside gate, must be well managed, to reach an efficient use of water resources, and to reduce the use of water measured as "*inside-gate water footprint*". The aim is to present the result of the design, management and proper operation of an irrigation system in blueberries (*Vaccinium corymbosum L.*) in Argentina, measuring the water footprint to evaluate water productivity, hand labor used per ha and net income reached per water used. Water volume used per unit of net income for farmers is a good indicator to decide in the crop in which water will be destined. The optimal design and managing of irrigation systems at farm level is a key factor for a rational use of water, economic development of the agriculture and its environmental sustainability.

Keywords: Irrigation design, Water management, Water footprint, inside gate water footprint, blueberries.

1. INTRODUCTION

Around eighty percent of plants is water and it is required for photosynthesis, which produces food for the plant with the help of sunlight. The growing dependence on irrigated agriculture coincides with an accelerated competition for water from other sectors. Availing and using fresh water is a human right. Irrigation uses nearly 70% of total fresh water available at a poor water application efficiency of 40% (Hoekstra *et al*, 2009). There is an increased awareness of unintended negative consequences of poor design and management of the irrigation system. Water is vital, multifunctional and scarce resource and these characteristics generate a strong competition among water users. A thorough planning is needed for exploiting and using the fresh water resources on the principle of economic and sustainable development.

English *et al*, (2002) mentioned that irrigated agriculture would need to provide two-thirds of the increase in food demand to feed the growing population. Optimum management of available water resources at farm level is needed in view of the

[1] Head Professor, University of Buenos Aires, Av. San Martin 4500, Buenos Aires, Argentina. Mobile: +549-11-5422-3000, Email: pannunzio@agro.uba.ar

[2] Professor, Centro de RecursosHídricospara la Agricultura y la Minería.Casilla 537, Chillán, Chile, Mobile: +56-981290583, Email: eholzapf@udec.cl

[3] Professor, University of Buenos Aires, Av. San Martin 4500, Buenos Aires, Argentina. Mobile: +549-11-6209-3000, Email: texeira@agro.uba.ar

[4] Field Engineer, Berries del Sol S.A., Ruta 28 km 5, Colonia Ayuí, Concordia, Entre Ríos Argentina, Mobile: +549- 11-6214-3000, Email: francobologna2000@yahoo.com

increasing demands, limited resources, water table variation in space and time, and soil contamination (Kumar and Singh, 2003). The use of indicators is basic to reach sustainability (Altieri and Nicholls, 2005) and to improve irrigation water management (Cañas *et al*, 2010). The water footprint is a good indicator of efficiency of water used in different processes, and it includes direct and indirect use of water to produce goods or services during a certain period. The high demand for labor in blueberries production and export give this category undoubted social and economic importance. Almost 80% of blueberry produced in Argentina is exported as fresh fruit to the North Hemisphere markets, taking advantage of commercial window during the period of September to December. The remaining 20% is used for industry or local consumption, improving the diet of local population. To produce in September, early growing varieties are required. These varieties need frost protection during the winter and early spring. Sprinkler, Micro-sprinkler solid set systems are used to avoid frost damages. The knowledge of water footprint in blueberry crop is an important issue to plan efficient water use, improving productivity, sustainability and competitiveness of irrigated crops (Pannunzio, 2010, Holzapfel *et al*, 2014). On the other hand this crop employs a lot of people for manual harvesting, helping to solve the local high unemployment rate. The general values for blueberries water footprint are around 341, 334 and 170 L/kg for green, blue and grey footprints, resulting in a total of 845 L/kg, values consistent with those obtained in Chile between 400 and 800 L / kg (Cifuentes and Merino, 2013).

2. METHODS

2.1 Climatic characterization of Concordia

The study area is located within 31°11'24'' S, 58° 02'54'' W at 58 meters above sea level in "Berries del Sol" farm in Colonia Ayuí, Concordia, Entre Ríos province. The Concordia climate is temperate and humid, with medium temperature varying between 17 and 20^{0}C. Rainfall in the area varies from 1000 to 1300 mm/year spread throughout the year. Rainfall is not enough to meet demands of water use for blueberry crop. Sandy soil of the area and the shallow root system of the crop, don't have enough capacity to store the required water provided by rains. Effective rainfall (Figure 1) was calculated with Soil Conservation Service of the USDA, modified by Dastane (1978).

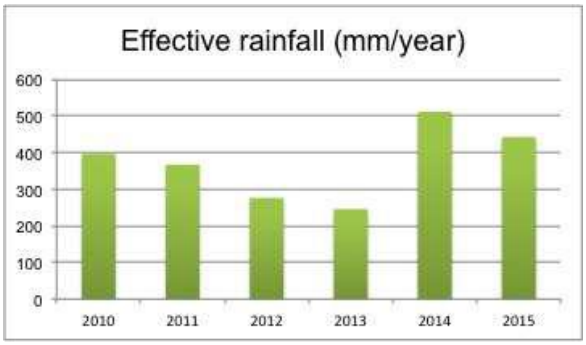

Figure 1: Effective rainfall of the area.

2.2 Soils and water of the area

Solis of the area are sandy, with a hard clay pan between 30 and 100 cm. Slopes of the area are 1,7 % on the average. Considering rainfalls of the area there is huge erosion potential for those unstable soils. Water are provided by rich aquifers, producing around 300 m^3/h, of water with 6.5 pH and 200 dS/m of electric

conductivity. Small dams are built also inside farm to store runoff water. Water potential of the typical soils are shown in Figure 2.

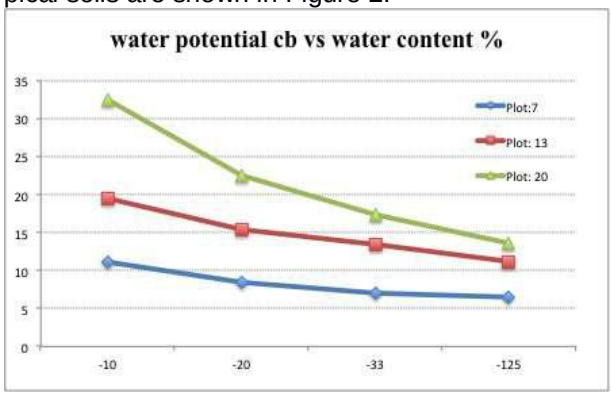

Figure 2: water potential vs water content for tree typical soils of the area.

2.3 Blueberry (*Vaccinium corymbosum L.*) crops in Concordia, Argentina.

About 90% of the blueberry plants of the area are varieties developed by Florida and Georgia University. Farmers pay royalty for their plants. The varieties: Southern Highbush, Emerald, Jewel, Star, Snowchaser, Primadonna, Rebel, Spring High and San Joaquín, are planted in the farm of the study. Pine bark @ 300 cubic meters per ha are added to soil to favor root development in raised beds. Plantation is design at 3,5 meters between lines and 85 to 90 cm between plants. Drip system is used for irrigation and sprinkler solid sets for frost protection.

2.4 Water requirements for blueberry crop in Concordia

Evapotranspiration demand of crop was measured using the Penman – Monteith formula and measuring crop coverage to determine crop coefficient factor (kc) (Holzapfel, 2002) (Pritchard *et al*, 1993).Peak evapotranspiration of the crop is.Water potential of the soil, was followed using sets of tensiometers at 15 and 30 cm, where the shallow roots of this crop is spread.

2.5 Design and evaluation of drip irrigation system

The drip irrigation system was designed considering two laterals of drippers at a dripper spacing of 30 cm and drippers with 1.34 lph discharge per emitter. Mini-sprinkler irrigation system is used for protection against frost damage. The Uniformity Coefficient of Christiansen (UCC) is a measure of dispersion between all values and the average value and the UCC for the study area was calculated as 95.14%. The Total Distribution Efficiency (EDT) develop by Holzapfel (2002) reflects irrigation design, management and maintenance. It tells about the soundness of the design and operation of irrigation systems. In the case of this trial the EDT found in an eight years system was 95.13%.

2.6 Hand labor crops, in high unemployment areas

Labor-intensive crops are very useful to solve the unemployment problem in rural areas with potential to develop crops destined to export market. Export markets require Global Risk Assessment on Social Practice, standardized requirements that address specific aspects of workers' health, safety and welfare, benefiting the development of those communities. Each hectare of blueberry plantation requires between 285 and 500 labor-days per year (Fig 3.) showing the importance of electing a hand labor crop that gives good employment opportunities.

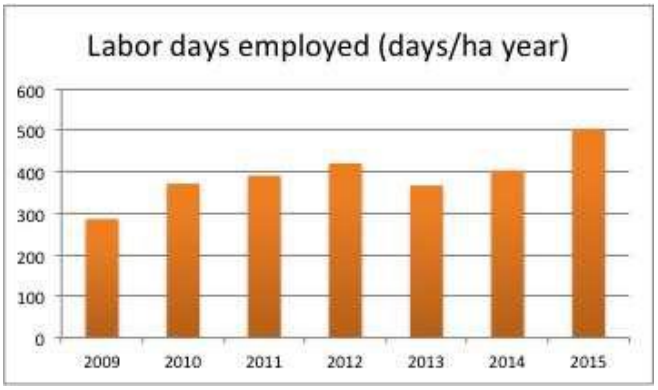

Figure 3. Labor days used per ha per year

2.7 Estimation of "inside-gate water footprint" for blueberry in Argentina.

Blue water is the water applied by the drip irrigation system. Green water is the water received by rainfalls and represents effectively storage in the soil volume explored by roots. Grey water is the water used by the frost protection system (Pannunzio *et al*, 2016a) to avoid frost damages to bud, flowers and/or fruits, when temperatures are below their damage threshold. We also consider all the other water used inside-gate of the farm, for fresh water, for bathroom for employees, for cleaning packing house, to wash machinery, etc. All water used inside-gate was considered adding all the water measured of each water meter installed at the outlet of the four pumps of the field since 2010 In figure 4 water for each well and total water pumped is shown.

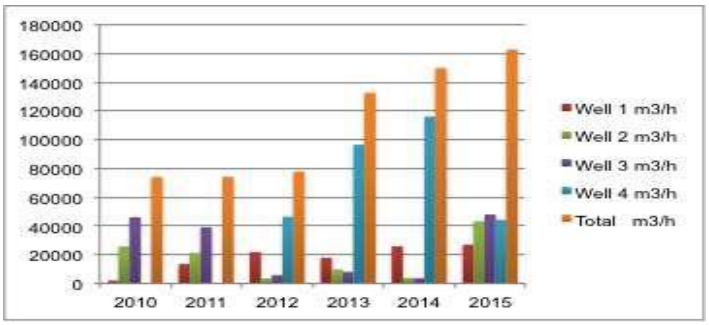

Figure 4. All water used in the farm for all purposes

3. RESULTS AND DISCUSSION

3.1 Irrigation design, management and maintenance

Irrigation design, management and maintenance of irrigated crops, are key factors in increasing water productivity, reaching high yields per hectare. This is an important tool to develop rural areas, employing available resources in a conservative way and producing added value by means of profitable crops. The fresh fruit harvested per hectare is shown in figure 5. The UCC coefficient of 95.14 % and the EDT found in an eight years system was 95.13 clearly demonstrates that the system was well designed and well maintained. This result describes a professional design a proper installation, moreover is showing that all cleaning procedures for filters, drip tubes had been done continuously as well us the regulation of pressure regulators.

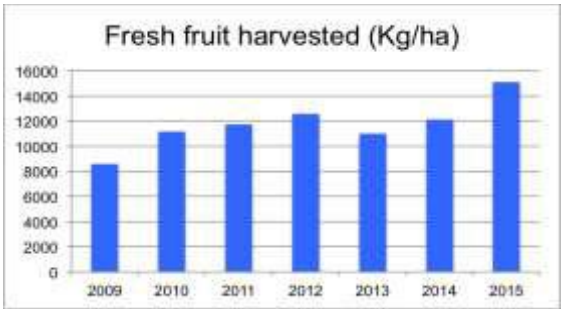

Figure 5. Fresh fruit of blueberries harvested per year

3.2 Hand-labour crops as a tool to develop rural areas

Blueberries are hand labour-intensive crops, due to the fact that till now they are harvested by hand for fresh market, at least with the current varieties. In fact as mentioned before, each blueberry hectare employs 285 to 500 labour-days. Not least important are the high yields obtained detailed in Figure 5. The net income for this crop, while exporting to northern hemisphere between September and December are shown in Figure 6, generating incomes of 65000 to 90000 USD per hectare, while there are offering hand labour for local workers, families and farmers.

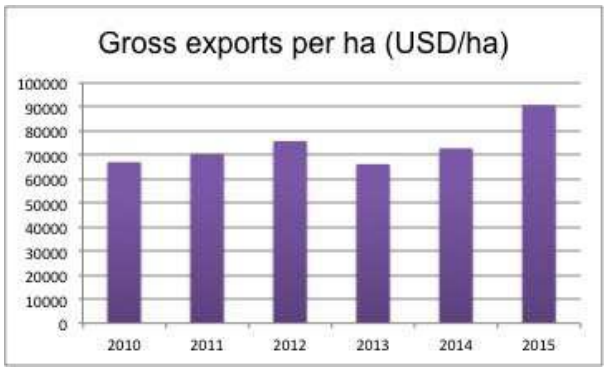

Figure 6. Gross export per blueberry ha

3.4 Water volume used per unit of net income

Water productivity was analysed, in terms of money per liter of water used inside-gate the farm (Figure 7). More important for farmers is the net income obtained (Figure 8). This trial is showing a net income between 1550 and 2000 dollars per liter of water used.

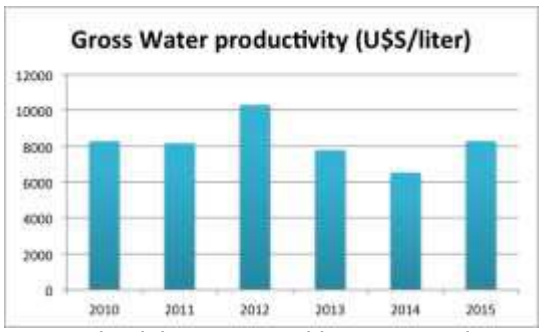

Figure 7. Gross water productivity measured in money units per litre of water used.

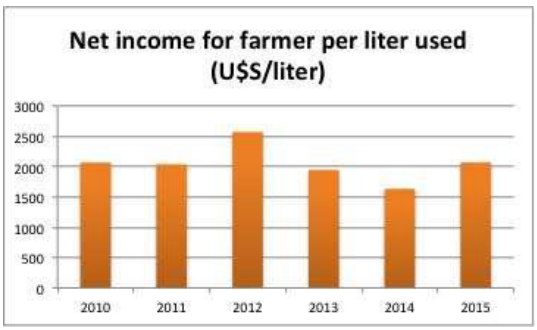

Figure 8. Net water productivity measured in money units per litre of water used.

3.5 Inside-gate water footprint" as tool to measure water productivity

Water productivity was less than values obtained only in one high yield variety (Pannunzio*et al*, 2016b) because in this measurements different varieties are considered together, using more water per kg produced, but spreading the harvest period from 8 to 30 weeks. Also, us mentioned water for all uses inside-gate of the farm was considered, giving values for the six harvested seasons of 580 to 910 litres per kg harvested. Cifuentes and Merino, (2013) mentioned an average of 845 liters of water footprint for blueberries in Chile, considering blue, green and grey water.

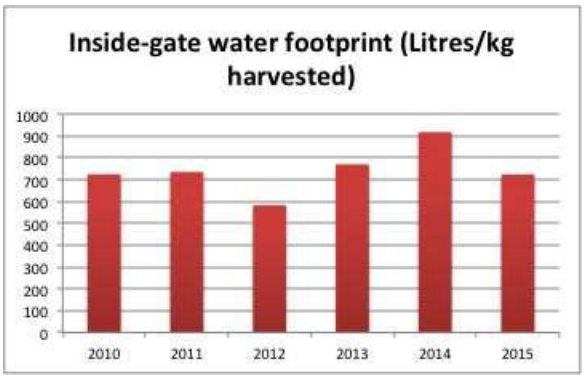

Figure 9. Inside-gate water footprint Net water productivity measured in money units per litre of water used.

4. CONCLUSIONS

Design and management of irrigation systems are key factors while following irrigation water productivity. The UCC and the EDT are strong indicators of design and management practices and also describes the maintenance state of the system. Human recourses must be trained in order to manage those systems; otherwise the best system will lose quality soon. Continuous extension practices with irrigation workers are key factors to improve the irrigation water efficiency, generating trained human resources to keep the original design quality of irrigation systems, the UCC and EDT of a eight year drip irrigation system were 95.14 and 95.13, respectively. High labor demanding crops must be selected to guarantee labor employment for rural communities. In the trial, 285 to 500 labor-days/ha were engaged. Productive crops must be elected for each area; in this case the gross exports were between 65000 to 90000 USD/ha. Water productivity can be measured with an indicator as net income in money per liter of water used inside-gate. In the trial the range of values obtained were between 1550 and 2000 USD per liter of water used. This indicator is a strong tool to decide the crop to irrigate. At last the "*inside-gate water footprint*" is

proposed to measure all the water used inside the farm for all purposes per kg of fresh fruit obtained. The values of the experiment were 580 to 910 liters per kg of fruit harvested of eight blueberry varieties in a 25 ha farm.

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