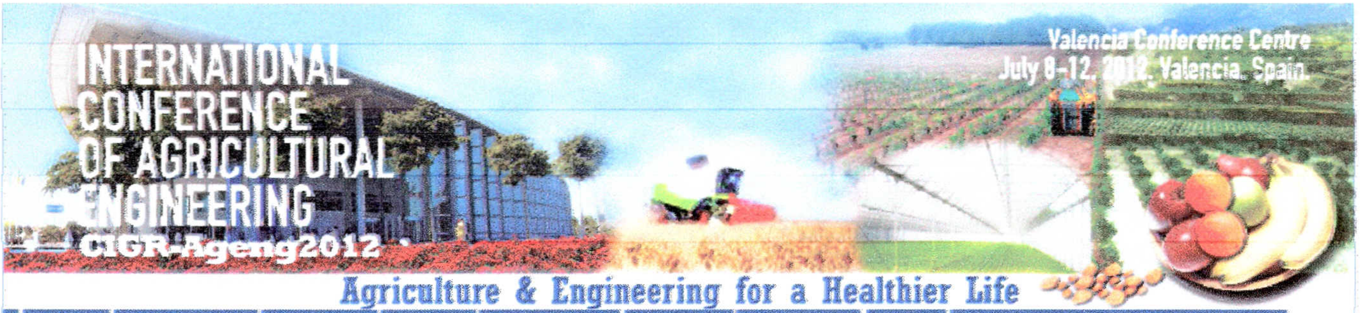

AGRICULTURAL WATER FOOTPRINT OF ETHANOL AND SUGAR FROM SUGAR CANE UNDER FERTIGATION PRODUCTION SYSTEM

Abstract Nº: P0739

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Type: Poster

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Key words:

Surface drip irrigation

Introduction:

The Water Footprint (WF) concept is an indicator to express the water use in the production chain of commodities. The WF of a commodity is defined as the total volume of freshwater that is consumed or polluted during the whole production process. For agricultural commodities, water consumption mainly refers to crop water consumption (green and blue water) during the growing period and water pollution (grey water) mainly relates to the leaching of fertilizers and pesticides that are applied to the field (Hoekstra and Chapagain, 2008). For bioenergy crops, Gerbens-Leenes et al. (2009) provide more detail on specific WFs of crops and crop products. Chapagain and Hoekstra (2004) have calculated the WFs of sugar and starch crops for all producing countries, but they did not make a distinction between green, blue and grey water, and did not take ethanol production into account. The study aims to calculate the green, blue and grey agricultural WF of ethanol and sugar produced from sugar cane, under subsurface fertigation production system, in Piauí State, Brazil.

Material and Methods:

Sugar and ethanol production data in response to different irrigation levels (288, 492 and 675 mm), nitrogen fertigation (90, 113 and 160 of kg N ha^{-1}) and potassium (60 and 133 kg of K2O ha^{-1}) plus a control treatment (2,080 mm of rain, 75 kg of N ha^{-1} and 75 kg of K2O ha^{-1}) were obtained from a trial under subsurface drip irrigation system, RB 867515 sugar cane variety, 1st ratoon, conducted in COMVAP - Sugar and Alcohol Inc., União county, Piauí State, Brazil.

Results/Conclusions:

The agricultural WF for sugar production ranged from 1,493 L kg^{-1} (1,175 L kg^{-1} - green water, 163 L kg^{-1} - blue water and 155 L kg^{-1} - grey water) to 1,172 L kg^{-1} (823 L kg^{-1} - green water, 267 L kg^{-1} - blue water and 83 L kg^{-1} - gray water). For ethanol production, the agricultural WF ranged from 2,081 L L^{-1} (1,638 L L^{-1} - green water, 227 L L^{-1} - blue water and 216 L L^{-1} - grey water) to 1,483 L L^{-1} (1,040 L L^{-1} - green water, 338 L L^{-1} - blue water and 105 L L^{-1} - grey water). Under non-irrigated condition, the agricultural WF for sugar production was 1,915 L kg^{-1} (1,763 L kg^{-1} - green water and 152 L kg^{-1} - grey water) and 2,658 L L^{-1} (2,448 L L^{-1} - water green and 211 L L^{-1} - grey water) for ethanol production. The agricultural WF for the ethanol production was superior to sugar production. Agricultural water footprint under fertigation was lower than that obtained under non-irrigated conditions, and should be a recommended practice for increasing water productivity to sugar and ethanol production from sugar cane crop in the region evaluated.

Acknowledgements/References:

Chapagain, A.K., Hoekstra, A.Y. (2004). Water footprints of nations. Water Research Report Series No. 16.

Gerbens-Leenes, P.W., Hoekstra, A.Y., van der Meer, Th., 2009. The water footprint of bioenergy. Proceedings of National Academy of Sciences of the United States of America 106, 10219–10223.

Agricultural water footprint of ethanol and sugar from sugar cane under fertigation production system

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Abstract

The study has objective to calculate the green, blue and grey agricultural water footprint (WF) of ethanol and sugar produced from sugar cane, under subsurface fertigation production system, in Piauí State, Brazil. Sugar and ethanol production data in response to different irrigation levels (288, 492 and 675 mm), nitrogen fertigation (90, 113 and 160 kg ha^{-1} N) and potassium (60 and 133 kg ha^{-1} of K_2O) plus a control treatment (2,080 mm of rainfall, 75 kg N ha^{-1} and 75 kg ha^{-1} of K_2O) were obtained from a trial under subsurface drip irrigation system, RB 867515 sugar cane variety, 1st ratoon, conducted in COMVAP - Sugar and Alcohol Inc., União county, Piauí State, Brazil. Under subsurface drip fertigation, the agricultural WF for sugar production ranged from 1,493 L kg^{-1} (1,175 L kg^{-1} - green water, 163 L kg^{-1} - blue water and 155 L kg^{-1} - grey water) to 1,172 L kg^{-1} (823 L kg^{-1} - green water, 267 L kg^{-1} - blue water and 83 L kg^{-1} - gray water). For ethanol production, the agricultural WF ranged from 2,081 L L^{-1} (1,638 L L^{-1} - green water, 227 L L^{-1} - blue water and 216 L L^{-1} - grey water) to 1,483 L L^{-1} (1,040 L L^{-1} - green water, 338 L L^{-1} - blue water and 105 L L^{-1} - grey water). Under non-irrigated condition, the agricultural WF for sugar production was 1,915 L kg^{-1} (1,763 L kg^{-1} - green water and 152 L kg^{-1} - grey water) and 2,658 L L^{-1} (2,448 L L^{-1} - water green and 211 L L^{-1} - grey water) for ethanol production. The agricultural WF for the ethanol production was superior to sugar production. Agricultural water footprint under fertigation was lower than that obtained under non-irrigated condition, and should be a recommended practice for increasing water productivity to sugar and ethanol production from sugar cane crop in the region evaluated.

Key words: subsurface drip irrigation, bioenergy, water demand, water productivity.

1. Introduction

The water footprint (WF) concept is an indicator to express the water use in the production chain of commodities. The WF of a commodity is defined as the total volume of freshwater that is consumed or polluted during the whole production process.

For agricultural commodities, water consumption mainly refers to crop water consumption (green and blue water) during the growing period and water pollution (grey water) mainly relates to the leaching of fertilizers and pesticides that are applied to the field (Hoekstra and Chapagain, 2008).

Chapagain and Hoekstra (2004) have calculated the WFs of sugar and starch crops for all producing countries, but they did not make a distinction between green, blue and grey water, and did not take ethanol production into account.

For bioenergy crops, Gerbens-Leenes et al. (2009) provide more detail on specific WFs of crops and crop products. The WF of sweeteners and ethanol depends on crop type, agricultural practice and climate. The WFs of cane sugar for the main producing countries appear to be 1,285 $m^3 t^{-1}$ for Brazil and 1,570 $m^3 t^{-1}$ for India. The weighted global average is 1,500 $m^3 t^{-1}$ (45% green, 49% blue and 6% grey) (Gerbens-Leenes et al., 2009).

However, in the case of Brazil, the inputs needed to calculate the water footprint for the production of sugar and ethanol produced from sugar cane was performed based on estimates obtained in the FAO tables, which do not represent well the reality of the production system of sugar cane under irrigation adopted in northeastern Brazil.

Therefore, the study aims to calculate the green, blue and grey agricultural WF of ethanol and sugar produced from sugar cane, under subsurface fertigation production system, in Piaui State, Northeast region, Brazil.

2. Material and Methods

Sugar and ethanol production data in response to different irrigation levels (288, 492 and 675 mm), nitrogen (90, 113 and 160 of kg N ha^{-1}) and potassium fertigation (60 and 133 kg of K_2O ha^{-1}) plus a control treatment (2,080.4 mm of rainfall, 75 kg of N ha^{-1} and 75 kg of K_2O ha^{-1}) (Table 1) were obtained from a trial under subsurface drip irrigation system, RB 867515 sugar cane variety, 1st ratoon, conducted in COMVAP - Sugar and Alcohol Inc., União county, Piaui State, Brazil (Andrade Junior et al., 2012).

TABLE 1. Stalk yield (TCH, t ha^{-1}), sugar (TAH, t ha^{-1}) and ethanol (VAH, m^3 ha^{-1}) obtained from the application of irrigation and levels of nitrogen and potassium in subsurface drip fertigation. COMVAP - Sugar and Alcohol Ltda., 2008/2009.

Treatment	ID* (mm)	TID** (mm)	N (kg ha^{-1})	K_2O (kg ha^{-1})	TCH (t ha^{-1})	TAH (t ha^{-1})	VAH (m^3 ha^{-1})
1	288.5	2368.9	113.3	133.0	149.4	17.7	12.7
2	492.0	2572.4	160.0	133.0	170.1	22.5	16.0
3	675.0	2755.4	90.0	60.0	207.4	25.3	20.0
C	0.0	2080.4	75.0	75.0	101.0	11.8	8.5

* Irrigation depth; ** Total irrigation depth (Irrigation depth plus rainfall of 2,080.4 mm); C - Control

In this study, was used the methodology proposed by Chapagain and Hoekstra (2004) considers that to calculate water footprint considered only water consumed in agricultural phase of sugarcane production system, such as rainfall, irrigation and water used in the fertilizer manufacturing process.

The WF has three components: the green, blue and grey WF. The green WF refers to the volume of rainwater that evaporates during the production process. The blue WF refers to the volume of surface water and groundwater that evaporates as a result of the production of the product. For crops, the blue WF is the evapotranspiration of irrigation water. For industrial production, the blue WF is the amount of fresh water withdrawn from ground or surface water that does not return to the system from which it came. The grey WF of a product is an indicator of freshwater pollution that can be associated with the production of a product over its full supply chain. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards.

Farmers apply fertilizers and pesticides to grow crops. Part of these substances leach to the groundwater and contribute to the grey WF. This study looks at nitrogen and potassium, which will lead to a conservative estimate of grey WFs in cases where other nutrients or pesticides actually constitute a larger problem than nitrogen. We have assumed that 10% and 85% of the total nitrogen and potassium application leaches to free water bodies, respectively (Chapagain et al., 2006; Ercin et al., 2011). As a approach for ambient water quality standards we took the drinking water quality standards of the EPA (1995) and the WHO (2006). These organizations recommend a maximum value for nitrogen and potassium in drinking water of 10 mg L^{-1} (NO3-N) e 860 mg L^{-1} (chloride). The grey WF was estimated by dividing the nitrogen and potassium load to the water by the maximum concentration of nitrogen and potassium of 0.01 kg m^{-3} and 0.86 kg m^{-3}, respectively.

3. Results and Discussion

Figures 1 and 2 show the results of calculating the agricultural water footprint to produce one kilogram of sugar and liter of alcohol for each treatment fertigation evaluated.

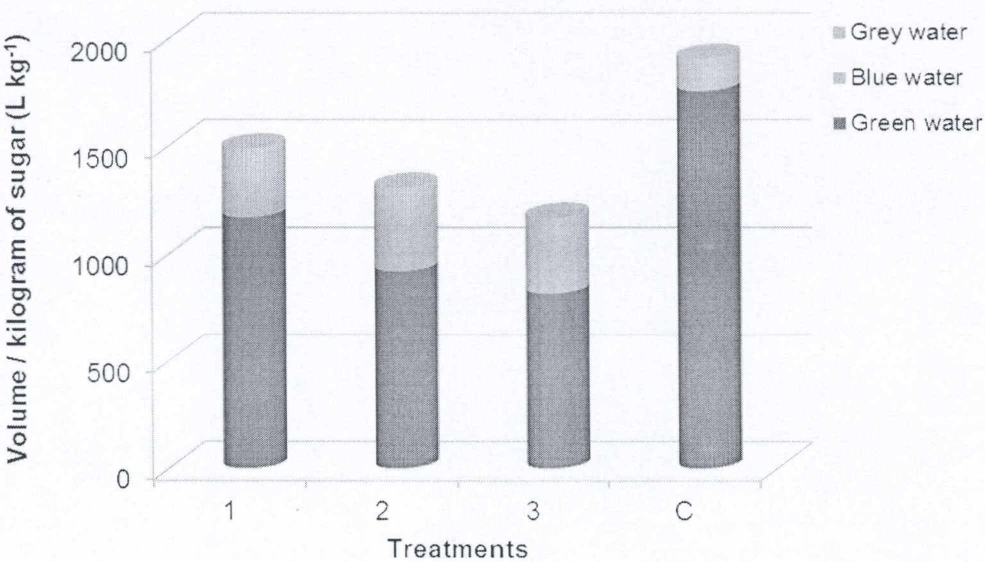

FIGURE 1. Volume of water consumed to produce one kilogram of sugar.

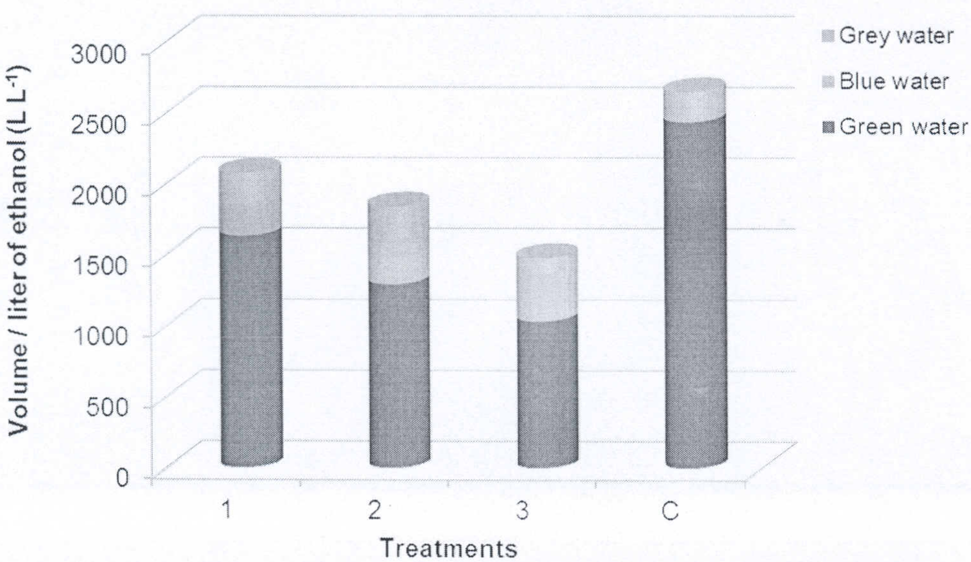

FIGURE 2. Volume of water consumed to produce one liter of ethanol.

The agricultural WF for sugar production ranged from 1,493 L kg^{-1} (1,175 L kg^{-1} – green water, 163 L kg^{-1} - blue water and 155 L kg^{-1} - grey water) to 1,172 L kg^{-1} (823 L kg^{-1} - green water, 267 L kg^{-1} - blue water and 83 L kg^{-1} - gray water). For ethanol production, the agricultural WF ranged from 2,081 L L^{-1} (1,638 L L^{-1} - green water, 227 L L^{-1} - blue water and 216 L L^{-1} - grey water) to 1,483 L L^{-1} (1,040 L L^{-1} - green water, 338 L L^{-1} - blue water and 105 L L^{-1} - grey water). Under non-irrigated condition, the agricultural WF for sugar production was 1,915 L kg^{-1} (1,763 L kg^{-1} - green water and 152 L kg^{-1} - grey water) and 2,658 L L^{-1} (2,448 L L^{-1} - water green and 211 L L^{-1} - grey water) for ethanol production.

The WF for sugar production values obtained to treatment 1 (1,493 L kg^{-1}) (Figure 1) was slightly higher than the values calculated by Gerbens et al. (2009) (1,285 L kg^{-1}). However, the proportion between the different components of the water footprint (78.7% green, 10.9% blue and 10.4% gray water) was quite different from those obtained by Gerbens et al. (2009) (45% green, 49% blue and 6% gray water). There was a better utilization of the green water component in the calculation of the water footprint, because the irrigation depth applied was reduced. Furthermore, in the present study was not considered in calculating the volume of water consumed in the process of industrial manufacture of sugar (blue water), as allowed for the calculation of Gerbens et al. (2009).

Moreover, the WF for sugar production values obtained to treatment 3 (1,172 L kg^{-1}) (Figure 1) was lower than the values calculated by Gerbens et al. (2009) (1,285 L kg^{-1}). However, the proportion between the different components of the water footprint (70.2 green, 22.8% blue and 7.1% gray water) was quite different from those obtained by Gerbens et al. (2009) (45% green, 49% blue and 6% gray water). In this case, the results demonstrate the improved efficiency of water application provided by subsurface drip irrigation, since there was a reduction of the total water footprint while there has been an increase in the applied irrigation depth (blue water). According Gerbens et al. (2009), the WF estimates are based on current conditions, so they do not reflect what is technologically possible. Particularly many of the large water footprints found can be reduced if better practices were adopted.

In all treatments, the agricultural WF for the ethanol production was superior to sugar production, in agreement with the results obtained by Scholten (2009), which estimated to growing conditions in Brazil, the water footprint for the production of ethanol from cane sugar in 2,447 L of water per liter of ethanol (54.9% green, 41.4% blue and 3.7% gray water). In this study, the calculated WF values were lower than those obtained by Scholten (2009), reinforcing once again the potential of subsurface drip fertigation to cane sugar and indicating that the levels of N and K_2O applied by drip fertigation subsurface increased straw yield and improved the technological quality of sugarcane juice (Andrade Junior et al., 2012).

Agricultural water footprint under fertigation was lower than that obtained under non-irrigated condition, and should be a recommended practice for increasing water productivity to sugar and ethanol production from sugar cane crop in the region evaluated.

4. Conclusions

The agricultural WF for the ethanol production was superior to sugar production. Agricultural water footprint under fertigation was lower than that obtained under non-irrigated conditions, and should be a recommended practice for increasing water productivity to sugar and ethanol production from sugar cane crop in the region evaluated.

5. Acknowledgements

The authors acknowledge the support provided by COMVAP - Sugar and Alcohol Ltda. in conducting field trials.

6. References

Andrade Junior, A.S., Bastos, E.A., Ribeiro, V.Q., Duarte, J.A.L., Braga, D.L., & Noleto, D.H. Níveis de água, nitrogênio e potássio por gotejamento subsuperficial em cana-de-açúcar. Pesquisa Agropecuária Brasileira, Brasília, v.47, n.1, p.76-84, jan. 2012.

Chapagain, A.K., & Hoekstra, A.Y. (2004). Water footprints of nations. Water Research Report Series No. 16, UNESCO-IHE, Delft, The Netherlands.

Chapagain, A.K., Hoekstra, A.Y., Savenije, H.H.G., & Gautam, R. (2006). The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries, Ecological Economics, 60(1): 186-203.

Ercin, A.E., A.E., Aldaya, M.M., & Hoekstra, A.Y. (2011). The water footprint of soy milk and soy burger and equivalent animal products. Value of Water Research Report Series No. 49, UNESCO-IHE, Delft, The Netherlands.

EPA. (1995). Compilation of air pollutant emission factors. Volume I: Stationary point and area sources. Fifth edition. Office of air quality planning and standards, Office of Air and Radiation, Environmental Protection Agency, US.

Gerbens-Leenes, P.W., Hoekstra, A.Y., & van der Meer, Th. (2009). The water footprint of bioenergy. Proceedings of National Academy of Sciences of the United States of America 106, 10219–10223.

Hoekstra, A.Y., & Chapagain, A.K. (2008). Globalization of water, Sharing the planet"s freshwater resources, Blackwell Publishing Ltd. Oxford, UK

Scholten, W. (2009). The water footprint of sugar and sugar-based ethanol. University of Twente Faculty of Engineering Technology, Civil Engineering and Management. Department of Water Engineering and Management. Thesis report. 148p.

WHO (2006). Guidelines for drinking-water quality. 3rd edition incorporating 1st addendum. World Health Organization, www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html.