Water footprint assessment of bananas produced by small banana farmers in Peru and Ecuador

L. Clercx[1], E. Zarate Torres[2] and J.D. Kuiper[3]

[1]Technical Assistance for Sustainable Trade & Environment (TASTE Foundation), Koopliedenweg 10, 2991 LN Barendrecht, The Netherlands; [2]Good Stuff International CH, Blankweg 16, 3072 Ostermundigen, Bern, Switzerland; [3]Good Stuff International B.V., PO Box 1931, 5200 BX, s'-Hertogenbosch, The Netherlands.

Abstract

In 2013, Good Stuff International (GSI) carried out a Water Footprint Assessment for the banana importer Agrofair and its foundation TASTE (Technical Assistance for Sustainable Trade & Environment) of banana production by small farmers in Peru and Ecuador, using the methodology of the Water Footprint Network (WFN). The objective was to investigate if the Water Footprint Assessment (WFA) can help define strategies to increase the sustainability of the water consumption of banana production and processing of smallholder banana producers in Peru and Ecuador. The average water footprint was 576 m^3 t^{-1} in Ecuador and 599 m^3 t^{-1} for Peru. This corresponds respectively to 11.0 and 11.4 m^3 per standard 18.14 kg banana box. In both samples, approximately 1% of the blue water footprint corresponds to the washing, processing and packaging stage. The blue water footprint was 34 and 94% of the total, respectively for Ecuador and Peru. This shows a strong dependency on irrigation in Peru. The sustainability of the water footprint is questionable in both countries but especially in Peru. Paradoxically, the predominant irrigation practices in Peru imply a waste of water in a context of severe water scarcity. The key water footprint reduction strategy proposed was better and more frequent dosing of irrigation water. This will generate increased water productivity and better quality of banana fruits. The increased water productivity not only decreases the blue water footprint, it also improves the competitiveness and livelihoods of small banana producers and their families in Peru and Ecuador.

Keywords: environment, water scarcity, water footprint, banana (*Musa* spp.), irrigation, water management

INTRODUCTION

The banana (*Musa* spp.) is described by FAO (2012a) as one of the most important tropical fruits. The production of banana in Ecuador and Peru for export, is an important economic activity with economic and social benefits for a large number of small producers. The banana is a plant that requires a substantial and frequent supply of water during its whole production cycle. Water deficits affect the growth and yield of banana and decrease the size as well as the quality of the fruit (FAO, 2012a). In both countries, the major part of banana production takes place in valleys and lowlands that depend on watersheds fed by rivers coming from the Andes mountain range. Most of the rivers are fed from Andean glaciers. As a result of climate change, glaciers are melting faster resulting in higher risks of inundations after heavy rainfall and an increases of low to no flow in rivers in the dry period. The El Niño events of 1982-83 and 1997-98 in Peru and Ecuador, led to extreme precipitation levels of 40 times the average rainfall (Skees and Murphy, 2009). Upstream land degradation in combination with high El Niño runoff levels led to soil erosion and sedimentation downstream. In Peru, sedimentation of the water reservoir of the Poechos dam (established in 1976) has reduced the reservoir capacity by almost 50%. About one third of this sedimentation was produced during the Meganiño event of 1982-83; one third during the Meganiño event of 1997-98 and one third during a period of 30 "normal" years (Rocha Felices, 2006). Another Meganiño event will reduce the Poechos reservoir capacity below critical levels impacting the irrigation of farming on 70,000 ha downstream. In

Ecuador, mining activities upstream have increased the probability of contamination of the river water impacting irri-gation of many farms downstream.

Apart from the approximately 6,000 small banana producers, there are other users of the water as well: thousands of small rice producers, big sugar cane estates for ethanol production, and a hydroelectric company. There are two important platforms aimed at the sustainable management of the water resources in North Peru: (1) the governmental inter-institutional Council for the Sustainable Management of Hydric Resources of the Chira and Piura Rivers; and (2) the multi-stakeholder platform IRAGER (Regional Institute in Support of the Management of Hydric Resources), with participation of government, universities, irrigation boards and companies. These bodies have a big role to play in mapping water footprint assessments of other users and sectors, and in promoting a territorial approach and negotiation processes to promote awareness, transparency, and fair distribution of this scarce resource.

The objective of the study was to investigate if the Water Footprint Assessment (WFA) can help define strategies to increase the sustainability of the water consumption of banana production and processing of smallholder banana producers in Peru and Ecuador that supply Fair Trade certified bananas to the Agrofair company in The Netherlands (Zarate and Kuiper, 2013).

MATERIALS AND METHODS

The water footprint is a comprehensive multidimensional indicator of water consumption. The water footprint specifies water consumption according to the source of water consumed as well as the volume of water polluted. The green water footprint specifies the water consumption from soil moisture stemming from precipitation. The blue water footprint addresses water consumption from surface or groundwater sources. The grey water footprint refers to pollution and is defined as the volume of freshwater required to assimilate the load of pollutants (Hoekstra et al., 2011).

The water footprint of banana production and processing was calculated following the global water footprint assessment (WFA) standard of the Water Footprint Network (Hoekstra et al., 2011). The WFA was executed for two samples of smallholder farmers in Ecuador and Peru. In Ecuador, the sample was selected from the province of El Oro in Ecuador, specifically the cantons of El Guabo, Pasaje, Santa Rosa and Arenillas. In Peru, the sample was selected from the Sullana province in the department of Piura. The Ecuadorian sample consisted of 15 farms with an average size of 10 ha each with its own packing station. The agricultural systems included were conventional and organic monoculture plantations and agroforestry systems. In Peru, the sample comprised 6 packing stations that processed bananas for 106 small producers. The average farm size in the Peru sample was 0.5-1.0 ha. In Peru all the bananas are cultivated in monoculture organic production systems.

All four phases of the WFA were addressed in the study: 1. setting scope and goals, 2. water footprint accounting, 3. water footprint sustainability assessment and 4. response strategy formulation. The water footprints associated with transport, marketing, production of inputs, as well as materials used in the supply chain were not addressed in the study. The green, blue and grey water footprint of banana processing and packaging were calculated and analysed.

The CROPWAT model developed by FAO was used to calculate the blue (from irrigation) and green water consumption (from precipitation) in the agricultural production phase, (FAO, 2012b). Using monthly climate data from the New_LocClim model (FAO, 2012c), available soil moisture (soil data was collected at all farms), and crop cultivation parameters, the CROPWAT model calculates a daily soil water balance. From the daily soil water balance, the total monthly evaporation of the crop was calculated. Irrigation data were collected for the sample farms. Monthly irrigation data were used in combination with monthly precipitation to derive the blue and green components of evapotranspiration of the crop (mm $month^{-1}$). Following the formulas of the WFA manual, locally collected annual banana yield data (in t ha^{-1} y^{-1}) were used to calculate the green and blue water footprints of banana production in m^3 t^{-1} (Hoekstra et al., 2011). The grey water footprint of the agricultural production phase was calculated for the pollution resulting from nitrogen application collected at all farms.

The packing phase has a blue and grey water footprint. The blue water footprint constitutes water that is evaporated in the process of washing and packing of bananas. Following van Oel et al. (2009) and Hoekstra and Mekonnen (2012), it was assumed that 10% of the water used in these processes evaporates. The grey water footprint of the packing phase was calculated for the BDO5 (biological oxygen demand) and COD (chemical oxygen demand) values of the effluent from the packing processes. The data for BDO and COD for each packing station were obtained from the producer associations.

The water footprint of bananas exported from Peru and Ecuador to The Netherlands was obtained by calculating the sum of the water footprints of the packing process and the water footprint of the fraction of banana production for export. The water footprint of the fraction of banana production for export was calculated by multiplying the total water footprint of banana production with the economic value fraction of the bananas for export.

The water footprint sustainability analysis was executed following the WFA manual (Hoekstra et al., 2011). The environmental sustainability of blue and grey water footprints was assessed using publicly available datasets complemented with qualitative data from farmer discussions. The public datasets used in the study were the online Water Risk Filter (WWF, 2012a, b), the online Water Footprint Asessment Tool (WFN, 2012) the 2050 water stress scenarios from Alcamo et al. (2007) and the water pollution level (WPL) maps generated by Liu et al. (2012). Social and economic sustainability of the water footprints was not assessed.

The water footprint reduction response formulation was done in a qualitative manner through a complementary analysis of the water footprints obtained and the yields observed in relation to the agricultural, irrigation and packing practices. Also the local water distribution policies and practices were brought into the qualitative analysis.

RESULTS AND DISCUSSION

Climate conditions

The climate in the locations in Ecuador and Peru constitutes of a dry period from June to December and wet period from December to May with an annual total rainfall of between 997-1410 mm in the studied zone in Ecuador (Province El Oro) and 140 mm in the studied zone in Peru (the Piura region) respectively (INAMHI, 2012; SENAMHI, 2001).

Irrigation practices

The sample farms in Ecuador use 33% flood irrigation, 66% sprinkler irrigation and 1% of the producers practice rainfed agriculture. In Peru, 83% of the producers use flood irrigation and 17% sprinkler irrigation (Zarate and Kuiper, 2013). Sprinkler irrigation allows the optimisation of water use by applying lower volumes of water to the crop at shorter intervals. This results in less water runoff and leaching of nutrients. Due to the prevailing water allocation policy, producers must receive water for several hours in a system of turns. For Ecuador, turns varied between 1-2 times per week in the dry period to 1-3 times in 3 weeks in the wet period. Irrigation boards reported supplying a quota of 22,000 m^3 ha^{-1} y^{-1} to banana producers. In Peru, producers received water between 1 time in 2 weeks and 1 time per 3 per weeks in the dry period and 1 time per 3 weeks to 3 times per 4 weeks in the wet period. For Peru in all cases, the water distribution frequency and volume did not allow producers to apply water in lower amounts and at shorter intervals. The sample in Peru clearly showed that the water efficiency advantages of sprinkler irrigation systems was seriously impeded by this. A similar pattern emerges for the flood irrigation practice where fields were over flooded during irrigation. The inefficient irrigation management and application practices lead to high evaporation losses, high runoff, erosion, leaching of nutrients, salinisation and bad drainage (Agrofair Sur, 2011a, b). In Peru, irrigation water is not available be-tween turns leading to water stress for the banana crop. Crop yield reductions associated with water stress of 27% were reported.

Yields

The average yield found in Ecuador was 29 t ha^{-1}. This was lower than the indicated average of 35 t ha^{-1} for Ecuador by FAO. The reason is that the sample contains 40% of agro-forestry banana producers. These producers mix banana with other crops like cacao, resulting in a lower banana planting density per ha. The average yield in Peru was 34 t ha^{-1}.

Water footprint calculation

The water footprint calculated per hectare per year, was 1,112 m^3 ha^{-1} y^{-1} and 1,603 m^3 ha^{-1} y^{-1} in Ecuador and Peru, respectively (Figure 1). The water footprint t^{-1} of banana for export obtained for Ecuador was 576 m^3 t^{-1} (48% green, 34% blue and 18% grey), whereas it was 599 m^3 t^{-1} (94% blue and 6% green) for Peru (Zarate and Kuiper, 2013). These values correspond respectively to 11.0 and 11.4 m^3 per standard 18.14 kg banana box. In both samples, approximately 1% of the blue water footprint corresponds to the washing and packing stage, which means that most of the blue water footprint is located in the agricultural phase. The blue water footprint was 34 and 94% of the total for Ecuador and Peru, respectively. This shows the strong dependency on irrigation in Peru. In Ecuador, 18% of the water footprint is grey. The grey water footprint is found in both the agricultural phase (leaching of nitrogen from the conventional practice) and packing phase (pollutant loads in the washing effluent). In Peru, where the agricultural practice is organic, it was assumed that there is no leaching of nitrogen, and therefore the grey water footprint of the agricultural production phase is zero. Water quality data for the packing effluents was not available. As a result it was not possible to calculate the grey water footprint of packing (Zarate and Kuiper, 2013).

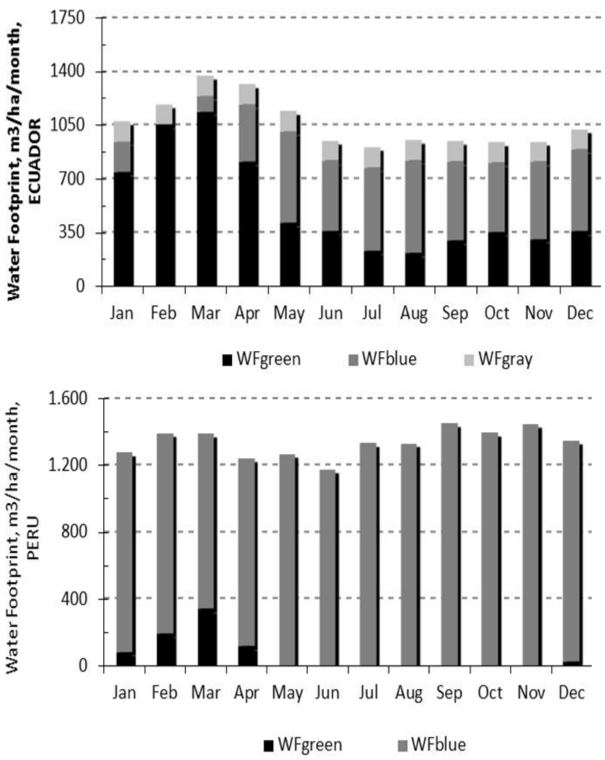

Figure 1. Green, blue and grey water footprint in m^3 ha^{-1} month^{-1}, in Ecuador (top) and Peru (bottom). In Ecuador, there is considerable variation in green and blue water footprint, depending on the rainy season. In Peru, the water footprint is al-most entirely a blue water footprint, which reflects the dependency on year-round irrigation.

Water footprint sustainability analysis

A very critical situation was found in the Chira river basin in Peru (including the connected Poechos reservoir and canals). There producers withdraw water for irrigation. The application of the tools and assessments (WFN, 2012a, b; Alcamo et al., 2007) showed that the Chira river basin is severe water scarce during at least 5 months per year. Also, water withdrawals do not respect environmental flow requirements. This result was confirmed in field level conversations that the Agrofair South team had with Peruvian producers. A strong competition for the resource with other crops like rice and sugar cane was perceived by them.

The sustainability analysis results show that there was a serious physical risk due to water scarcity in Peru, which is affecting the banana export chain. It is paramount that the main players in the export chains understand these risks. Subsequently they can develop actions to improve water use efficiency in both countries.

Formulation of water footprint reduction strategies

The key water footprint reduction strategy is to ensure a better water distribution. This means irrigating with lower quantities of water, with shorter intervals between turns. To do this, water that is received during each turn but not required for irrigation should be temporarily stored in reservoirs. The stored water will be used to irrigate at a later time. Improved irrigation systems with hoses and outlets with regulators are already available. A better dosing will lead to an increase in the yield, better fruit quality, less nutrient leaching and a reduction of the blue water footprint. Different sectors, including the banana sector, should invest in more appropriate irrigation systems and precision irrigation (supply water in quantities and frequency what the banana plant really uses, depending also on the soil type). Current productivity levels are believed to be far below the potential. The strategy will increase overall water productivity. This is vital for the competitiveness of small banana producers and their viability in north Peru.

CONCLUSIONS

The water footprint assessment methodology was applied on two samples of small scale banana producers that supply bananas to Agrofair. One sample comprised 15 producers of the ASUGUABO association in Ecuador. The second sample consisted of 88 producers grouped around 6 packing stations of the APROBOVCHIRA, APPBOSA and CENBANOR associations in Peru.

The average water footprint of the Ecuadorian sample was 576 and 599 m^3 t^{-1} for the Peruvian sample. This is equivalent to 11 and 11.4 m^3 per box of fresh bananas. In the Peruvian case, 94% of the average water footprint corresponds to the blue water footprint whereas for Ecuador, the blue water footprint corresponds to 34% of the total. In both countries, the agriculture production phase contributes more than 99% to the total water footprint.

In the region studied in Peru, the river basin of River Chira that supplies irrigation water and the Poechos reservoir show important water stress, during five months of the year. The water footprint sustainability analysis shows that the production of bananas for Agrofair in Peru is not environmentally sustainable with the prognosis of increasing water stress in the future. The water risks associated with the production in Peru concerns physical water stress as well as a lack of means to improve the efficiency of water management.

Impacted catchments of the Jubones, Arenillas and Chaguana rivers in Ecuador do not have data on water stress status. Producers experience increasing competition for water and reported a diminishing availability of water in the dry period.

Irrigation practices of producers in Peru and Ecuador are largely artisanal. Irrigation water allocation frequency and volumes are out of sync with banana crop water requirements. This creates an alternating system of water excess and water stress for the banana crop. As a result the yield and banana fruit quality is seriously impaired.

The study shows that the Water Footprint Assessment can help define actionable strategies to increase the sustainability of the water consumption of banana production and processing of smallholder banana producers in Peru and Ecuador.

ACKNOWLEDGEMENTS

The authors wish to thank Linett Duque (Agrofair South team), for the collection of field data; Agrofair Benelux B.V. and the producer organisations ASOGUABO in Ecuador and APPBOSA, APROBOVCHIRA and CENBANOR in Peru, for their collaboration; Marco Oviedo, Edison Aguilar and Trossky Maldonado (technical team of ASOGUABO); Guillermo Ladines and Diego Balarezo (technical team of Grupo Hualtaco / CENBANOR); the officials of several irrigation commissions; Juan Pablo Mariluz of the National Information System of Water Resources in Peru; Carla Toranza de COSUDE in Lima for her explanation on environmental norms; Ben Huyghe, manager of the Agrofair South team for his useful comments; and the LOTEX Foundation, Vaduz, for co-founding the Agrofair South programme. The water footprint assessment was part of this programme.

Literature cited

Agrofair Sur, TASTE, ApecoInca, Master SRL. (2011a). Introducción de bananos "savanna grown" y "mountain grown": hacia nuevos conceptos para una fruta tropical más sostenible. Estudio territorial ambiental y estudios de caso socioeconómicos y ambientales de fincas bananeras en Perú.

Agrofair Sur, TASTE, ApecoInca, Master SRL. (2011b). Introducción de bananos "savanna grown" y "mountain grown": hacia nuevos conceptos para una fruta tropical más sostenible. Diseño metodológico de investigación: enfoque agronómico y enfoque ambiental.

Alcamo, J., Florke, M., and Marker, M. (2007). Future long-term changes in global water resources driven by socio-economic and climatic changes. J. Hydrol. Sci. *52* (*2*), 247–275 http://dx.doi.org/10.1623/hysj.52.2.247.

FAO. (2012a). Crop water information for banana. http://www.fao.org/nr/water/cropinfo_banana.html.

FAO. (2012b). Programa para el cálculo de los requisitos de agua de un cultivo, Cropwat (Roma, Italy). http://www.fao.org/nr/water/infores_databases_cropwat.html.

FAO. (2012c). Programa para interpolación de datos climáticos, New_LocClim (Roma, Italy). http://www.fao.org/nr/climpag/pub/en3_051002_en.asp.

Hoekstra, A.Y., and Mekonnen, M.M. (2012). The water footprint of humanity. Proc. Natl. Acad. Sci. U.S.A. *109* (*9*), 3232–3237 http://dx.doi.org/10.1073/pnas.1109936109. PubMed

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., and Mekonnen, M.M. (2011). The Water Footprint Assessment Manual: Setting the Global Standard (London, UK: Earthscan). http://www.waterfootprint.org/?page=files/WaterFootprintAssessmentManual.

INAMHI. (2012). República del Ecuador. Instituto Nacional de Meteorología e Hidrología (Quito, Ecuador: Anuario Meteorológico). http://www.serviciometeorologico.gob.ec/.

Liu, C., Kroeze, C., Hoekstra, A.Y., and Gerbens-Leenes, W. (2012). Past and future trends in grey water footprints of anthropogenic nitrogen and phosphorus inputs to major world rivers. Ecol. Indic. *18*, 42–49 http://dx.doi.org/10.1016/j.ecolind.2011.10.005.

Rocha Felices, A. (2006). La problemática de la sedimentación de embalses en el aprovechaniento de los ríos peruanos, aplicada al embalse de Poechos. Paper presented at: Primer Congreso Internacional de Hidraúlica Hidrología, Saneamiento y Medio Ambiente (Lima, Peru). http://www.imefen.uni.edu.pe/Temas_interes/ROCHA/Sedimentacion_de_embalses_cas_%20Poechos.pdf.

SENAMHI. (2001). Servicio Nacional de Meteorología e Hidrología del Perú. Variabilidad pluviométrica, a escalas anual y cuatrimrestral, en la vertiente peruana del Océano Pacífico. www.senamhi.gob.pe.

Skees, J., and Murphy, A.G. (2009). ENSO Business Interruption Index Insurance for Catastrophic Flooding in Piura, Peru (Lexington, KY, USA: GlobalAgRisk). www.globalagrisk.com.

van Oel, P.R., Mekonnen, M.M., and Hoekstra, A.Y. (2009). The external water footprint of the Netherlands: geographically-explicit quantification and impact assessment. Ecol. Econ. *69* (*1*), 82–92 http://dx.doi.org/10.1016/j.ecolecon.2009.07.014.

Wallace, J., Jackson, N., and Ong, C. (1999). Modelling soil evaporation in an agroforestry system in Kenya. Agric. For. Meteorol. *94* (*3-4*), 189–202 http://dx.doi.org/10.1016/S0168-1923(99)00009-X.

Washington University. (2012). Compost fundamentals. http://whatcom.wsu.edu/ag/compost/fundamentals/

benefits_benefits.htm.

WFN. (2012). Online water footprint assessment tool. http://waterfootprint.org/en/resources/interactive-tools/water-footprint-assessment-tool/.

WWAP (World Water Assessment Programme). (2012). The United Nations world water development report 4: managing water under uncertainty and risk (Paris, France: UNESCO).

WWF. (2012a). Filtro de riesgo de agua. http://waterriskfilter.panda.org.

WWF. (2012b). Online water risk filter tool, http://waterriskfilter.panda.org/.

Zarate, E., and Kuiper, D. (2013). Evaluación de la huella hídrica de banano para pequeños productores en Perú y Ecuador. www.goodstuffinternational.com.