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Water use management in food supply chain: Case study of sweet potato noodle

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Abstract

Fresh water is increasingly becoming a global resource driven by growing international business. Due to the concerns of global water scarcity and food security, there has been much interest in the water footprint indicator which is popular with sound public perception to assess product environmental impact of water use and to further undertake supply chain management. This study applied a process-based life cycle assessment (LCA) method to calculate the water footprint of sweet potato noodle at brand level. The results demonstrated well practicality of water footprint as streamlined indicator in product supply chain management for the selected product. Footprinting value was compared among different life cycle stages and possible mitigation strategies were put forward for water use reductions throughout the supply chain.

Key words: Water use management, water footprint, food supply chain, mitigation options.

Introduction

For humanity's profound dependence on fresh water, basic water security is an essential condition for securing food production, improving living conditions and providing employment and income to reduce poverty [1]. However, freshwater has now become a scarce resource and nearly 80% of the world's population is exposed to high levels of threat to water security [2]. The most significant way that humans influence the terrestrial water cycle is in the production of agri-food products [3]. Almost 70% of global "blue" water withdrawals (80-90% of consumptive use) from surface and ground hydrological systems are devoted to irrigation[1, 4]. Driven by growing international business, fresh water is increasingly becoming a global resource and local consumption of agri-food products is intervening in the hydrological cycle throughout the world to an unprecedented extent [5]. Reducing the effects of food production and consumption patterns on freshwater resources constitutes an international security concern well into the future.

Agri-food industries have traditionally focused on water use in operations, not in the supply-chain. However, supply-chain water use was much larger than operational water use [6]. For many agri-food products, the major impacts from life cycle water use occur in the agricultural stage of production [7]. As such, there has been much recent interest in the concept of water footprint, to make transparent the impacts of humanity's consumption and production on global freshwater scarcity [8-10]. Water footprint of a product is typically defined as the summation of direct and indirect water use for its various stages of production [6]. Stemmed from the concept of ecological footprint and carbon footprint, water footprint is developing under the life cycle assessment (LCA) based methodology [7, 10], making it possible to form an integrated LCA-based footprinting framework to assist sustainability assessment on products. Stakeholders should have access to the environmental performance of a certain product or service if willing to be informed. Water footprint is under way to become part of mainstream dialogue in product supply chain management.

Despite the emergence of a series of water footprinting case studies in different sectors, few studies were reported in the Chinese context, especially within the agri-food sector at brand level. Food products, usually with lengthy and complex life cycles, deserve much more attention in research and application of supply chain management. This study applied an LCA-based water footprinting to sweet potato noodle at brand Guangyou® [7]. Our purposes were twofold. First, to report the water footprint of sweet potato noodle produced in Sichuan, China. Second, to provide specific guidance to manufacturer on steps that could be taken to improve the sustainability of the product. This study has relevance beyond the noodle company, it can also provide implications for other agri-food industries to improve their awareness of environmental impact and stimulate innovative solutions.

Methods and Data

Goal and scope definition: The goal of this research was to assess the water footprint of the sweet potato noodle by applying a compressive method and firsthand primary data and also to provide useful information applicable to similar studies in the future. For the product, the functional unit was defined as one stock keeping unit for sale in the market, that is 300 g sweet potato noodle (Guangyou®). The product was manufactured in Sichuan, which is the biggest sweet potato-producing province in China.

The system boundary for this study extended from farming, plant operation, packaging, transportation through to consumption (Fig. 1). Since no coproduction occurred in the plant manufacturing process, allocation was not considered in this study.

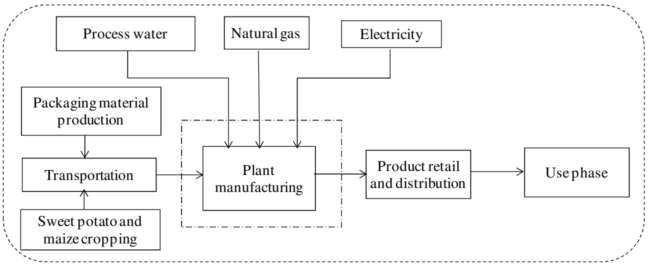

Figure 1. System boundaries for life cycle of sweet potato noodle Guangyou®.

Inventory analysis: The inventory throughout the value chain related to water footprint modeling was established covering the financial year 2013. The main agricultural ingredients of the product were sweet potato powder and maize starch. For the sweet potato and maize cropping subsystem in Sichuan province, the on-farm input data, such as irrigation and fertilizer application rate were obtained from the company's own farm (Table 1). For the plant operation subsystem, the input-output data such as energy consumption, process water use and product conversion factors, were collected according to the company's production records and consultation with plant engineers. The information about package weight and supplier were provided by purchase department. For the transportation phase of sweet potatoes and maize, packaging materials and the sweet potato noodles, the information about truck size and average transportation distance was obtained from logistic department. Pre-farm activities such as the production and transportation of inputs used in the cropping system and plant operation phase were also included in the assessment. Capital inputs such as the construction of workshop, machinery and equipment were excluded from the assessment according to PAS 2050. As much foreground data was collected as possible in the inventory phase. Where local data for some unit processes were not available, international LCA database such as Ecoinvent was used.

Table 1. Characteristics of the crop farming subsystems in Sichuan, China.

	Sweet potato	Maize
Irrigation, m^3 ha^{-1}	0	25.7
Rain water, m^3 ha^{-1}	10920	3829
Pesticide, kg ha^{-1}	15	2.4
Fertilizer, kg ha^{-1}		
N	225	240
P_2O_5	180	72
K_2O	360	90
Yield, kg ha^{-1}	52500	5147

Water use was differentiated as green water, blue water and grey water. Green water is effective rain water intercepted in crops. Blue water is ground or surface water appropriated into agri-food product life cycles mainly as irrigation in farming systems, as process water in factories and water used for cooking. Grey water refers to the volume of water needed to assimilate the pollutants in water body. The grey water footprint was calculated as the N leaching divided by the permissible concentration [12]. The standard recommended by US EPA (10 mg L^{-1}) for drinking water was used to calculate the necessary dilution water volume. Blue water use associated with transportation and the production of input materials such as electricity and fertilizer was derived from Chinese Life Cycle Database (CLCD; www.itke.com.cn) implemented in LCA eBalance software (version 4.0) as listed in Table 2.

Table 2. Water use associated the production inputs from LCA databases.

Item	Water use, kg kg^{-1}	Database source
Nitrogen fertilizer	152.4	CLCD 0.7
Phosphate fertilizer	101.7	
Potash fertilizer	13.9	
Natural gas	0.71[a]	
Electricity[b]	3.7[c]	
Polyethylene	9.7	
Transportation[d]	0.3[e]	
Insecticide	2.2×10^5	Ecoinvent 2.2
Fungicide	1.6×10^5	
Herbicide	2.3×10^4	

[a] Unit: kg m^{-3}; [b]Produced and supplied in South China; [c] Unit: kg kwh^{-1}; [d] By medium-sized truck (8t); [e] Unit: kg $(t*km)^{-1}$.

Impact assessment: Impact assessment is used to link water consumption to freshwater scarcity, expressing the product water footprint in units which are normalized according to the local water stress. For the calculation, the green water was not included. That's because the consumption of green water is not equivalent to the consumption of blue water. Green water consumption does not contribute to water scarcity unless it changes rainwater runoff and drainage patterns. Local characterization factors for freshwater consumption were taken from the Water Stress Index (WSI) of Pfister *et al.* [11]. The WSI of the study region was 0.068 and the national average WSI for China (0.478) was used in relation to farm and industrial inputs where the location of production was uncertain. For calculation of the water footprint, each instance of consumptive water use was multiplied by the relevant WSI and then summed across the product life cycle. To enable comparisons between products produced in different regions, the water footprint was then normalized by dividing by the global average WSI (0.602) and expressed in the units H_2O equivalents (H_2Oe). The full picture for the calculation was presented as Fig. 2.

Result interpretation: Unlike the complete LCA analysis which considers all relevant midpoint or endpoint impact categories, this research just assessed water performance of the products, with the objective to address water use within the life cycles of sweet potato product as already stated in goal and scope definition. Water footprint values were compared between different life cycle stages. Implications and recommended strategies were then put forward to detect potential fields for water use reductions throughout the supply chain and assist product supply chain management.

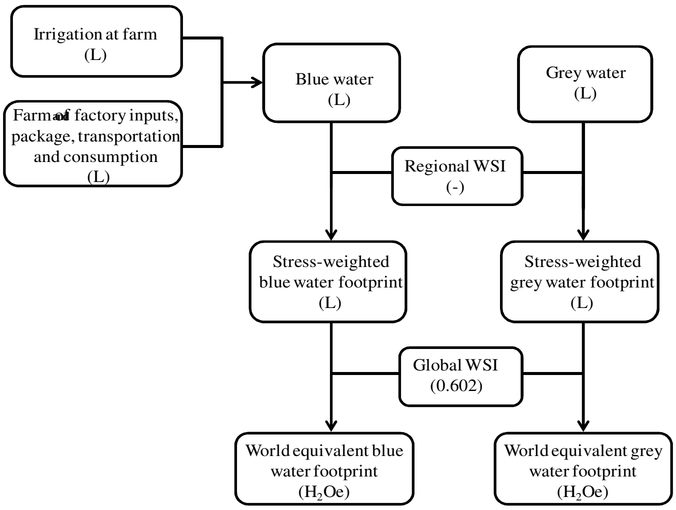

***Figure* 2.** Revised method of calculating product water footprints incorporating water stress characterization factors[7].

Results and Discussion

Water use inventory: The volumetric water use in different stages is documented in Table 3. Green water consumptions were much higher than grey and blue water for the product. This was resulted from the fact that sweet potato and maize cropping relied heavily on rainwater. Water degradation also should not be neglected according to the results. Plant operation and consumption accounted for the majority (86%) of blue water use. The production of farm inputs, packaging, retailing and distribution resulted in much less water use compared with the other stages.

Table 3. Water use inventory for 300 g Guangyou® sweet potato noodle.

Water use inventory	A functional unit
Green water (L)	188.5
Grey water (L)	57.6
Blue water (L)	14.4
Irrigation	0.6
Farm input	1.3
Manufacturing	7.9
Packaging	0.1
Retail and distribution	<0.1
Use phase	4.5

Water footprint: For the case study product, 300 g sweet potato noodle Guangyou®, total water footprint was 12.2 L H_2Oe. Most of the water footprint occurred in the agricultural stage of the life cycle (Fig. 3). Agricultural production accounted for more than 60% of the total water footprint. The second biggest contributor was use phase, which accounted for 30% of the total. That's because to cook a certain amount of sweet potato noodle, 15 times drinking water is needed usually. Less than 10% of the life cycle water use occurred in the manufacturing of the product, packaging materials and retailing and distribution.

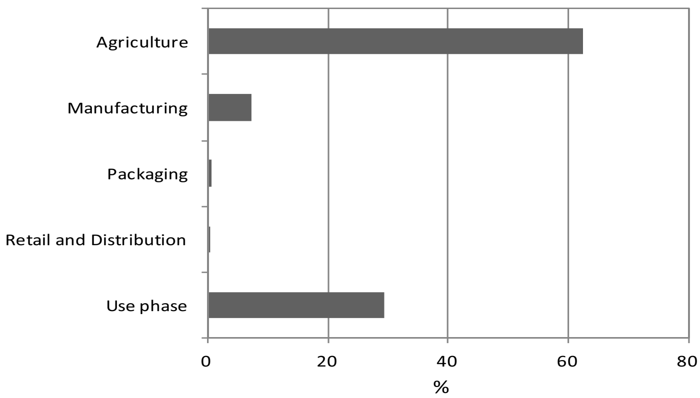

***Figure* 3.** Water footprint across the life cycle as a proportion of the total water footprint for 300 g sweet potato noodle Guangyou®.

Implications for supply chain management: Farming was illustrated to be a significant stage for environmental impact associated with water use, without being adequately highlighted before in the minds of food producers and consumers. Therefore, mitigation options to reduce water footprint should first focus on this hotspot. The following measures could be considered: 1) improve farm practices to increase irrigation water use efficiency in crop production and to decrease the agro-chemical pollution; 2) import agricultural ingredients with lower water consumption from other regions or other countries which have even lower local water stress; and 3) sign environmental agreement with ingredient suppliers to encourage local farmers to adopt water-saving practices. This case study also identified that the use phase was a big contributor of life cycle water footprint for the sweet potato noodles. The mitigation options to reduce the impact at this stage can consider making change in product design. Designing a recipe which is easy for cooking and requires a small amount of water would have big potential to save water.

Plant operation, as the main focus in traditional product supply chain management, was identified to be the small contributor to water footprint in general. However, there is still some potential for company to reduce its operational water use. Reducing ingredient waste and improve energy use efficiency will be both effective ways to reduce water footprint in this stage. While water use was identified to be quite small (contributing less than 1% to the whole life cycle in all cases), packaging and transportation stages should not be neglected if the business aims to reduce other environmental impact, such as greenhouse gas emissions. Packaging materials were recommended to be sourced from suppliers with cleaner production techniques. The product logistic department can be better adjusted to reduce average distance for each functional unit. To reduce products' environmental impacts from distribution stage, less amount of water use in the transportation by heavy trucks than lighter trucks should be taken into account.

Conclusions

As the first application of the LCA-based water footprinting on sweet potato product in China, this study applied a quantitative method for product supply chain water use management in agri-food sector through a case study. Water footprint value was calculated and interpreted between different stages of the product life cycles. It was useful to identify hotpots across and within the studied life cycle stages to mitigate environmental impacts. The significance of farming stage for water use reduction is confirmed. Enormous potential exists for LCA-based water footprint to facilitate supply chain management and corporate sustainability development. However, interventions to reduce water footprints should not be taken without due consideration given to the potential consequences for other environmental impact categories (e.g. GHG emissions), as well as social and economic factors.

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References

[1]Gleick, P.H., Cooley, H., Cohen, M.J., Morikawa, M., Morrison, J., and Palaniappan, M. 2009. The World's Water 2008–2009: The Biennial Report on Freshwater Resources. Island Press, Washington, DC.

[2]Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R. and Davies, P.M. 2010. Global threats to human water security and river biodiversity. Nature **467**:555-561.

[3]Rost, S., Gerten, D., Bondeau, A., Lucht, W., Rohwer, J. and Schaphoff, S. 2007. Agricultural green and blue water consumption and its influence on the global water system. Water Resour. Res. **44**:W09405.

[4]UNESCO-WWAP 2006. Water: A shared responsibility. The United Nations World Water Development Report 2. Available online: http://www.unescoorg/water/wwap/wwdr/wwdr2/.

[5]Hoekstra, A.Y. and Mekonnen, M.M. 2012. The water footprint of humanity. Proc. Natl Acad. Sci. USA **109**:3232-3237.

[6]Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. 2011. The Water Footprint Assessment Manual: Setting the Global Standard. Earthscan Press.

[7]Ridoutt, B.G. and Pfister, S. 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Glob. Environ. Change **20**:113-120.

[8]Chapagain, A.K. and Orr, S. 2009. An improved water footprint methodology linking global consumption to local water resources: A case study of Spanish tomatoes. J. Environ. Manage. **90**:1219-1228.

[9]Jefferies, D., Muñoz, I., Hodges, J., King, V.J., Aldaya, M., Ercin, A.E., Milà i Canals, L. and Hoekstra, A.Y. 2012. Water footprint and Life Cycle Assessment as approaches to assess potential impacts of products on water consumption. Key learning points from pilot studies on tea and margarine. J. Clean. Prod. **33**:155-166.

[10]Ridoutt, B.G., Eady, S.J., Sellahewa, J., Simons, L. and Bektash, R. 2009. Water footprinting at the product brand level: Case study and future challenges. J. Clean. Prod. **17**:1228-1235.

[11]Pfister, S., Koehler, A. and Hellweg, S. 2009. Assessing the environmental impacts of freshwater consumption in LCA. Environ. Sci. Technol. **43**:4098-4104.

[12]Chapagain, A.K., Hoekstra, A.Y., Savenije, H.H.G. and 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. Ecol. Econ. **60**:186-203.