VIRTUAL WATER IN AGRICULTURAL PRODUCTION

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ABSTRACT
Virtual water refers both to water consumed during the process of production and water remaining as the constituent of the product. Apart from its quantity, easily calculated, it can also be determined in qualitative terms, through the water footprint, which describes the amount of water used by any biological entity. It can be presented as three-portion system, comprised of blue, green and gray water. The attempts to solve agricultural problems in the countries suffering from water shortage, the importance of green water has been emphasized, pointing to adequate water management. Virtual water concept enabled understanding of the international water trading ways, as it remains within the products traded. Adjusting export oriented food production any country can save significant amounts of domestic water, thus implementing its water sustainability that is important for all the countries. Since large quantities of good quality water for agricultural irrigation are the utmost requirement, it is often a limiting factor, implying that new methodology of water-food transformation should be developed.

Keywords: virtual water, agriculture, water footprints

THE WATER USED IN AGRICULTURAL PRODUCTION

The water that is used during the production of any product, including agricultural products and remains a constituent of the product is called "virtual water" (ALLAN, 1998). Although this idea was firstly developed to analyze water scarcity-caused agricultural problems in the Middle East, it was widely recognized as the means of interconnecting trading, food and water, both freshwater and soil water. It takes into the account all the water consumed during the production process, regardless of the nature of the product. For example, for the production of 1000 g of beef, a total amount of over fifteen thousand litres of water must be used. Some grains (e.g. wheat) need an input of thirteen hundred litres of water, for the production of 1000 g of final product (MERRETT ET AL., 2003).
Obviously, such situation raises questions regarding the international trade of water contained in traded products. If any country imports 1000 kg soybeans, it also imports all the water used in their production, e.g. 2752 m^3 (*Table 1*). Some countries stopped exporting water demanding crops, hence reducing virtual water export. Indeed, those countries import such products, and some significant amounts of water contained within them. For example, 13805 m^3 virtual water was imported by some Middle East countries during every single year between 1995 and 2000, as opposed to only 642 m^3 water exported (COSGROVE AND RIJSBERMAN, 2000; HOEKSTRA, 2003). Adjusting export oriented food production, any country can save significant amounts of domestic water thus implementing its water sustainability that is important for all countries. Specific amounts of water needed for the production of some vegetal products are given in the *Table 1*.

Table 1. Specific Water Demands of some primary vegetal products

Products	Specific Water Demand (m^3/T)	Products	Specific Water Demand (m^3/T)
Wheat, millet, rye	1159	Groundnuts	2547
Barley	1910	Sunflower	3283
Oats	2374	Tomatoes	130
Sorghum	542	Onions	168
Rice	1408	Vegetable, others	195
Maize	710	Grapefruit	286
Cereals, others	1159	Lemons, limes	344
Potatoes	105	Oranges and other citrus	378
Sugar beet	193	Bananas	499
Sugar Cane	318	Apples	387
Pulses	1754	Pineapples	418
Tree nuts	4936	Dates	1660
Rape and Mustard seed	1521	Grapes	455
Soybeans	2752	Fruit, others	455
Olives	2500		

(http://www.igd.com)

The analysis of virtual water flow includes any additional water consuming product or service, used for the production of a certain product. The amount of water incorporated into some of the products is given in *Table 2*.

Table 2. Estimates of the volume of water incorporated into different products

Item	Liters	Item	Liters	Item	Liters
Hamburger, 150g	2400	Cup of coffee, 125ml	140	Glass of orange juice, 200ml	170
Glass of milk, 200ml	200	Apple, 1 kg	700	Glass of apple juice, 200ml	190
Cup of tea, 250ml	35	Glass of wine, 125ml	120	Egg, 40g	135
Slice of bread, 30g	135	Tomato, 70g	13	Bovine leather shoes	8000

(http://www.igd.com)

Surprisingly, one pair of bovine leather shoes carry the load of about 8000 litres of incorporated water, while ordinary hamburger "contains" 2400 litres of water used during its production (*Table 2*).
The international virtual water trade may be the way of preserving world water, although it would be realistic only if water rich countries should export products "containing" large

amounts of embedded water. There are also suggestions that monetary value of embedded water should be incorporated into the product price.

BLUE, GREEN AND GREY WATER FOOTPRINT

The idea of the ecological footprint was initially developed in 1996 (WAKEMAGEL AND REES, 1996) and quickly adopted by the UNESCO-IHE as water use indicator (HOEKSTRA, 2003). It defines the amount of water used by any biological entity, from an individual to the entire nation.

Water footprint comprises three components: blue, green and grey water (AHLENIUS, 2012). The blue water footprint is the amount of freshwater irreversibly used from surface and ground water. The green water footprint is the amount of consumed rainwater stored as soil moisture, evaporating from global green water resources. The grey water footprint is the amount of water polluted during the production of goods and services (water needed for the assimilation of pollutants). Provided that green water management is efficient, even some countries with water shortage could be able to produce enough food for their populations.

A particular blue-green-gray water footprint distribution can be assigned to each agricultural product, determining the dominant water source type and its polluting impact on the entire environment. In animal husbandry it is known that an average beef production consumes 93% green, 4% blue, 3% grey water, mainly using surface and ground freshwater sources. The portion of virtual water needed to carry the load of the pollutants created during the production process is 3%, while wheat production includes 11% grey water (KIRBY ET AL., 2003).

HEALTHY AGRICULTURAL FOOD PRODUCTION

Since large quantities of good quality water for agricultural irrigation are the utmost requirement, it often presents a limiting factor (KIRBY ET AL., 2003). The water used for the irrigation is classified by its trophic level, type and quantity of dissolved matter (salts and suspended solids), all of which can have negative impact not only on plants but also on other important organisms that maintain soil fertility and viability. Assessments of global water availability predict that seven out of ten people in the world will experience some water-related stress, by the year 2050.

In many areas water supply is limited and the cost of irrigation system construction is high. That implies that the new methodology of water-food transformation should be developed (RENAULT AND WALLENDER, 2000; ROSEGRANT AND RINGLER, 1999). There was a five-fold increase in water use for the agricultural production during the last decade of 20^{th} century (500 to 2500 km^3 per year). It is estimated that agriculture uses 70% of available water resources (NITTI, 2011). Water is essential in assuring the food hygiene, hence it is used not only in primary food production, but also for food processing, washing, cleaning, blanching, peeling, cutting, mixing, steaming, freezing, heating, boiling etc.

There may be crucial vital difference between the agricultural strategies that had focused on blue water irrigation (e.g. irrigation) and new strategies that rely on green water

(SABMILLER PLC., 2009). As illustrated in *Figure 1*, crops for beer production require 85% green and only 6% blue (irrigation) water. The pollution output is 9% (gray water, assimilating the resultant production pollutants).

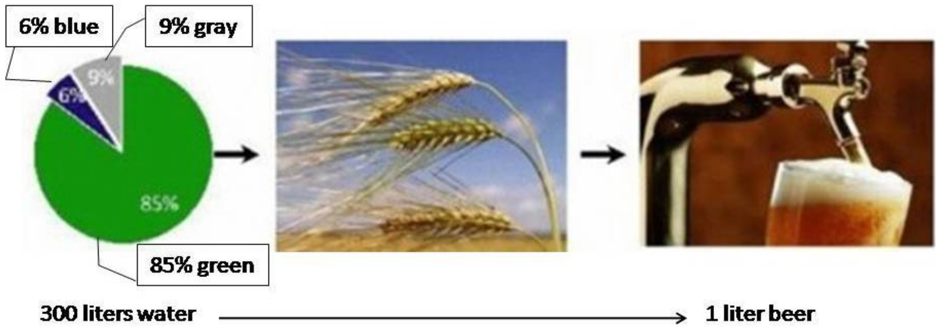

Figure 1. **Proportion of blue, green and gray water in beer production**

Greatest water consumers amongst crops are rice, (more than 20% total water used in global crop production) and wheat (12% of global crop water use). All those should be taken into account when determining the national water footprint (NITTI, 2011).

CONCLUSIONS

The concept of virtual water interconnects freshwater (surface and ground) and soil water, used in the production of agricultural goods, considering it incorporated into the product or service. Any trade also implies trading embedded water. The total volume of virtual water can be presented through the water footprint that shows the amounts of fresh or rainwater used for the production, and the amount of water needed for the assimilation of production-born pollutants. Adjusting the three portions of national water footprint enables adequate water resources management. At this time, Serbia does not have virtual water strategy and needs to account for all its agricultural production inputs and outputs as well as export and import balance.

ACKNOWLEDGEMENT

This research was supported by the Ministry of Education and Science of the Republic of Serbia, as a part of the project TR31031, entitled "Promotion of sustainability and competitiveness in organic plant and stock production using new technologies and inputs".

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