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Water Footprints of Philippine Agricultural Products

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ABSTRACT

Compared to the usual measuring of national water usage using water withdrawals from the different sectors, the use of water footprint as a tool for calculating water usage provide more insights on the efficiency of the use of freshwater resources. Various water footprints of Philippine agricultural products were calculated together with the corresponding energy water productivity. The findings in this paper also showed that the Philippine per capita water requirement for food (CWRF) is significantly higher compared to other developing countries since it needs more water to produce a food item and affects the total water usage as shown in total water requirement (TWRF). In terms of TWRF, the computed data indicates that it will continuously increase in the next four decades and will become a big factor in determining water sustainability. This paper recommends that water scarcity should be identified and be recognized as a major threat to sustainable development besides population growth and externalities of uncontrolled economic growth. Accurate identification of the "blue" "green," and "gray" water" components of food production will help in the formulation of appropriate strategies in water productivity and its efficient use.

Keywords: *energy water productivity, water footprint, water management, food security, sustainability*

INTRODUCTION

With climate change, rapid land conversion, and urbanization, water for agriculture becomes a clear and present threat in the attainment of a sustainable food source (*Wang et al. 2015*) since 70% of the world's freshwater withdrawal is for irrigation (*Gordon et al. 2010*). Studies by *Tuong and Buoman* (*2003*) estimated that that 15–20 million hectares of area for irrigated rice would experience water scarcity by 2025. The demand for water in developing countries is predicted to increase by 50% (*Boretti and Rosa 2019*). This puts more pressure to agricultural workers, especially on the government, to produce more products per unit land in order to meet the food demands and food requirements of a fast growing population especially in the Philippines where a large portion of the population depends on subsistence agriculture (*Belder et al. 2004*).

Water is an essential element for growth and development of agriculture. Being such, the importance of measuring water usage and consumption becomes primary. Unfortunately, measuring water usage at the national level is usually limited to statistics on water withdrawals from the various sectors in the economy. This method of measurement is deficient since water withdrawals are not only confined to direct usage but also includes indirect usage coming from pollution control, evaporation that influence water supply. This indirect water usage is called the virtual water content (VWC) defined as the volume of water used to produce a unit of product at the place where the product is actually produced (*Chapagain and Hoekstra 2011*). VWC or water footprint (WF) is also defined as the sum of the direct and indirect water use in the full supply chain including by source and polluted volumes in water (*Gheewala et al. 2014*). The WF consists of three components: green WF, which refers to the rainwater consumed; blue WF, which refers to the volume of surface and groundwater consumed (evaporated) as a result of the production of a product; and the grey WF, which refers to the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards (*Hoektra et al. 2011*). The WF concept is considered as an alternative tool to improve the water use plan and management under the existence of a limited resource due to climate change (*Hoekstra et al. 2012*).

Liu and Savenije (*2008*) reported that 90% of the individual's water requirement is needed for food production. Water scarcity, therefore, may originate from insufficient water needed for food production *(Hoektra et al. 2011*). For example, about 1 to 2 cubic meters of water is required to produce 1 kg of cereal (*Allan 1998*) and more water is needed to produce the same weight of meat. Since the basic function of food is to provide enough energy and nutrients for body functions and physical activity, therefore water footprints of food products, therefore are related to the required energy and nutrient intake of the population (*Pareja 2018*). Calculations about food security have focused on these basic functions (*Liu and Savenijie 2008*). Food availability is one of the pillars of food security. It is achieved when there is sufficient quantities of food for everyone are always available. Sufficient food quantities can be attained by increasing food production. Actual food consumption patterns provide this relationship between water footprint of the product, the required energy intake and social aspects of consumption. Increasing production can guarantee food security, but it does not guarantee a sufficient availability of all the foods needed to satisfy consumer demand.

This study presents the water footprints of selected Philippine agricultural products and its relationship with per capita energy and nutritional intake requirement and food consumption patterns of Filipinos. The study calculated energy water productivity values or the values between energy requirements for basic and subsistence levels on the one hand and of actual food consumption patterns on the other with the water footprint of the product.

MATERIALS AND METHODS

Categories of Philippine Agricultural Products

In order to analyze food requirements, the food items were grouped in six categories (*Liu and Savenijie 2007*): cereals and starchy roots (including rice, wheat, maize, other cereals, potatoes and other starchy roots); sugar and sweeteners; oil crops and vegetable oils; vegetables and fruits; alcoholic beverages; and animal products (including beef, pork, poultry, mutton and goat, fish and seafood, eggs, milk, animal fats). These foods accounted for 98% of both the total food consumption in weight and the total calorie intake in the Philippines based on *Food and Agriculture Organization (FAO)* (*2017*).

Calculation of Water Footprint

The calculation of each food water footprint adopted the WF assessment of *Hoekstra et al.* (*2011*) as shown in this equation:

$$WF = WFgreen + WFblue + WFgrey \quad (1)$$

The green and blue WF were estimated using crop water use that is based on evapotranspiration with data and tool using FAO CROPWAT 8.0 model (*FAO 2009*) and procedures suggested by *Mekonnen and Hoekstra* (*2011*). Meteorological data were provided by the Philippine meteorological agency, *PAGASA* (*2018*). These data were incorporated using CROPWAT 8.0 following procedures suggested by *Mekonnen and Hoekstra* (*2011*). CROPWAT 8.0 is a computer program, developed by FAO for the calculation of crop water requirements and irrigation requirements from soil, climate and crop data. The equation is adopted from *Kaewjampa et al.* (*2016*).

$$ETgreen, blue = Ks \times Kc \times ET0 \quad (2)$$

Where Ks a water stress coefficient, Kc is the crop coefficient, and ET0 the reference evapotranspiration (mm/day).

Grey WF calculation followed the protocol made by *Charoensuk et al.* (*2012*), *Allen et al.* (*1998*), and *Mekonnen and Hoekstra* (*2011*) which suggested that the grey water footprint can be calculated by multiplying the chemical application rate per hectare (kg ha^{-1}) with the leaching-run-off fraction (α) divided by the maximum acceptable concentration (C_{max}, kg m^{-3}) minus the natural concentration for the pollutant considered (C_{nat}, kg m^{-3}) and then divided by the crop yield (t ha^{-1}).

Energy Water Productivity

Energy water productivity can be computed as the energy produced by one unit of water. This is calculated by dividing the energy content of a food crop by its WF. The data on energy content have been taken from the FAO Food Balance Sheets for Philippine food consumption in 2015 (*FAO 2017*). This is based on the recommended energy and nutrient intakes for Filipinos 2002 as recommended by *Barba and Cabrera* (*2008*).

RESULTS AND DISCUSSIONS

The assertion posited by *Mekonnen and Hoekstra* (*2011*) underscores a critical disparity in water consumption between animal-based and plant-based food production. This distinction is particularly salient in the Philippine context, where the cultivation of staple crops like rice, maize, and wheat necessitates significantly lower volumes of water per kilogram compared to the production of animal-derived products, such as beef, pork, poultry, and goat meat. Specifically, the disparity in water footprint (WF) values starkly illustrates this contrast. Rice, a fundamental staple in the Philippines, demands 3.34 m^3 of water per kilogram, whereas beef production commands an exponentially higher requirement of 8.46 m^3 kg^{-1}. This striking difference extends to other plant-based staples like maize (2.15 m^3 kg^{-1}), wheat (0.98 m^3 kg^{-1}), and potatoes (1.10 m^3 kg^{-1}), showcasing their relatively lower water usage compared to rice. The presentation of these statistics serves not only to delineate the water usage discrepancies among food products but also highlights potential substitutes for high water-consuming crops like rice. Comparative analysis with neighboring Southeast Asian nations, Thailand and Vietnam, amplifies the water usage disparity. The Philippines registers significantly higher water footprints in staple crops like rice, corn, beef, and sugar production, magnifying the disparity in water efficiency across these countries. This elevation in water consumption for equivalent food output in the Philippines can be attributed to multiple factors such as disparities in water supply sources, extent of irrigated lands, and differences in technological utilization across agricultural practices. The utilization of Water Footprint as a metric in this discourse emerges as an instrumental tool. It unveils the efficiency of water utilization within crucial agricultural sectors, illuminating the disproportionate utilization of freshwater resources across various food production processes. This analytical framework not only quantifies the disparities but also provides a foundational basis for policy formulation, guiding interventions aimed at enhancing water use efficiency, promoting sustainable agricultural practices, and steering resource allocation towards more judicious and sustainable ends.

Philippine agricultural products are included in the balance sheets of the Food and Agriculture Organization or FAO. As expected, the energy water productivity of animals is low (between 151 kcal m^{-3} for bovine meat to about 398 kcal m^{-3} for goat meat and 333 kcal m^{-3} for milk) given its high water footprint. Likewise, as predicted, cereals have high values ranging from 996 kcal m^{-3} for maize to 2848 kcal m^{-3} for wheat. Rice (1074 kcal m^{-3}) has also a water energy productivity with 1074 kcal m^{-3}. Energy water productivity was measured following methods conducted by *Liu and Savenji* (*2008*), and was estimated based on the recommended energy and nutrition index (RENI) set by the Food and Nutrition Research Institute of the Philippine government. It is an effective measuring tool to assist in determining collect allocation of food intake vis-à-vis water usage in the production of those food. The calculated EWP values suggest beef requires almost 10 times more water than

Table 1. Water footprint and energy water productivity of Philippine agricultural products.

Food Items	**Water Footprint (m^3 kg^{-1})**	**Energy Content (kcal kg^{-1})**	**Energy Water Productivity (kcal m^{-3})**
Cereals and Roots			
Rice	3.34	3588	1074
Wheat	0.98	2791	2848
Maize	2.15	2141	996
Other cereals	3.08	3650	1185
Potatoes and other starchy roots	1.10	972	884
Sugar and Sweeteners	1.55	3493	2254
Oil crops and Vegetable oils			
Soybeans and other oil crops	3.37	1799	534
Vegetable oils	4.90	8837	1803
Vegetables and Fruits			
Vegetables	0.52	280	538
Fruits	1.02	501	491
coffee and other stimulants	16.49	1043	63
Animal products			
Beef	8.46	1278	151
Pork	3.55	3534	995
Poultry	4.82	1231	255
Mutton and goat meat	3.06	1217	398
Fish and sea food	5.00	755	151
Eggs	4.77	1499	314
Milk	1.29	430	333
Animal fats	7.07	7019	993
Alcoholic beverages	0.18	450	2500

rice to supply the same amount of recommended energy intake per capita per day of Filipino. If the average energy requirement of 2000 kcal cap day^{-1} (*Barba and Cabrera 2008*) is covered by rice, then about 2.1 m^3 cap day^{-1} of water is required, which if this energy requirement will be covered by beef, the needed amount of water is 13.2 m^3 cap day^{-1}.

The amount of water used to produce certain food requirements per capita is called the per capita water requirement for food or CWRF (*Liu and Savenji 2008*). CWRF is calculated by multiplying the food requirements per food item of an individual by the WF of the corresponding food item and getting the sum for the food categories. The requirements per food item was based on the basic food and energy requirement set by the national government through the Food and Nutrition Research Institute in which in this case is 2490 kcal cap day^{-1} and 1860 kcal cap day^{-1} for Filipino male and female, respectively. At the basic level, the average for a Filipino adult is 2175 kcal cap day^{-1} and thus was used in the computation of CWRF. The Philippine WRF was estimated to be at 1233 m^3 cap yr^{-1}. Compared to other developing countries as computed by *Liu and Savenijie* (*2007*), the CWRF of these countries averages to 85 m3/cap/year, which is almost only half of an average adult Filipino's consumption of water to get the recommended energy intake from food.

On the other hand, total water requirement for food (TWRF) is the total amount of water consumed to produce certain food requirements for all the individuals in a country. It is calculated for the Philippines by multiplying CWRF by the population. TWRF for the Philippines for 2020 is computed to be 128 km^3 and may be predicted to increase due to increasing population. High CWRF and TWRF will have implications on water management, diet, food preferences and lifestyle. Possible factors in the increase of CWRF and TWRF are rapid urbanization, changing food consumption patterns caused by increased in income, and low agricultural technology.

The holistic evaluation of water consumption through the prism of Total Water Requirement for Food (TWRF) delineates the cumulative water usage necessary to meet the dietary needs of an entire nation. In the Philippine context, TWRF is derived by multiplying the Country Water Requirement for Food (CWRF) by the country's population, yielding an estimated TWRF of 128 cubic kilometers for the year 2020. Forecasts suggest an anticipated surge in this metric owing to the persistent trajectory of population growth.

The augmentation in both CWRF and TWRF carries multifaceted ramifications that extend beyond mere statistical increments. Such elevated water demands pose substantive challenges and impinge upon various facets of societal structures and behaviors. The implications reverberate across the domains of water resource governance, dietary habits, culinary preferences, and lifestyle choices of the populace.

Noteworthy factors contributing to the escalating CWRF and TWRF encompass the manifold impacts of rapid urbanization. The burgeoning urban landscape alters consumption patterns and dietary choices due to increased access to diverse food sources, altering traditional diets and consequently escalating water demands. Concurrently, a shift in food preferences influenced by rising incomes often leads to a propensity for resource-intensive diets, further exacerbating water requirements. This shift is compounded by the relatively lower efficiency in agricultural technology adoption, amplifying the strain on water resources.

The ramifications of amplified CWRF and TWRF necessitate a multifaceted response. Strategic interventions in water management practices, coupled with initiatives promoting sustainable agricultural technologies and dietary diversification, emerge as imperative measures. Policies aimed at optimizing water usage efficiency, encouraging technological innovations in farming practices, and fostering public awareness regarding the water footprint of various food choices are integral in steering towards a more sustainable trajectory.

Addressing these challenges mandates a concerted effort encompassing policy reforms, technological advancements, and behavioral changes at both individual and collective levels. The nexus between water usage and dietary patterns underscores the need for a comprehensive, interdisciplinary approach that harmonizes agricultural, environmental, and societal imperatives to ensure equitable access to water resources while fostering sustainable food production systems.

CONCLUSIONS AND RECOMMENDATIONS

In contrast to conventional methodologies reliant on sector-specific water withdrawals for gauging national water utilization, the adoption of water footprint assessment emerges as a more nuanced and comprehensive approach, furnishing heightened perspectives on freshwater resource efficiency. This paper presented diverse water footprints associated with agricultural goods in the Philippines, juxtaposed with their corresponding energy water productivity. Notably, the outcomes disclosed herein underscore a significantly elevated Philippine per capita water requirement for sustenance (CWRF) vis-à-vis analogous needs in other developing nations, thereby exerting discernible implications on the overall water consumption delineated by the total water requirement (TWRF). TWRF may be affected by several factors which includes Philippine importation of agricultural products that may affect food security and priority of water allocation on irrigation. The Philippines would need to reduce its blue and gray WF by increasing its green WF can be favorable direction on water management. Without interventions, TWRF will continuously increase in the next four decades and will become a big factor in determining water sustainability.

This study recommends that water scarcity should more and more be recognized as a major threat to sustainable development besides population growth and externalities of uncontrolled economic growth. There is a need to appreciate the utility of WF methods in the Philippine context especially the use of available data, method and approaches. The identification and quantification of the distinct "blue," "green," and "gray" water components intrinsic to food production represent a critical undertaking within the realm of water resource management. Such need in discerning these diverse water components allows for a comprehensive understanding of the intricate water usage patterns embedded in agricultural processes. This, in turn, empowers the formulation of targeted strategies and interventions specifically tailored to optimize water efficiency within the agricultural sector.

By delineating these water components, stakeholders gain insights into the varying sources, types, and impacts of water usage throughout the food production cycle. "Blue" water signifies surface and groundwater utilization, while "green" water represents precipitation absorbed by soil and vegetation, and "gray" water denotes pollution generated during production. Understanding these can lead to precise approach towards devising effective water management strategies.

Accurate identification of these water components serves as a foundational pillar in the development of sustainable practices that balance agricultural productivity with the conservation of scarce water resources. Therefore, integrating this precise delineation into policy frameworks and resource management initiatives is crucial to foster sustainable agricultural practices and ensure the resilience of water ecosystems in the face of escalating water scarcity challenges.

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