Water Footprint and Virtual Water

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***Abstract*-Freshwater is vital to life. As our population and prosperity grow, use of freshwater also increases. This is always a concern since water is already scarce in most parts of the world. People use lots of water for drinking, cooking and washing, but even more for producing things such as food, paper, cotton clothes, etc. This invisible use of water is called virtual water content. The adjective virtual refers to the fact that most of the water used to produce a product is in the end not contained in the product. The real water content of the product is generally negligible if compared to the virtual water content. Virtual water helps us realize how much water is needed to produce the goods we use and the food we eat. Water footprint is a popular method for demonstrating the total amount of water needed to produce a variety of goods and services. This concept was introduced in 2002 by Arjen Hoekstra of the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a comprehensive indicator of water use.**

A water footprint is a comprehensive measure of freshwater consumption that connects consumptive water use to a certain place, time, and type of water resource. The water footprint includes the total amount of freshwater consumed along the supply chain of a product. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. A water footprint differs from the typical measure of water use or water withdrawals, because a water withdrawal is a temporary diversion or drawl of water from surface or ground whereas water footprint accounts for consumptive water use that permanently withdraws water from its source and that water is no longer available because it has been evaporated, been transpired by plants, incorporated into products or crops or consumed by people or livestock. Water footprint accounts separately for three types of freshwater consumption: green water use, which is consumption from rainfall; blue water use, which is consumption from groundwater or surface water; and grey water use, which would be the dilution water required to reduce pollutant concentrations to acceptable values.

Water footprint is an important concept in creating a public awareness of the amount of water that is used to make everyday items. It helps individuals, businesses and countries by revealing water use patterns, from the individual level all the way to the national level. It shows the water used in all the processes involved in manufacturing and production of our goods and services. Water footprint also accounts for how much water is contaminated during manufacturing and production process because that water become unusable and is taken out of the system. The water footprint gives a sound frame of reference and helps us all be more efficient and conservative with our water.

Keywords: Fresh water, virtual water, Water footprint, green water, blue water and grey water

I. INTRODUCTION

Fresh water is one of the most precious resources and vital for everyone's everyday life. Total amount of water available on our planet is about 1,400,000,000 km³ that covers two thirds of the Earth's surface. However, only 2.5% of this volume is fresh water, of which 69% is locked up in glaciers and polar ice caps. The remaining 13 million km³ of usable freshwater sustain life on our planet but are distributed very unevenly around the globe. While some regions abound in water with greater than 3000 mm annual precipitation while other places are extremely dry with less than 100 mm precipitation per year.

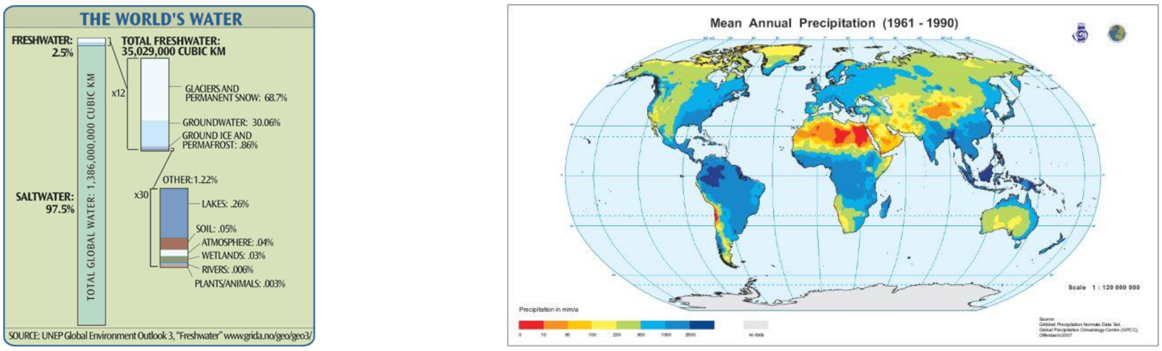

Figure 1: water consumption

As our population and prosperity grow, use of freshwater also increases. This is always a concern since water is already scarce in most parts of the world. During the past century, water use has grown twice as fast as the world's population and has led to an increased water scarcity in many regions around the globe. Today, 1.2 billion people live in such water scarce regions and another 1.6 billion people suffer from economic water shortage i.e., they don't have access to safe drinking water due to missing opportunities to withdraw, purify, or transport water from aquifers and rivers. As a consequence of climate change, population growth, and changing consumption patterns in emerging nations, water scarcity is expected to increase significantly in many parts of the world.

II. VIRTUAL WATER CONCEPT

People consume water not only when they drink it or take a shower. In 1993, Professor John Anthony Allan from King's College London demonstrated this by introducing the "virtual water" concept. According to him, the virtual-water of a product (a commodity, good or service) is the volume of freshwater used to produce the product. Virtual water is the amount of water that is embedded in food or other products needed for its production. It is the consumptive water use of freshwater that either evaporates, incorporates into a product, gets contaminated or is not returned to the same area where it was withdrawn. All four uses result in water being unavailable for local reuse. This term recognizes both the renewability of freshwater and its limited availability in a certain time period and location. Evaporation is the most significant consumptive water use and it often be equated with total water use as the other three components are negligibly small in comparison.

The adjective 'virtual' refers to the fact that most of the water used to produce a product is not contained in the product. The real-water content of products is generally negligible if compared to the virtual-water content. For example, 1500 cubic meters of water on average is used to produce one metric tonne of wheat. But once the wheat is grown, the real water used to grow it is no longer actually contained in the wheat. Similarly, behind a cup of coffee are 140 litres of water used to grow, produce, package and ship the beans. This is roughly the same amount of water used by an average person daily for drinking and household needs. Americans consume around 6800 litres of virtual water per capita every day; over triple that of a Chinese person.

Virtual water trade refers to the hidden flow of water, if food or other commodities are traded from one place to another. When a country imports one tonne of wheat instead of producing it domestically, it is saving about 1500 cubic meters of real indigenous water. If this country is water scarce, the water that is saved can be used towards other ends. If the exporting country is water scarce, however, it has exported 1500 cubic meters of virtual water since the real water used to grow the wheat will no longer be available for other purposes. This theory explains how and why nations such as the US, Argentina and Brazil export billions of litres of water each year, while others like Japan, Egypt and Italy import billions.

The virtual water concept opens the door to more productive water use. The concept of virtual water helps us realize how much water is needed to produce different goods and services. In semi arid and arid areas, knowing the virtual water value of a good or service can be useful towards determining how best to use the scarce water available. Virtual water has major impacts on global trade policy and research, especially in water-scarce regions, and has redefined discourse in water policy and management. National, regional and global water and food security can be enhanced when water intensive commodities are traded from places where they are economically viable to produce to places where they are not.

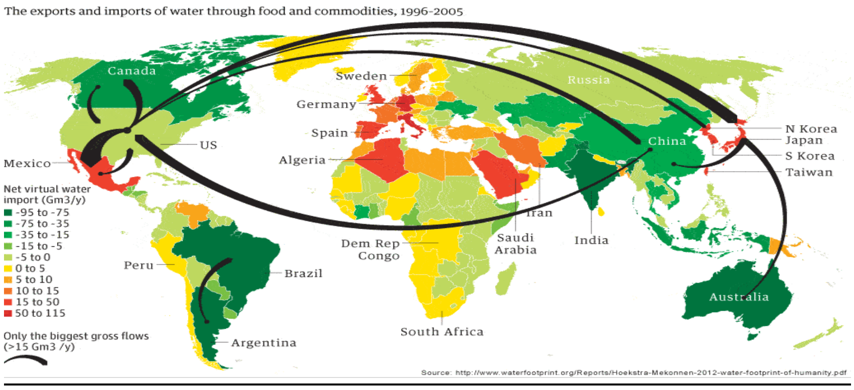

Figure 2: Virtual water trade

III. WATER FOOTPRINT

Arjen Hoekstra of the United Nations Educational, Scientific and Cultural Organization (UNESCO) expanded the virtual water concept to develop the water footprint as a comprehensive indicator of water use in 2002. A water footprint can be defined much like an ecological footprint. While an ecological footprint is the bio productive area required to support a population, a water footprint is the volume of consumptive water used to support a population. A water footprint is a comprehensive measure of freshwater consumption that connects consumptive water use to a certain place, time, and type of water resource. The water footprint includes the total amount of freshwater consumed along the supply chain of a product. A water footprint differs from the typical measure of water use or water withdrawals, because a water withdrawal is a temporary diversion or drawl of water from surface or ground whereas water footprint accounts for consumptive water use that permanently withdraws water from its source and that water is no longer available because it has been evaporated, been transpired by plants, incorporated into products or crops or consumed by people or livestock. Both virtual water and the water footprint are measures of direct and indirect water consumption and only account for freshwater appropriation. The difference between these two is that the water footprint is a multidimensional indicator, not only referring to a water volume used, but also making explicit where the water footprint is located, what source of water is used and when the water is used unlike virtual water. Additionally, the quality of the water again released is also considered.

The water footprint shows the link between consumer goods or a consumption pattern and water use and pollution. Water footprint accounts separately for three types of freshwater consumption: Green water use, which is consumption from rainfall; Blue water use, which is consumption from groundwater or surface water; and Grey water use, which would be the dilution water required to reduce pollutant concentrations to acceptable values. This distinction among green, blue, and grey water footprints recognizes that the consumptive use of rainfall, groundwater or surface water, and the water quality impacts have different economic costs and ecological impacts.

Agriculture is by far the largest global consumer of freshwater. In this sector, a water footprint measures the volume of evapotranspiration (ET), the term used to describe the combined evaporation of water from soil surfaces and the transpiration from plants. ET represents water use of an agricultural or forestry crop or water use of a crop per unit mass of yield. Comparing water footprints of different management practices in agriculture can help evaluate drought tolerance, water use efficiency, the effective use of rainfall, and the significance of irrigation. Presently, there is much discussion and research concerning adaptation of agricultural systems to a changing climate, but there are few metrics that can compare the resilience of different systems. Many of the risks agriculture faces from climate change are the result of precipitation changes, which makes the water footprint a useful measure to compare resilience of agricultural systems to droughts and dry spells.

IV. WATER FOOTPRINT APPROACHES

There are three principally different approaches currently being applied for the calculation of a water footprint:

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1. The volumetric approach, which is based on an assessment of the volume of water associated with a particular production activity; the quantification of the elementary flow freshwater crossing the system boundary from nature to techno-sphere. The flow is subdivided into green, blue, and grey water.
2. The stress weighted approach, which is based on an assessment of the amount of freshwater consumed in an activity combined with an assessment of the implications of that consumption in terms of water stress. Stress weighted approach is an assessment method to compare the use of different types of resources through a distance-to-target normalization approach. This Method provides a set of eco-factors to assess freshwater resource use. It uses two concepts: the relationship between water scarcity and the rate of depletion (i.e. the scarcer the resource, the higher the weighting factor assigned to freshwater depletion) and the spatial variability of that rate. The methods allow direct and broad applicability for different countries and generic scarcity situations.
3. The impact assessment approaches, which draw on water consumption using an inventory analysis similar to that of the volumetric approach but additionally including an element of impact assessment. The impact of water is based on estimates of water consumption, and an inventory list of all inputs and outputs of water is created for a product or a service, and net water consumption is determined then from the difference between inputs and outputs.

V. WATER FOOTPRINT EXAMPLES

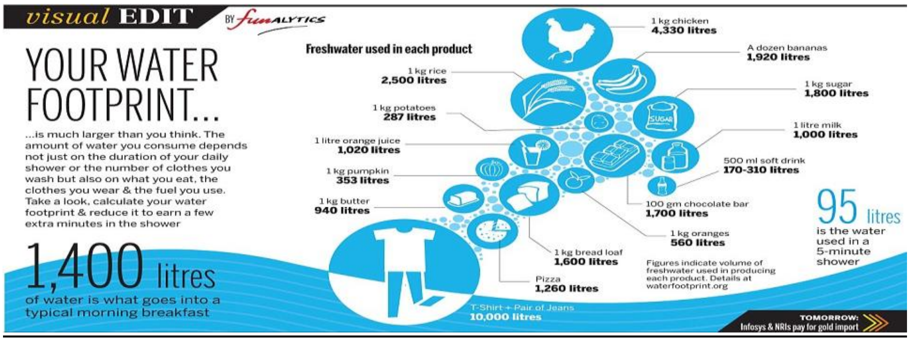
A water footprint can be calculated for anything - a product, a person, or a land area. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.

VI. WATER FOOTPRINT OF PRODUCTS

The water footprint of a product is the total volume of freshwater used to produce the product, summed over the various steps of the production chain. The water footprint of a product refers not only to the total volume of water used; It also refers to where and when the water is used. The water footprint of a product can be used to give consumers information about the water related impacts of products they use or to give policy makers an idea of how much water is being traded through imports and exports. Examples of water footprint of various common foods are as follows:

VII. WATER FOOTPRINT OF INDIVIDUAL CONSUMERS

The water footprint of an individual refers to the sum of his or her direct and indirect freshwater use. The direct water use is the water used at home, while the indirect water use relates to the total volume of freshwater that is used to produce the goods and services consumed. The average global water footprint of an individual is 1385 m3 per year. The average consumer in the United States has a water footprint of 2850 m3 per year, while the average resident in China and India has a water footprint of 1050 and 1100 m3 per year, respectively. The water footprint of a consumer is useful for illustrating what parts of a lifestyle have the biggest impacts on water use. Typically, calculating the water footprint of a consumer demonstrates that a person's diet has the biggest impact on their water footprint.



VIII. WATER FOOTPRINT OF COMPANIES

The water footprint of a business or the corporate water footprint is defined as the total volume of freshwater that is used directly or indirectly to run and support a business. It is the total volume of water use to be associated with the use of the business outputs. The water footprint of a business consists of water used for producing/manufacturing or for supporting activities and the indirect water use in the producer's supply chain. By making its water footprint better, the company can reduce costs, improve the environment, and benefit the communities in which it operates. The water footprint of a process step is used in calculating a product water footprint in order to identify specific processes where reductions in consumptive water use could be made.

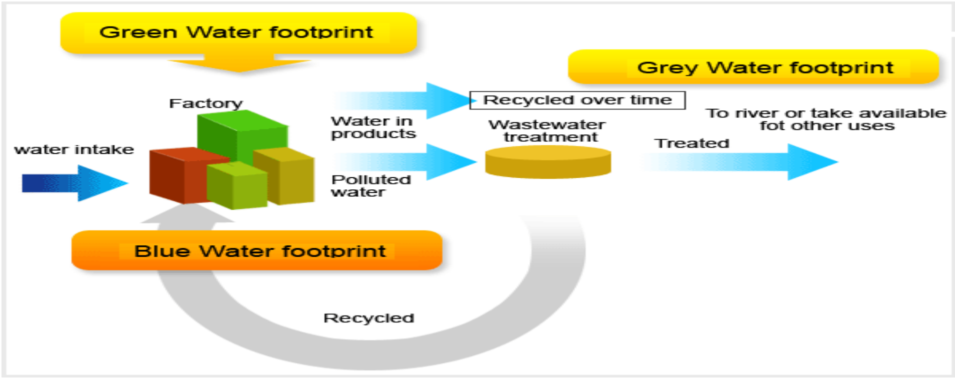


Figure3: Corporate water footprint

IX. WATER FOOTPRINT OF NATIONS

The water footprint of a nation is the water used to produce the goods and services consumed by the inhabitants of the nation. The internal water footprint is the appropriation of domestic water resources; The external water footprint is the appropriation of water resources in other countries. About 65% of Japan's total water footprint comes from outside the country; About 7% of the Chinese water footprint falls outside China. The water footprint of a country helps to account for consumptive water use inside and outside the country. This allows accounting for the trade in water through the trade in agricultural products. For example, the United States has the highest water footprint of any nation and also by far the leading exporter of water because of the large amount of agricultural exports.

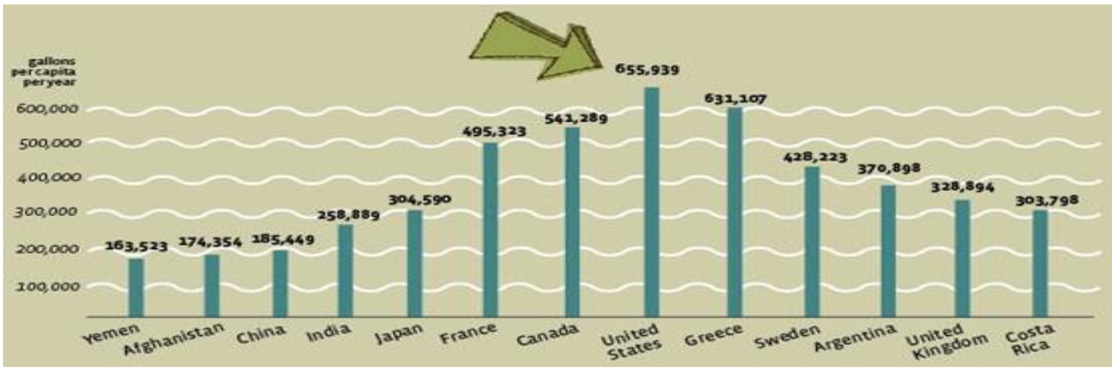


Figure 4: Water footprint of nations

X. PURPOSE OF WATER FOOTPRINT

Monitoring of freshwater use is important because, despite its renewability, its availability is limited in space and time. In order to sustain human populations, a certain amount of consumptive water use is needed, estimated at about 1400 m3/year. Water foot printing provides a way to account for what types of freshwater resources are used (rainfall, surface water, or groundwater) and where they are used. Blue water resources, including lakes, rivers, and groundwater resources, are replenished at a rate determined by atmospheric and landscape characteristics. The green water resource depends on rainfall during some time period and the partitioning of that rainfall into green and blue flows. Sustainability of blue water use can be evaluated by comparing a blue water footprint of area with the estimated renewal rate of the blue water resources. This has been done on a global scale and it was estimated that up to 25% of consumptive uses of irrigation water are unsustainable, meaning they exceed local renewal rates.

XI. INTERNATIONAL STANDARDS

ISO is developing a new standard to provide internationally harmonized metrics for water footprints. The work on ISO 14046 water footprint began in 2009. The efforts are at the stage of compilation of a Preliminary Work Item (PWI), ISO 14046, Water footprint - Requirements and guidelines. The scope defined for the standard is that it will specify requirements and guidelines to assess and report water footprints. The standard will:

1. Deliver principles, requirements and guidelines for a water footprint metric of products, processes and organizations, based on the guidance of impact assessment;
2. Define how the different types of water sources and water releases should be considered and how local environmental and socio-economic conditions should be treated;
3. Address the communication issues linked to water foot printing; and be compatible with the rest of the ISO 14000 family of environmental management standards.

The standard would address direct positive aspects, such as the benefits of decreasing the water footprint.

XII. CONCLUSIONS

Sustainability is a function of the interactions between human activities on the Earth's life support systems. Today humanity is consuming more resources than our planet is able to produce and regenerate. Interventions are needed to raise awareness about the environmental consequences of our consumption behaviour and generate concrete actions that will result in more sustainable consumption styles and patterns.

Water is an archetypal resource to preserve quality and quantity of the resource for present and future generations. Freshwater is increasingly becoming a local resource of global concern, driven by growing international trade in water-intensive commodities. It has been suggested that international trade could be used to move processes that cause a high amount of virtual water consumption from comparatively advantaged regions to regions where water is scarce, thereby creating a means for water-poor countries to achieve water security. Conversely, such a shifting of water-intensive production to water-rich countries also allows water-rich countries to benefit economically from their natural resources. This would be similar to the development of energy-intensive industries moving to water-power or geothermal power rich countries.

The strength of water footprint accounting is that it measures consumptive water use of different types, including green, blue, and grey water, and then it connects those water uses to a specific place and time. This recognizes the renewability of freshwater and emphasizes the need to use it efficiently because of its limited availability in an area during some time. Water foot printing can provide information when it is used alongside some measure of water scarcity.

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