Virtual Water Trade to achieve Sustainable Development

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Abstract: Water is at the heart of sustainable development and is critical to socio-economic development, healthy ecosystems, and human survival. This is important for raising the global disease burden and improving people's health, education, and productivity. It is central to manufacturing and preserving a host of benefits and services for humans. However, Water is at the center of adaptation to climate change and serves as the essential connection between the climate system, human society, and ecosystem. A significant case of embedded complex systems is the globalization of water, related to the transport of virtual water supplies from one area to another. Due to insufficient water supplies, many nations rely on imports of food. This is similar to importing virtual water, but it could be useful for countries with water shortages. It is often noted that net imports of virtual water in a water-scarce country can reduce the water supply pressure and that virtual water can be seen as an alternative source of water. This additional source will be a tool in the planning and management of water supplies. Virtual water trade is thus an actual reality, and it would not be feasible to argue whether or not countries can trade food products in virtual water. The virtual water strategy explores ways to use internal and external water supplies consciously and effectively to mitigate water scarcity. VWT work has demonstrated the presence of national and global social and environmental benefits. VW transfers are widely used to aid malnutrition and alleviate the impact of national food crises.

Keywords: water scarcity, water vulnerability, water in sustainable development goals, virtual water trade, virtual water trade consequences, virtual water trade impacts, and benefits.

Introduction:

One of the essential elements of life is water. Globally, the quantity of water available diminishes rapidly, impacting the supply and access of drinking water, sanitation and agriculture. Water scarcity is an urgent and rising problem. Water scarcity is characterized as the absence of accessibility, clean water supplies, and water to satisfy the culture's needs. Statistics illustrate that, internationally, there are 2.1 billion people who lack access to water, which is secure to eat, and a lack of connectivity for 4.5 billion people to the sanitation services. It is estimated that 40 percent of water impacts the global population scarcity, which is expected to grow. The definition of access to drinking water is clearly expressed in Sustainable Development

Goal (SDG 6), "Ensure a Sustainable Development Goal" availability and sustainable water management and hygiene for all (UN, 2018).

1- Water Pricing and Scarcity:

Pricing is a significant contributor to the overconsumption of water. Water is considered a standard commodity, and it is consumed on a want basis rather than a need basis; because of its low price, the overuse of water results in this. The price-setting method leaves out externalities, such that the cost of water is distorted by perceived supply-side abundance and demand-side market strength. Different countries have different access to varying quantities of water supplies and have various water recycling and treatment resources, resulting in changes in value and expense (Skene and Murray, 2017).

Water scarcity is caused by biological variables, such as drought (Bates et al., 2008). On the other side, this is due to drinking water and "water stress," which occur when water rivals demand water. With population increase, urbanization, and economic growth, water scarcity is on the rise. However, the supply of fresh water is unevenly distributed in spatial terms concerning the population. A human being requires a minimum of 7.5-15 L per day of water for survival (drinking and eating 2.5-3 L per day), basic hygiene practices (2-6 L per day), and basic cooking needs (3-6 L per day), according to the World Health Organisation (WHO, 2013).

Globally, around 300,000 km^3, in lakes or rivers, are available to humans without difficulty. This water, nevertheless, is unevenly distributed spatially and temporally, contributing to regional water scarcity. The uneven distribution of rainfall provides one explanation for the unequal distribution of water. The Middle East, North Africa, and most of Asia are geographically the most vulnerable to water scarcity (FAO AQUASTAT, 2013). 60% of the world's population lives in Asia, but that continent is home to 36% of the world's water supplies. 40 percent of people worldwide live in areas where water is scarce, a figure that will rise more in the future (UN Water, 2016).

2- Water Vulnerability:

Agriculture requires water and accounts for 70% of water use in developing countries. Water intensity puts more difficult pressures on developing countries; water consumption is lower in developed countries. For example, only 37% of water withdrawals are used for agriculture in the United States. There are inadequate irrigation methods and agricultural practices in developing countries, leading to unnecessary withdrawals and slow replenishment. Their procedures often contribute to lower water tables, highlighting the danger of degradation in these nations (Weil, 2013).

Water use in developing countries is at high levels because of extensive irrigation systems and customer overconsumption. An average family consumes 552 gallons of water daily in the United States alone. The global shortage of water is rising with these human impacts. The pace of human-made climate change is further exacerbating water access and supply. Climate change contributes to rapid rises in snowmelt and runoff rates. Because of the early, unexpected runoff, the pace disrupts water storage. Reservoirs and dams probably constructed to store this water cannot sustain the rapid accumulation that has been witnessed globally, resulting in flooding (Haddeland et al., 2014).

The failure to collect water leads to restricting the availability of available water. Human interference by technology has been based on the desalinization of sea or saltwater supplies and even cloud seeding to address natural scarcity and emerging risks. Besides, there has been a technical emphasis on irrigation and bioengineering related to drought-resistant crops, considering water in agriculture (Zellmer, 2012).

3- Water in Sustainable Development Goals:

Goal six of SDGs address all facets of both the water cycle and the sanitation process. The relationship between water and health, education, economics, and the environment can be found in the systems and the link between SDG 6 and the SDGs' achievement. Sustainable Development Goal 6 includes six sub-sections of the goals that are to be accomplished by 2030. These have universal access to secure, accessible drinking water, access to adequate sanitation, reduction of water contamination by reducing chemical dumping, enhancement of sustainable withdrawals, development of integrated management of water supplies, and improvement of the conservation of water-providing natural ecosystems (UN, 2018).

SDG 6 also contains collaboration and interaction priorities at both the local and international levels. Water is essential for the production of energy, food production, and every ecosystem, including humans. In agriculture, 70% of water withdrawals are used internationally, about 75% of industrial water withdrawals are used in energy production, and 80% of untreated wastewater flows into natural habitats (UN, 2018).

A water footprint is the quantified water use-value and water used for products and services in manufacturing processes. Three types of water contribute to this water footprint, and blue, green, and greywater are classified. Bluewater includes groundwater and is characterized as freshwater evaporated from surface water. Green water has evaporated from rainwater deposited in the soil, and greywater contains dirty water from human use and development activities. The use and creation of these types of water affect the limited amount of water that is naturally available (Hoekstra and Mekonnen, 2012).

4- Water and three Sustainable Development Dimensions:

The 2012 UN Conference on Sustainable Development (Rio+20) outcome paper, The Future We Want, recognized that 'water is at the heart of sustainable development' and its social, economic, and environmental aspects. Water is the planet's lifeblood and vital to all socio-economic growth (Jia et al., 2017).

From a **social perspective**, there are noticeable connections between access to safe and adequate water and health, drinking first, hygiene, and sanitation at the household, community, and national levels. Access to safe and predictable water sources is essential to addressing the multiple forms of deprivation related to poverty, directly through drinking water and its relation to human health. Still, also indirectly, Water is required in most economic activity (Carr et al.,2013).

Economically, addressing the lack of safe drinking water and sanitation will lead to long-lasting human capital and growth effects. Recent studies show that, internationally, the benefits of attaining worldwide access to sanitation outweigh the costs by a factor of 5.5 to 1. Simultaneously, the figure is calculated at 2 to 1 for universal access to drinking water (Carr et al.,2013).

Sustainable water resources management and associated services will significantly improve productivity in the agricultural and food sectors. More productive use of water is vital. The production and consumption of agricultural products alone account for more than 70 percent of water withdrawals in many developing countries. Beyond the primary economic sectors, Water is vital to all other economic activities, mainly because of its energy production, mining, and tourism. Water scarcity could be a significant impediment to expanding the power sector, especially in Asia, South Africa, and the Middle East, where demand is expected to develop rapidly (Rosa et al., 2018a).

Water may also contribute to economic losses due to water-related risks that have risen dramatically over the last decade. After the 1992 Rio Earth Summit, floods, droughts, and storms have impacted 4.2 billion people (95 percent of all disaster-affected people) and caused the loss of US$ 1.3 trillion (63 percent of all loss) (D 'Odorico and Rulli, 2014).

The **Environmental Dimension** of Water and Sustainable Development includes the role of healthy ecosystems that provide water services of enormous societal value through flood control, groundwater recharge, riverbank stabilization, and erosion prevention, water purification, conservation of biodiversity, transport, recreation, and tourism. Drivers influencing water quality and quantity, such as emissions, the introduction of organisms, land-use changes, and climate change, may also affect ecosystems' capacity to manage themselves properly, impacting other ecological resources in turn. Therefore eliminating or reducing these stresses is a critical factor for maintaining the environment's integrity (Carr et al., 2017).

5- **Virtual Water Trade as Water Scarcity Solution:**

Water strategies and various mitigation steps are proposed in areas suffering from water shortages or imminent water shortages, such as the Middle East. The demand management policies were implemented with the growing population and the rising demand for food and drinking water with a fixed water supply. Virtual water was introduced as an alternative water supply or as a possible alternative. Virtual Water must be treated as a means of water when implementing Integrated Water Resources Management (IWRM). The virtual water strategy explores ways to use internal and external water supplies consciously and effectively to mitigate water scarcity (Hoekstra, 2003).

Virtual Water is economically invisible and politically silent. This had made it possible in the past for water-scarce countries to cope with the water deficit by importing food without cultivating a policy discourse of national water scarcity. Since the term virtual water explicitly came to light in the mid-1990s, it has drawn growing attention among policymakers, scientific communities, and the public (Renault, 2003).

What is Virtual Water?

Tony Allan introduced "virtual water" in the early nineties (Allan, 1994). Global awareness of the value of the definition for achieving regional and global water security took nearly a decade to reach. The first international meeting on the subject was held in Delft, the Netherlands, in December 2002. At both the third and fourth World Water Forums, a special session was devoted to the virtual water trade (Hoekstra, 2003).

As sometimes mentioned, the "virtual water" content of a product is the amount of water used to manufacture the product, measured at the location where the product was made (production site-specific definition). It is also possible to describe the virtual water content as the amount of water needed to manufacture the product in the position where the product is consumed (consumption site-specific definition)(Hoekstra and Chapagain, 2004). Virtual Water Trade (VWT) is the (international or intra-national) trade-in virtual water-related products. By trade in derivatives, water supplies, which are physically used in production, are essentially transferred to the area of consumption. This transfer creates a virtual flux of water, which connects the output to consumption (D'Odorico et al., 2019).

6- Virtual Water Trade Socio-environmental Consequences:

Although VWT can minimize local water deficits by practically redistributing water supplies, water scarcity is not a real long-term solution. Water remains a globally limited resource under growing pressure from agricultural, industrial, and municipal uses (Suweis et al., 2013).

Human utilization of freshwater resources for agriculture will increase sustainably by 48%, which would increase overall agricultural water consumption by 5%. The estimated rise in food water demand by the mid-century is expected to be an order of magnitude greater (Rosa et al., 2018a).

It is rising water demand by allowing more effective water use through soil water conservation, 'more crop per drop' methods, and the adoption of water-efficient diets. Though rising food demand and food waste, long-term water management seems a much-needed solution.

Establishing telecommunications between people and the resources they rely on the separate consumers from their decision's environmental impact undermines the ethics of environmental stewardship. Many of trade's environmental externalities have only recently begun to be discussed (Rosa et al., 2018a).

7- Impacts of Virtual Water Trade and Benefits:

VWT work has demonstrated the presence of national and global social and environmental benefits. VW transfers are widely used to aid malnutrition and alleviate the impact of national food crises. The VWT prevents major migrations from arid regions where water supplies are inadequate to meet local communities' needs (food security). For this reason, it has been argued that it prevents conflict and wars (Allan, 1998).

According to the international trade theory, the economic argument behind virtual water trade is that nations should export goods with a relative or comparative advantage. In contrast, they should import products in which they have a comparative disadvantage. Hoekstra and Hung (2002, 2003) argue that virtual water trade between nations can be a tool for the 'global efficiency of water usage.'

From an economic point of view, in those places where water is most abundantly available, it makes sense to manufacture the water-intensive products needed in this world. Water is cheaper in these areas, there are smaller negative externalities to water use, and less water is also required per product unit. Virtual water trade from a country where water productivity is relatively high to a country where water productivity is relatively low means real water savings are made globally (Carr et al., 2015).

Many studies have also highlighted how trade raises the disparity between countries in obtaining water to produce food. Export decisions, however, are influenced by water requirements, as several other factors (including resource supply, raw materials, labor, technological expertise, and policies) contribute to deciding the global patterns of production and commerce (Seekell et al., 2011).

In the following section, some of the benefits and impacts of VWT:

1- **Water Savings:**

Foreign trade can save national water supplies by importing water-intensive goods from outside the world. Through trade, national water savings will lead to global water savings if the flow is from high sites to low water productivity sites (Brindha, 2017).

It has been reported that VWT is saving 352 km^3 $yr^{-1,}$ which would otherwise be used in the importing countries to manufacture agricultural products (Chapagain et al., 2006). Other studies found lower savings and recorded an increasing increase, from approximately 50 km^3 yr^{-1} in 1986 to 240 km^3 yr^{-1} in 2008 (Dalin et al., 2012a).

Water-scarce nations and regions conserve water supplies on average through the purchase of food commodities. VWT, for example, is estimated to ease water tension and foster water quality in China. VWT alleviates water scarcity when entering wealthy countries, although it has minimal water scarcity effects in poorer countries (Zhao et al., 2018).

In some instances, foreign trade can also increase agricultural commodity production's water consumption if crops are grown in less environmentally productive and more wasteful ways. Many countries generate food at the risk of more pressure on their water supplies. For example, they are often traded from an area with low water productivity to a region with higher water savings from processing (Lamastra et al., 2017).

However, regional trade in Africa is much more effective regarding embodied water supplies than any other region in the world. So internal African trading patterns in domestic production systems can compensate for low water productivity. Konar et al. (2013) have shown that the amount of water savings is likely to grow under a changing environment. Even though under climate change, the total amount of VWT is expected to grow due to higher crop prices. Power savings occur under climate change as crop exchange reorganizes into a more power-efficient system (Konar et al., 2013).

The amount of global water savings increases even more, when free trade policies are allowed under a changing environment. This suggests that trade liberalization leads to more effective water supplies in the global trading system, making it a potentially important measure for adapting to climate change. These results are backed by recent causal inference work that shows that openness to trade leads nations to use on average less of their domestic water supplies (Dang and Konar, 2018).

2- **Hydro-politics of VWT:**

VWT is a concept that has radically influenced the development of hydro-political theories. As a result of several years of research into the role of embedded water in crops, Allan introduced this idea to understand critical issues of food security and social stability in water-scarce countries, such as the Middle East and North Africa (Allan 1996, 1998, 2002).

One of the main theoretical consequences is its potential to refute the illusion of future water wars. The analytical definition of water wars, which should not be confused with the general notion of water conflicts, has several functional categorizations. A vital characteristic of the formal definition is that a water war occurs when violence is at the State level, specifically when there is interstate military confrontation (Dell'Angelo et al., 2018a).

Referring to this accurate theoretical description, many scholars have worked consistently to refute the 'water leads to the thesis of war.' One of the strongest statements in the literature leading to this water peace hypothesis stems from the VWT evaluation. Allan explained how many water-stressed countries like the Middle East lack adequate water to develop locally the food needed to meet their populations' needs (Allan 1996, 1998, 2002). This state of hydrological scarcity could lead to anticipated social tensions, instability, and rivalry with neighboring countries, leading to violent escalation and probably formal military action between different countries.

Allan's work shows that foreign trade enables countries to bypass their local constraints on physical water scarcity. His studies have shown that countries' dependency on agricultural production, which is the most water-intensive sector in society on average, can be almost entirely fulfilled by importing agricultural commodities (Allan, 1996, 1998).

Allan's underlying reasoning is that it is much more feasible for water-scarce countries to benefit from virtual water by importing agricultural commodities than to compete and battle for direct control of physical water supplies with other countries. Despite some criticism, VWT 's position is one of the fundamental arguments invoked to refute (Ansink, 2010).

3- **VWT and population growth:**

The prediction of human demographic growth regarding Earth's resources has been at the center of essential debates since Malthus (1789) founded his theory that the human population grows faster than increasing capital availability. This situation ultimately should restrict population growth. This hypothesis was subsequently criticized because technological advances have traditionally allowed humanity to increase food production tremendously. There is no evidence that food supply has limited population growth globally (Sen, 1981).

Therefore, as a determinant of fertility and mortality rates, most demographic models do not even account for resource constraints. However, in recent years, whether the world has adequate natural resources to feed it, the population has resurfaced (Warren, 2015).

Since crop production requires water, a finite resource, and contributes to approximately 85 percent of human freshwater usage, the same water resource constraint has been specifically reworded (Suweis et al., 2013).

Questions emerged as to whether the world had adequate water supplies to meet the increasingly demanding human population's rising needs. But this challenge isn't just for the near future. Many countries are still in water shortage conditions today and need to import food as they consume more virtual water than their water balance (Allan, 1998, Hoekstra and Chapagain, 2008).

That means that trade has allowed their population to expand well beyond the limits imposed by the water supplies available locally (Suweis et al., 2013). In other words, VWT has sustained part of the global demographic growth and would not have been possible without growing dependence on food imports from water-scarce regions such as North Africa and the Middle East (Allan, 1998).

It's not clear to what extent trade trends have been traditionally influenced by demographic factors or, vice versa, the trade-affected population growth. Several studies have merged population growth forecasts with water supply estimates and agricultural production under various climate change and land-use scenarios in recent years. These forecasts were used to determine whether humanity would run out of water in the coming decades and explore potential solutions to cope with the global nexus of food-water resources. These studies have demonstrated how effective strategies and policies for managing water can account for global and local resources (Hoekstra and Wiedmann, 2014).

4- **Water pollution and other environmental externalities of VWT:**

Trade's environmental effects were at the forefront of commercial policy study. One of the implications of the principle of comparative advantage that every country specializes in the products it can manufacture most effectively in a free trade scenario because production is supposed to move to regions around the world of weak, absent, or poorly implemented socio-environmental regulations (Davis et al., 2017).

While free trade does not inherently entail environmental reform, its combination with low socio-environmental standards (weak pollution controls or labor rights) may have adverse effects on local environmental conditions, as businesses may move to low-level countries. Alternatively, those who already work under tighter environmental regulations can outcompete companies, resulting in lower production costs. Therefore, calls were made to integrate environmental and worker protection clauses into international trade agreements (Bailey, 1993).

The General Trade and Tariff Agreement did not follow environmental legislation but accepted countries' right to prohibit imports of products made with prison labor. The same notion could be applied to ecological standards through a mechanism of 'environmental harmonization' of trade policy, accepting different countries of identical product and development standards (Charnovitz, 1993).

Therefore, sustainable water supplies could be accomplished by adjusting both supply and demand for water use in agriculture to appropriate rates. To optimize land and water use productivity, crop production could be optimally distributed throughout the world. In contrast, national food self-sufficiency policies in regions without adequate renewable water resources may need to be abandoned and replaced through multilateral trade agreements to allow food imports (Davis et al., 2017).

5- VWT and resilience in the global food system:

The global food system relies heavily on foreign trade because there is a difference between food production rates and consumption in various world regions, which explains areas with food availability surpluses and deficits (D' Odorico et al., 2014).

Owing to the non-uniform distribution of resources (e.g., land, water, and energy) and population density, only 15% of the world's countries are entirely self-sufficient. At the same time, the majority are dependent on imports of agricultural products. Food imports help countries overcome resource shortages, reduce temporary decreases in food production and partly respond to changes in productivity caused by climate change (Puma et al., 2015).

However, international trade exposes countries to potential food supply shocks in response to output crises that arise in other parts of the world. Governments tend to reduce their exports during emergencies, diminishing the total amount of food (and virtual water) available for trade (Puma et al., 2015; Tamea et al., 2016).

Therefore, the globalization and intensification of foreign trade pose questions about the water-food system's vulnerability and its resistance to shocks. However, food production shocks are well studied, with less understanding of their responsibilities and the complex mechanisms contributing to food shortages on a larger scale (Jones & Hiller, 2017).

Tools for analyzing networks were used to investigate the structure and dynamics of food commerce. Scaling properties of food flow networks have been found to have consistent statistical distributions from the village to the global scale, suggesting that similar governing mechanisms can drive food redistribution across spatial scales (Konar et al., 2018).

Other work concludes that the global food network is becoming more connected but not necessarily less stable and that shocks induce long-term structural changes leading to an evolution in the network's capability to absorb shocks (Fair et al., 2017).

The key factors that decide a country's resilience, defined as its capacity to react and adapt to food supply disruptions, are local food production and economic power (expressed as the ratio of low-income levels and food costs) (Seekell et al., 2017).

During food crises, stocks buffer the temporary food shortage caused by a loss of local production or a decrease in imports and limit food availability on the local population. Therefore, the spatial distribution of food stocks is as important as international trade in determining the impact of food supply shocks and must be taken into account when developing food crisis propagation models (Marchand et al., 2016).

International food exchange dynamics are closely related to the global economics of agricultural commodities and food price dynamics. Trade shocks and other non-trade-related factors (e.g., crop failures due to droughts or plagues) are likely to cause increases in food prices, which may cause food shortages socio-political instability (Bren d'Amour et al., 2016).

Conclusion:

Water scarcity is a significant problem worldwide; however, its effect among developed and developing countries is disproportionately felt. Developing countries are grappling with inefficient overuse of agricultural water, inadequate drinking water availability, and insufficient services to promote adequate sanitation. There are existing ways of using and improving them to solve the water crisis, including the virtual water trade that achieves water saving. VWT's advantages as an approach to coping with local or regional water scarcity (either by trade or food aid) and feeding people living in water-stressed areas have also been highlighted in the literature without causing significant displacement or water wars. Some of the socio-environmental impacts of increasing dependence on VWT and related dependency on water supplies occurring in other regions of the world have been critically addressed in this study. SDG 6 is committed to water and sanitation and is also related to eradicating poverty, the SDGs' central theme. The SDGs lift the burden of ensuring access to water to the global forum by discussing water in the sense of a fundamental human right. A further phase in the history of water is this latter attribution.

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