International Journal of Contemporary Applied Researches Vol. 7, No. 8, August 2020
(ISSN: 2308-1365) www.ijcar.net

CONCEPTS OF VIRTUAL WATER AND WATER FOOTPRINT IN GLOBAL PERSPECTIVES

P.C.K. RANATHUNGAMAGE
Agricultural Officer, Lanka Sugar Company Limited-Sevanagala, Sri Lanka
krgamage@gmail.com

ABSTRACT
Water has become an essential commodity and, at the same time, a limited resource. Due to its scarcity and limited availability across the globe, researchers are interested in studying water-related concepts. Studies mainly aim to mitigate associated issues and forecast better production and consumption protocols that would help understand water in the per-capita consumption level. This research focuses on the concepts of virtual water and water footprint values of each country. Water is an integral part of producing goods and services. The amount of water consumed by agricultural or industrial products during its production process is called as the virtual water of the product. The water footprint is defined as the cumulative virtual water content of all goods and services consumed by one individual or by the individuals of one country. A meat diet implies a much larger water footprint than a vegetarian one, at an average of 4 m^3 of water per day versus 1.5 m^3. Being aware of the water footprint can help us use water more carefully. People in Asia, consume an average of 1.4 m^3 of virtual water per day, whereas, in Europe and North America, people consume about 4 m^3 of virtual water per day. It was also found that the importation of virtual water through food or industrial products could be a viable option for water scarcity in arid countries. These new concepts are fundamental when formulating water-related strategies locally and internationally to prevent it from being a crisis since water has been identified as a rare entity. The global average Water Footprint was estimated to be 1385 m^3 Person-1 Year-1. Bangladeshis' average water footprint was 769 m^3 Person-1 Year-1, which is considered one of the world's lowest water footprints. The United State's water footprint was 2842 m^3 Person-1 Year-1, and it is the most significant water footprint recorded in the world. It also was found that one American is equal to four Bangladeshis or three Indian/Chinese from a virtual point of view. The average water footprint of Sri Lankan was 1256 m^3 Person-1 Year-1. Each country should consider these values and review their water consumption and production processes for sustainable water usage and distribution.

Keywords: Virtual Water, Water Foot Print, Virtual Water Trade

1. INTRODUCTION

Water is considered as an economic good as well as a scarce resource. The topic has been discussing in many national and international conferences. Problems of water scarcity, unequal distribution of water, and deterioration of water quality would have been solved if water was considered as an economic good. Since clean freshwater is a scarce good, it should be handled economically.

When sustainably managing the available water, there are three different levels that we can make improvements. The first level would be the user level in which price and technology play a crucial role. At this level, local water use efficiency can be increased. Creating awareness, introducing rates based on the marginal cost of production, and encouraging water-saving technologies among water consumers could be the main areas where we can increase water use efficiency in the local level.

The second would be at the catchment or river basin level. At this level, decisions should be made to allocate the available water resources for different sectors in a logical way. Generally, people allocate water for specific purposes, while some other purposes are not addressed. Therefore, the decision on how the water should be allocated can be dependent on the value of water in its alternative uses. Water use efficiency is a crucial concept at this level.

Beyond the local water use and water allocation efficiencies, it is imperative to review these efficiencies globally. Therefore, global water use efficiency is a crucial concept at this level. The water distribution over the world is not even while some regions of the world are water-scarce, and others are water abundant. At the same time, the water demand is also varies depending on the area. There is a lower demand for water in some regions while there is a higher demand in the other areas. However, the relationship between demand and availability is not always correlated.

Open economy lets any country manage their water balance by importing goods that may consume high virtual water while exporting goods consume less virtual water, leaving the net virtual water value a surplus of the country. Therefore, importing water-intensive products and shipping products that consume less water would help a nation have surplus water balance.

The water footprint of a county is a useful indicator of the demand for global water resources. The water footprint is equal to the total virtual water content of all products consumed by the person concerned at the individual level. The calculated global average Water Footprint is 1385 m^3 Person-1 Year-1 (Hoekstra and Mekonnen, 2011).

Under these perspectives, the concept of virtual water, water footprint, per capita water consumption, nation's water footprint, global water footprint, and virtual water trade are relevant scenarios when formulating water-related strategies locally and internationally. Consequently, the primary objectives of this study were to:

1). Compile information about concepts of virtual water and water footprint.
2). Collect information on the virtual water values of different commodities
3). Compare the per capita consumption of water in various countries
4). Compile information on virtual water trade (export & import)
5). Predict future water-related issues and suggest mitigation strategies.

2. METHODOLOGY

Information was collected by referring research papers and proceedings of International water conferences held during the last two decades. Virtual Water Values of different commodities and water Footprint of different nations were collected by reviewing the literature. The values obtained were plotted against the country or the products to observe the trends of water consumption. Other useful facts were collected by referring to books, journals, e-books, and articles. Proceedings of independent case studies that have been done by researchers in different territories were also referred.

3. RESULTS AND DISCUSSION

3.1. Importance of concepts of virtual water and water footprints in the global WaterEconomy

The increasing population at an alarming rate has always demanded water supply at a global level. "In 1995 the world water withdrawal amounted to 3,906x106 m3. By 2025, water withdrawal for most uses has been projected to increase by at least 50 %" (Rosegrant et al., 2002). Therefore, water scarcity should be considered a significant issue in the 21st century, especially in arid territories, where food security has been interrupted. This will eventually affect human health as well as natural ecosystems.

According to Seckler et al. (1999), nearly 1.4 billion people (or one-third of the world's population) live in regions where severe water scarcity experiences. Out of these 1.4 billion more than 1 billion people live in the arid areas that will face absolute water scarcity by 2025. These regions do not have sufficient water resources to maintain the per-capita consumption levels they had in the 1990s to meet the water requirement for domestic, industrial, and environmental purposes. Global food production may severely be affected as 80% of global water goes for irrigation agriculture, and water inadequacy will negatively affect food production in Agricultural counties.

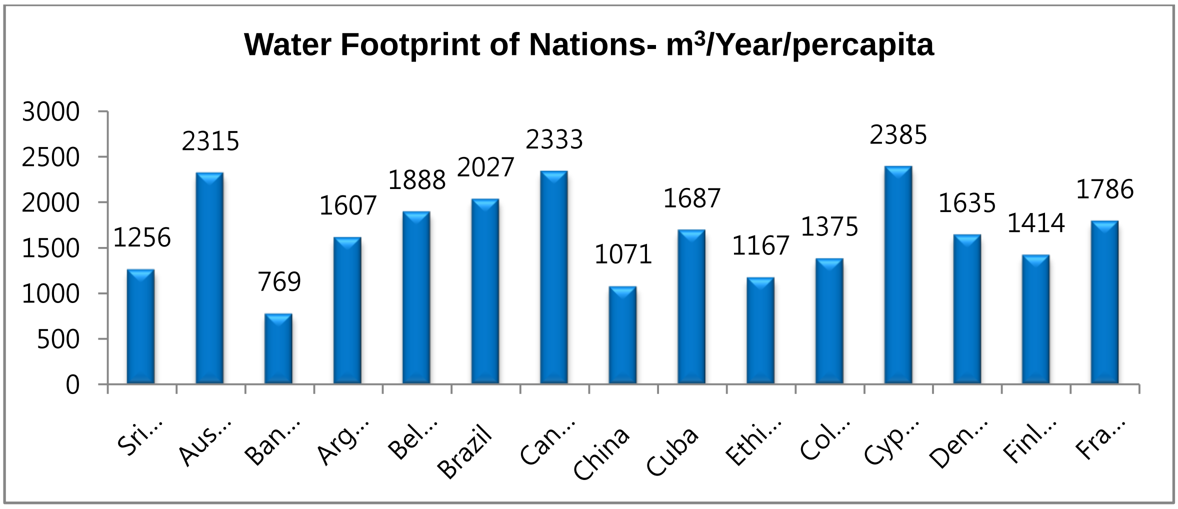
Developing water scarcities would be a challenge for national governments, international development, and environmental authorities. The issue is augmented by groundwater depletion, water pollution, degradation of water ecosystems, and soil contamination that would eventually affect water quality. The free supply of irrigation water subsides, and incentives based on water for farming communities, improper irrigation schedules, and improper storage methods will negatively affect the sustainable use of water in any territory regardless of water availability. Hence, it is a requirement for every local government to work together with the international community to efficiently reform policies to manage the world's water resource efficiently on a local, regional, and global scale. The concept of virtual water helps countries with low available water import commodities that require high water quantities from other countries.

Out of many sectors, water management for food production industries has considerable attention. The increased demand for water between each sector, the necessity of food production for the emerging population, and increasing water scarcity in many regions are essential reasons to look at sustainable water distribution management on the planet.

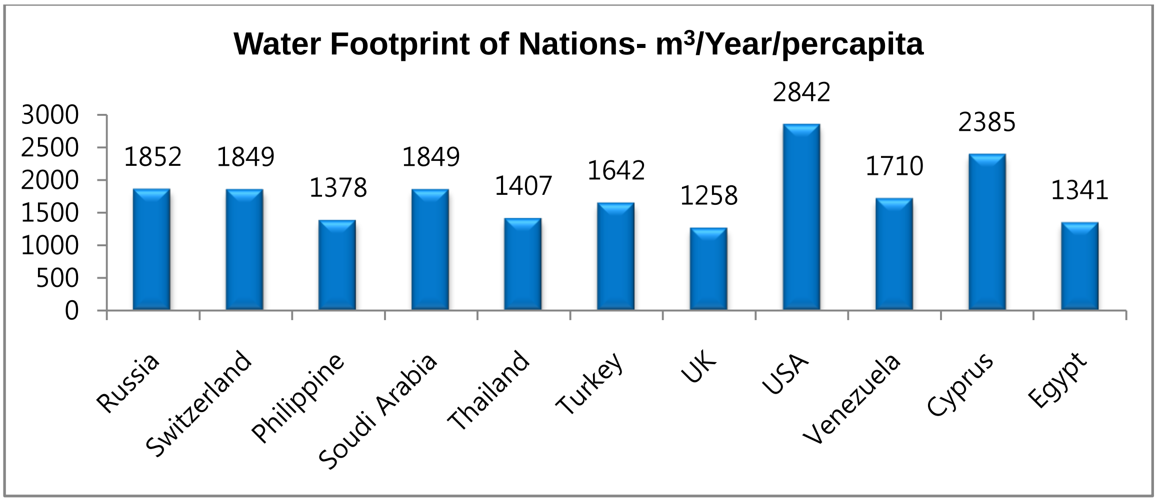
Rosegrant and Ringler (1999) pointed out that the importance of virtual water is likely to increase dramatically across the globe due to increased food trade. He further explained that according to projections, cereals' water requirement would be two times than usual, while it will be three times for meat production between 1993 to 2020. Therefore, transferring virtual water embedded in the foods via trade would become an essential component of water management strategies locally and internationally.

3.2 Comparison of the water footprint of different nations

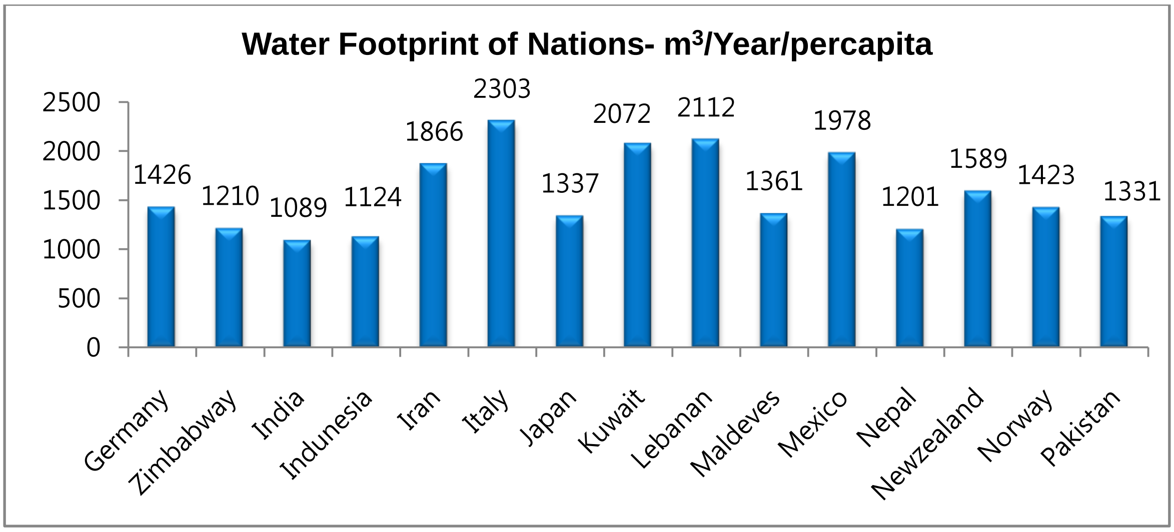
The global average Water Footprint was 1385 m³ water/person/year (Hoekstra and Mekonnen, 2011). It means a person anywhere in the world consumes 1385 m3 water per year. Further, the Graphs 4.2.a, 4.2 b, 4.2.c, and 4.2.d show the water footprints of 51 nations across the globe.



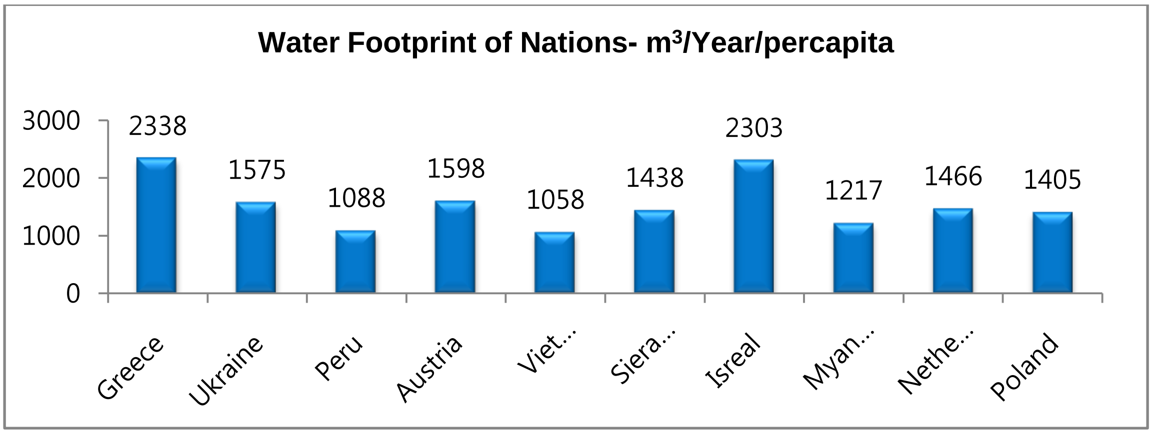
Graph 4.2 a.



Graph 4.2.b.



Graph 4.2 c.



Graph 4.2 d.

According to Graph 4.2a, the virtual water footprint of Sri Lankan was 1256 m3 per year, whereas it was 769 m3 per year being Bangladeshis. The water footprint of Canadians, Cypresses, and Australians was comparatively high compared to the other countries. Particularly the water footprint of Sri Lankans, Bangladeshis, and Chinese were well below the global average water footprint. In contrast, it was well above countries like Australia, Canada, Cyprus, and Brazil, etc.

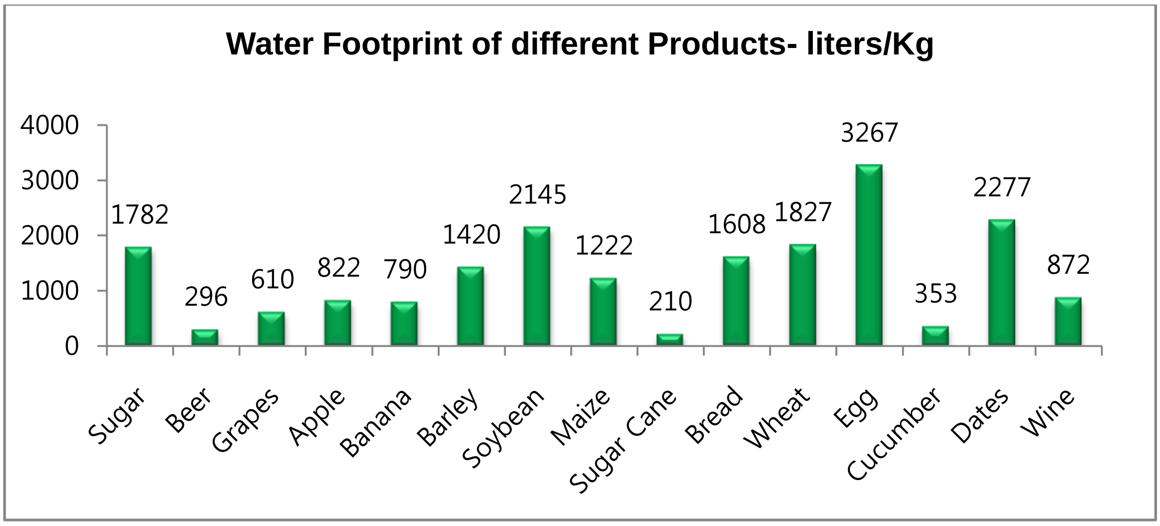
According to Graph 4.2.b water footprint of the USA was 2842 m3/year/person. The water footprint of Switzerland and Saudi Arabia showed the same number. In contrast, the values of countries like the Philippine, Thailand, etc. were more or less similar to the global average water footprint (1385 m3/year/person).

According to the Graph 4.2 c water footprints of Indian, Pakistanis, Napoleon, Japanese, Indonesian and Moldavian were below the average global water footprint whereas those were well above the global average water footprint of the countries like Germany, Zimbabwe, Iran, Italy, Kuwait, Lebanon, Mexico, New Zealand, and Norway.

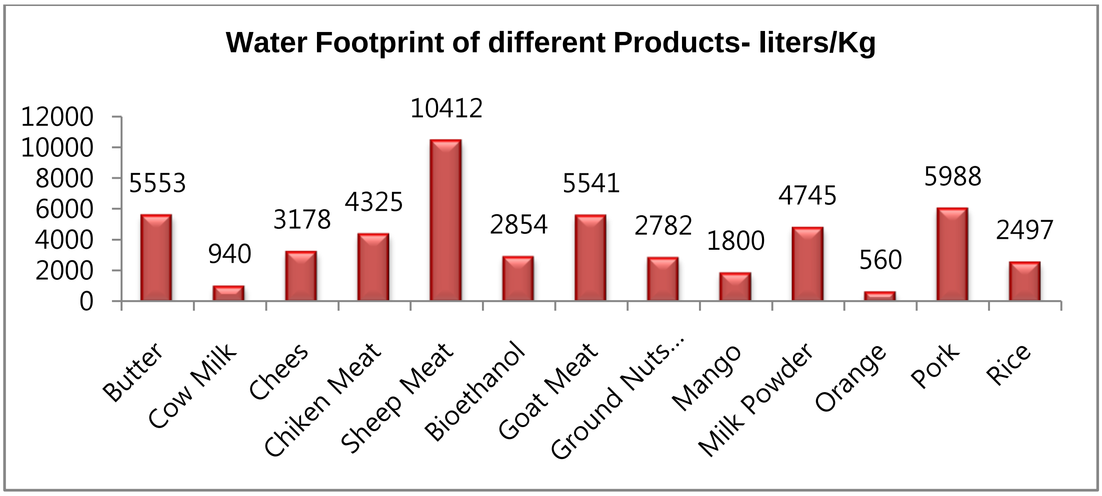
Graph 4.2 d shows that the water footprints of Grecian and Israelis were comparatively high while the Perish and Vietnamese water footprint was well below the global average water footprint. Ukrainian and Australian water footprint was more or less similar, while the same as Sierra Leonean, Netherland, and Poland were also more or less similar. According to Graph 4.2 a, 4.1 b, 4.2 c, and 4.2 d, the heist water footprint reported from America while the lowest reported from Bangladesh. It was evident that the water footprints of Asians were comparatively small, whereas those of Europeans were high. According to the water footprint values, one American is equal to four Bangladeshis or three Indian/Chinese from a virtual point of view.

According to the literature, a significant difference can be seen in water consumption between continents. Generally, the water consumption in Asia is lower in contrast with Europe or USA. This can be attributed to the water footprint values given by Hookestra (2011), "In Asia, people consume an average of 1,400 liters of virtual water a day while in Europe and North America people consume about 4,000 liters". Out of all the water consumed by humans, nearly 70% goes to food production.

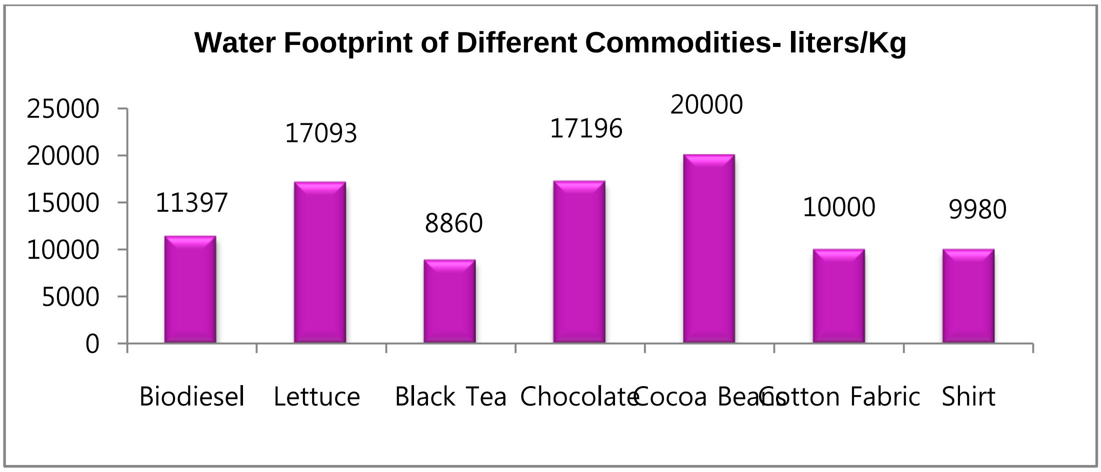
3.3 Global Average Water Footprint of Different Products



Graph 4.3 a



Graph 4.3 b



Graph 4.3 c

Graph 4.3 a, 4.3 b, and 4.3 c show the water footprints of different commodities. It gives an idea of how much water is required to produce I Kg of the concerned product. According to Graph 4.3 a water footprint of beer, sugar cane, and cucumber was comparatively low (less than 500 l/Kg).

It also indicates that the production of meaty products consumes much water rather than vegetable products. However, lettuce's water footprint was 17893 l/Kg, whereas it was 20000l/Kg when the cocoa bean was concerned. These values are essential when the virtual water trade is concerned.

If a nation can import meat rather than produce it in the concerned country, it can save a lot of water while increasing its water stock inside the county. Therefore, some states have imposed strict rules and regulations on their export and import processes. For example, water-scarce countries like Israel discourage the export of oranges (relatively heavy water guzzlers) precisely to prevent large quantities of water from being exported to different parts of the world.

3.4Virtual water and water wars?

Out of many territories, Middle Eats has been identified as the most challenging region due to scarcity of water resources, maybe little freshwater, and negligible soil water is available. Therefore, water is a critical strategic element for policymakers. Researchers predict that water scarcity will create social unrest and be a political weapon in terms of bi-lateral or multi-lateral relationships with other regions and will create a similar ground as petroleum oil.

Conflict in sharing water dates back to ancient times in India and other Asian countries. The political harmony between countries is highly dependent on sharing natural resources like water. It could be India-Pakisthan, India-Bangladesh, or India-Nepal; there were developing issues in the last few decades. The phenomena are common over Europe to the USA as well. Israel- Palestine, Euphrates-Tigris, USA- Canada, and USA-Mexico are few examples of sharing water resources leading to a conflict. Same time developing countries have now invested in invasive water projects in developing countries.

Viewed from above, one should clearly understand that the perverse as well as favorable impacts that would result owing to issues arisen from sharing water between nations. "However, the global trade system has slowed the pace of water policy reform and has distorted international relations where shared freshwater resources are in contention" (Allan J.A. 2003).

3.5 Public policies and farm-level decisions

In most agricultural systems, farmers choose their crop varieties and cultivation methods based on their expectations, demand, and inputs. Price, human capital, resource availability, household necessities, and market forces are a few factors. However, there are some instances that the farming community is directed by the government to achieve national goals, and the Gezira production system in Sudan is an example where the government is determined the combination of crops cultivate each year. In the Gezira production system, key inputs, cultivation protocols, and crops are decided by the government. The phase of water utilization, type of fertilizers, pest and disease control methods, and harvesting methods are components of protocols. The Mahaweli Development Project in Sri Lanka is a famous Settler based farming system where Mahaweli Authority (Government wing) will be decided on the irrigation schedules, crop combination (upland or low land crops), and cultivation methods, etc.

In a system like Gezira or Mahaweli, the farmers have to implement the seasonal government program of crop production subjected to government market strategies, which may eventually leave profits. The main drawback is that the farmers cannot decide inputs or end products.

In a production system like Gezira, the government could implement a virtual water program rather quickly by imposing government objectives on production and marketing alternatives. In most of the other cases, governments do not play a direct role in farm-level decisions. However, the governments which impose their production strategies on farmers are naturally bound to buy their outputs at reasonable prices or compensates them on a possible crop failure due to unforeseen reasons. Since most local authorities have failed to implement sound programs to tackle the issues, they again end up with a conflict.

However, when farmers choose their crops and production practices, governments may influence farmers' decisions through public policies. For example, government policies that provide irrigation water to farmers at subsidized prices encourage the production of water-intensive crops. In contrast, no subsidy will help them to cultivate highland crops that need less water.

The government's virtual water strategies will affect depending on the policies that have already been set. If the policies encourage the farmers to select low-valued water-intensive crops rather than high demanded economic crops that may consume less water, the nation's virtual water program will still negatively affect. However, farm-level decisions do not always depend on national goals but individual or community preferences.

According to Wichelns D (2003), in arid regions where the opportunity cost of water may be substantial, farmers would still choose water-intensive crops if the farm gate price or water availability does not reflect its scarcity value. Complementary inputs may also have an impact on farm-level production decisions.

3.6 Public policies and virtual water trade in different nations

There are specific policies to achieve national goals in water management in different counties. Egypt is one country that has many regulations on water management. According to the literature, Egypt meets most of its water requirements from the Nile River. Wichelns D (2003) explained that the annual water supply from the Nile River is subjected to their agreement with Sudan. The volume has been estimated to be around 55.5 billion m3 water from the Nile River each year. This volume considered to suffice its aggregate demand despite its unequal distribution. However, uneven distribution along canals, periodic dry spells, storage constraints, and undulated topography will negatively affect the fair opportunities for water every user.

As does by many nations, Egypt is trying to balance its virtual water demand by importing export adjustments. Recent records indicate that they have increased their rice export volumes than previous years while cotton export value remains far below. Production strategies and increase the export of rice in combination with declining export of cotton may be beneficial to maximize sustainable water utilization in the country.

Wichelns D. (2003) further explains that the Egyptian exports of rice have increased in recent years, while cotton exports have remained far below the levels observed in the 1960s and 1970s. These increases in the production and subsequent export of rice combined with declining exports of cotton might appear to be inconsistent with a virtual water strategy that may be suggested to maximize the value of Egypt's limited water supply. However, changes in import-export volumes its self would not help a country to meet their increased demand for food, that production programs in the country to be encouraged that ensure food security. Public policies would affect farmers' decisions and help them select a combination of varieties in the limited lands given to them. Sometime land scarcity would be a limitation to achieve production targets though they have enough water to meet production requirements.

When comparing the agricultural policies of land and water utilization in Sri Lanka in contrast to Egypt, Sri Lankan farmers have been given two acres of lowland and a half-acre of upland in most development schemes, the famous one being the Mahaweli. In the Mahaweli System, the cultivation depends on irrigation water, and the primary crop concerned is paddy. Paddy should be cultivated in low lands where banana, chili, brinjal, ladies' fingers, groundnuts, etc. are grown in uplands. However, in some areas, people have shifted from paddy to banana-like crops owing to high water consumption and the cost of production apply to rice.

3.7 Effect of trade of virtual water in global water economy

Many countries import and export water through their agricultural commodities. According to Turton et al. (2000), South Africa has exported 10.8 million tons of water through its exports of 9,000 tons of maize to Zimbabwe in 2011. Interestingly, the amount of water entering the middle east in the form of subsided grain purchase is equivalent to the annual flow down of the Nile river. (Allan, 1997).

Many counties are compensating for their poor water management by food imports. Southern Mediterranean countries comparatively record high import volumes. In this context, the application of the concept of virtual and associated trade is a potential solution to water scarcity in arid geographical areas. Generally, the trade of real water between water available and water scars counties would not always be possible due to geographical barriers and cost involves. Therefore, virtual water trade would be significant in balancing the water budgets of water-deficit countries. However, as described by Meissner (2002), implementing a viable virtual water strategy is more complex, being influenced by many multitude factors at both national and international scales.

3.8 Implementing a viable virtual water strategy

Although virtual water is an important concept that a nation can achieve its water and food security, implementing a virtual water strategy should be a part of the country's long-term development goals in a holistic manner. Providing national security, achieving economic growth, and improving citizens' living standards would be critical objectives of any country at the national level.

If the key production factors such as land, labour, and capital are limited in any country, promoting virtual water itself would not help them to achieve maximum social benefits out of limited resources. If labour factor is abundant can export value-added products that may bring many incomes over for communities. The opportunity cost of water would be another factor in deciding the best practice, whether to export or utilize for another purpose.

According to Turton (2000), the allocation of water could be based on the contribution of the sector made to the Gross Domestic Production (GDP) of the country. If the industrial sector makes more contribution to GDP than that of the agriculture sector, which consumes more water, promoting the industrial sector would be a smart option to increase the degree of efficiency of water use of the economy. Generally, the water use efficiency of the agricultural industry is lower than in the industrial sector. For example, paddy cultivation may need a high volume of water in an agrarian country, whereas its contribution to GDP is lower than the industrial sector. Therefore, diverting the industrial sector from the agricultural industry would be 70 times beneficial in terms of virtual water.

Sound national trade policy is in harmony with regional trade policies that facilitate the exchange of goods; cooperation between states will help ensure a viable virtual water strategy. The establishment of an independent organization to regulate global food trade would be a sound approach to balance virtual water distribution. However, the distribution and regulation should not be a political weapon in any manner.

3.9 Criticisms on concepts of water footprint and limitations of virtual water measure.

The concept of virtual water is most used as an indicator of water use. However, interpretations may sometimes be a marketing strategy to promote certain goods while discriminating against other products. Understanding of virtual water values may be oriented to promote industrial activities without discussing further consequences. There are consequences of measuring virtual water as the calculations rely on some assumptions as well. There may be instances that wastewater coming from industry may be useful for another purpose that accurate values or boundaries cannot be made. Also, water has religious importance in many religions, and treating it as an economic commodity contradicts some religious myths. Some religions teach that humans are partners in three, water, herbs, and fire. Some people consider water as a gift from god and treated as a sacred good. The economic interpretations contradict with these myths. Self-sufficiency has always been the pride of some Asian countries. Virtual trade depends on imports and exports of commodities, but not self-sufficiency.

4. CONCLUSIONS

1. The concept of 'virtual water' is a potential solution to water scarcity in semi-arid and arid regions that can achieve water and food security by purchasing water-intensive agricultural commodities from water-rich countries.
2. In general, European countries consume a large portion of global water resources, while Asian and Middle East countries consume a smaller part of global water recourses.
3. The water resource management could be enhanced by adopting concepts of virtual water and water footprint, particularly in water-scarce regions like the Middle East and Africa.
4. Virtual water trade is essential to balance the unequal distribution of water resources between different geographical regions.
5. Water should be treated as an economic good which will facilitate concerned management strategies.
6. The water footprint is an important phenomenon to understand the water consumption of a nation concerned.
7. Virtual Water and water footprint are important scenarios for policymakers of water management.
8. Virtual water can be explained as a diplomatic and economical tool for attenuating conflict potential between nations and creating new enduring modes of international communication

REFERENCES

Allan J.A. (2003). Virtual water eliminates water war? A case Study from the Middle East, In. Virtual water trade proceedings of the International Expert Meeting on Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), page. 137

Allan, T., (1997), 'Virtual water': a long-term solution for water short Middle Eastern economies, Water Issues Group, University of London, In. Virtual water trade proceedings of the International Expert Meeting on Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), cited by El- Fadel &Maroun R. Page. 172

Hoekstra A.Y., (2003), Virtual Water: Introduction, In: Virtual water trade proceedings of the International Expert Meeting on Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), Delft, Netherland. Page 13.

Meissner, R. (2002), Regional food security: Using the concept of virtual water. African Security Review,11 (3),. Virtual water trade proceedings of the International Expert Meeting on Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), cited by El- Fadel &Maroun R. Page. 172

Mekonnen, M.M. and Hoekstra, A.Y. (2011), National water footprint accounts: the green, blue and grey water footprint of production and consumption, Value of Water Research Report Series No. 50, UNESCO-IHE, Delft, Netherlands

Mekonnen, M.M. and Hoekstra, A.Y. (2011), The green, blue and grey water footprint of crops and derived crop products, Hydrology and Earth System Sciences, 15 (5): 1577-1600

Rosegrant M. and C. Ringler, (1999), Impact on food security and rural development of reallocating water from agriculture. IFPRI. Washington DC

Rosegrant, M.W., Cai, X., and Cline, S.A., (2002), Global water outlook to 2025: Averting an impending crisis. International Food Policy Research Institute (IFPRI), Washington, D.C., and International Water Management Institute (IWMI), Colombo, Sri Lanka. In: Virtual water trade proceedings of the International Expert Meeting on Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), Cited by El- Fadel M. &Maroun R. page 171

Seckler, D., Barker, R. and Amarasinghe, U. (1999), Water scarcity in the twenty first century, Water Resources Development, 15 (1), 29-42, In: Virtual water trade proceedings of the International Expert Meeting on Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), Cited by El- Fadel M. &Maroun R. page 171

Turton, A.R., Moodley, S., Goldblatt, M. and Meissner, R., (2000), An analysis of the role of virtual water in Southern Africain meeting water scarcity: an applied research and capacity building project.Group for Environmental Monitoring (GEM) and IUCN (NETCAB), Johannesburg. In. Virtual water trade proceedings of the International Expert Meeting on

Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), cited by El- Fadel &Maroun R. Page. 171-175

Wichelns D. (2003), The role of public policies in motivating virtual water trade, with an example from Egypt, In. Virtual water trade proceedings of the International Expert Meeting on Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), page 148-151

Wichelns, D., (2001), The role of virtual water in efforts to achieve food security and other national goals, with an example from Egypt, Agricultural Water Management, 49, 131-151. In: Virtual water trade proceedings of the International Expert Meeting on Virtual Water Trade, Ed. By Hoekstra A.Y. (2003), cited by El- Fadel &Maroun R, page 173

Williams, E.D., Ayres, R.U. and Heller, M. (2003), The 1.7 kilogram microchip: Energy and material use in the production of semiconductor devices, Environmental Science and Technology36(24): 5504-5510