ABSTRACT

India being an agrarian economy needs to value its wealth of water as an economic asset. To ensure sustainable development, Virtual Water Trade is a recent concept to evaluate the volume of water withdrawn from a country and received by a country. It is important because agricultural sector contributes an appreciable part in the overall trade of a country, leading to major part of water consumption from the available fresh water resources.

This study is a way forward effort to drive the thought processes of policy makers and practitioners to adopt the virtual water trade as a tool to check the water control both within a nation and at the global level. Virtual Water Trade implies hidden flows of water embedded in a product, traded from one place to other. And this concept is the actual measurement of the total volume of water contained in the commodity. Agriculture is the major sector that consumes large amount of water and it is in a fitness of things to focus on this sector for the purpose of conservation and saving water to avoid the future water massacre which is on the verge of happening in some next decades.

Hence, the researcher has conducted a study on “Virtual Water in Food Production and Global Trade in India” in order to meet the aim of providing new avenue, fulfilling the mishap of the water crisis lacunae within the array of home country.

Water is one of the scarcest resources and found to be critical for agricultural production and non-agricultural products, which have been consumed and traded around the world (Hoekstra and Chapagain, 2007). Due to growing concern about environmental degradation and risk of managing the water resources for sustainable development of production system, water has become the prominent factor in several trade agreements at regional, national and international levels. Globally, virtual water is one of the solutions for water management, particularly in food deficit and water scarce countries (Shiklomanov, 1997). According to Allan (1997), the virtual water content in the products refers to the volume of water used in its production. (Chapagain, et al., 2005) argued that most of the water scarce nations save their local water resources by importing water intensive products and exporting less water intensive products.
A virtual water flow is associated with the water flow, which is embedded in the commodities and has a technique for handling the issues of water scarcity, water stress and food security, as it reduces the need of water for food production in importing country and increases the water use in exporting country. It is clearly indicated in empirical evidences that virtual water trade of agricultural products has been taken as a mitigating tool for reducing the risk of water shortage for the food production in the water deficit regions across the globe (Allan, 1997; Hoekstra, 1998; Earle & Turton, 2003). Therefore, food security management is one of the essential rationales for encouraging the virtual water trade as an instrument of water policy. In fact, most of the water deficit countries rely on increasing the imports of foods to fulfill their needs because agricultural production consumes the largest percentage of water resources. Within the context of food security, there is an imperative requirement to assess how the growing food deficit can be managed under water constraints and what role virtual water trade can play in narrowing the gap of unequal distribution of water resources. The aim of this study is to examine the virtual water flow and its importance in handling the food security problem. The analysis shows that the policy of virtual water required a thorough understanding of the impacts and the interaction of virtual water trade across the countries.

Due to an increasing water scarcity in many parts of the world, virtual water trade both as policy instrument and practical means to balance the local, national and global water budget has gained much attention in recent years. Based on extensive literature review, this study assesses the efficiency of water embodied in the international food trade from the perspective of exporting and importing countries at national as well as global levels. Virtual water trade is one of the alternatives to reduce the water consumption for food production. It contains various products, particularly agricultural goods, which may vary greatly within India. In the present globalized era and water crisis, this study has a special significance.

**Research Gap**

Following are the research gap of concerned aspect regarding the proposed topic:

- There is a need for proper planning to minimize the gap between the water availability and requirement through better utilization of water resources.
• There is a need to assess the virtual water trade content of various tradable agricultural products for different agro-climatologically division.

• There is also a need to estimate the virtual water trade between different states of the country.

• The current estimates of virtual water content and water footprint are quite approximate, which require accuracy based on more data analysis as well as improved methodology.

**Objectives of the Study**

The objectives of the study are to:

1) Analyse the extent and pattern of water usage in production of major agricultural commodities across the country.

2) Examine the volume and direction of agricultural trade in India during last two decades.

3) Assess the water food-print by analysing the virtual water trade.

The study has been conducted on the basis of secondary data and information, which have been collected from various published sources. The data of water consumption in the production of agricultural commodities has been retrieved from various issues of Agricultural Statistics, Ministry of Agriculture, Government of India and Food & Agricultural Organization (FAO) of the United Nation Database, AQUASTAT database, Central Water Commission reports, Ministry of water resources. For the calculation of volume and direction of agricultural trade, data has been accessed from the DGCIS, ministry of commerce data bank and collected from the National Institute of Public Finance and Policy, New Delhi since 1985 to 2014.

All the collected relevant data has been dissected on MS-Excel for applying the statistical formula and techniques. The statistical techniques like mean, standard deviation, coefficient of variation etc. and virtual water coefficients derived by Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2011) have been used to analyze virtual water trade. Herfindhal - Hirchmen Index has been used.
to evaluate the concentration and diversification of agricultural trade over a given period of time i.e. 1985-2014.

The estimation of virtual water has been done with the help of an extensive literature review on water contents in agriculture production (e.g. Allan, 1993; Haddadin, 2003; Chapagain & Hoekstra, 2003; Chapagain & Hoekstra, 2004). Virtual water can be defined as the volume of water usage to produce a commodity or service. This concept was introduced by Allan in the early 1990s (Allan, 1993, 1994) when searching the solution for problem of water scarcity in the Middle East and found the option of importing virtual water as a partial solution for the issue of water scarcity, which also reduce the pressure of the scarcely available domestic resources. Various estimates indicate that to produce one kilogram of grain, cultivate under rain-fed and favorable climatic condition, there is a requirement of about one to two cubic meter of water i.e. 1000 to 2000 kg. If the same of grain is cultivated under arid or unfavourable condition then the water requirements will increase and estimated to be high as up to 3000 to 5000kg (Chapagain & Hoekstra, 2003; Fraiture, et al., 2004; Hoekstra & Hung, 2005; Burke et al., 2008). It can be calculated by multiplying commodity traded volume (tones/year) by their related water content (m$^3$/tones). Therefore, the formula of virtual water trade is as follow:

Mathematically,

$$ VWT_t = \sum_{i=1}^{n} (QT_{it} \times VWC_{it}) $$

Where,

- $VWT_t$ = Total volume of virtual water traded by net import/ export of $i^{th}$ food produce in time $t$.
- $QT_{it}$ = Net quantity imported/ exported (tonne/ year) of $i^{th}$ food produce in time $t$.
- $VWC_{it}$ = Virtual water content (m$^3$/tonne) by $i^{th}$ food produce in time $t$. 
Limitation of the Study

1. The study is totally based on secondary data collected from authentic sources of government database. In case of any discrepancy with regard to data, researcher is not responsible. It is hard to collect all the trade data from all the countries. There could only be accessed the data, provided by the government agency of the data collection.

2. This study only considers the agricultural products for analysis for which virtual water trade data is available, other crops have not been considered.

3. Generalised Global virtual water content coefficients were applied in this study, which perfectly representing India’s VWC.

The present study has highlighted the extent and pattern of virtual water usage in food production and global trade in India. With growing demand for food and an increasing water scarcity in many parts of the world, virtual water trade both as a policy instrument and a practical means to balance the local, national and global water budget has received much attention in recent years. This study has thrown light on the extent and pattern of water usage in the production of major agricultural commodities across the country, the volume and direction of agricultural trade in India during last two decades and has assessed the water food-print by analyzing the virtual water trade. The present study of virtual water flow through agricultural commodities in India, following important facts have been found.

- India had trade surplus in agricultural trade from 1985-1998. Export and import both increased manifold from 1985 to 2014. But from 1998, imports had increased at a faster pace as compared to export, as the tariff rates were reduced under economic reforms to a greater extent. The crisis of East Asian regions had severe effect on export of India. Devaluation of the currencies of ASEAN countries decreased the competitiveness of exports of India in global market, which led to almost continuous trade deficit thereafter.

- Through analysis of HHI of export and import from 1985, it was found that there had been huge fluctuations in the import’s HHI values as compared to export. And from 1994 to 2004 import concentration was not stable while from 1989 to 2004 export concentration was not stable.
From the whole analysis of export composition it can be concluded that the export composition has fluctuated much. Drastic increase has taken place in export of meat and edible meat offal increasing its share in total export of agricultural commodities from 3.29% in TE-1988 to 28.26% in TE-2014 followed by fish and crustaceans with 14.16% share in TE-1988 to 25.11% share in TE-2014 and edible vegetables whose share went up from 3.06% in TE-1988 to 7.87% in TE-2014. Increase in export value of coffee and decrease in its export share indicates that there is a need to undertake measure to improve exports of coffee from India to the world.

Analysis of import composition shows that in every triennium ending, import is concentrated to edible vegetables, edible fruits and nuts, peel of citrus/lemons; coffee, tea, mate and spices, animal and vegetable fats, oils and waxes due to the rising middle class income and changing consumption patterns.

Export of most of the commodities have shown acceleration growth during 1998-2014 as compared to 1985-98, which includes dairy, eggs, honey & ed. products; milling industry products; sugar & sugar confectionary; cocoa & coca preparations and meat and edible meat offal. Growth has been negative for vegetable plaiting materials and animal or vegetable fats, oils & waxes in both the sub periods. More than 50 percent of the items have shown negative compound annual growth rate for the entire study period.

Eighteen commodities have shown growth in 1998-2014 as compared to 1985-98. Remaining six commodities has shown low growth during 1998-2014 as compared to 1985-98. Growth has been negative for dairy, eggs, honey and edible products in the sub period 1985-98. Exactly 75% of the items have shown no growth for the entire study period.

There have been high fluctuations in export of all the commodities. More or less the value of SD of all products is high and CV is also high. Out of which eight commodities have remarkably high standard deviations and coefficient of variation which includes meat and edible meat offal; fish and crustaceans; edible vegetables; live tress and other plants; cereals; coffee, tea, mate and spices; edible fruits & nuts, peel of citrus/ melons and residues from food industries,
animal feed. Mean, SD and CV of all exported commodities is Rs 198.90 billion, 206.58 and 103.86% CV. High degree of CV reflects high instability in export. Value of standard deviations and coefficient of variation is greater during sub-period 2001-14 and low in former sub period 1985-2001. High degree of fluctuation in export of all commodities has resulted in very low growth in the value of export between 1985-2001, but in subsequent period 2001-14 it is improved.

- There has been high instability in the import of all commodities which has been marked. Some commodities has shown very high fluctuations like edible preparations of meat, fish, crustaceans etc., cereals, meat and edible meat offal. The import in India from the world has been instable during the study period. Value of arithmetic mean of animal or vegetable fats, oil and waxes (Rs.480.85 billion) and edible vegetables (Rs. 329.14 billion) is more than the sum of the average value of all other commodities. Reason for this extremely high mean values of these two commodities is the import of vegetable oils and high breed vegetables alone constitutes 34% share and 18% in the major importing commodities in India (DGCIS, 2014) Import has increased drastically after the liberalization and especially in the recent decade. Standard deviation and coefficient of variation has been high for all the agricultural commodities in consideration i.e. 1410.887 and 108.56%.

- Export of virtual water through agricultural commodities has fluctuated more than import of virtual water through agricultural commodities during the study period. As far as mean values of import and export of VW via agricultural commodities is concerned, it has been 2003530 Cubic km/Ton and 1078142 cubic km/ton respectively. Values of mean of import and export of VW show that India has been the net virtual water exporter. This is not desirable for long term sustainable agricultural growth.

- According to commodity-wise analysis, India had remained virtual water exporter in case of all commodities except three products i.e. edible vegetables, edible fruits & nuts, peel of citrus/ melons and sugar and sugar confectionary. Major export of virtual water has taken place through meat & edible meat offal due to its high virtual water content.
• Exporting high virtual water commodities is not in the long run economic interest of India from the point of view of sustainable development. Because it is not favorable to export water from country, which will lead to depletion of water resources in a country (Hoekstra, 2012). India must regulate policies to control those commodities such as meat & edible meat offal and coffee, tea, mate & spices which are having high virtual content in this category. VWCs must be taken into account while trading agricultural commodities being agrarian economy. Either some quantification tools must be develop to check water exchange with physical quantity or pricing policies must be formed to count virtual water content while trading agricultural commodities.

• Quantity of virtual water exported through agricultural commodities has fluctuated more than the quantity of virtual water imported during 1985 to 2014. Overall variation in quantity of agricultural products exported and imported on HHI index is more than the variations in import and export of virtual water that is traded through import and export of these agricultural products. This signifies that agricultural trade (in terms of quantity) is diversified and virtual water trade is concentrated.

• Mean value of quantity exported of all commodities to the world during 1985-2014 is 371790.1 tons with standard deviation of 328570.7. Value of standard deviation indicates that there is high deviation from the mean. The reason behind this deviation is that the quantity of export has decreased very much in the post liberalization period. Coefficient of variation for quantity exported of all agricultural commodities has been 88%, indicating high inconsistency in quantity of export from India to the world during the study period. Mean for virtual water that has been exported with all the agricultural commodities has been 2003530 cubic km/ton. Standard deviation for virtual water exported with all the agricultural commodities is 2355317. Deviations are very high from the mean. And coefficient of variation for virtual water exported with all the commodities is 118%, which clearly shows that there have been high fluctuations in virtual water trade during 1985 to 2014.

• There have been very high fluctuations in quantities imported of all the commodities but virtual water imported through all the agricultural commodities
has not fluctuated much comparatively. Mean and standard deviation of all imported commodities are 562140.43 tons and 632098.25 respectively. Coefficient of variation is also high i.e. 112%. More or less the value of standard deviation of all commodities for quantity imported as well as for virtual water import is high i.e. 639194.17 and the coefficient of variation (59%) is also high. The reason for this high fluctuation is the extremely high values of some imported commodities, which include edible vegetables followed by cereals, sugar and sugar confectionary, ed. fruits & nuts, peel of citrus/melons and oilseeds/ misc. grains/ med. plants/straw.

- Compound annual growth rate of virtual water exported through agricultural commodities was -12.5% during 1985-86 to 2013-14. This is a desirable trend. It reflects that India is able to reduce the export virtual water in these years. Cereals (10.4% CAGR), meat & edible meat offal (7.6% CAGR) and sugar & sugar confectionary (1.6% CAGR) have shown positive growth, constituting 23% of agricultural commodities. Remaining 77% commodities have negative growth during entire study period. During sub-period 2000-01 to 2013-14, 46% of commodities had positive growth rate. 8% of commodities have shown no growth and remaining 46% had negative growth leading overall growth rate of 3.6%. In 1985-86 to 1998-99, only meat & edible meat offal had shown positive growth with 18.3% growth rate which constitutes 8% of commodities. Remaining 92% commodities had negative growth which led to -19.5% growth rate. It reflects that after 2000-01 export of agricultural commodities with high virtual water footprint has increased as compared to earlier sub-period. We shall look at our export of agricultural commodities and focus on export of only those items whose Virtual water content are low so as to reduce export of virtual water.

- CAGR of virtual water imported through agricultural commodities has been positive through entire study period but decreased over the time. CAGR of total volume of virtual water of agricultural commodities imported was 7.6% during 1985-2014. CAGR was 18.1% in sub period 1985-86 to 1998-99 and 0.8% in subsequent sub period. The reason for this decreasing trend is achieving self reliance in the production of those commodities which has high virtual water content i.e. vegetables, coffee, fruits etc. and some processed food (Hoekstra and
Mekonnen, 2012). During 2000-01 to 2013-14, 86% of commodities has positive growth rate, 7% of commodities have no growth and 7% of commodities have shown negative growth rate. On the other hand, sub-period 1985-86 to 1998-99 recorded highest CAGR with 18.1% aggregate growth rate. In this time period 27% of commodities have shown negative growth including four product categories namely dairy, eggs, honey & edible products (-18.9%), animal or vegetable fats, oils and waxes (-0.9%), live animals (-5.9%) and meat & edible meat offal (-26.5%). 73% of commodities had positive growth rate during this sub period. CAGR growth rate of virtual water imports was positive but it has shown decreasing trend. Only 33% of commodities have shown increasing trend which includes some sub products of meat & edible meat offal; dairy, eggs, honey & edible products; animal or vegetable fats; oils & waxes; preparations of cereals, flour, starch and milk and preparations of vegetables, fruits, nuts etc.

- Direction of virtual water flow shown in this study from 2001-14 shows that Africa is the major hub of export and import of virtual water by securing around 28% of virtual water exports and 35% of virtual water imports. Meat & edible meat offal; coffee, tea, mate & spices and cereals were the major virtual water exporting commodities. whereas, edible fruits & nuts, peel of citrus/melons are the major virtual water importing commodities. Asia stands at second position followed by America and Europe in terms of total virtual water flows taking place between India and world. India must discourage export of water intensive products to Africa and Asia to reduce volume of virtual water export to these regions. And encourage water intensive products like meat products because livestock and poultry consumes large amount of water or having high virtual water contents. Dairy products rank at second position in terms of high virtual water content followed by vegetable oils and some processed foods, mainly beverages.

Suggestions and Recommendations

- Water management strategies should be developed in such a way that the water intensive commodities must be grown in water abundant region and vice-versa at the national and international level.
• India must discourage export of water intensive products to Africa and Asia to reduce volume of virtual water export to these regions.

• Virtual Water Trade must be included in the policy framework by the governmental water institutions to overcome the problem of water management.

• Some pricing policies must be developed to treat water as an economic asset, keeping in view its importance from future perspective.

• While accumulating the monetary value of BOT of agricultural trade, volume of water must be accounted.

• Some extension and voluntary program be launched to create awareness about the virtual water trade among the farmers for the proper utilization of water resources considering the value of water in the production of crops.

• Due importance should be given to the concept of Virtual Water Trade by the policy makers and encourage researchers at institutional level and farmers at field level.

• Projects must be launched by govt to develop some tools and techniques to calculate Virtual Water Trade for the products produced from agriculture sector.

• Govt. should estimate virtual water content of different crops in different regions of India. So, that, exact virtual eater trade could be ascertained for sustainable agriculture.

Possible Research Areas for Future

This research will provide the base for future researcher to determine the real volume of water consumed by agricultural trade. This will help to develop sustainable model to control the water crisis problem in future by generating some tools and policy framework to secure water resources.