Chapter 3

RESEARCH FRAMEWORK AND METHODOLOGY

The aim of this chapter is to give detail of the need for the study, objectives of the study and detailed research methodology and framework.

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 becomes 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 have 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 increase 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 rationale 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.

3.1 Need of the study

Due to an increasing water scarcity in many part of the world, virtual water trade as both as policy instrument and practical means to balance the local, national and global water budget has gain 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 assumes special significance.

3.2 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.
3.3 Objectives of the Study

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 analyse the virtual water trade.

3.4 Conceptual Research Framework

The study is based on secondary data. This is an analytical research which stands on three tier system approach for fulfilling the objectives of this study. First tier based on the analysis of the extent and pattern of water consumption in cultivation of major crops within the country which has been done on the basis secondary data available at various authentic published sources.

![Research Framework based on three tier strand](image)

*Figure 3.1: Research Framework based on three tier strand*

Second tier consists of a calculation of the volume and direction of agricultural trade in India during the last two decades, which has been done by using statistical tool on the collected data from secondary sources. Last tier deals with assessment of water footprint by considering the virtual water trade policy and the implication for improving water use efficiency.
3.5 Research Methodology

This study is based on secondary data which has been collected from different sources and further processed by using various statistical tools to do analysis as per the requirements of the study.

3.5.1 Sources of Data

The study has been conducted on the basis of secondary data and information has 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 have 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.

3.5.2 Data Analysis

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) are 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 following data analysis techniques have been used to present the finding of the study in an appropriate way.

3.5.3 Concept & Technique used for Data Analysis

- **Virtual Water Trade**: 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
sarcity in the Middle East and found that the option of importing virtual water as a partial solution for water scarcity problem 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 trade volume (tonnes/year) by their related water content (m³/tonnes). Therefore, the formula of virtual water trade is as follow:

Mathematically,

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

Where,

\[
\begin{align*}
VWT_t &= \text{Total volume of virtual water traded by net import/export of } i^{th} \text{ food produce in time } t. \\
QT_{it} &= \text{Net quantity imported/exported (tonne/year) of } i^{th} \text{ food produce in time } t. \\
VWC_{it} &= \text{Virtual water content (m}^3/\text{tonne) by } i^{th} \text{ food produce in time } t.
\end{align*}
\]

**Virtual Water Content:** The virtual water content of is a product related to the freshwater embodied in the product, not in the real sense rather in a virtual sense. It refers to the volume of water used or wasted for producing the product and measured over its full production process and chain. If a country’s trades such a product then it trades water in virtual form. The former refers to the water volume embodied in the product while the latter term refers to that volume, including which sort of water is being used, also when and where that water is being used. Therefore, water footprint of a product is a multidimensional concept and indicator, whereas virtual water content refers to the only volume of water embedded in the product.
**Virtual Water Flow:** The virtual water flow is associated with product transfer agreement between geographically delineated areas (e.g. between two nations). The volume of virtual water that has been transferred from one nation to another nation is a result of product trade.

**Virtual Water Export:** The virtual water export can be described as the volume of virtual water that is being transferred geographically from one water intensive nation to water scare notion. It is related to the volume of freshwater consumed and polluted in the export procedure of the products.

**Virtual Water Import:** The virtual water import can be described as the volume of virtual water that is being transferred to water scare nation by the water intensive nation. It is associated with the total volume of freshwater used to produce the products in the exporting region. With the perspective of the importing country, this water can be considered as an additional source of water that is transferred from water intensive region within the area itself.

**Balance of Trade:** The difference between the country’s export and imports is called as balance of trade. It is a major component of a country’s balance of payment. If the imports are more than exports then it means that country is suffering from trade deficit, whereas reverse situation implies as trade surplus. It also referred as trade balance or international trade balance.

**Trend Analysis:** The trend analysis represents the virtual water trade between India and world through agricultural commodities. It includes commodity-wise and country-wise trend analysis of export and import are done to evaluate the composition variation and direction of agricultural and virtual water trade between India and the rest of the world.

**Simple Growth Rate:** The growth rate of export, import and trade balance has been calculated with the help of simple percentage growth on the basis of the previous year as a base year.

Mathematically,

\[
\text{SimpleGrowthrate} = \frac{\text{Current year} - \text{previous year}}{\text{previous year value}} \times 100
\]
**Compound Annual Growth Rate:** The compound annual growth rate (CAGR) is a useful measure of growth over multiple time periods. The following is a formula to analyze the growth rate of export and import in the different time period within 1985-2014.

Mathematically,

\[
CAGR = \left( \frac{Ending\ value}{Beginning\ value} \right)^{\frac{1}{n}} - 1
\]

Where, \( n \) = Number of years

**The Herfindahl-Hirschman Index (HHI):** The U.S. department of Justice, the Federal Trade Commission and state attorneys general have used HHI to measure the market concentration. The HHI is a statistical tool which is used to measure the market concentration for the purpose of antitrust enforcement. Similarly, it is used to analyze concentration/diversification of commodity wise export and import of India to the world. It is calculated by squaring each commodity share in the export and import respectively. After squaring the each unit, the resulting values have to sum up.

Mathematically,

\[
HHI = \sum_{i=1}^{n} S_i^2
\]

Where,

- \( HHI \) = Herfindahl-Hirschman Index
- \( S_i \) = share of export and import of particular commodity
- \( N \) = number of years
- Value tends to 1 = concentration in export/import
- Value tends to 0 = diversification in export/import

**Mean:** The mean or average is used to describe the whole export and import data full time period by a single value.

Mathematically,
\[
\text{Mean} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]

Where,

\[n = \text{number of years}\]
\[X_i = \text{value of export and import of } i^{th} \text{ year}\]

**Standard Deviation:** Standard deviation is used to measure the spreads of a data set. It is a fundamental calculation for analyzing the data set in relation to its mean. It helps in calculating the wideness range of the data from its means, if the value close to its means, then it implies that the data is contracted to central position or vice-versa. In the context of trade, it is related to change, i.e. the higher SD value, and then higher will be the change in trade data.

Mathematically,

\[
\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2}
\]

Where,

\(\sigma = \text{Standard deviation}\)
\(N = \text{Number of observations}\)

**Coefficient of Variation:** The coefficient of variation is used to measure the consistency of the data. It can compare the scatters of the variable expressed in the different units. It is equal to the standard deviation divided by the mean. It may be expressed in fraction or in an absolute number. It can also represent as CV and known as relative variability. If the CV is lower, then the consistency of the series is higher.

Mathematically,

\[
CV = \frac{\text{Standard deviation}}{\text{Mean}} \times 100
\]
3.6 Limitation of the Study

1. The study is totally based on secondary data and collected from an authentic sources of government database. In case of any discrepancy with regard to data, researcher is not responsible. It is not possible for us to collect the different countries trade data and could only access the data which will be provided by the government agency of 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.