Virtual Water Trade and Its Implications for Pakistan's Agriculture Sector

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Reg No: 08/MS-ENV-PIDE/2011

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DEDICATION

I dedicate this to my late parents whom I miss and love very much.

Also to my brother and sister

ACKNOWLEGEMENT

I would like to start by showing gratitude to Almighty Allah. I am highly grateful to the teachers, who made me work and think hard to collaborate and improvise for the successful completion of the assigned task. Especially I would like to thank the unfailing and untiring helps of my supervisor Dr. Zafar Mahmood, and Dr. Rehana Siddiqui, Head of Department and Joint Director at Pakistan Institute of Development Economics (PIDE), Islamabad. And the patience shown by my supervisor cannot be ignored. I also place on record my deep sense of gratitude and indebtedness to my friends and class fellows especially Mr. Kausar Abbas, Mr. Fidaullah Shah, and Mr. Mussawir Shah for helping me in this research. Then there are my family members who helped me and were praying for my success though every step. They all are very dear to me. All of them deserve credit of this work.

Rehan Rasheed

Abstract

This study analyzes the virtual water (content) embedded in major crops and fruits in Pakistan. It can help to identify crops that need relatively less water, hence provide insight for future planning. Identification of water contents may be used to understand water requirements and usage in different crop production. Furthermore, it may be used as a policy tool for better water management as well as open avenues for further detailed studies. It also helps to identify those crops which may be produced locally with less water consumption as well as identify those crops which needs to be imported due to higher water contents in them. For analysis three crops were chosen including wheat, sugarcane and rice. The fruits included in the analysis are mangoes, oranges and apples, while the vegetables covered are potatoes and onions. Data used for the analysis are secondary in nature. Data required foremost were the water crop requirement for each crop, production, yield and harvested area. The data on import and export of each crop were also essential to determine virtual water content. Results of the study indicate that the water use for each crop has risen over time. Pakistan is a net virtual water exporter with yearly average of about 134 km^3. The rise in water net export is due to increase in scale of production for export purposes. The gap between virtual water import and virtual water export is increasing with each passing year. The virtual water export has risen steadily while virtual water imports have more fluctuating trend. These fluctuations come across due to increase in imports as well as fluctuating crops production within country.

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LIST OF ABBREVIATIONS

CWR	Crop Water Requirement
CY	Crop Yield
ET	Evapotranspiration
FAO	Food and Agriculture Organization
GVWI	Gross Virtual Water Import
GVWE	Gross Virtual Water Export
GDP	Gross Domestic Product
ITC	International Trade Centre
Kc	Crop Coefficient
MAF	Million Acre Feet
NVWI	Net Virtual Water Import
NVWE	Net Virtual Water Export
PWP	Pakistan Water Partnership
SWD	Specific Water Demand
UN	United Nations
UNEP	United Nations Environment Program
VW	Virtual Water
VWC	Virtual Water Content
VWT	Virtual Water Trade
VWE	Virtual Water Exports
VWI	Virtual Water Imports
WWC	World Water Council
WB	World Bank

Chapter 1

INTRODUCTION

Background:

Water is very similar to other natural resources in its usability. It is even more critical factor for the survival of life in universe. However, other resources don't share water's worth as the most important component for life's existence. Although water is available in ample quantity worldwide, even if unequally distributed in time and space. Water is becoming rarer for human beings living in the globe by two ways, i.e., increased global population, mostly in underdeveloped regions and the increased pollution of freshwater. Cosgrove and Rijsberman (2000) believe that unless measures are taken to rectify the situation of decreasing water availability, impending doom is unavoidable.

Without water there would be no life on the earth. Water management is quite important task for survival of mankind. According to UNESCO-WWAP (2003), the Millennium Development Goals (MDGs) can only be met by better management of water resources as non-availability of water will make it hard to achieve other goals. This study also points out that at least one in every four people in 2050 is likely to be in areas, which will be extremely stressed with water. Falkenmark and Rockström (2004), note the problem of water scarcity is already causing panic in certain circles and with crisis increasing rapidly the situation would be enormous in next 50 years. World population is forecasted to increase by 3 billion people and to provide food for them three times more water is needed.

In the past 100 years, three major factors have increased the water demand: population growth, industrial development and the expansion of irrigated agriculture. According to UNEP (2002), the negligence on implementation of laws as well as more importance to water supply has contributed to inefficient water resource management especially in regions that are still in development stage.

Gleick (1991), hypothesis is that freshwater consumption is positively related to population growth. And these could create external conflicts as progress of industry and living standard people will demand more food, which requires more water. Hoekstra and Hung (2002; 2005) have identified levels of water use that can help in better water use efficiency. The efficient use of the global water resources is rapidly becoming a challenge for water scarce countries. Both physical and economic efficiency are important. All resources may have alternative uses hence most appropriate alternative is picked for best return. Economic efficiency means that marginal cost of water used in a particular case does not exceed the marginal benefits obtained. Therefore, best out of alternative use of water is picked on economic return it provides as compared to their cost. Usage of water should be in such quantity that its marginal cost should offset the marginal benefit.

Water scarcity problem can be solved at two separate stages. One way is to be more is to be more efficient by using less water to produce the same commodity. Secondly try to decrease demand of product by changing consumption patterns. The focus of supply management is to increase water flows and availability to meet demand, whereas focus of water demand management is to increase efficiency by trying to produce the same product with less water use and if beyond the economic optimum level then reduce consumption.

Decision making is always based on economic benefit. According to Savenije and Van Der Zaag (2002), economists have considered water pricing as the focal tool of demand management and this is a main downside of it too. Other tools of demand management that can be used are quota, water use licenses, tradable water rights, user charges, subsidies, grants and penalties.

Alternatively, as form of demand management, one can import a water intensive good instead of local production. This form leads to indirect water import besides the import of product and this concept is known as 'virtual water trade'.

The term 'Virtual Water' was coined by Allan (1993, 1994). It is defined as the volume of water required to produce a commodity or service (Allan, 1998b; 1999b; Hoekstra, 1998). Trade of a product from one location to another doesn't lead to direct physical water transfer but since the product's content also includes water, no matter how insignificant, there is transfer of water and that is virtual water transfer.

Haddadin (2003), has termed this water also as 'exogenous water', if considered from a country's point of view. Savenije (2004), has further categorized this virtual water by giving it color codes such as blue (irrigated water), green (rain water), grey (polluted water due to production usage) etc. Virtual water can also be explained through two different methods. According to Hoekstra (2003), one approach is through production and other is through usage. First method can be used when production of a product requires that virtual water be quantified to measure against real water use, therefore it is production site specific as water efficiency, conditions of location where production took place as well as time of production affect it. Second method is used to find the virtual water content of the product to allow us to compare how much water would have been needed to produce it in case it is not produced locally. Thus it is explicitly dependent on site of use.

Whenever we are interested in quantifying an impact of using product or resource on environment first method would be adopted. This method would provide actual water usage for production. Second method can be useful to deduce how much water a country has saved by importing the product.

Hoekstra (2003) further developed the virtual water definition by classifying water used in production of different products across different sectors such as agricultural and industrial. He also “included the water applied in the use and waste stages of the product.” By this method he did a calculation of numerous agricultural products Virtual Water Content (VWC). Also he did a widespread estimation of the Virtual Water Transfers (VWT) between nations due to trade.

Wackeragel and Rees (1996), developed ecological footprint of virtual water which help in computation of Water Footprint. The Water Footprint for a community or an individual can be defined as the accumulated amount of fresh water used to manufacture goods consumed by that community or individual. The WF is an effective tool for people to analyze the impact they have on natural resources they consume directly or indirectly. Mindfulness of one’s individual water footprint can substantially convince and motivate people to use water more carefully or efficiently.

It was observed by Allan (1994), that virtual water can be a mechanism through which water stressed countries can save water by importing products from water rich countries. His idea was also to use it as a tool to attain water efficiency on the global level; he argued that water intensive products trade from high water productive area will lead to low VWC to low water productive area. As there are not many sources of water in the world, import of water intensive commodities reveals invisible source of power for countries which may save domestic water resources by the way of import of water intensive commodities. (Allan 2003), stated that as Germany is not a water scarce state but it is still a net importer for virtual water. The UK imports two-thirds of its water footprint. Exporting countries are increasingly facing the menace of environmental degradation. Of late, the climate change and virtual water exports relationship has been gaining expert's attention.

Michal Kravcik (2010), Slovakian hydrologist, states that weather extremes, frequent floods and droughts, water scarcity and conflicts are occurring due to reduced volume of drenched rainwater in soil which in turn reduces evaporation increasing heat gathered in atmosphere, which disturbs the atmosphere cycle. All this puts food security in danger.

The estimation and analysis of the virtual water trade for Pakistan, from both a hydrological, economic and ecological perspective, can be very useful in developing policy prescription for ensuring competent allocation for water. The analysis, no doubt provides a clear and multi-disciplinary framework for optimization of decisions associated with water consumption policy in Pakistan whose 25% of the GDP is dependent on the agricultural sector.

The agricultural commodities' trade indirectly shows water trade, which is the level of 'virtual water trade'. Furthermore, a nation can save its domestic water resource by importing water intensive products rather than producing or exporting them domestically like a pattern of shift in trade could be viable option for an arid or semi-arid country like Pakistan to efficiently utilize its scare water resources.

According to Falkenmark & Rockstrom (2004), besides emphasis on potential water saving due to virtual water trade, it is also important to categorize the form of water used in production. Rainwater store in soil known as green water, or from surface water and/or groundwater known as blue water are two types. Grey water which is defined as water polluted due to production process is the third category. The opportunity cost of green water is lower than blue water as rainwater use is limited to natural vegetation or alternative rain fed crops according to Hoekstra & Chapagain (2008).

Though there are no standard methods through which virtual water level can be calculated. As there are different methods applied by different experts depending on the commodity and process through which it was made. Still VWT can provide a base to which changing scenarios due to climate change can be compared and an efficient water policy can be devised. In 21st century, the resources for global water are increasing as important concern for economic progress, eco systems as well as sustenance of human life. The movement for water and its origin are interlinked with each other globally between multi parts of world that is why it needs to be addressed in a comprehensive way.

The above cited literature is available only for countries other than Pakistan. Some studies makes only passing remarks on Pakistan. The available literature suggests that no study is available that works out virtual water trade for Pakistan. This gap in the literature motivated me for this thesis to fill it by examining Pakistan's water and agriculture sector in this new perspective which is gaining importance worldwide. Besides, the fast increasing population and shortage of water calls upon to devise a new strategy to combat future food and water shortages especially as inadequate techniques are being used to contest the climate change effects so far.

No major initiative is being taken to come up with alternative means for food production or utilizing already scarce water resource in an efficient manner or for water storage no water reservoirs are being constructed. It increased the drastic effect of net water export many folds.

Water world council also points that virtual water accounts should be developed for integration in to water and agriculture policy by developing common procedures and standards (World Water Council 2004). Concept of virtual water trade can be applied to understand the opportunity cost as well cost and benefit of sharing the irrigation costs upon the crops produced.

And as Pakistan is already a water scarce country with depleting water resources and unmitigated climate change effects which are quite visible now over the past decade with extreme weather and changed weather patterns. Also as on-farm water savings alone are unlikely to justify investment in water saving technology — labor savings and yield or quality increases are valuable complementary benefits of the technological change (Appels, Douglas and Dwyer 2004), the integration of virtual water trade into agriculture policy which also increase yields and develops crops that are less water intensive as well as more output yielding.

Though the standard system has yet not been developed, virtual water trade is seen as a tool to relive pressure on water sources globally as well as achieve food security (World Water Council 2004).

Objectives:

The aim of this study is to analyze the virtual water trade of Pakistan's agricultural commodities including wheat, rice and sugarcane, potatoes, onions, oranges, mangoes and apples. In this context, more specific objectives of the study are to:

- Estimate the virtual water content of eight agricultural commodities.
- Comparing crops on the basis of water consumption
- Decision about production or import of crops on the basis of water contents required for that crop.

Contribution of the Thesis:

Through the mentioned method it would be possible to calculate the virtual water content of the crops in agriculture sector. Furthermore it would be possible to quantify issues related to water management in the agriculture sector as well as steps for improving water management policies.

Organization of Study:

Rest of the study is divided into five chapters:

First chapter is comprised of introduction to the tropic. Second chapter would consist of literature review. Data type, sources of data and nature of data used would be discussed in chapter three. Methodological frame work would be discussed in chapter four. It would discuss the methodology of the thesis in detail. Fifth chapter would cover results and discussion part of the thesis. Conclusion and policy implications would be discussed in last chapter.

Chapter 2

Overview of the Agricultural Sector

Agriculture sector is like backbone for the economy of Pakistan. In 2010, agriculture sector accounted for 21% of gross domestic products (GDP) and provided livelihood to 45% of population. Nearly 62 percent of the country's population resides in rural areas, and is directly or indirectly linked with agriculture for their livelihood (Economic Survey 2009-10). But this sector's percentage is decreasing in GDP; even though the Agriculture sector's strong linkages with the rest of the economy are well established. While on the one hand, the sector is a primary supplier of raw materials to downstream industry, contributing substantially to Pakistan's exports, on the other, it is a large market for industrial products such as fertilizer, pesticides, tractors and agricultural implements.

The reason for choosing 1980 as starting point was that after creation of Bangladesh in 1971, this deemed suitable year to start for comparison. In 1980 agriculture sector's share was 36% of GDP, with about 5% growth rate in this sector. Pakistan's current population estimated at 180 million, has already increased more than double from 1980's figure of 80 million, and is further set to double in next 25 years.

This increase in population also leads to water scarcity issue as according to Pakistan water partnership (PWP), the total surface water available is about 153 million acre feet (MAF), and reserve of total ground water is almost 24 MAF. The availability of sweet water is about 144 MAF from which 97% is used in agriculture sector. This means that the per capita availability of water will decrease. There is likely to be a net decrease, rather than an increase in the country's water resources, due to a number of factors including population growth, climate change, and exploitation of water. Pakistan is now a water-scarce country at 1200 m^3 per capita per year. According to water specialist Simi Kamal, based on current projections, water availability (per capita) will be 855m^3 by the year 2020

Pakistan produces different fruits and crops according to season. Pakistan's food security and other sectors are dependent on its agriculture sector especially wheat, rice and sugarcane production. Cotton production ensures a steady stream of revenue for its textile sector. Pakistan is heavily dependent on irrigation water for its agriculture sector and as shown in tables below the increase in harvest area and production but not a significant increase in yield, means Pakistan requires more land and water for its agricultural products to maintain pace with its growing population.

Below are the tables which show decade wise production, harvest area, yield and export and import of selected crops, fruits and vegetables. Each product shows increase in all areas such as production, export and harvest area except for yield. Apples yield has declined over the 3 decades. Onions, Oranges, Wheat and Rice show a very marginal increase in yield over time. The production of each crop has increased along with harvest area which in one way is an improvement for our food security issues but also shows signs of increasing population which again leads to need of efficient water usage.

Nakayama (2003) suggests that existing water policies should be re-examined as aiming at food self-sufficiency by a basin country may lead to a conflict with other nations sharing an international water system. This data shows that there is a need for concentrating on water management and Virtual Water Trade can provide a helpful analysis if used as a tool in water management, as our conflict with India and dependence on irrigation water along with increasing population will keep stretching our decreasing water resources.

Decade-wise Harvest Area, Production, Yield and Export

Apples					
Year	**Harvest Area (Ha)**	**Production (tonnes)**	**Yield (tonnes/Ha)**	**Export (tonnes)**	**Export 1000$**
1980's	17,494.00	177,751.30	100,911.60	2.80	1.20
1990's	42,471.40	471,016.70	112,655.30	1,323.70	350.80
2000's	62,580.70	384,270.60	66,446.60	659.80	235.40
Mangoes					
1980's	106,005.20	690,952.20	66,501.60	9,538.80	3,734.50
1990's	89,024.90	867,312.10	97,338.60	24,866.40	5,727.40
2000's	138,464.80	1,459,168.60	105,013.80	68,785.80	22,518.30
Onions					
1980's	49,972.80	554,681.20	110,301.20	54,260.10	5,434.30
1990's	77,067.70	1,038,097.00	133,401.40	30,226.40	5,956.00
2000's	124,165.50	1,688,210.70	136,073.10	52,436.60	7,382.10
Oranges					
1980's	104,980.00	989,890.00	94,600.20	-	-
1990's	133,370.00	1,314,260.00	98,469.60	1,172.90	219.90
2000's	133,925.80	1,413,974.70	105,433.80	687.60	181.40

			Potatoes		
1980's	56,430.60	569,374.90	101,028.00	4,663.60	524.10
1990's	87,140.00	1,183,650.20	133,132.60	31,599.20	4,246.00
2000's	123,290.50	2,206,796.00	177,448.90	114,783.50	17,395.80
			Rice		
1980's	2,010,420.00	4,928,510.00	24,527.50	1,047,800.30	344,800.60
1990's	2,242,780.00	6,155,576.70	27,285.60	1,573,194.00	446,834.80
2000's	2,524,840.00	8,017,042.60	31,535.40	2,719,913.50	1,110,405.90
			Sugarcane		
1980's	859,780.00	34,486,190.40	403,284.80	885.10	919.60
1990's	978,500.00	44,636,389.60	454,455.20	1,273.10	1,534.70
2000's	1,025,080.00	50,751,320.00	494,663.90	917.00	1,072.30
			Wheat		
1980's	7,419,820.00	12,512,680.00	16,845.10	36,765.00	6,696.40
1990's	8,182,580.00	16,980,920.00	20,723.00	3,866.00	872.10
2000's	8,459,970.00	21,041,970.00	24,829.60	284,030.80	39,694.90

In 2010, Pakistan produced 24 million tons of wheat production and it was 11.6 million tons in 1980. This shows steady increase in wheat production due to increased population.

Rice is also a major production of Pakistan. Its production has more than doubled and rise to 8 million tons from 4 million tons. This also helps earn Pakistan $2.2 billion in foreign exchange through rice export.

Another major product is cotton which has become industrial feedstock by increase in production to 12 million bales in 2010 which was 4.5 million bales in 1980. Production of livestock is also has substantially increased with a value of US $758.604 million from US $51.51 million in 1980. (FAO 2011) in 2010 its total export was US $37.46 million from US $1.170 million comparatively in three decades ago.

Pakistan though has made huge progress in its agriculture sector but still lags behind world standards on yield per hectare. Pakistan requires investing in techniques to improve yields rather than age old techniques which are based on manual labor as well as intensive water use.

Pakistan is greatly dependent on monsoon rains and annual glacier melts because the water flows towards river and sea. There are seepages in ground as well as water bearing rocks which absorb and store water. Many parts of country receive a little rainfall and do not have access to surface water.

Thus, keeping the current and future scenario in mind, virtual water trade and water resource availability can be of utmost importance as Pakistan can no longer afford to continue with old practices of water use. It needs to come up with an efficient water management system to maintain its agriculture production in pace with population growth as well as use water more efficiently to manage dwindling water resources. And VWC can also benefit in deciding which commodities to produce locally and which to import as agriculture sector uses up most of water resources. This is precisely what is studied in this thesis.

The tables 2.1 and 2.2 below show average water requirement calculated by author as well as by Riaz. There is not much difference in average water requirements results except for in case of wheat. The difference could be due to different reasons such as Riaz's data is based on Punjab while I have calculated based on total wheat production in Pakistan. The second reason can be due to difference in calculation method.

Average Crop Water Requirement of Major Crops in Pakistan

Crop	Crop Water Requirement (mm)
Potatoes	954.5
Onions	1451.1
Rice	1764.72
Sugarcane	2458.75
Wheat	1088.71
Oranges	895.79
Mangoes	2045
Apples	820.37

Table 2. 1, Source: Author's own calculation

Crop	Crop Water Requirement (mm)
Wheat	480
Sugercane	1800
Rice	1500
Cotton	620
Maize	550
Sorghum	500

Table 2. 2, Source: Riaz A. (2001) Crop Management in Pakistan, Government of Punjab, Agriculture Department, pp 280

- Vegetables: Types of vegetables in Pakistan, In how many are vegetables are harvested, how much water is required

- More than 35 kinds of vegetables are grown in numerous eco-systems in Pakistan from the dry zone to the wet zone, low elevation to high elevation, rain fed to irrigated and low input to very high input systems such as plastic houses.

- During summer and spring season, tomato, chilies, brinjal, potato, cucumber, gourds and okra are abundantly available. During rainy season, gourds, cucumber, beans, okra and brinjal are common. The winter season is the most important for growing a wide variety of vegetables including, cauliflower, cabbage, lettuce, spinach, onion, potato, carrot, radish, turnip, coriander, fenugreek and peas.

- Vegetables produced in different zones by using different production technologies during different seasons are traded across regional markets of Pakistan in order to meet consumer demand across the country. Varied agro-climatic conditions prevailing in different provinces of the country also contribute to year round production of different kinds of vegetables. Thus many vegetables can be grown and seen in the market during any season.

- The crop water need mainly depends on:

· **The climate:** for example, in a sunny and hot climate crops need more water per day than in a cloudy and cool climate

· **The crop type:** crops like rice or sugarcane need more water than crops like beans and wheat

· **The growth stage:** grown crops need more water than crops that have just been planted

- Fruits: Types of fruits in Pakistan, In how many are fruits are harvested, how much water is required.

Pakistan's climatic diversity hold enormous advantage for production of fruits, vegetables and floricultural (flower farming) products and has a potential to exploit world's US$561 million annual fresh fruits and vegetables market. Fresh fruits and vegetables production wise Pakistan is on no. 06 in producing oranges and Kinno in world ranking.

All the provinces have suitable atmosphere / climate for fruits production. In Pakistan total fruit grown area is around 758,000 hectors. In 2010-20 the fruit production of Pakistan remained about 6.1 million tons and exports remained just 660 tons while the left over were either utilized within country or decomposed.

Noor Ahmed Memon (2012) depicted that "Fruits exports shown increase of 22% in 2010-11".

Average Crop Water Requirement of Major Fruits in Pakistan

Crop	Crop Water Requirement (mm)
Apples	853 to 1393
Dates	920 to 1809
Grapes	566 to 1209
Apricot/Almonds	854 to 1393

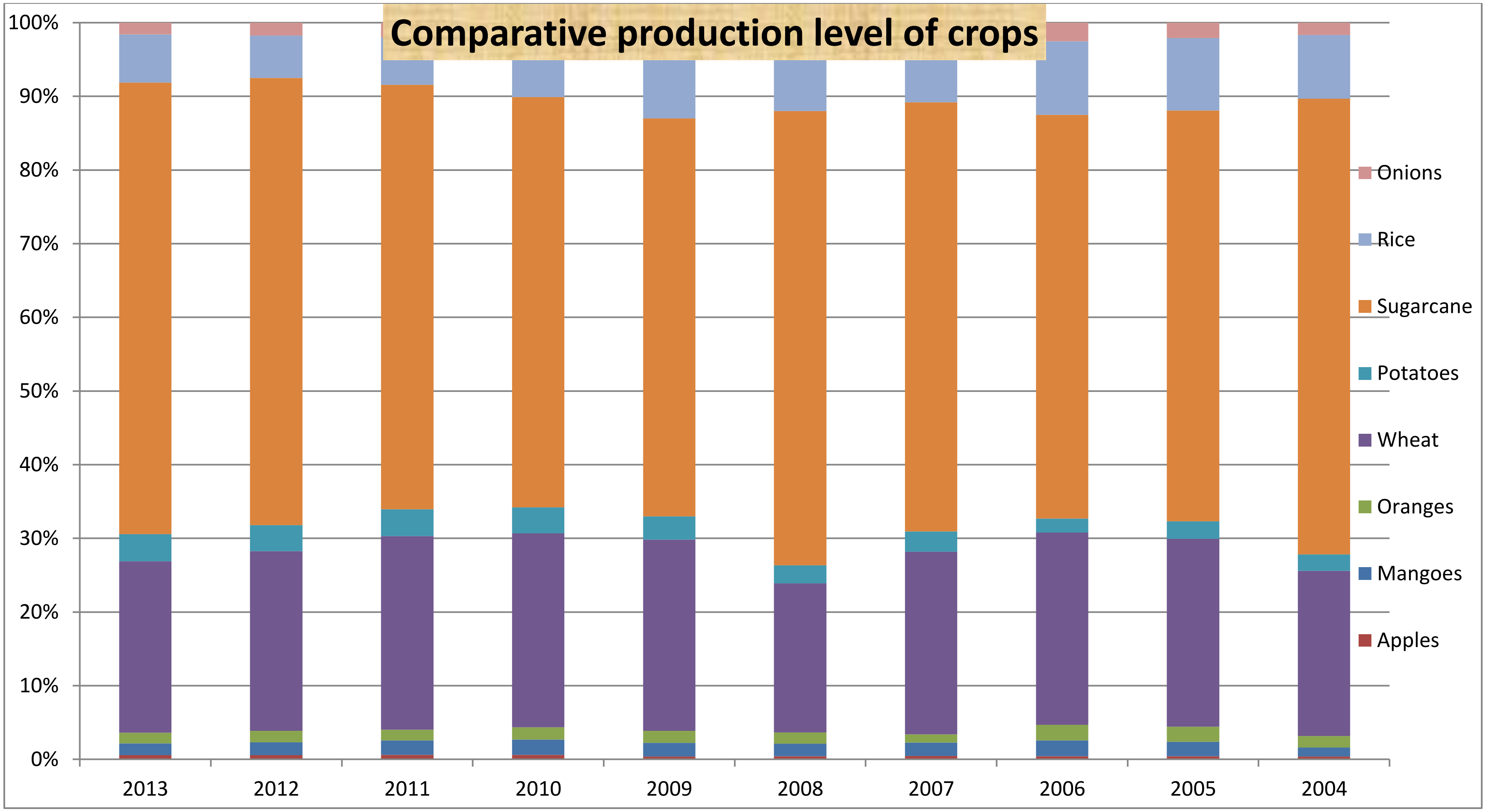
INDICATIVE VALUES OF THE TOTAL GROWING PERIOD

Crop	Total growing period (days)	Crop	Total growing period (days)
Alfalfa	100-365	Millet	105-140
Banana	300-365	Onion green	70-95
Barley/Oats/Wheat	120-150	Onion dry	150-210
Bean green	75-90	Peanut/Groundnut	130-140
Bean dry	95-110	Pea	90-100
Cabbage	120-140	Pepper	120-210
Carrot	100-150	Potato	105-145
Citrus	240-365	Radish	35-45
Cotton	180-195	Rice	90-150
Cucumber	105-130	Sorghum	120-130
Eggplant	130-140	Soybean	135-150
Flax	150-220	Spinach	60-100
Grain/small	150-165.	Squash	95-120
Lentil	150-170	Sugarbeet	160-230
Lettuce	75-140	Sugarcane	270-365
Maize sweet	80-110	Sunflower	125-130
Maize grain	125-180	Tobacco	130-160
Melon	120-160	Tomato	135-180

Source: http://www.fao.org/docrep/s2022e/s2022e02.htm

2.2.1 Production (In Tons)

Production (tonnes)										
Crop/Period	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**
Apples	606016	556307	598804	525855	366360	441062	441575	348440	351232	351916
Mangoes	1658562	1680388	1888450	1845530	1727930	1753690	1719180	1753910	1673950	1055990
Oranges	1505000	1503140	1387540	1505000	1492400	1606150	1030730	1720870	1721000	1360600
Wheat	24211400	23473400	25213800	23310800	24033000	20958800	23294700	21276800	21612300	19499800
Potatoes	3802200	3393000	3491800	3141500	2941300	2539000	2581500	1568000	2024900	1938100
Sugarcane	63749900	58397000	55308500	49372900	50045400	63920000	54741600	44665500	47244100	53820000
Rice	6798100	5535900	6160400	7235190	10334400	10428000	8345100	8157600	8320800	7537200
Onions	1660800	1691800	1939600	1701100	1704100	2015200	1816400	2055700	1764800	1449025



Comparative production level of crops
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2013
2012
2011
2010
2009
2008
2007
2006
2005
2004
Onions
Rice
Sugarcane
Potatoes
Wheat
Oranges
Mangoes
Apples

Apple: Production level of apples increased almost up to double in the ten years. This would create chances of net virtual water loss.

Mangoes: Production level of the crop is almost same over the period of ten years.

Oranges: Production level of orange is increasing hence more export created net virtual water loss.

Wheat: Production level of wheat is fluctuating; however harvested area of the crop is decreasing. This elaborate that yield of wheat has better value in the specified period of ten years.

Potato: Production level of potatoes does not showed decreasing trend even area under cultivation for potatoes is reducing with the passage of time.

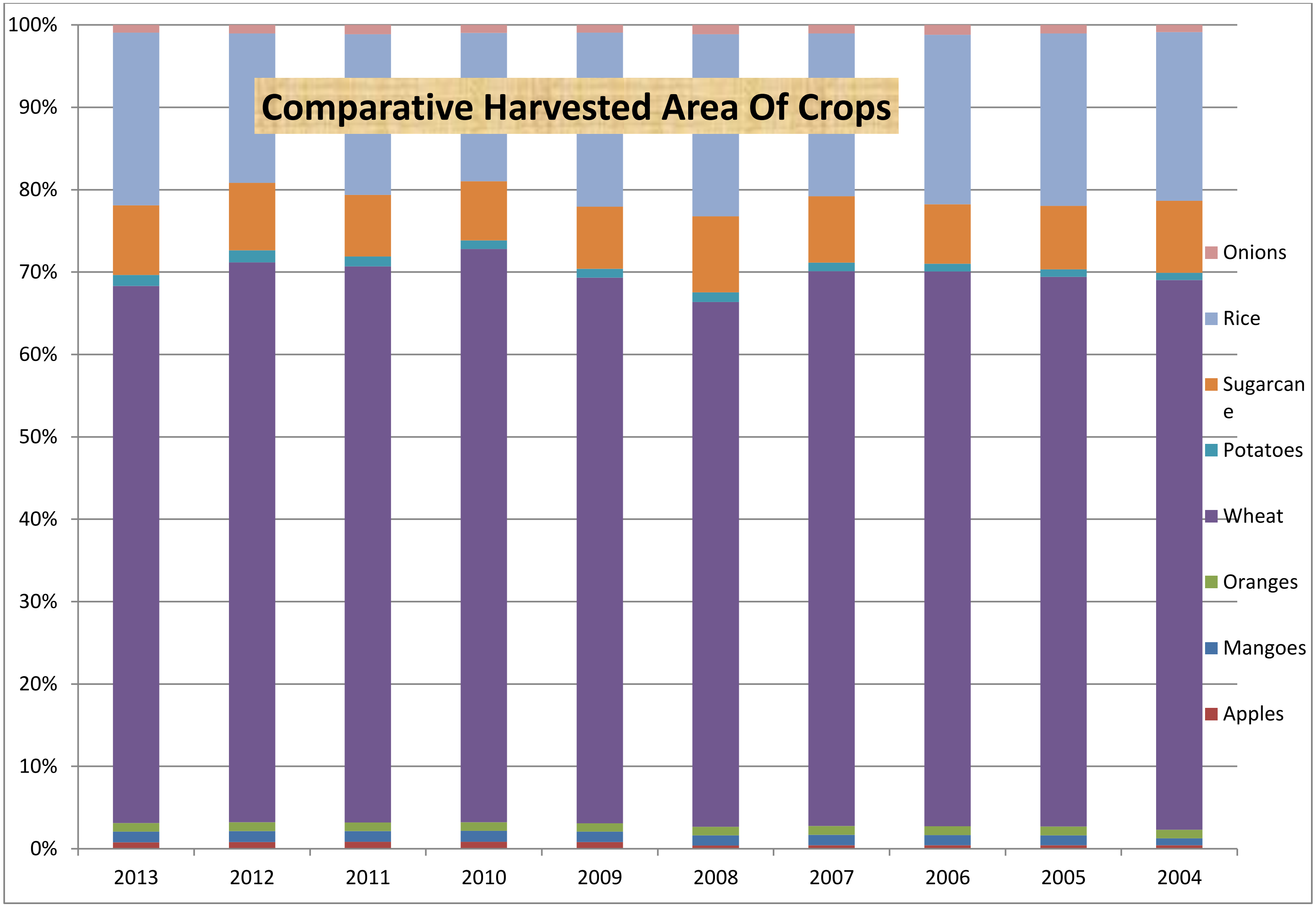
Sugarcane: Sugarcane production is stable even there is reducing trend in harvested area of the crop.

Rice: Production of rice is decreasing with the time. Harvested area for the rice crop is quite fluctuating as evident from graph of last ten years. However decline in production level is a good sign for net virtual water.

Onion: Onion is having lower production level in the specified period of ten years. Onion is one of the most important crops being affected by the awareness of net virtual water.

2.2.2 Area Harvested (In Hectares)

Area Harvested (Ha)										
Crop/Period	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004
Apples	105153	103830	110411	110562	111597	51700	51700	51500	51200	51000
Mangoes	171289	170510	172008	173731	170166	166223	164558	156570	151535	103110
Oranges	136800	136000	136150	138880	139958	139580	135248	134592	135000	129000
Wheat	8686602	8649800	8900700	9131600	9046000	8549800	8578000	8447900	8358000	8216200
Potatoes	174400	185000	159300	138500	145000	154300	133400	117500	112000	109700
Sugarcane	1128800	1046000	987700	942800	1029400	1241300	1029000	907300	966400	1074500
Rice	2789200	2308800	2571200	2365300	2883100	2962600	2515400	2581200	2621400	2519600
Onions	125900	129700	147600	124700	129600	153100	131400	148700	127800	108931


Comparative Harvested Area Of Crops
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2013
2012
2011
2010
2009
2008
2007
2006
2005
2004
Onions
Rice
Sugarcan
e
Potatoes
Wheat
Oranges
Mangoes
Apples

Apple:

Harvested area of apple has increasing trend in the period of ten years. It is a good sign for virtual water gain as crop is one of those crops having net virtual water gain.

Mangoes: Minor increase in harvested area for mangoes occurred in the period of last ten years. However there is not an obvious trend being followed as far as net virtual water gain/loss is concerned.

Oranges: Harvested area of oranges is almost stable in last decade or so. But rise in net virtual water loss indicated that there may be some other reasons for loss. One of the most important reason for loss may be population rise.

Wheat: Area for cultivating wheat is decreasing for the one or the other reason.

Potato: Area under cultivation for potatoes is reducing with the passage of time.

Sugarcane: Area under cultivation for the subject crop is unstable. However it showed a reducing trend as a whole.

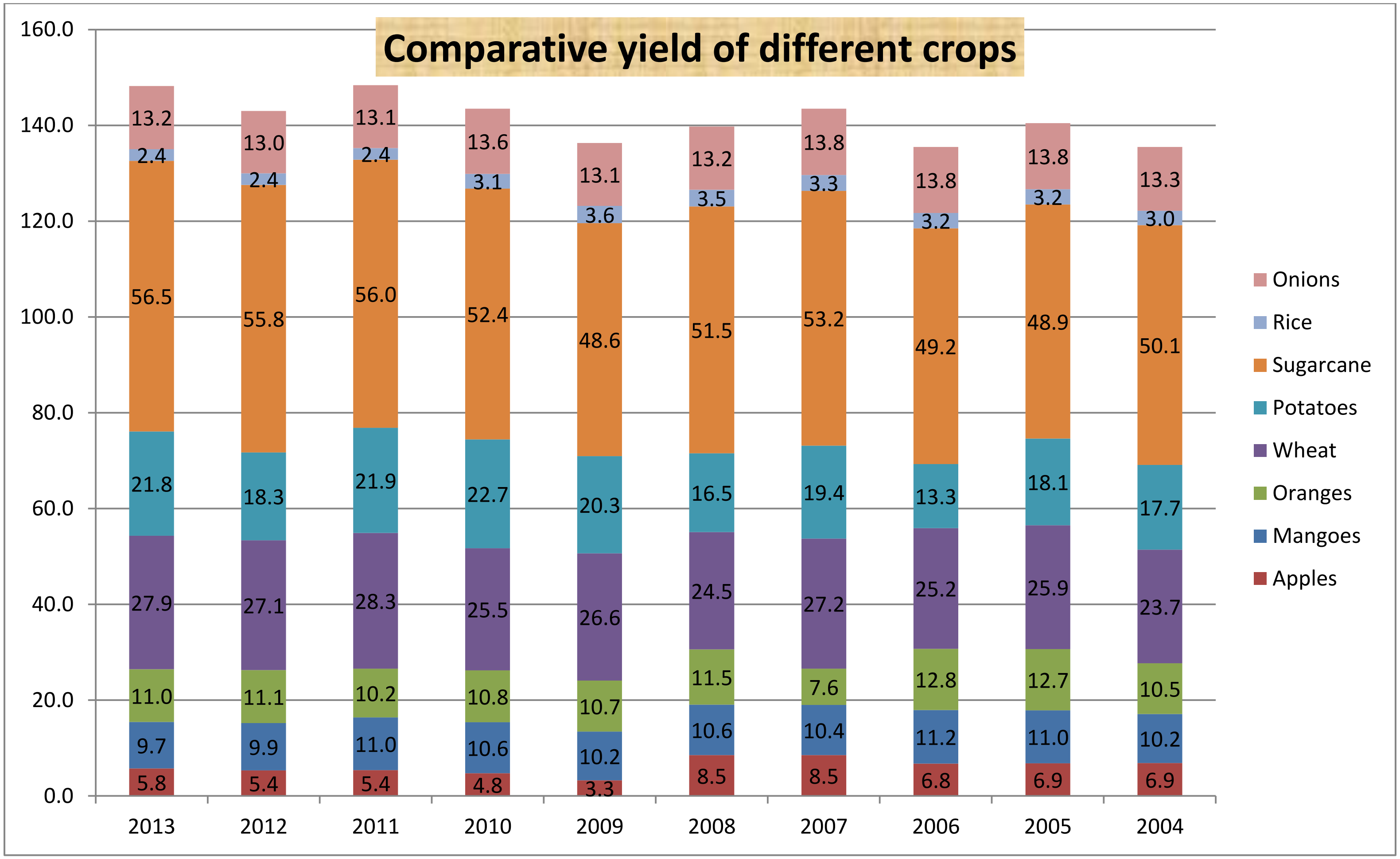
Rice: Harvested are for the rice crop is quite fluctuating as evident from graph of last ten years.

Onion: Onion is one of the most important crops being affected by the net virtual water. Harvested are for the crop is changing each year with no specific pattern.

2.2.3Crop yields (Ton/Hectare)

Yield (ton/Ha)										
Crop/Period	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**
Apples	5.8	5.4	5.4	4.8	3.3	8.5	8.5	6.8	6.9	6.9
Mangoes	9.7	9.9	11.0	10.6	10.2	10.6	10.4	11.2	11.0	10.2
Oranges	11.0	11.1	10.2	10.8	10.7	11.5	7.6	12.8	12.7	10.5
Wheat	27.9	27.1	28.3	25.5	26.6	24.5	27.2	25.2	25.9	23.7
Potatoes	21.8	18.3	21.9	22.7	20.3	16.5	19.4	13.3	18.1	17.7
Sugarcane	56.5	55.8	56.0	52.4	48.6	51.5	53.2	49.2	48.9	50.1
Rice	2.4	2.4	2.4	3.1	3.6	3.5	3.3	3.2	3.2	3.0
Onions	13.2	13.0	13.1	13.6	13.1	13.2	13.8	13.8	13.8	13.3

The yields (Ton/Ha) for each crop are shown graphically below which show an increasing trend.



- **Apples**

The above results presented in graphical form are showing that the trend of the yield from the fruit (Apples) from 2004 to 2013. The results are depicting that the yield of apples approximately have the same trend during this time of period. The yield from apples during year 2004 was 6.9 ton per hectare. During 2005 the yield of apples was with the same figure as it was during 2004. A little bit change was there in the yield of apple during 2006 as the yield was found 6.8 ton per hectare. However, the yield of apples during 2007 was found 8.5 ton per hectares. The similar figure was found of the yield of apples during 2008 as compare with the year 2007. A sharp and huge decline was found in the yield of the apples during 2009 as it was found as 3.3 ton per hectare. However, the yield from apples is showing the increasing trend during the year 2010 as the figure of yield ton per hectare was found 4.8. The figure of yield of apples during the year 2011 was found 5.4 ton per hectare and the same figure of yield in respect of apple was found during the year 2012. The yield of apples was found 5.8 ton per hectare during 2013, which was showing increasing trend as compare to previous year. The graphical presentation is showing that the yield from apples at number 7 in all other items including in the study (Crops, Vegetables and fruits).

- **Mangoes**

The above results presented in graphical form are showing that the trend of the yield from the fruit (Mangoes) from 2004 to 2013. The results are depicting that the yield of mangoes approximately have the same trend during this time of period. The yield from mangoes during year 2004 was 10.12 ton per hectare. During 2005 the yield of mangoes was increased upto 11 ton per hectare. A little bit change was there in the yield of mangoes during 2006 as the yield was found 11.2 ton per hectare. However, the yield of mangoes during 2007 was found 10.4 ton per hectares, which is showing decline as compare to previous year. The yield 10.6 ton per hectare was found during 2008 and it is a little bit improvement as compare with the year 2007. A little decline was found in the yield of the mangoes during 2009 as it was found as 10.2 ton per hectare. However, the yield from mangoes is showing the increasing trend during the year 2010 as compare with previous as the figure of yield in year 2010 was found as 10.6 ton per hectare. The figure of yield of mangoes during the year 2011 was found 11 ton per hectare and the figure of yield in respect of mangoes was found during the year 2012 as 9.9 ton per hectare. The yield of mangoes was found 9.7 ton per hectare during 2013, which was showing decreasing trend as compare to previous year. The graphical presentation is showing that the yield from mangoes at number 6 in all other items including in the study (Crops, Vegetables and fruits).

- **Oranges**

The above results presented in graphical form are showing that the trend of the yield from the fruit (Oranges) from 2004 to 2013. The results are depicting that the yield of oranges approximately have the same trend during this time of period. The yield from oranges during year 2004 was 10.5 ton per hectare. During 2005 the yield of oranges was found 12.7 ton per hectare, which is showing increasing trend as compare to previous year. A little bit change was there in the yield of oranges during 2006 as the yield was found 12.8 ton per hectare. However, the yield of oranges during 2007 was found 7.6 ton per hectares, which is huge decline during 2007. The figure of yield in respect of oranges was found as 11.5 during 2008, which is increasing trend as compare with the year 2007. A little decline was found in the yield of the oranges during 2009 as it was found as 10.7 ton per hectare. However, the yield from oranges is showing the increasing trend during the year 2010 as the figure of yield ton per hectare was found 10.8. The figure of yield of oranges during the year 2011 was found 10.2 ton per hectare and the figure of yield in respect of oranges was found as 11.1 ton per hectare during the year 2012. The yield of oranges was found 11 ton per hectare during 2013, which was showing decreasing trend as compare to previous year. The graphical presentation is showing that the yield from oranges at number 5 in all other items including in the study (Crops, Vegetables and fruits).

- **Wheat**

The above results presented in graphical form are showing that the trend of the yield from the fruit (Wheat) from 2004 to 2013. The results are depicting that the yield of wheat approximately have the same trend during this time of period. The yield from wheat during year 2004 was 23.7 ton per hectare. During 2005 the yield of wheat was found 25.9 ton per hectare, which is showing increasing trend as compare to 2004. A little bit change was there in the yield of wheat during 2006 as the yield was found 25.2 ton per hectare. However, the yield of wheat during 2007 was found 27.2 ton per hectares. The figure of the yield of wheat was found as 24.5 ton per hectare during 2008, which is decreasing trend as compare with the year 2007. An increasing trend was found in the yield of the wheat during 2009 as it was found as 26.6 ton per hectare. However, the yield from wheat is showing the decreasing trend during the year 2010 as the figure of yield ton per hectare was found 25.5. The figure of yield of wheat during the year 2011 was found 25.8 ton per hectare and the yield in respect of wheat was found as 27.1 during the year 2012. The yield of wheat was found 27.9 ton per hectare during 2013, which was showing increasing trend as compare to previous year. The graphical presentation is showing that the yield from wheat at number 2 in all other items including in the study (Crops, Vegetables and fruits).

- **Potatoes**

The above results presented in graphical form are showing that the trend of the yield from the fruit (Potatoes) from 2004 to 2013. The results are depicting that the yield of potatoes approximately have the same trend during this time of period. The yield from potatoes during year 2004 was 17.7 ton per hectare. During 2005 the yield of potatoes was found as 18.1 ton per hectare, which is showing increasing trend during 2005 as compare to 2004. A change was there in the yield of potatoes during 2006 as the yield was found 13.3 ton per hectare. However, the yield of potatoes during 2007 was found 19.4 ton per hectares, which is huge increase as compare with previous year. The figure of the yield of potatoes was found 16.5 ton per hectare during 2008, which is decreasing trend as compare with the year 2007. A sharp and huge increase was found in the yield of the potatoes during 2009 as it was found as 20.3 ton per hectare. However, the yield from potatoes is showing the increasing trend during the year 2010 as the figure of yield ton per hectare was found as 22.7. The figure of yield of potatoes during the year 2011 was found 21.9 ton per hectare and the figure of yield in respect of potatoes was found as 18.3 during the year 2012. The yield of potatoes was found 21.8 ton per hectare during 2013, which was showing increasing trend as compare to previous year. The graphical presentation is showing that the yield from potatoes at number 3 in all other items including in the study (Crops, Vegetables and fruits).

- **Sugarcane**

The above results presented in graphical form are showing that the trend of the yield from the fruit (Sugarcane) from 2004 to 2013. The results are depicting that the yield of sugarcane approximately have the same trend during this time of period. The yield from sugarcane during year 2004 was 50.1 ton per hectare. During 2005 the yield of sugarcane was found 48.9 ton per hectare, which is decline as compare to year 2004. A little bit change was there in the yield of sugarcane during 2006 as the yield was found 49.2 ton per hectare. However, the yield of sugarcane during 2007 was found 53.2 ton per hectares. A decline was seen in yield of sugarcane during the year 2008 as it was found 51.5 ton per hectare. A decline was found in the yield of the sugarcane during 2009 as it was found as 48.6 ton per hectare. However, the yield from sugarcane is showing the increasing trend during the year 2010 as the figure of yield ton per hectare was found 52.4. The figure of yield of sugarcane during the year 2011 was found 56.0 ton per hectare and yield was found as 55.8 in respect of sugarcane during the year 2012. The yield of sugarcane was found 56.5 ton per hectare during 2013, which was showing increasing trend as compare to previous year. The graphical presentation is showing that the yield from sugarcane at number 1 in all other items including in the study (Crops, Vegetables and fruits).

- **Rice**

The above results presented in graphical form are showing that the trend of the yield from the fruit (Rice) from 2004 to 2013. The results are depicting that the yield of rice approximately have the same trend during this time of period. The yield from rice during year 2004 was 3.0 ton per hectare. During 2005 the yield of rice was found as 3.2 ton per hectare, which is increasing trend as compare to 2004. No change was there in the yield of rice during 2006 as the same yield was found as it was during the year 2005. However, the yield of rice during 2007 was found 3.3 ton per hectares. The little increase was found of the yield of rice during 2008 as compare with the year 2007. A little increase has also been found during 2009 as it was found as 3.6 ton per hectare. However, the yield from rice is showing the decreasing trend during the year 2010 as the figure of yield ton per hectare was found 3.1. The figure of yield of rice during the year 2011 was found 2.4 ton per hectare and the same figure of yield in respect of rice was found during the year 2012 and 2013. The graphical presentation is showing that the yield from rice at number 8 in all other items including in the study (Crops, Vegetables and fruits).

- **Onion**

The above results presented in graphical form are showing that the trend of the yield from the fruit (Onion) from 2004 to 2013. The results are depicting that the yield of onion approximately have the same trend during this time of period. The yield from onion during year 2004 was 13.3 ton per hectare. During 2005 the yield of onion was found 13.8 ton per hectare. No change was found during the year 2006 and 2007 as the same yield has been found during these years as were found during 2005. The yield was decline up to 13.2 during the year 2008. A little decline was found in the yield of the onion during 2009 as it was found as 13.1 ton per hectare. However, the yield from onion is showing the increasing trend during the year 2010 as the figure of yield ton per hectare was found 13.6. The figure of yield of onion during the year 2011 was found 13.1 ton per hectare and yield in respect of onion was found as 13.0 during the year 2012. The yield of onion was found 13.2 ton per hectare during 2013, which was showing increasing trend as compare to previous year. The graphical presentation is showing that the yield from onion at number 8 in all other items including in the study (Crops, Vegetables and fruits).

Chapter 3

LITERATURE REVIEW

Virtual Water:

Water plays an important role in the production of goods and in provision of some services. The quantity of water consumed during the process of growing an agricultural product or manufacturing an industrial product is termed as "virtual water" embodied in the item. For example in order to get 1 kg grain there is a need of around 1000-2000 kg water. Similarly to get 1 kg of dairy related products (food) there is a need of much more water. In order to attain 1 kilogram of cheese there is a requirement of around 5000- 5500 kilogram of water and to acquire 1 kilogram of beef the water utilization is around 16000 kg of water (Chapagain and Hoekstra, 2003). The importance of virtual water at global level is likely to increase dramatically as projections made by IFPRI (Rosegrant and Ringler, 1999) show that food trade will increase rapidly: doubling for cereals and tripling for meat between 1993 and 2020. Williams *et al.* (2002) find that there is a need of 32 Kilogram of water to produce a 32 MB (megabyte) computer chip.

When a nation sells any water-demanding good to another nation it can be said that the countries are trading water in virtual form. Many nations are helping other countries to meet their water demands by virtual trading of water. Countries / territories having abundant water resources cannot trade water in real form to nations with scared water resources because it is not feasible due to long distances and heavy cost involved in the projects. But water trade can be done in virtual form by supplying the goods / products which are water exhaustive (virtual water trade) which is practical.

Proponents of the 'virtual water' thesis argue that countries which are water scarce have been able to ameliorate their scarcity by importing water in 'virtual' form. This is based on the premise that a number of semi-arid countries, most notably in the MENA region, have consciously formulated policies for reducing water intensive exports, most notably crops, in favour of water intensive imports. Until recently, however, the quantification of ‘virtual water’ as an ameliorator of water scarcity, and indicator of global water dependence, received relatively little attention. Of the most prominent studies to date, all agree that it is in the international trade of crops that the majority of ‘virtual water’ can be found, with figures ranging from 67% (Hoekstra and Hung, 2002, 2003) and 69% (Oki *et al*., 2003) from the perspective of exporting countries to 60% (Renault, 2003; Zimmer and Renault, 2003) and 76% (Oki *et al*., 2003) from the perspective of importing countries.

The nations having low water resources can attain water security through import of goods which require more water rather than growing them locally. On the other hand countries having greater resources of water can generate revenues through export of water rich products. In the start of 90’s a scholar, Tony Allan, presented the idea of “virtual water” (Allan, 1993; 1994). The idea took ten years to attain universal attention and acknowledgement concerning the national and international water security. First time a conference was organized on the subject of “Virtual Water Trade” at Delft, the Netherlands in December 2002. Similar nature meeting was arranged in Japan (March 2003) on the issue of virtual water trade.

The term “virtual water” means the water contained in a products but not in physical form rather virtual meaning. It denotes the water required to produce a crop / product. The term “virtual water” is also named as ‘entrenched water’ or ‘exogenous water’. Through purchase of products (which requires much water to produce) from countries having bigger water resource to save the water from spending on these crops to produce them indigenously. The water saved in this manner is basically the volume of indigenous water enhanced (Haddadin, 2003).

Virtual water content

Mainly two diverse methodologies have been intended and used until now in defining virtual water contents. According to first methodology, the virtual water content (VWC) is described as the quantity of water consumed in realism to get a product (crop). The major factors that effects the production includes time of cultivation / production, place of cultivation / production and efficient usage of water resource. In order to get1 kg of wheat in a state having scarcity of water there is a requirement of 2 or 3 times more water than the same amount in a moist state. As per

2nd methodology, the user of product is taken into account instead of a producer viewpoint. In this prospect the definition of the virtual water content for a crop / good is the quantity of water which might be needed to produce / manufacture specific product at the point where it is required. 2nd concept is quite appropriate in the situation if anyone asks the question? What quantity of water we will save if we import particular commodity rather than growing it locally. The problem appears in the 2nd approach for the explaining of "virtual water" in a condition if any country imports a crop or merchandize that cannot be grown or produced in that country due to different climatic situations. Then in that case what will be the VWC of any product? For example in some countries rice cannot be produced they just import it.

In this case the Hoekstra & Renault (2003), suggests viewing the VWC of an appropriate alternate of the good taken into account. There may be a point of view about this approach of VWC that fish of sea freshwater has virtual fresh water count but in actual this does not totally dependent on freshwater. The suggestion in this case given by Renault (2003) to calculate the virtual freshwater content of seawater fish is the application of the nutritious equality rule. As per this rule the VWC of a product will be considered equivalent to a substitute product (The products must have the similar nutritious value).

Virtual water analysis is a study much similar to the 'life cycle analysis.' This study takes into account the effects made by the products on the environment during its life cycle. Considering from the point of view of life cycle approach, the definition of virtual water is not limited to production stage of the product. But it must be extended by counting the water required during the process of consumption or use and considering the waste phases of product.

A little work has been done on this approach. Calculating the VWC of any produce is a difficult job, as there are numerous elements that effects the quantity of water utilized in a growing a product. The subsequent issues must be kept in mind and if possible be made available along with the assessments:

- The area and time of productivity. (for example particular year, specific spell)

- The measurement stage. In situation of watered crop harvest, the issue is for example either someone gauge water utilization at the theme of water pulling out or at the agricultural field level.
- The production techniques and related efficient use of water. The point is that whether the water wastage has been included in the assessment.
- The system of ascribing water involvement into intermediate products to the VWC of the concluding produce.

As per the studies conducted earlier, there is slight convergence occurs regarding the use of general approach.

Few researchers take VWC of a produce considering the place where it has been grown, while some scholars take in to consideration the imagined VWC considering that who much water it might require / use to produce a certain product at a place where it was actually used. Difference also exist in studies regarding the measurement stage: few gauge at field level while others take into account the wastage of water during extraction and use.
Three important research papers that must be given due consideration which contains the valuable material on approaches to measure the VWC of processed products: Oki *et al.* (2003), Zimmer and Renault (2003) and Chapagain and Hoekstra (2003).

In order to determine the VWC of a product, Zimmer and Renault (2003) has made a division amongst prime produce (crops), products made from prime produce after applying some process (like sugar, flour and vegetable oil), transformed produce (involving animal products), by-produce (like cotton seeds), multiple produce (like coconut plants) and little or non-water consuming produce (for instance sea fish).Different writer have worked out and mentioned VWC in their publication. Many other terminologies have been or still being applied to refer the VWC of a product. Other terminologies which have been applied are for example “specific water demand (SWD)” or “water-use intensity (WUI)” of a produce (Hoekstra, 1998) or “unit water requirement (UWR)” (Oki *et al.*, 2003). Renault (2003) talk about the ‘virtual water value (VWV)’ of a produce rather than its ‘virtual water content (VWC)’.

Chapagain and Hoekstra (2003) studied the ‘production trees’ which indicate varying product intensity. VWC of meat varies on the basis of animal body that is further dependent on the VWC of living animal. If we move further from body the living animal also made available the leather, due to this factor the VWC of the living animal is distributed among body and skin according the financial worth ratio. VWC of a living animal greatly relies on the VWC of the feedstuff eaten by the animal during the lifetime. Similarly the water requirement by the animal during the entire life either for drinking or for cleaning is also added up.

The realistic importance of the virtual water notion:-

There are two significant forms of virtual water idea in practical term.

Water security and effective use of water can be accomplished through Virtual water trade (VWT)

Countries which have water scarcity can rely on import of Virtual Water to save their own water reservoirs.

Virtual water may be perceived as an unconventional base of water. The nations can utilize this extra water base to attain water security.

From the start of deliberations over the virtual water, Tony Allan (from political point of view) said that VWT may help in resolution of geopolitical glitches and can avoid the clashes over water issue. (Allan, 1998, 2003). Another aspect focused by him is economic, (Allan, 1997; 2001). Major reason forcing for VWT is that as per International Trade Theory “Countries must export produce in which they are having proportionate benefit and import those produce that are not viable to be produced in the country” (Wichelns, 2001).

Hoekstra and Hung (2002, 2003), contend that while valuing and expertise may become measures to raise domestic water consumption efficacy and rationalizing water at basin level to its greater-worth other use can be a measure to raise water division efficacy – VWT among different countries may add to worldwide water usage efficacy. It is also economically viable to grow / cultivate water consuming crops / fruit trees in those parts of the world which are water rich regions. Water is either free or cheaper than other parts of the world and there are less adverse effects concerning water consumption. Internationally factual water savings can be made through VWT between a country which is water rich and other which is water scared.

VWT amongst or inside countries may be perceived as an alternate to physical, inter-basin water movements / relocation. China is the example which is actively considering the plans for actual water transfer from its southern region to northern regions can use this as an alternate. Similar is the position of Africa (Southern region) here also the VWT is a viable, justifiable and much environment friendly option rather than making physical water distributions proposals, (Meissner, 2003, Earle & Turton, 2003). Nakayama (2003), is of the view (studying 2 Asian countries) that using the concept of VWT can have significant effect on the running routines of global river basins. According to Renault (2003), the matter of optimum output is not just an issue of prudently selecting the sites of production. It is also an issue of suitable scheduling of production. Through the creation of artificial storage facilities of water a country can attempt to overcome times of water scarcity. As a substitute water can also be stored in virtual form that is through storage of food. It could be much economical in addition to environment convivial method to bridge dry period water gaps rather than construction of large dams for interim water storage.

Water footprints: Creation of linkage between Utilizing patterns and the effects on water

2nd realistic usage of the virtual water concept remain in the actuality that the virtual water content (VWC) of any produce express somewhat regarding the ecological effect of utilizing the specific produce. Understanding the VWC of produces creates knowledge about the quantity of water required to produce the different products, consequently giving a picture about the products which have greater effect on the water and from where water can be saved. The idea of water footprint was presented by Hoekstra and Hung (2002), it is basically the sum of VWC of all goods and services consumed by one individual or by the individuals of one country. In analogy of the *Virtual water: An introduction to* ecological footprint (Wackernagel and Rees, 1996; Wackernagel*et al*., 1997), the water footprint can be a strong tool to show people their impact on the natural resources.

Calculation of a nation's 'water footprint'

The total amount of water use by a country is not right calculation of a state's actual allotment of water resources globally. If a country is importing virtual water than the net import volume is to be added in total domestic water use to get that country's real picture on global water resources. Likewise if a country is exporting the virtual water than amount of water is to be excluded from total volume of water use domestically. As the similarity of ecological foot print, the total amount of water import and used domestically can be seen as type of water footprint within an economy. Simply the letter refers to quantity of land required for production and manufacturing as well as for the services for consumption of consumers of nation.

Wackernagelet et al., (1997) stated that many studies are showing that in some states the ecological footprint is less than its territory and in other cases it is much greater. The latter actually means that some states require land outside of their territory for production of goods and services. The meaning of water foot print is amount of water per year consumed by a nation.

However, it can be further defined as the equation "Water footprint = WU + NVWI. WV represents total amount of water use domestically and NVWI donate to total volume of virtual water import by a nation. The latter can also have negative sign. Domestic water use WV refers to use of total blue water and use of green water refers for precipitation. The data of total use of green water on country base is not available. It previous defined that total import of virtual water includes blue and green water.

Virtual water trade:

The trade of virtual water refers to exchange of water in virtual form. A commodity is when exported, its content of virtual water is exchanged as well. Similarly, when a product is imported from any country the water in production of that product is also imported in form of virtual. The flow of virtual water related to trade can be measure as total amount of water used by a country which exports that product. Reimer (2012), explained that the share water plays a tiny role in production of agriculture that is why it cannot be counted as a major determinant for trade as a societal point of view.

So, virtual water trade follows the regulations and trend to global commodity trade which cannot be influenced by water related consideration. Roson and Sartori (2010), explained the many reasons for water scare countries of world which import net virtual water; whereas some water abundant countries are importer of net virtual water. Horlemann and Neubert (2007), stated the concept of virtual water trading promotes the idea that water-scarce stated should greatly meet their requirements for food by importing crops from water rich countries, thereby saving the amount of water that would have been required for production of the crop locally (WWC, 2004). Mekonnen and Hoekstra (2011), further explained that the greater role of the virtual water flows within countries (over 75%) is associated with international trade in crops and its products, whereas trade in animal products and industrial products contributed 12% each to the global virtual water "flows". Chapagain et al. (2006), suggested the most positive effect generated by virtual water trade is the water savings that are generated in the countries that import agricultural products.

Virtual water import

Virtual water trade refers to the embedded exchange of water by conventional trade. Water is actually a basic factor of production from all of traded commodities, therefore, when a country imports or exports a commodity, it also imports or exports the water that was needed to manufacture it in the country of origin. We have to differentiate in imports and exports of virtual water. A nation is said to be a net virtual water importer when it imports are more than it exports in terms of virtual water. Mekonnen and Hoekstra (2011), stated that after Japan and Mexico, Italy is ranked as the 3rd net virtual water importer in the world (62,157 mm^3/ year) with Germany and the UK rounding top 5.

Water is a precious natural resource which needs to be used carefully for ourselves as well as global economy. Care for water resources and vigilance in its use may be obtained through virtual water trade. It would not only ensure security but effective use of water as well, however virtual water trade is not being given due attention in Pakistan. It needs to be discussed and implemented for securing our water resources through planned production as well as import of crops.

Blue water, Green water and Grey water

Virtual water covers three components of multi colors of the blue, green and grey waters. Blue water is available in our surface and groundwater reservoirs. In irrigated agriculture, blue water is excluded to maintain transpiration. Green water is transpired by a plant that comes from rain water, which is stored in soil. It is essential that it is used with a high level of efficiency. Soil is a storage reservoir for green water that falls from the sky, or that which has been included through irrigation from blue-water reservoirs. Grey water polluted during production, say in agriculture because of the leakage of nutrients and pesticides.

The Water Footprint considers not only the place where water comes from but it also adds a qualitative part to it. Water gets divided into three different parts which are blue, green and grey. The management, environmental impacts and the opportunity costs of each of these parts greatly from one to the other. Brent Clothier et al., (2010), explained that grey-water volume can be quantified by calculating the blue water that would be essential to reduce the receiving water body to an acceptable standard quality.

Most of global water consumption in agriculture is intended for national consumption. As traditionally, the food available locally determines food patterns and thus the demand for products, demand can largely be met in local markets. Ideally, only the quantity that cannot be produced locally and non-local products are purchased in other markets or in the world market, (Lena Horlemann & Susanne Neubert, 2007).

In principle, import and export relationships occur because of different production conditions encountered by countries and producers, which result in different levels of productivity of the factors of production – labour, land and capital. “The reasons for the differences in productivity remain open. According to an extension of the principle of comparative cost advantages (Heckscher-Ohlin theory), a country concentrates on the products for whose production it can use factors of production of which it has, compared to other countries, a surplus, since they will be comparatively cheaper.

Brüntrup (2005) demonstrates in his statement that water has hitherto influenced the productivity of the other factors of production only as an indirect factor, where, for example, the productivity of land declines because of inadequate rainfall. In irrigated farming in particular, water can become a factor of production in its own right only if (a) it has to be paid for or (b) “subsidized water is provided only when the economic costs of alternative uses are charged for.

He also argues that as water can normally be used free of charge at present and in most countries is not yet so scarce that it can no longer be used, Virtual Water Trade has so far attracted little attention globally as a trade policy strategy. Taking full advantage of the concept of national Virtual Water Trade would be a good idea for any country having this heterogeneous distribution of water resources.

There are in principle two ways of quantifying the virtual water content of a product. On the one hand, the quantity of water actually used in the production of a good in the exporting country can be measured. On the other hand, the quantity which would hypothetically have been used if the importing country had produced the good can be calculated. The difference between these two quantities is the quantity of water saved from a global point of view. In this way Oki et al. (2003), have calculated that worldwide some 455 km3 of water is saved every year as a result of the global trade in food.

Chapter 4

METHODOLOGY AND DATA

4.1 Proxies used for the measurement of the variables

The overall scheme adopted for the quantification of virtual water trade and other indicators are shown in Figure 4.1 taken from A.Y. Hoekstra, P.Q. Hung (UNESCO-IHE Institute for Water Education). First the virtual water flux (α) between nations is quantified based on trade volumes (₮) and the associated virtual water content of the products (*υ*). Each production region has a unique virtual water content of a product as the latter highly depends upon the agro-climatic factors at the production sites. Moreover, the processing techniques and the volume of water consumed in the processes and the processed output per unit of product processed can be different per production region even for the same product. This creates a difference in water productivity (production per unit of water consumed) between different production sites. The import of a product from highly water productive site to one with low productivity can save use of global water resources (ΔSg) due to this difference in water productivity. The option of import of a product instead of producing itself is directly releasing the water resources (ΔSn) for other uses at the import-sites.

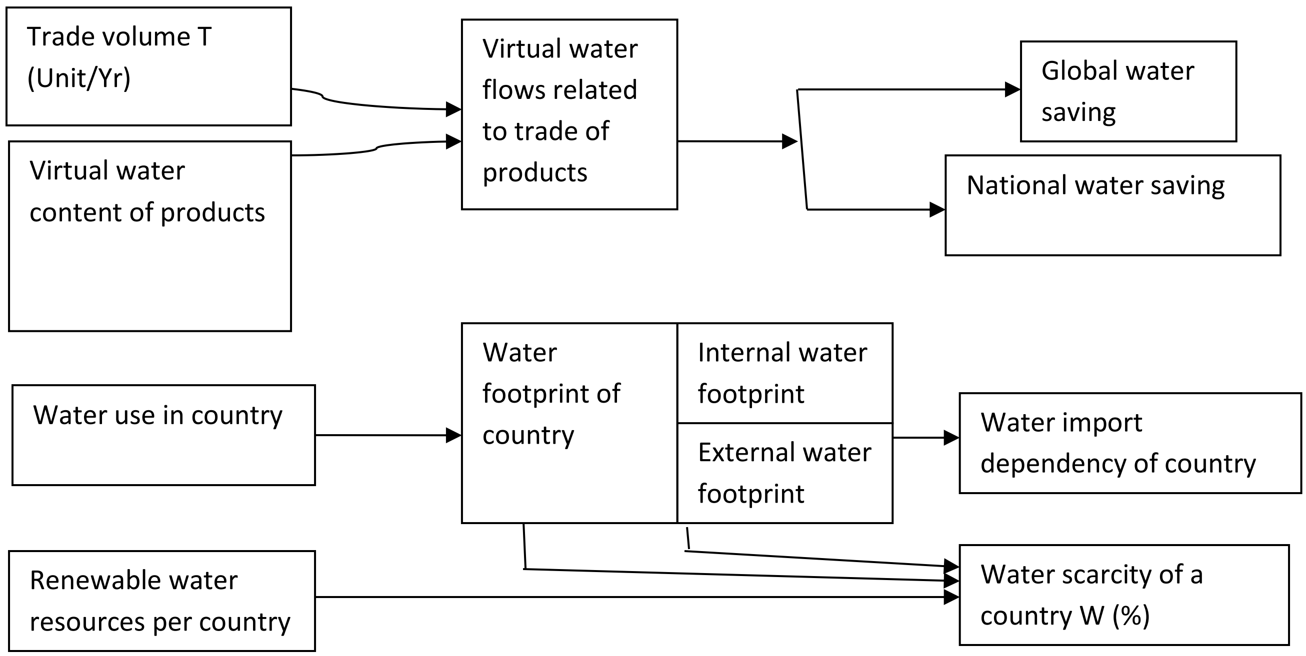


Figure 4.1 source: A.Y. Hoekstra, P.Q. Hung, (UNESCO-IHE Institute for Water Education, 2003)

The volume of water use in each country (U_{nat}) is estimated based on the domestic production of goods and their virtual water content. Form this volume, the virtual water export related to the export of domestic production is deducted to get the volume of water consumed by the inhabitants of a country from their own domestic water resources ($F_{internal}$). Similarly, as not all the products imported are consumed domestically, the virtual water export related to the export of the imported products is deducted to get the actual volume of virtual water imported for the consumption in a country ($F_{external}$). The volume of renewable water resources available per country and their consumption of water, both from internal and external sources, can be used to get new estimates of water scarcity (W_s), water dependency (W_d) and water self-sufficiency (W_{ss}). But these steps are beyond the limit of the study therefore not further elaborated.

The virtual water content of a product is the volume of water used to produce the product, measured at the place where the product was actually produced (production site specific definition). The virtual water content of a product can also be defined as the volume of water that would have been required to produce the product in the place where the product is consumed (consumption site specific definition). The adjective 'virtual' refers to the fact that most of the water used to produce a product is in the end not contained in the product. The real water content of products is generally negligible if compared to the virtual water content.

The virtual water content of a product P in a country (m3/unit) is calculated as the ratio of total volume of water used (T in m3) for X unit of the production in that country.

$$Vp = T / X \qquad (1)$$

Depending upon the source of water used, the definition virtual water content can be further elaborated as the green virtual water content (Vg, resulting from the use of effective rainfall applicable for crop production), blue virtual water content (Vb, resulting from surface and renewable ground water sources). One can even translate the pollution effect of a production system into the equivalent volume water necessary for dilution per unit of production.

Reference crop evaporation

The reference crop evaporation (*Er*) is the evaporation rate from a reference surface, not short of water. The Penman-Monteith equation is used to estimate the reference evaporation *Er*. The FAO Expert Consultation on Revision of FAO Methodologies for Crop Water Requirements accepted the following unambiguous definition for the reference surface: "A hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance (*rs*) of 70 (s/m) and an albedo of 0.23" (Allen *et al.*, 1998).

The FAO **Penman-Monteith** method is recommended as the sole ETo method for determining reference evapotranspiration.

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

Based on Penman-Monteith method, per crop type, average specific water demand has been calculated separately for each relevant nation on the basis of FAO data on crop water requirements and crop yields:

$$SWD[n,c] = \frac{CWR[n.c]}{CY[n,c]}$$

Here, *SWD* denotes the specific water demand (m^3/ton) of crop *c* in country *n*, *CWR* the crop water requirement (m^3/ha) and *CY* the crop yield (ton/ ha).

The overall scheme for the calculation of specific water demand is drawn in Figure 4.2

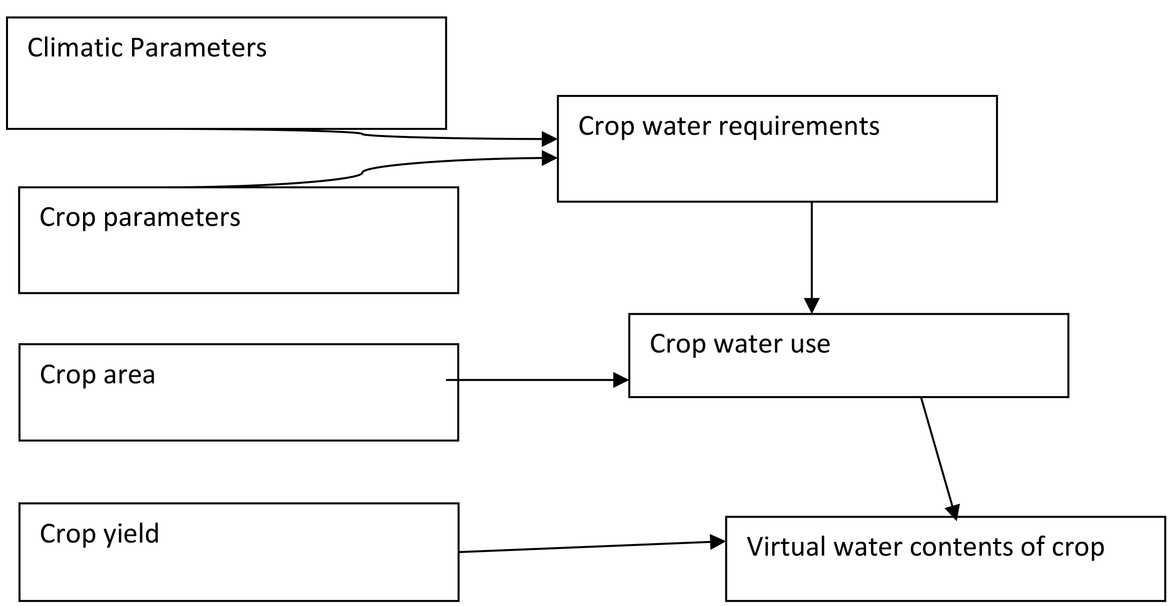


Figure: 4.2: GLOBALISATION OF WATER OPPORTUNITIES AND THREATS OF VIRTUAL WATER TRADE, CHAPAGAIN (2006)

Virtual water trade flows between nations have been calculated by multiplying international crop trade flows by their associated virtual water content. The latter depends on the specific water demand of the crop in the exporting country where the crop is produced. Virtual water trade is thus calculated:

$$VWT[n_e,n_t,c,t]=CT[n_e,n_i,c,t]XSWD[n_e,c]$$

in which *VWT* denotes the virtual water trade (m3yr-1) from exporting country *ne* to importing country *ni* in year *t* as a result of trade in crop *c*. *CT* represents the crop trade (ton yr-1) from exporting country *ne* to importing country *ni* in year *t* or crop *c*. *SWD* represents the specific water demand (m3 ton-1) of crop *c* in the exporting country. Above equation assumes that if a certain crop is exported from a certain country, this crop is actually grown in this country (and not in another country from which the crop was just imported for further export). Although a certain error will be made in this way, it is estimated that this error will not substantially influence the overall virtual water trade balance of a country. Besides, it is practically impossible to track the sources of all exported products.

The gross virtual water import to a country *ni* is the sum of all imports:

$$GVWI[n_{i,}t]=\sum VWT[n_e,n_i,c,t]$$

The gross virtual water export from a country *ne* is the sum of all exports:

$$GVWI[n_{e,}t]=\sum VWT[n_e,n_i,c,t]$$

The net virtual water import of a country is equal to the gross virtual water import minus the gross virtual water export. The virtual water trade balance of country *x* for year *t* can thus be written as: NVWI[x,t]=GVWI[x,t]-GVWE[x,t]

Where, *NVWI* stands for the net virtual water import (m3 yr-1) to the country. Net virtual water import to a country has either a positive or a negative sign. The latter indicates that there is net virtual water *export* from the country.

The total water use within a country itself is not the right measure of a nation's actual appropriation of the global water resources. In the case of net import of virtual water import into a country, this virtual water volume should be added to the total domestic water use in order to get a picture of a nation's real call on the global water resources. Similarly, in the case of net export of virtual water from a country, this virtual water volume should be subtracted from the volume of domestic water use. The sum of domestic water use and net virtual water import can be seen as a kind of 'water footprint' of a country, on the analogy of the 'ecological footprint' of a nation.

The various steps in the calculation of virtual water flows leaving and entering a country are also presented schematically in Figure 4.3.

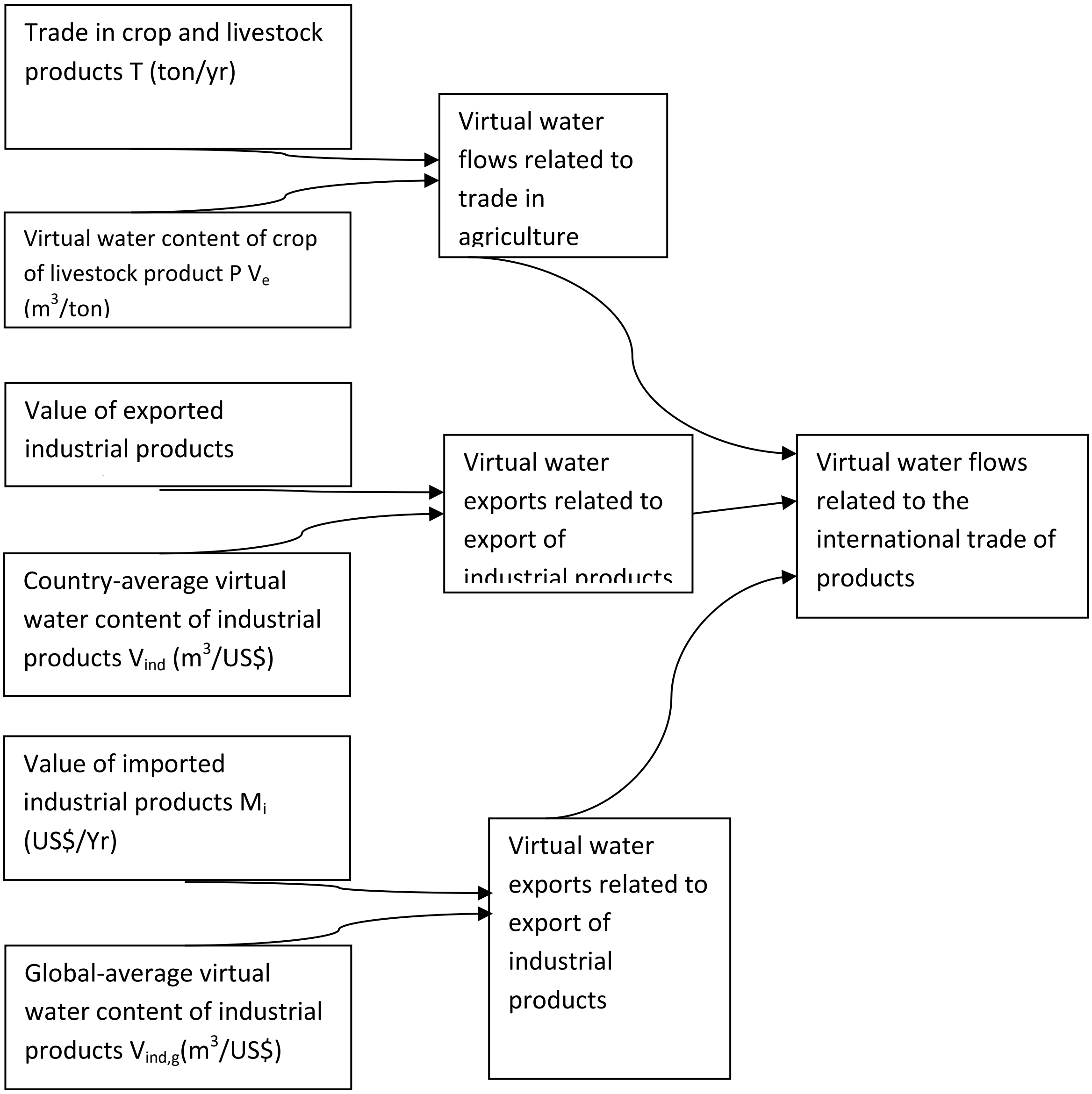


Figure: 4.3: GLOBALISATION OF WATER OPPORTUNITIES AND THREATS OF VIRTUAL WATER TRADE, CHAPAGAIN (2006)

4.2 Techniques for data analysis

The data for 10 years (2004-2013) of different crops, vegetables and fruits used in each variable of the study has been presented and compared with visual aids (Bar graphs). Bar graphs would be prepared by incorporating time period at one axis and data on other axis in excel for better understanding through graphical representation.

Virtual water content:

The virtual water content of a product is the volume of water used to produce the product, measured at the place where the product was actually produced (production site specific definition). The virtual water content of a product can also be defined as the volume of water that would have been required to produce the product in the place where the product is consumed (consumption site specific definition). In this thesis, unless otherwise mentioned explicitly, the production site-specific definition has been used.

The adjective 'virtual' refers to the fact that most of the water used to produce a product is in the end not contained in the product. The real water content of products is generally negligible if compared to the virtual water content. The virtual water content of a product *p* in a country (m3/unit) is calculated as the ratio of total volume of water used (*U* in m3) for Y unit of the production in that country.

Virtual water trade:

The gross volume of virtual water import (*GVWI*) to a country is the sum of crop imports (*CI*c) multiplied by their associated crop water contents (*CVWC*c) in that country: $GVWI = \sum (CI\,c \times CVWC\,c)$

Virtual water export:

The gross volume of virtual water export (*GVWE*) from a country is the sum of crop exports (*CE*c) multiplied by their associated crop water contents (*CVWC*c) in that country: $GVWE = \sum(CEc \times CVWCc)$

Net Virtual Water:

Net virtual water trade for individual countries, $NVWT = GVWI - GVWE$

Net virtual water trade indicates that either the country remained as importer or exporter of virtual water in the end.

4.3 Data

In this research the data for the crops (Wheat, Sugarcane and Rice), vegetables (Potatoes and Onion) and fruits (Apples, Mangoes and Oranges) have been taken into account for the purpose of the analysis. The secondary data has been used in this research. Furthermore, the data for 10 years (2004-2013) have been used for analysis purpose. Therefore, panel data has been utilized in the research.

4.4 Variables of the research and Source of data

In this research the following variables have been taken into account:

i. **The production of the crops:** The secondary data for the production of the crops for 10 years from 2004 to 2013 has been gathered from FAOSTAT database. The units of productions have been taken in tones.

ii. **Yield from the production:** The secondary data for the yield from the production of the crops for 10 years (2004-2013) has been gathered from FAOSTAT database. The unit for the yield has been used as tones/Hectare

iii. **Harvested area:** The secondary data for the area harvested for the selected crops, vegetables and fruits for 10 years (2004-2013) have been gathered from FAOSTAT database. The unit for the yield has been used as Hectare.

iv. **Import and Export of the crops, vegetables and Fruits:** The secondary data for the import and export of the crops, vegetables and fruits for 10 years (2004-2013) have been gathered from FAO and ITC database. The unit for the yield has been used as tonnes.

v. **Virtual water content:** The secondary data for virtual water content for 10 years (2004-2013) have been estimated on the basis of various FAO databases (FAOSTAT, AQUASTAT). The unit for the yield has been used as m^3/hectare.

vi. **Virtual water trade:** The secondary data for virtual water trade for 10 years (2004-2013) have been obtained by multiplying the virtual water content with import and export to calculate virtual water export and virtual water import. The unit for the yield has been used as km^3.

CHAPTER 5

RESULTS AND DISCUSSIONS

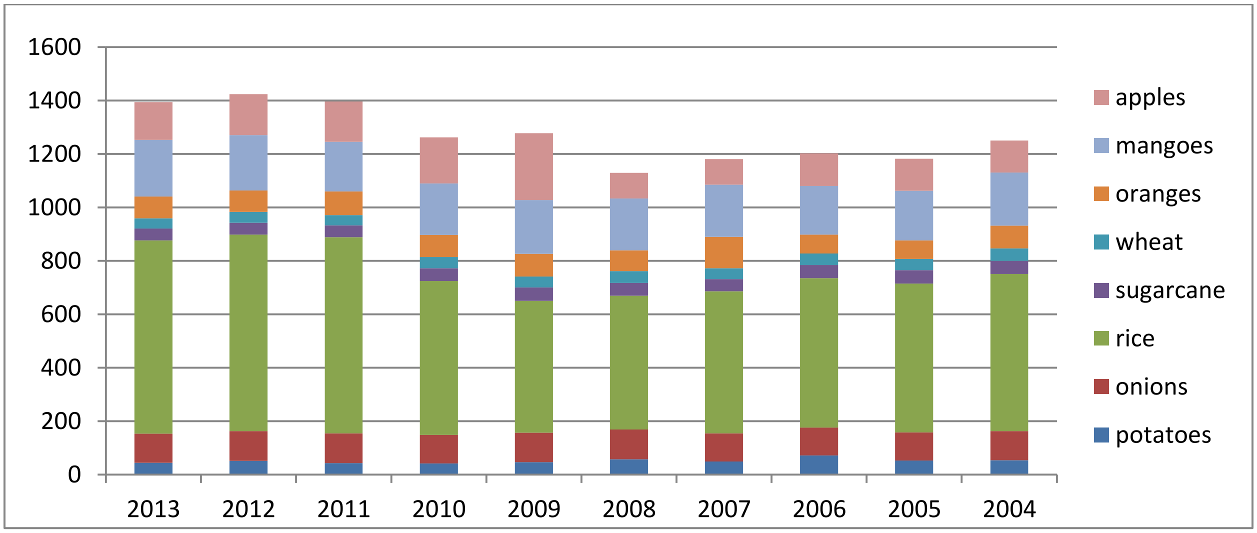
5.1. Introduction

This chapter includes the descriptive analysis of the virtual water import, export, Production of selected crops, vegetables and fruits, Area of harvested, crops yields have been explained by virtual aids (Graphically).

5.1 Results (In Graphical presentation)

5.1.1Virtual water Content

Virtual Water Contents (m3/ton)										
Crop/Period	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**
potatoes	43.78	52.04	43.56	42.08	47.06	58.02	49.32	71.55	52.82	54.04
Onions	110.01	111.28	110.43	106.39	110.35	110.27	105	105	105.08	109.12
Rice	723.25	735.3	735.3	576.71	492.94	501.34	531.54	558.46	556.69	588.24
Sugarcane	43.53	44.04	43.91	46.95	50.57	47.74	46.22	49.95	50.29	49.09
Wheat	39.06	40.11	38.43	42.64	40.98	44.4	40.09	43.22	42.1	45.88
Oranges	81.44	81.07	87.91	82.64	84.03	77.83	117.56	70.2	70.26	84.91
Mangoes	211.26	207.4	186.25	192.56	201.48	193.84	195.69	182.59	185.07	199.71
Apples	142.42	152.49	151.36	172.35	250.11	96.17	96.06	121.18	119.59	118.9

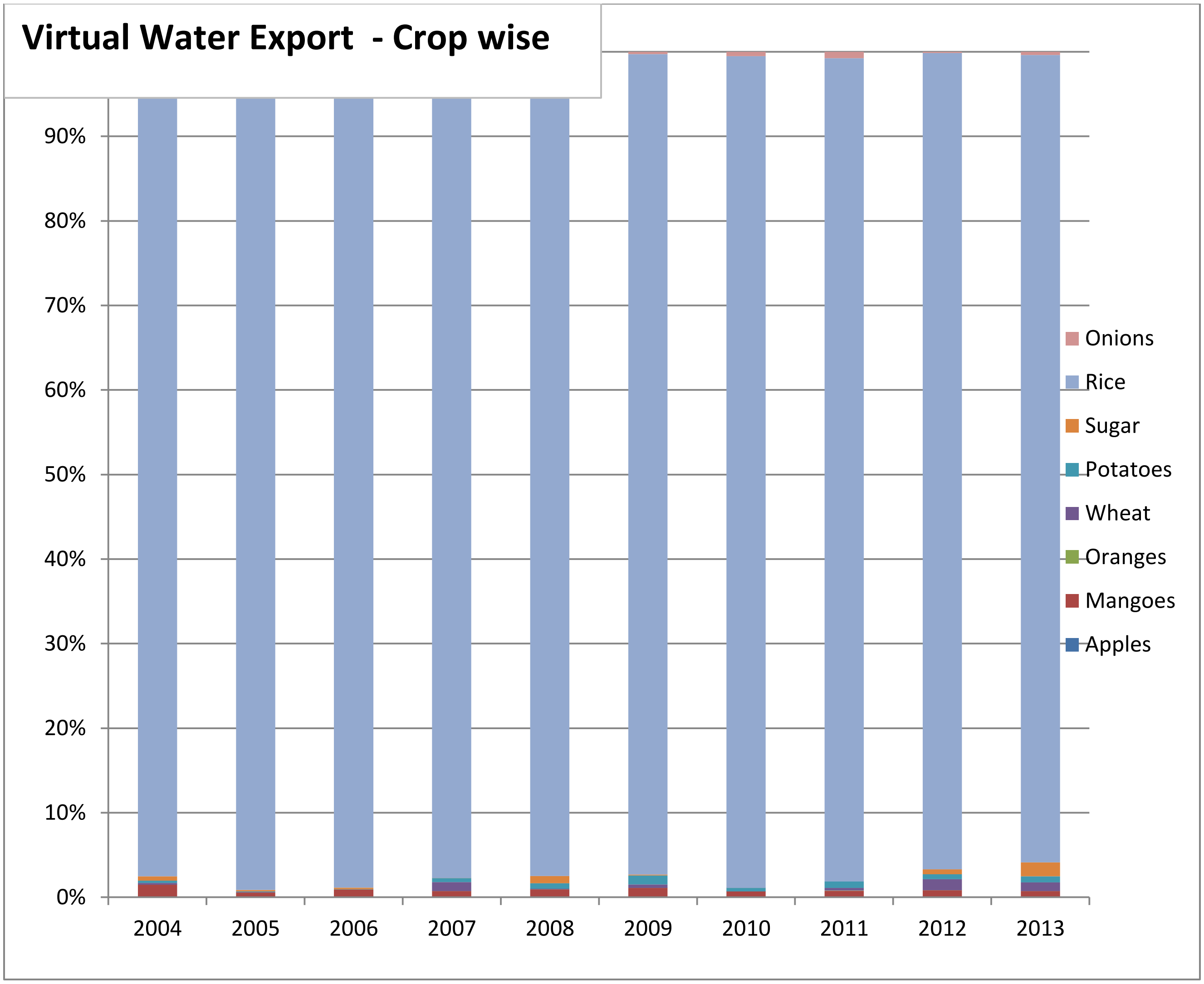


The results regarding the virtual water content have been presented above by bar chart. These results are elaborated that the potatoes are almost have the same pattern (Values in m^3/ton) of virtual water content during the time period 2004-2013. The same pattern has also been found in case of onions as the values of virtual water content remained almost the same during this time period. However, a little bit change has been seen in case of rice during the years 2010-2013.

However, all other crops, vegetables and fruits are showing almost the similar values of virtual water content during the time period 2004-2013.

5.1.2 Virtual Water Exports

Virtual Water Export (Km^3)								
Crop/Period	**Apples**	**Mangoes**	**Oranges**	**Wheat**	**Potatoes**	**Sugar**	**Rice**	**Onions**
2004	11.53	16387.18	141.97	1966.55	3029.81	5703.03	1072208	5355.39
2005	11.96	9041.60	5.97	1147.31	1101.09	2750.10	1609607	3110.05
2006	17.69	19281.14	8.21	0	1097.11	3116.73	2060015	3562.76
2007	41.11	12143.93	28.68	18396.58	8001.89	0.56	1663336	1024.17
2008	1.92	13437.76	23.19	1318.28	9029.07	12834.61	1408424	3903.23
2009	569.73	14823.89	0.25	5839.90	14846.25	1216.08	1355912	3630.07
2010	271.11	16545.33	204.62	211.07	10323.44	2.35	2409978	12979.79
2011	150.75	19580.46	598.93	8021.96	19314.24	0	2509211	19121.18
2012	330.14	20988.55	27.64	34093.50	15614.55	15414	2517410	3981.04
2013	85.31	20899.11	580.14	29295.00	21350.72	47883	2783983	11132.79



The results of the virtual water import are showing that the volume of the virtual water, which was exported in respect of onions during 2004-2013, has very less volume as compare to rice. As a huge volume of rice is being exported as compare to other crops, vegetables and fruits.

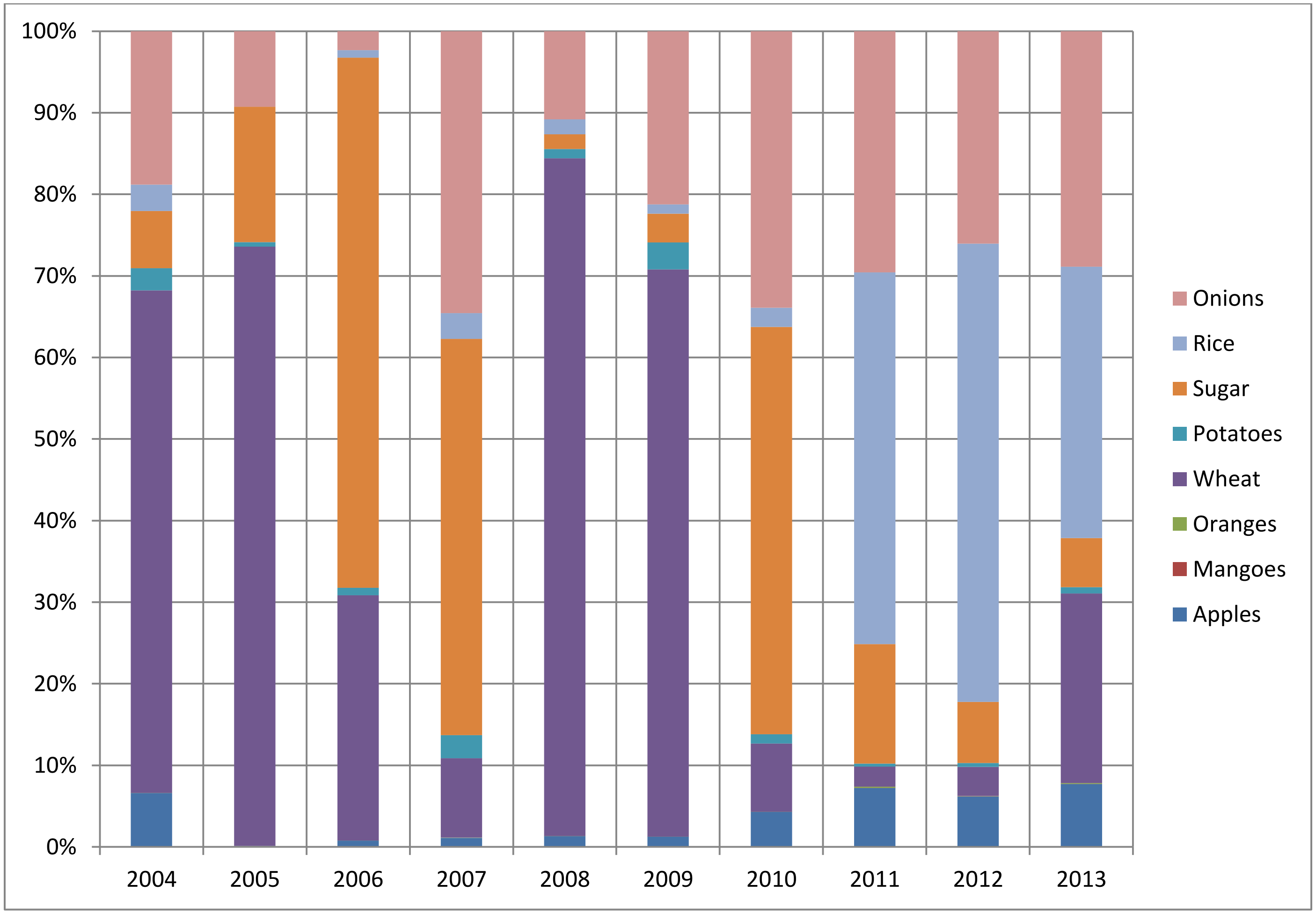
However, the results regarding the mangoes are showing that almost the same volume of the mangoes was exported during the year 2004-2013. It is further added, a fluctuation has been observed in exported volume of other crops, vegetables and fruits. A huge volume of rice can be seen, which was exported during the year 2004 to 2013.

5.1.3 Virtual Water Imports (km^3)

Table

Virtual Water Import (Km^3)								
Crop/Period	**Apples**	**Mangoes**	**Oranges**	**Wheat**	**Potatoes**	**Sugar**	**Rice**	**Onions**
2004	532.6	0.0	0.3	4954.0	219.9	563.7	258.2	1514.7
2005	97.3	0.0	0.0	59304.6	448.8	13397.9	0.0	7482.2
2006	916.5	0.0	10.7	35268.5	1070.1	76295.1	1048.2	2752.4
2007	630.4	0.0	5.9	5450.6	1579.9	27169.1	1766.3	19320.5
2008	1298.0	0.0	3.0	80818.0	1128.1	1757.4	1772.7	10522.0
2009	2302.4	0.0	2.5	127145.9	6039.7	6427.7	2053.6	38856.0
2010	2057.7	0.0	1.6	4010.6	546.5	23907.1	1110.2	16240.1
2011	2464.4	0.2	46.5	839.3	116.2	4976.9	15479.5	10053.3
2012	3647.1	1.0	41.3	2085.7	282.8	4404.0	33088.5	15331.5
2013	5035.8	0.4	54.9	15155.3	501.1	3917.7	21697.5	18805.8

Virtual Water Import Graph



- **Onion**

The results of the virtual water import are showing that the volume of the virtual water which was imported in respect of onions during 2004 as 1514.7 Km^3. This figure showing the increasing trend during next year i.e. year 2005 and figure was found as 7482.2 Km^3. In next year i.e. year 2006 the volume of imported virtual water in respect of Onion was declined to 2752.4 Km^3 and then showing increasing trend during year 2007 i.e. reached up to 19320.5 Km^3. The figures for the volume of imported virtual water in respect of Onion are showing the fluctuating trend during the time period (2004-2013). However, in year 2013 the volume of imported virtual water was 18805.8 Km3, which is huge volume as compare to previous years.

- **Rice**

The results of the virtual water import are showing that the volume of the virtual water, which was imported in respect of rice during 2004 as 258.2 Km^3. This figure reached to zero during next year i.e. year 2005. Next year i.e. year 2006 the volume of imported virtual water in respect of Rice was increased to 1048.2 Km^3 and then showing increasing trend during year 2007 i.e. reached up to 1766.3 Km^3. The figures for the volume of imported virtual water in respect of Rice are showing the fluctuating trend during the time period (2004-2013). However, in year 2013 the volume of imported virtual water was 21697.5 Km^3, which is huge volume as compare to previous years.

- **Sugar**

The results of the virtual water import are showing that the volume of the virtual water, which was imported in respect of sugar during 2004 as 563.7 Km^3. This figure showing the increasing trend during next year i.e. year 2005 and figure was found as 13397.9 Km^3. In next year i.e. year

2006 the volume of imported virtual water in respect of Sugar was increased to 76295.1 Km^3 and then showing decreasing trend during year 2007 i.e. reached upto27169.1 Km^3. The figures for the volume of imported virtual water in respect of Sugar are showing the fluctuating trend during the time period (2004-2013). However, in year 2013 the volume of imported virtual water was 3917.7 Km^3, which is huge volume as compare to previous years.

- **Potatoes**

The results of the virtual water import are showing that the volume of the virtual water, which was imported in respect of potatoes during 2004 as 219.9 Km^3. This figure showing the increasing trend during next year i.e. year 2005 and figure was found as 448.8 Km^3. In the next year i.e. year 2006 the volume of imported virtual water in respect of Potatoes was declined to 1070.1 Km^3 and then showing increasing trend during year 2007 i.e. reached upto1579.9 Km^3. The figures for the volume of imported virtual water in respect of Potatoes are showing the fluctuating trend during the time period (2004-2013). However, in year 2013 the volume of imported virtual water was 501.1 Km^3.

- **Wheat**

The results of the virtual water import are showing that the volume of the virtual water, which was imported in respect of wheat during 2004 as 4954.0 Km^3. This figure showing the increasing trend during next year i.e. year 2005 and figure was found as 59304.6 Km^3. In year 2006 the volume of imported virtual water in respect of Wheat was increased to 35268.5 Km^3 and then showing decreasing trend during year 2007 i.e. reached upto5450.6 Km^3. The figures for the volume of imported virtual water in respect of Wheat are showing the fluctuating trend during the time period (2004-2013). However, in year 2013 the volume of imported virtual water was 15155.3 Km^3, which is huge volume as compare to previous years.

- **Oranges**

The results of the virtual water import are showing that the volume of the virtual water, which was imported in respect of oranges during 2004 as 0.3 Km^3. This figure reached to zero during next year. In the next year i.e. year 2006 the volume of imported virtual water in respect of Oranges was declined to 10.7 Km^3 and then showing decreasing trend during year 2007 i.e. reached upto5.9 Km^3. The figures for the volume of imported virtual water in respect of Oranges are showing the fluctuating trend during the time period (2004-2013). However, in year 2013 the volume of imported virtual water was 54.9 Km^3, which is huge volume as compare to previous years.

- **Mangoes**

The results of the virtual water import are showing that the volume of the virtual water, which was imported in respect of mangoes during 2004 as 1514.7 Km^3. This figure showing the increasing trend during next year i.e. year 2005 and figure was found as 7482.2 Km^3. Next year i.e. year 2006 the volume of imported virtual water in respect of Mangoes was declined to 2752.4 Km^3 and then showing increasing trend during year 2007 i.e. reached up to 19320.5 Km^3. The figures for the volume of imported virtual water in respect of Mangoes are showing the fluctuating trend during the time period (2004-2013). However, in year 2013 the volume of imported virtual water was 18805.8 Km^3, which is huge volume as compare to previous years.

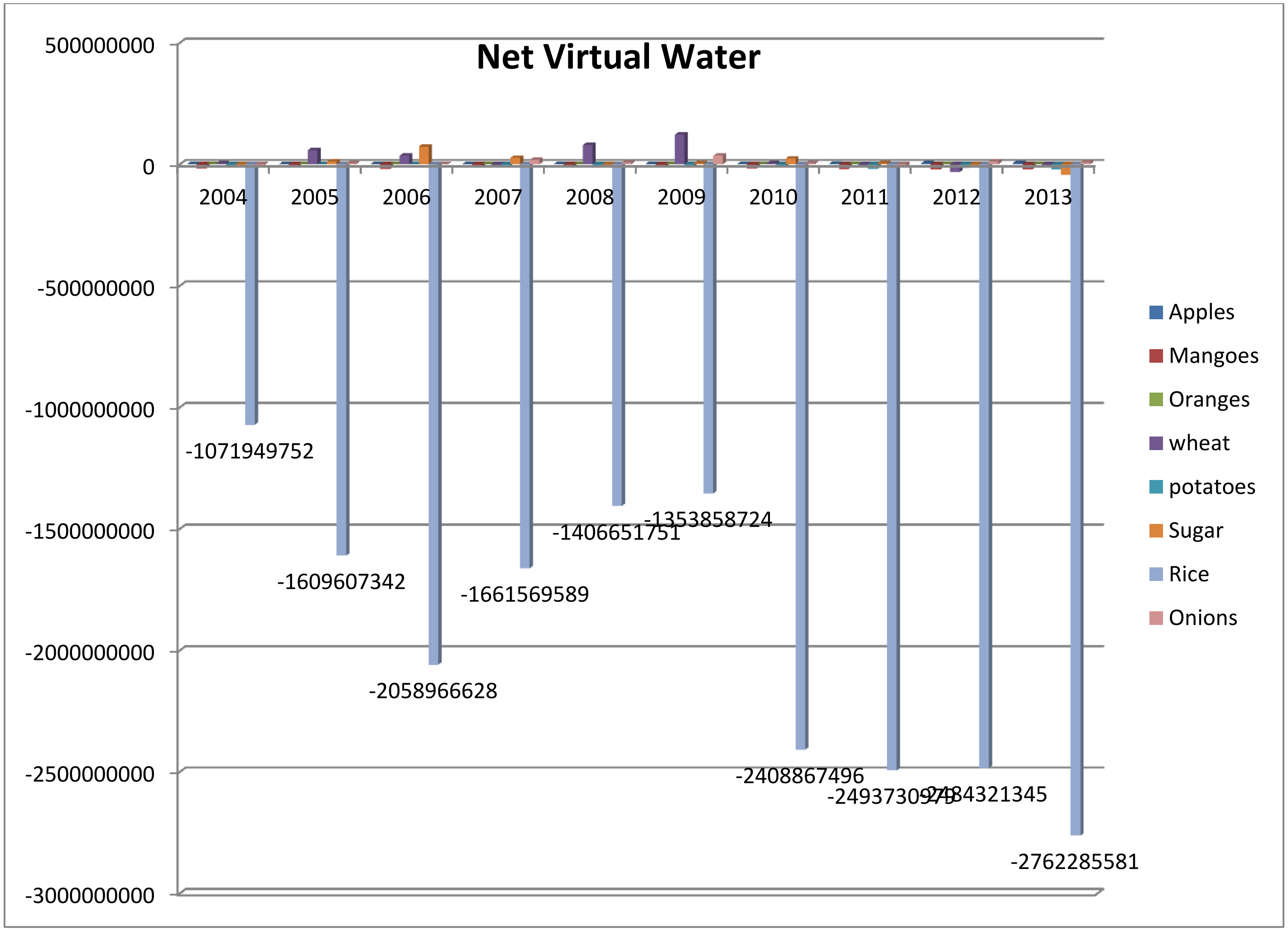
- **Apples**

The results of the virtual water import are showing that the volume of the virtual water, which was imported in respect of apples during 2004 as 532.6 Km^3. This figure showing the decreasing trend during next year i.e. year 2005 and figure was found as 97.3 Km^3. Next year i.e. year 2006 the volume of imported virtual water in respect of Apples was increased to 916.5 Km^3 and then showing increasing trend during year 2007 i.e. reached up to 19320.5 Km^3. The figures for the volume of imported virtual water in respect of Apples are showing the fluctuating trend during the time period (2004-2013). However, in year 2013 the volume of imported virtual water was 18805.8 Km^3, which is huge volume as compare to previous years.

5.1.4 Net Virtual water (Import-Export)

Net Virtual Water (Km^3)									
Crop/Period	**Apples**	**Mangoes**	**Oranges**	**Wheat**	**Potatoes**	**Sugar**	**Rice**	**Onions**	**Total**
2004	521.0	-16387.2	-141.7	2987.5	-2809.9	-5139.3	-1071949.8	-3840.7	**-1096760**
2005	85.4	-9041.6	-6.0	58157.3	-652.3	10647.8	-1609607.3	4372.2	**-1546045**
2006	898.8	-19281.1	2.5	35268.5	-27.0	73178.4	-2058966.6	-810.4	**-1969737**
2007	589.3	-12143.9	-22.8	-12945.9	-6422.0	27168.5	-1661569.6	18296.4	**-1647050**
2008	1296.1	-13437.8	-20.2	79499.7	-7900.9	-11077.3	-1406651.8	6618.7	**-1351674**
2009	1732.7	-14823.9	2.3	121306.0	-8806.5	5211.7	-1353858.7	35225.9	**-1214011**
2010	1786.6	-16545.3	-203.0	3799.6	-9777.0	23904.7	-2408867.5	3260.3	**-2402642**
2011	2313.7	-19580.3	-552.4	-7182.6	-19198.1	4976.9	-2493731.0	-9067.8	**-2542022**
2012	3317.0	-20987.5	13.7	-32007.8	-15331.7	-11010.0	-2484321.3	11350.4	**-2548977**
2013	4950.5	-20898.7	-525.2	-14139.7	-20849.6	-43965.3	-2762285.6	7673.0	**-2850041**
Total	**17491.1**	**-163127**	**-1452.8**	**234742.6**	**-91775**	**73896.1**	**-19311809.2**	**73078**	

Net Virtual Water Graph



Eight crops have been elaborated for net virtual water in a period of ten years from 2004 to 2013. Negative lines depicts that net virtual water loss is occurring. Net virtual water loss depends upon quantity of net of exports.

It is evident from the graph that net virtual loss is occurring in case of rice as huge quantity of rice as huge quantity of crop is being exported every year to other countries. Orange, wheat, sugar and onion crops have mixed trends in the period of ten years. Net virtual water gain is occurring in few years while loss occurred in the few others. However, other crops did not show more dispersion from mean and converge to mean value; hence there is quite lower gain or loss in comparison to rice.

In case of apples Pakistan is at advantageous position being net importer. During ten year period net virtual water gain is occurring. Mango, potatoes and rice is creating net virtual water loss during period of ten years as these products have excessive export. Orange, wheat, sugar and onion crops have mix trend in the period of ten years.

Net virtual water gain is occurring in a year and loss occurred in the next year. It may be noted that gain or loss in different crops is minor as compared to rice hence we needs to preserve water by importing rice from other rice producing countries. Furthermore, saved water resources may be utilized for those crops having less water such as wheat. In this way we may be able to attain competitive position by focusing crops with less water content in it.

Chapter 6

CONCLUSION & POLICY IMPLICATIONS

Major Findings of the study:

The major findings of this study are below.

1. Pakistan is a virtual water exporter with average of 134 km^3each year worth of export of water.
2. The most water consuming products that we export are rice, wheat and potatoes with rice being the highest. These crops alone average about 90% of whole virtual water export in the period studied.
3. While the most water intensive crops we import are wheat, apple, sugar and onions. They contribute almost 80% of the whole virtual water import over the studied period.
4. Average water requirements for crops studied vary from 800 mm to 2400 mm

Conclusion:

The estimates carried out in the study conclude that Pakistan is a net virtual water exporter meaning that Pakistan exports more water through the exports than it imports water through the imports. Pakistan's average water export each year is about 134 km^3 which for a water scarce country is a lot and it is increasing over the period as we import lesser agriculture products and export more products. Mangoes, Sugarcane, Rice and Onions require more water on average than other crops to produce as is evident from table 2.1.

Increase in exports is a good sign but the yield and water management needs to be improved as Pakistan is a water scare country, the scarcity is expected to rise as population size is increasing. Therefore, virtual water trade can be used in policy making as a helping tool in its water management policy. Concept of virtual water trade can be applied to understand the opportunity cost as well cost and benefit of sharing the irrigation costs upon the crops produced. And as Pakistan is already a water scarce country with depleting water resources and unmitigated climate change effects which are quite visible now over the past decade with extreme weather and changed weather patterns. Due to the political situation in the country construction of new water reservoirs is already on hold and even if construction on new dams is started, construction of dams requires time. Therefore if we want to come up with alternative means for better water utilization we cannot do so without expanding our knowledge base and this can be a helpful tool.

Mango, potato and rice showed negative impact as water is exported in the form of these products. However apple is another big export of the country having positive effect. Few products have mix trend like orange, wheat, sugar and onion. Eight crops have been elaborated for net virtual water in a period of ten years from 2004 to 2013. Negative lines depicts that net virtual water loss is occurring. Net virtual water loss depends upon quantity of net of exports.

It can be seen that net virtual loss is occurring in case of rice as huge quantity of rice as huge quantity of crop is being exported every year to other countries. Orange, wheat, sugar and onion crops have mixed trends in the period of ten years. Net virtual water gain is occurring in few years while loss occurred in the few others. However, other crops did not show more dispersion from mean and converge to mean value; hence there is quite lower gain or loss in comparison to rice. In case of apples Pakistan is at advantageous position being net importer. During ten year period net virtual water gain is occurring. Mango, potatoes and rice is creating net virtual water loss during period of ten years as these products have excessive export. Orange, wheat, sugar and onion crops have mix trend in the period of ten years.

Net virtual water gain is occurring in a year and loss occurred in the next year. It may be noted that gain or loss in different crops is minor as compared to rice hence we needs to preserve water by importing rice from other rice producing countries. Furthermore, saved water resources may be utilized for those crops having less water such as wheat. In this way we may be able to attain competitive position by focusing crops with less water content in it.

Policy Implications:

The study obviously has its limitations but further detailed study of Virtual water trade of all the crops of Pakistan can be done to verify the helpfulness of the VWT tool. As world is already taking serious the growing situation of water scarcity we also need to keep in mind that how much water can we allow to be exported virtually and come up with cost benefit analysis of substituting our agriculture exports to a more industrial base which comprises of products that use less water but can be worth at least same in export value if we forgo exports of such crops

Therefore, virtual water trade can be used in policy making as a helping tool in its water management policy. As Water world council also points that virtual water accounts should be developed for integration in to water and agriculture policy by developing common procedures and standards (World Water Council 2004). Concept of virtual water trade can be applied to understand the opportunity cost as well cost and benefit of sharing the irrigation costs upon the crops produced. And as Pakistan is already a water scarce country with depleting water resources and unmitigated climate change effects which are quite visible now over the past decade with extreme weather and changed weather patterns.

Also as on-farm water savings alone are unlikely to justify investment in water saving technology — labor savings and yield or quality increases are valuable complementary benefits of the technological change (Appels, Douglas and Dwyer 2004), the integration of virtual water trade into agriculture policy which also increase yields and develops crops that are less water intensive as well as more output yielding.

Though the standard system has yet not been developed, virtual water trade is seen as a tool to relive pressure on water sources globally as well as achieve food security (World Water Council 2004). Also due to the political situation in the country construction of new water reservoirs is already on hold and even if construction on new dams is started, construction of dams requires time. Therefore if we want to come up with alternative means for better water utilization we cannot do so without expanding our knowledge base and this can be a helpful tool.

I would recommend following points;

1. I would recommend that VWT tool can at least be used in future water management policies.
2. I would recommend state institutes to conduct an even detailed study to come up with figures for both agriculture and industrial sector.
3. I would recommend more strict usage of water and an efficient form of irrigation techniques by farmers which can be only implemented through state institutes.
4. The state would benefit a lot with better utilization of irrigation water as well as rainfall including storage and discharge.
5. Research on crop varieties that yield better results in terms of both output and less water usage should be increased with starting point that we can take world standards into consideration.

Limitations of the Study:

The study has been conducted on a limited number of crops and time period due to lack of time and primary data. Therefore a detailed study of the topic can also lead to more relating concepts like virtual water green, virtual water blue, water footprint, etc. that can be helpful in a much better water management policy in each agricultural, industrial, services and consumer sector. They can also be helpful in determining water quality as well.

Future scope of the Study:

The scope for further study is vast ranging from doing study on primary data, doing work on other crops, calculating virtual water content for industry, calculating water footprint, etc. But most importantly this study can lend a helping hand in integrated resource water management and as a tool for water policy formulation

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