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Virtual Water Trade Flows for Sustainable Use of Water Resources – Linking the environment, economy and policy

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Abstract

'Virtual water trade' (VWT) is an indicator of freshwater use in production and trade as it is based on the rationales of 'distribution of scarcity' and 'global water use efficiency'. It is an important concept for the science and policy discussions. The research paper aims to provide the critical analysis of the literature on the conceptual framework of VWT and discuss the potential of the concept to bridge the science and policy gap for sustainable use of water resources. The discussion was on the extensive review of the literature on the conceptual framework of VWT flows and its policy relevance, in order to critically analyze the potential of the concept as a policy supporting system for production, consumption and trade decisions. The review also comprises the possible avenues of considering water as a factor of production in Indian economy to link the environment, economy and policy. Policies are important in adoption of water efficient technologies, the signals coded in policies on prices of various inputs like land, water, and others influence the production, consumption and trade decisions. The findings of the paper suggest that the concept is being internalized in the water policy discussions as it provides a helpful perspective for policies in water scarce areas. The policy relevance of the VWT concept is evolving as it addresses the crucial and multifaceted development issues of food, water and energy securities, economic growth, employment creation, and poverty reduction. However, the policy relevance of the concept can be further enhanced by addressing concerns of dependency of a nation on food imports, integration of arable land, access to secure markets, and opportunity cost. The discussion emphasizes that there is a need for an institutional arrangement to enhance the effective use of the concept in policies other than the supply-side policies. The paper concludes the suitability of the concept to developing countries like India which are approaching water scarcity and facing impacts of climate change on water resources; and emphasizes on the future research on the quantitative assessment of the VWT flows to bridge the science and policy gap as well as identify sustainable use benchmarks.

Keywords: efficiency, India, policy, scarcity, sustainable use, VWT

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1. Introduction

"Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment"

-4th Principle of Dublin Statement on Water and Sustainable Development, 1992

The 4th Principle of Dublin Statement on Water and Sustainable Development describes the finite nature of resources and also indicates the linkage between environment, economy and society. Environment is perceived as a composite asset which provides a variety of goods and services to the economy and the society. There are bidirectional ***flows*** between the environment and the economy; the environment provides raw materials and energy, and receives waste from the economy. Hence, the environment acts as a 'source' as well as a 'sink' for the economy; the problem of source arises when there is resource scarcity whereas the problem of sink arises when the assimilative capacity of the environment to accommodate the impacts of the economic activity is under consideration. Discussion on the environment as a source to and sink of the economy necessitates an assessment of the linkage between the economy and the environment (Tietenberg,2003; Common and Stagl, 2005).

The ***environmental scarcities*** or natural resource scarcities result from a distorted view of development. Various paths of development lay stress on the vital natural resources to variable extent. The realization that the resources are depletable and, in some cases, irreversibly depletable, has led to the discussion on ***sustainability***, ***efficiency*** and ***equity***. These concepts form the basis of the linkage between the environment, economy and society (Hoekstra & Chapagain, 2008).The environment, society and the economy are ***interdependent*** systems. Trade and development contribute significantly to the economy, but they thrive on the environmental resources and with the background of the above discussion the concern of **scarcity** and **security** arise from both the environment and the economy centric approaches (Iyer, 2003; Common and Stagl, 2005; Daly and Farley, 2004).

Freshwater is a very complex resource unlike static resources; it flows in a dynamic cycle of rain, runoff and evaporation, which varies temporally and spatially. Freshwater is only 2.5% of the global water resources while the 97.5% is saltwater; the freshwater which is available for use is merely 0.1 % of the total global water resources (Allan, 2011). The concept of freshwater scarcity finds importance in crucial issues, such as food security issues, human development, economic sustainability, and ecological sustainability. To address these issues ***water security*** needs to be ensured; which refers to sustainable use and protection of water systems, the protection against water induced hazards like floods and droughts, the sustainable development of water resources and the safeguarding of access to water functions and services for humans and the environment (Schultz and Uhlenbrook, 2007). The present view on water security is a result of transition in the approaches to manage water scarcity from 'hard path' (infrastructure) to 'soft path' (institutions and policies) as inadequate water management induced by policy incentives to be more of a cause of water conflict than physical water scarcity (Allan, 2011).

One of the emerging concepts to manage water scarcity and generate information to plan a strategy for attaining water security is ***'virtual water trade flows'*** *(hereafter referred to as VWT flows).* VWT flows is the trade of water embodied in the good or service and is considered as a mechanism to 'alleviate physical water scarcity' implicitly in water-scarce areas and thereby preventing potential water conflicts (Allan,1993; Oki and Kanae, 2004). It is a crucial concept in the context of the present challenge of achieving ***'water sustainability'*** by meeting the basic water requirements in such a way that the extraction of water does not affect the functioning of freshwater ecosystems (Gerbens-Leenes, Hoekstra, & Van der Meer, 2008). Sustainability refers to the comparison between the water demand and the extent to which the Earth can support it. Sustainability in water use has a geographic connotation, i.e. sustainability in consumption by the producer and consumer depends on whether they are located in water scarce or water rich areas.

The major challenges faced in the water sector in India are uncertainties posed by climate change; over-use and exploitation of groundwater largely by informal sector; huge inefficiencies in water use; water deficits and pollution; poor governance and fragmented institutional framework. The emphasis of policies, plans, projects and implementation strategies has been on supply–side mega solutions rather than demand management (Kulkarni & Thakkar, 2012). The hydrological and economic processes that lead to water scarcity appear to be invisible. Therefore, an integrated approach of hydrology, economy and society is necessary to establish the sustainability of the system. Realizing the importance of the VWT flow concept to bridge this gap, the research intended to provide the critical analysis of the literature on the conceptual framework of VWT flows and discuss the potential of the concept to bridge the science and policy gap for sustainable use of water resources.

2. Potential of 'Virtual Water Trade flows' concept in bridging the science and policy gap for sustainable use of water resources

2.1. Conceptual framework

The rationales of the VWT flows concept are "global water use efficiency" and "distribution of scarcity" which leads to 'net water savings' (Roth & Warner, 2008). Virtual Water was initially referred to as 'embedded water' till 1988 but due to its unsuccessful adoption in water research, Prof Tony Allan termed it as virtual water in early 1990s. It is also called as 'encapsulated', 'shadow', 'supposed', 'exogenous' or 'ultraviolet' water (Haddadin,2003; Savenije, 2004; Roth and Warner, 2008; Allan, 2011). VWT assessment aids in identification of the unsustainable flows and therefore is emerging as a crucial concept in scientific and policy discussion on global, national, and sub-national or regional water scarcity among academicians, development agencies, agriculture researchers , planning institutions and development policy institutions (Rosegrant, Cai, Cline, & Nakagawa, 2002; World Water Council, 2004; Kumar & Singh, 2005; UNESCO , 2006).

It is based on a holistic approach which considers water as an economic and environmental good with social and political relevance (Hoekstra & Hung, 2002; Hoekstra,2003). The environmental aspect is crucial for sustainability in ecological structure and functions, and present scientific findings on climate change and its impact on water resources would be a potential source of continuing virtual water research. Socio-political relevance is at the centre of the state –society relations, for instance political motives of government's investment in water infrastructure is to protect the farmers, compromising on the environmental and economic value of water. Physical water scarcity has been underrepresented through political manipulation to make certain economic choices. The framework in the Figure1 explains the environmental, social and economic sustainability aspects which are crucial to identify the hotspots of unsustainability. The environmental sustainability is indicated by the extent to which the environmental flow requirements of rivers and green water environmental requirements are met; and level of water quality. The social sustainability encompasses the water allocation for the basic human needs like for the domestic needs and to meet food security requirements. The economic sustainability refers to the water allocation in an efficient manner and internalizes the externalities, opportunity costs and scarcity rents.

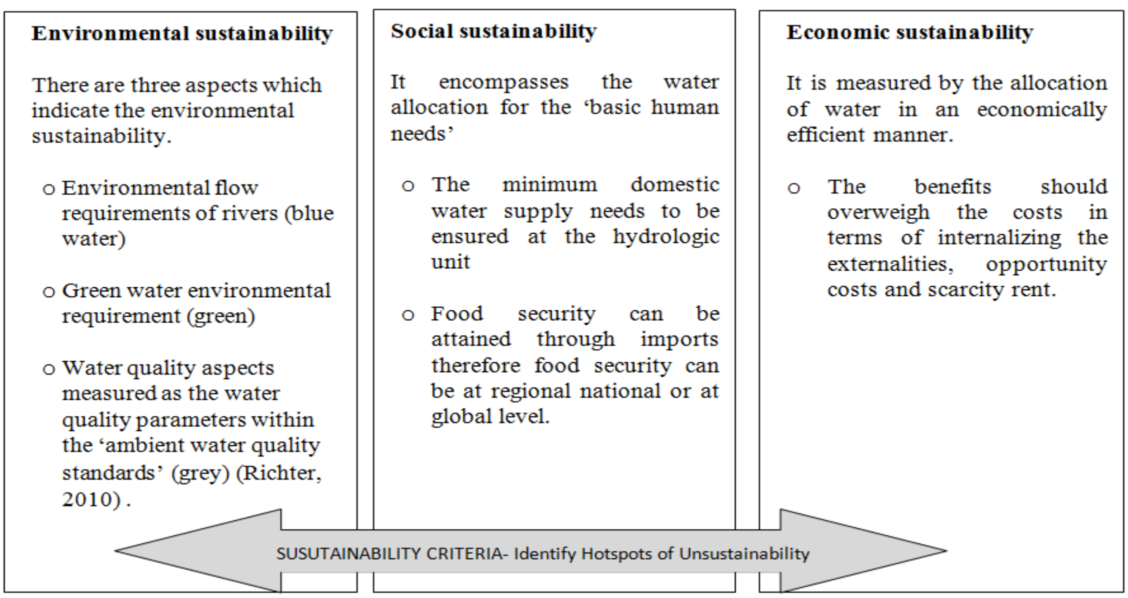

Figure 1: Criteria for the Environmental, Social and Economic Sustainability

VWT concept was developed on the empirical findings from food trade in Middle East, North Africa, and South African Development Community (Allan,1997; Warner, 2003; Velázquez, 2007). The concept was applied to investigate whether the trade flows are aligned with the water resources endowments (De Fraiture, Cai, Amarasinghe, Rosegrant, & Molden, 2004; Oki & Kanae, 2004; Wichelns, 2004; Kumar & Singh, 2005; Hoekstra & Chapagain, 2007; Wichelns,2009). Besides assessment of VWT flows in parts of Middle East and North Africa (MENA) (Allan, 1997; Wichelns, 2001; Roth & Warner, 2008)it has been assessed in Spain (Aldaya, Matinez-Santos, & Llamas, 2009; Galan-del-Castillo & Velazquez, 2010; Cazcarro, Duarte, Choliz, & Sarasa, 2011); Australia (Lenzen & Foran, 2001); China (Guan & Hubacek, 2006; Zhang, Shi, Yang, & Chapagain, 2011); and India (Kumar & Jain, 2007; Roth & Warner, 2008; Verma, Kampman, Zaag, & Hoekstra, 2009).The concept has also been extended to include the industries and services sector along with agriculture (Allan, 1997; Hoekstra, 2003; Guan & Hubacek, 2006).

Virtual water refers to both the water used and the wastewater generated as an outcome of the production process, measured in m^3/kg (Hoekstra & Hung, 2002; Zimmer & Renault, 2003). It has been linked with the concept of ***water footprint*** which forms the accounting basis to determine the water content of the goods and services (Figure 2). The 'virtual water content' of a product is same as the water footprint of the product, the difference lies in the former being from the production and latter being from the consumption perspective; i.e. Virtual water refers to water volume embedded in the product whereas water footprint is the volume as well as the type of water is being used, when and where it is being used. A conceptual framework developed by integrating the virtual water and water footprint approach links a large spectrum of sectors and issues and provides an appropriate framework to support optimal water management practices by informing the production and trade decisions (Figure 2). Identification of damaged water resource hotspots, which are the water- scarce regions loosing water in the form of export of water-intensive crops to water- plenty regions.

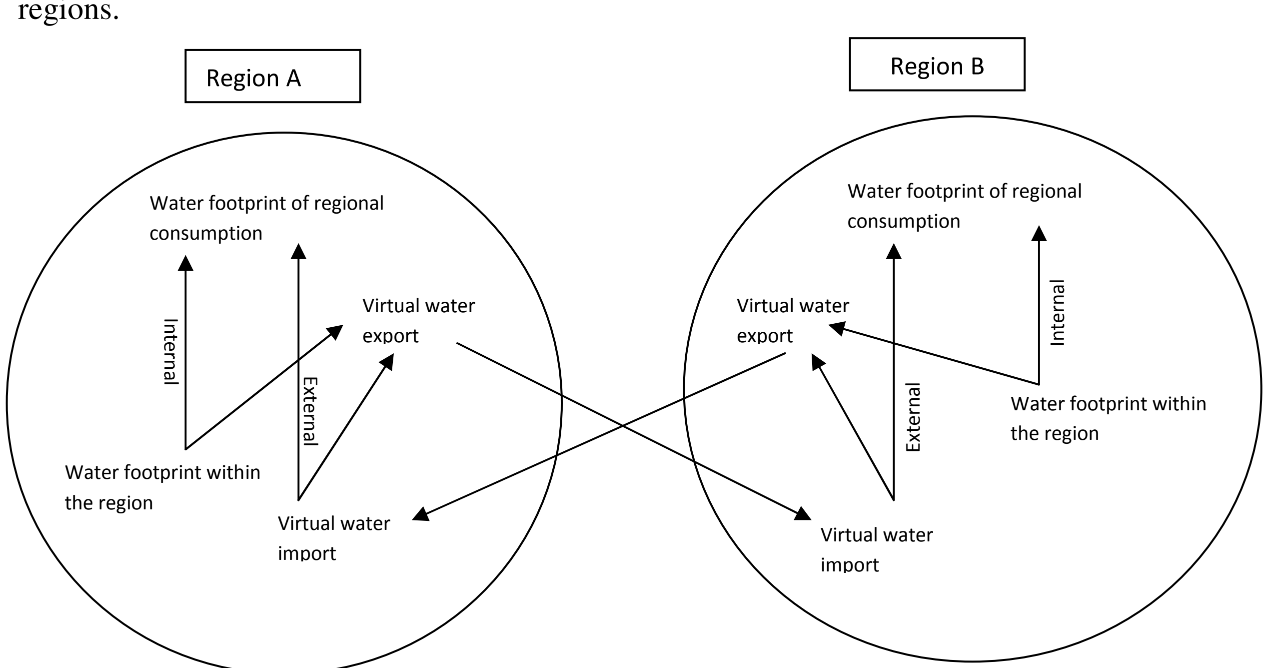

Figure2: Linkage between water footprint and virtual water
Source: (Hoekstra et al., 2011)

The important aspects of the conceptual framework are ***water productivity***, ***efficiency*** and ***water savings*** in the production, consumption, and trade patterns of goods and services. These are determined by the environmental (water resource availability), social, and economic (water use) aspects, influenced by the policy incentives which are not necessarily and directly associated with water resource. At the national scale domestic water resources are saved by importing more water-intensive products and exporting less water-intensive product. The national water savings result in global water savings if the flow is from higher water productivity site to lower productivity sites. In terms of physical quantity, national water savings are equivalent to the product of volume of water imported and the volume of water required domestically to produce it. Water savings can be used to produce higher value agricultural crops, support environmental services or serve growing domestic needs. Therefore, virtual water import is increasingly being perceived as an opportunity to preserve environmental flows in water–stressed nation (Chapagain, Hoekstra, & Savenije, 2006).

The VWT flows concept is gaining importance to solve water scarcity problems at various scales and levels of governance by making optimal use of comparative advantage and differences in resource availability; and prevent water conflicts in a politically silent manner. Virtual water was termed as politically silent as many countries import a large portion of their food supply whether or not they are explicitly implementing a virtual water strategy (Allan, 2011). The virtual water that flows is described to either have light or dark implication by Allan in 2011. Light side implies that the VWT flow aids in water security and saves water whereas the dark side refers to the hidden nature of virtual water which deludes decision makers and slows policy reforms. The dark side has been discussed in the context of water –scarce Egypt by Allan (2011), the argument put forth is in terms of water as a political good. Deluding the citizens about water abundance is a favorable option for politicians in the short-run even though it may create major issues, in some cases irreversible impacts, in the long-run due to delay in policy reforms.

2.2. Applications of virtual water trade flows

Yang and Zehnder (2007) identified three main applications of virtual water concept emerging from the literature; these are water availability and food security, water use efficiency, and conflict mitigation and water scarcity management (Table 1).

Table 1: Applications of VWT flows concept

Water availability and food security	Water use efficiency and economic diversification	Conflict mitigation and water scarcity management
Provides opportunity to achieve food security by importing water-intensive food products, rather than allocating their limited water resources for water-intensive food production (Wichelns, 2003).	Identify opportunities for adjusting production/ marketing activities to increase the values generated from scarce water resources (Wichelns, 2001; Wichelns, 2003)	Knowledge created from virtual water trade flows-useful in conflict resolution on shared water resources.
Role of virtual water embedded in international trade in global water savings (Hoekstra and Hung, 2002; Hoekstra, 2003; De Fraiture et al.,2004)	The concept is useful in generating ***public awareness*** on the water requirements of production and consumption process. The use of tools like virtual water and water footprint can indicate how to allocate and use water in a more sustainable and judicious manner. This knowledge creation would reduce the anthropogenic pressure on water resources and encourage sustainable production and consumption (Wichelns, 2003; Elena & Esther, 2010).	Realizing the '***limits to growth***' and ***sustainable management*** of water for conflict resolution is an important application of virtual water and water footprint analysis.
Determines the extent of dependency of nations on food imports to achieve food security (Allan, 2011) Concern: to achieve food security, food self sufficiency is compromised, it also leads to loss of employment in agriculture and quality of livelihoods. E.g. increase in agriculture subsidies in EU and USA agriculture subsidies → increased imports from EU and USA to the Nile countries → increased impacts of drought on farm employment and poverty in Egypt and Sudan (Allan,2011).	Economic diversification: a weak political economy is an unadaptive and undiversified, while a strong one is diversified, (Allan ,1997). Non agriculture sectors are more remunerative than agriculture therefore diversified economy is a way of reducing water scarcity; this is also evident from the present discussion on 'More jobs per drop' in developing and undiversified economies (Allan, 2011) E.g. Norway and Switzerland (water rich, developed, produce non –water intensive products) & Afghanistan and Malawi (water scarce, non diversified land rich, net export VW)	It is essential to constrain the internal and external water footprint to reduce the global and regional water use in order to avoid shifting the pressure (of overexploitation and inefficient water management) to other nations or regions. Inappropriate water scarcity management leads to ***environment degradation***, for instance, the developing countries exports are usually dominated by water resource intensive agriculture products and the exports of the developing country might lay increased pressure on its water resource base due to the high demand from the importing country. This has been observed in Thailand, India and Spain where the detrimental impacts are seen on the groundwater reserves as a result of exports (Van Hofwegen, 2003). The virtual water assessment is necessary as it highlights these unsustainable patterns and helps in making appropriate water scarcity management strategies.

2.3. Policy relevance:

Policy relevance in water resources management is enhanced by the persistent water scarcity despite infrastructure creation and realization about the importance of policies as signals which influence the decisions of producers and consumers and traders. Policies are useful in adoption of water efficient technologies and influence the prices of various inputs like land, water, and others. In this section the potential of the VWT flows and water footprint concepts as a policy supporting system is explored.

'The 'VWT flows' concept was intended to aid in decision on policy options that influence ***water use*** and introduce the optimal use of water resource (Allan, 2011). It is being considered as a useful decision support system to derive economical, political and environmental benefits, through identification of imbalances, and unsustainable hotspots. Both the 'VWT flows' and 'water footprint' concepts provide opportunities for efficient management of water resources (Meinzen-Dick & Bruns, 2000; Wichelns, 2004; Kumar & Singh, 2005; WWF-SDC, 2012; Rulli, 2013). Their policy relevance is enhanced as they address crucial and multifaceted development issues of national security (which includes water and food security), promotion of economic growth, employment creation and poverty reduction (Wichelns, 2001). The utility of the concepts is in the form of promoting production of those goods which are most suited to local environmental conditions as well as socio-economic conditions. The virtual water concept is specifically gaining importance in water scarce parts of the world where there is a paradigm shift as well as transition in policy focus from 'self-sufficiency' in food production to 'food imports' because of the fear of future water insecurity (Wichelns, 2009). Economy, employment and poverty are linked with the water resources as water acts as an important factor of production in livelihoods, i.e. 'source' and also a recipient of the waste, i.e. 'sink'. Realizing the importance of water footprint, the Ministry for the Environment, Government of Spain enacted a regulation to use the concept as informative tool in River Basin Management Plans. This is in accordance with the EU Water Framework Directive (Garrido, Llamas, Varela-Ortega, Novo, Rodríguez-Casado, & Aldaya, 2010).

However, Wichelns (2010) and Gawel and Berson(2011) do not consider the 'VWT flows' concept as a sufficient environmental policy indicator. This is because further research is needed on concerns like 'dependency' of a nation on food imports, possibility of integrating arable land along with water, access to secure markets to enhance the economic value water-intensive products, and the concept of opportunity cost of water resources (Wichelns, 2004;Verma, Kampman, V, & Hoekstra, 2009). It is also emphasized that sound understanding of the impacts of policies on socio-cultural, economic, and environmental conditions at the catchment and user scales are necessary for enhancing the effectiveness of the concept as a policy indicator (Allan,1997; Hoekstra, 2003).One of the most important need is that of adequate institutional arrangement to ensure that the use of the concept is not restricted to only supply-side policies but goes on to influence the consumption and trade decisions as well (Mori, 2003; Galan-del-Castillo & Velazquez, 2010).

Among the emerging economies, virtual water research has become significant in China, Brazil and India. India is an interesting case among the emerging economies as India has an important role in the global economy, being one of the BRIICS nations (Allan, 2011), and is characterized by high water use. For instance, India was the main water user in 1995 with 13% of the global water use. In 2008, India was second highest water user, with 12.2% of the global water use. Even in absolute terms of highest growth in water use, India figures as the third highest user with the water use equivalent to 332 km^3 (Arto, Andreoni, & Rueda-Cantuche, 2012). These estimates raise concerns about the water security at national and at global scale.

2.3.1. . Indian Context

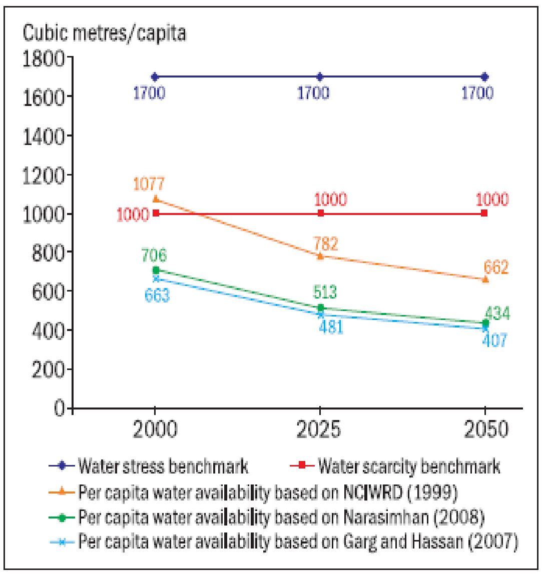

Figure 3: Per capita water availability estimates

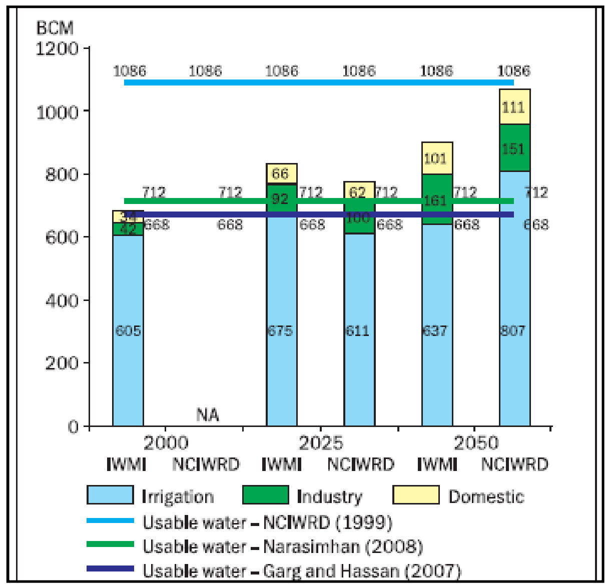

Figure 4: Usable water in comparison to water use estimates

Total water resource potential in India is 1869 km^3, this includes surface and groundwater; only about 60% of it is accessible for beneficial use. With this limited water available for use, there is a need for efficiency in water use to meet water needs of all the sectors. There are several future projections of water supply, represented as per capita water availability, the three estimates by National Commission on Integrated Water Resources Development (NCIWRD), Narasimhan, and Garg and Hassan (Figure 3) indicate that India has become water scarce, benchmarked at 1000m^3/capita/yr in early 2000's. Water scarcity will deepen resulting in water availability as low as 407 m^3/capita/yr. On the demand side, the projections of water use in agriculture, industry and for domestic purpose are depicted in Figure 4. The water use is highest in irrigation (87% of the total use) followed by industry and domestic use as per the estimates of NCIWRD and International Water Management Institute (IWMI). The usable water estimates of Garg and Hassan (2007) and of Narasimhan (2008) are very close, i.e. 668 BCM and 712 BCM, respectively. In the year 2000 the usable water levels by both the independent researchers are slightly exceeded by the cumulative water use by the three sectors. The usable water limit is only able to meet the water demands of agriculture sector in 2025; and the projections of 2050 indicate

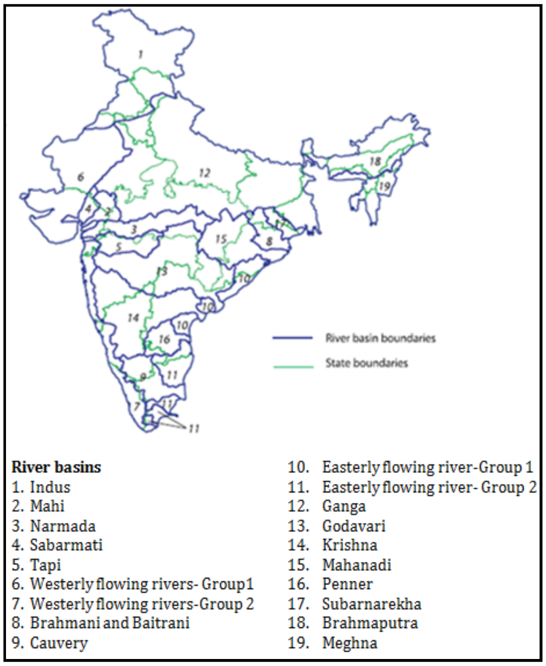

Figure5: River basins of India
Source: (Amarasinghe, Sharma, Aloysius, Scott, Smakhtin, & Fraiture, 2004)

that the usable water levels fall short of even meeting the water demands of the agriculture sector. The usable water level estimated by NCIWRD (1999) is 1086 BCM which is very close to the estimates of the cumulative water use for 2050.These estimates indicate a significant mismatch in the water supply and demand, deepening of water scarcity as the water demand exceeds water supply.

Water stress is indicated by water availability of less than 1700m^3/capita/year as per the Falkenmark physical water scarcity index, although the national average of water availability in river basins of India is 1731m^3/ capita/year indicating no water stress. Many of the river basins are water stressed and scarce, for instance, when the classified basin, Brahmaputra and Barak, is excluded the national water availability falls to 1345m^3 / capita/year (as on 1st March 2004). The basins which are water scarce (water availability < 1000m^3/ capita/year) are Cauvery, Sabarmati, East flowing rivers and West flowing rivers (see Figure 5) (Falkenmark, 1989; University of Cambridge ; CWC, 2012).

There are five main challenges faced by India which indicate an increase in water scarcity. Firstly, the water resources of India are **unevenly distributed** across regions. The uneven distribution refers to high population density, high agriculture activity, and water intensive industries where water availability is low. Secondly, groundwater is becoming the dominant source of irrigation as it is more reliable and accessible source. India is the main user of groundwater in the world, the exploitation of this reliable resource is a result of a weak institutional framework. Thirdly, 26% of the population in India is affected by desertification, land degradation and drought (DLDD) which is a concern in the context of the impacts of climate change on water resources (UNESCO). Fourth challenge is that there are also huge inefficiencies in water use in all the three sectors leading to exertion of additional stress on the water resources. High water use in agriculture is also due to low water productivity in water abundant regions (UNESCO).

Lastly, poor water quality is also a challenge for the water sector which is majorly contributed by pollution from the production processes (Government of India, 2009; Kulkarni & Thakkar, , 2012). Therefore, **'water savings'** in India would be beneficial nationally as well as globally.

I. National Water Policy

In this section the National Water Policy *(hereafter referred to as NWP)* of India is considered; as it is an important subset of the sustainable production and consumption policies. As the water and development linkage was established in the NWP, 1987 and continues to be significant, *'Water is one of the most crucial elements in developmental planning'*. There has been a transition in the NWP of India as traced in the Figure 6. The National Action Plan on Climate Change, 2008 (hereafter referred to as NAPCC) has also laid emphasis on water resources by setting the National Water Mission (NWM). The conceptual framework of 'VWT flows' figures in these policy and mission documents; this is the point of discussion of the section.

The NWPs of India has evolved with time and is intended to be more holistic and comprehensive. For instance, water is recognized as natural resource which varies with space and time. It is indivisible resource comprising rainfall, surface water and groundwater; and is scarce. There are large differences in water endowments, developments, and use at regional scale in India (Ministry of Water Resources, 1987; Ministry of Water Resources, 2002; Government of India, 2008; Ministry of Water Resources, 2012). The term ***'sustainability'*** entered in the 2002 version of NWP due to the realization of its significance globally in 1992 when Dublin Principles were framed. The importance of sustainability is also prominent in the Draft NWP, 2012 which states that water is ***'fundamental to life, livelihood, food security and sustainable development'***. For instance, in the water rich eastern and north eastern regions of India, the water use infrastructure is weak (Draft NWP, 2012)The important issues and challenges that emerged from NWP, 1987 are water stress and scarcity; development of surface water and its use in agriculture sector. In addition, NWP, 2002 also focuses on the groundwater use in agriculture. Draft NWP, 2012 highlights various challenges ranging from impacts of ***climate change***, changing lifestyles, consumption patterns, water use in economy; weak ***institutional*** framework, fragmented approach in project implementation, negligence of ***optimum utilization***, ***environment sustainability*** and holistic benefits to people, to water conflicts at various scales. Poor ***water productivity*** and ***water use efficiency*** are persistent challenges in most parts of India (NWP, 1987; NWP, 2002; NAPCC, 2008; Draft NWP, 2012). The most important goal of the NWM in the NAPCC, 2008 is of a 20% improvement in water use efficiency through price and other mechanisms to deal with water scarcity as a result of climate change.

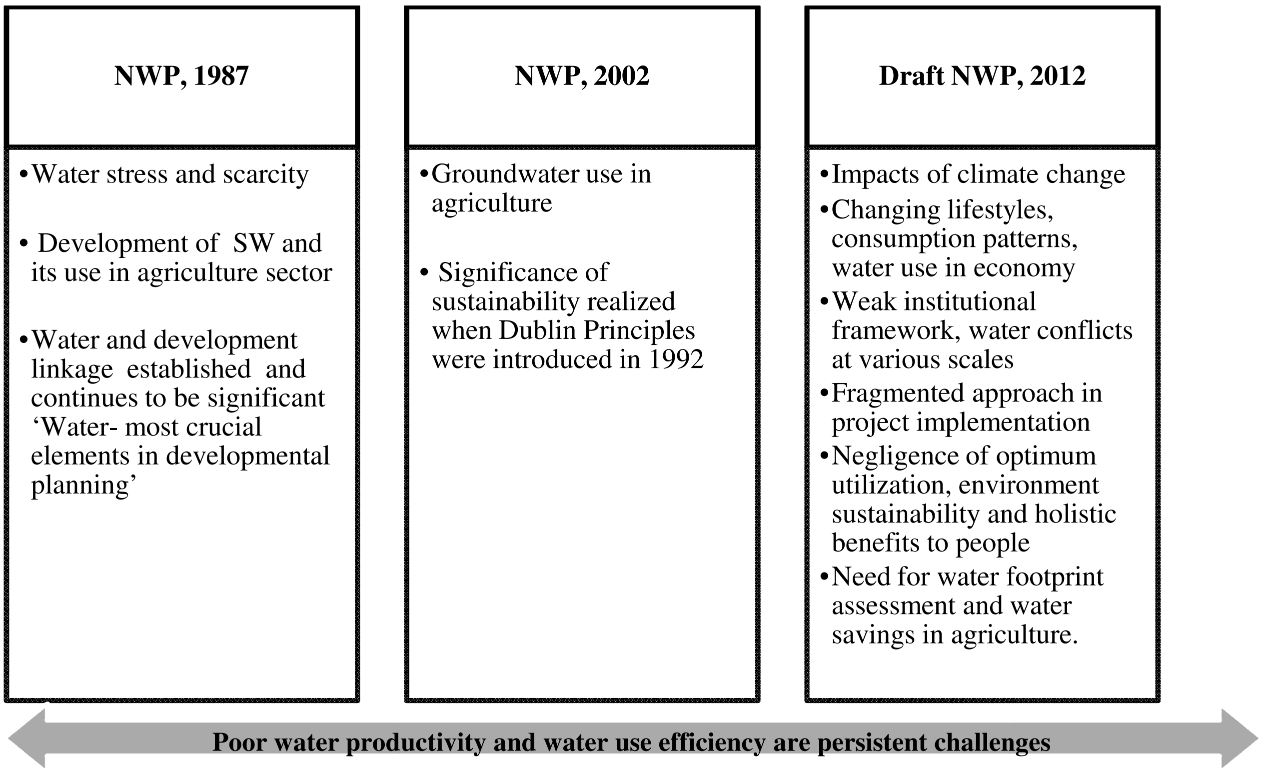

Figure 6: Transition in the National Water Policy of India to integrate the water and development linkages

The need for assessment of ***water footprints*** in India for determining the efficiency in use of water resource was mentioned in the Draft NWP, 2012. It is worth mentioning here again that Spain has integrated water footprint concept in institutional framework in 2009 (see section 2.3). India is also on the path of setting up institutional framework to recognize the importance of the water footprint concept for efficient use of scarce water resources. Another emerging concept in the policy discussions is ***water savings,*** Draft NWP, 2012 recognizes the importance of water savings in irrigation use in order to align the cropping patterns with the endowments of water resources. These transitions in the NWP to include the important concepts in virtual water research, like water productivity, water use efficiency, water footprint and water savings, provide avenues for further research on virtual water trade flows in India.

One of the major criticism of NWP pertaining to VWT flows concept is emphasis on the largest inter basin water transfers project, known as National River Linking Project (NRLP). VWT flows and inter-basin water transfers are alternative policy options for alleviating water scarcity. Inter- basin water transfers have been in the policy discussions since the NWP, 1987 with a pro-active support from the legislation (Supreme Court). The criticism from the ***'sustainability'*** dimension are the contentious issues associated with it, for instance, the social and environmental impacts of NRLP are not completely researched like the impact on the ecology and the impacts on the 'environmental flows' which is essential for environmental sustainability. Other contentions are inadequate justifications given for functionalizing NRLP; gaps in the findings of the assessments, technical and financial feasibility of the project; and incomplete exploration of options like land and water productivity improvements, and VWT flows which are more in favor of ecological conservation instead of mega infrastructure creation (Iyer, 2003; Amarasinghe, 2012). A striking feature is that water is a state subject in India and there could be increased conflicts between states regarding inter-basin water transfers through NRLP. The contentions are recognized in the Draft NWP, 2012; it is stated that *'Inter- basin transfers of water should be considered on the basis of merits of each case after evaluating the environmental, economic, and social impacts of such transfers'*. This also provides an avenue for virtual water research in the water policy of India. Further the rationales of 'VWT flows' concept, i.e., "distribution of scarcity" and "water use efficiency" are already featuring in the NWP, there integration in science and policy discussion on food security, water security, and environmental sustainability at all the scales of governance would be crucial in ensuring sustainable water use. Water is a state subject and the NWP provides the guidelines for the State Water Policy, and the NAPCC also provides it for the State Action Plan on Climate Change. These are discussed in the subsequent sub-section.

II. **State water policy**

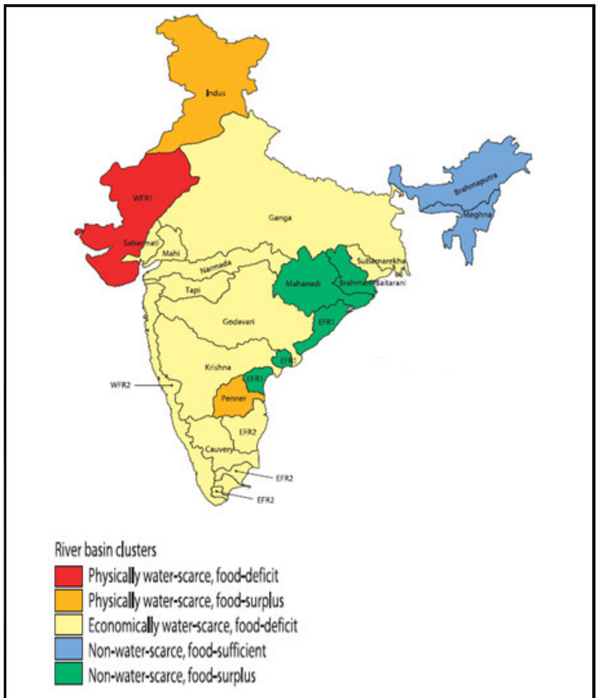

Figure 7: Water scarcity and food scarcity in river basins of India
Source: (Amarasinghe, Sharma, Aloysius, Scott, Smakhtin, & Fraiture, 2004)

Barely nine states of India have developed State Water Policy (*hereafter* SWP), and three have developed Drafts of State Water Policies (*hereafter* Draft SWP) to address the issues of water scarcity and food scarcity since 1994 (Table 2). Orissa was the first state to frame a SWP. The impetus to frame a SWP was given by the NWP, 2002, as it suggested to the States to frame SWP within a time period of 2 years. Proactive states of India in water management like Karnataka, Maharashtra, Himachal Pradesh and Madhya Pradesh developed their SWP in between 2002 and 2005. Orissa, Andhra Pradesh, Kerala and Rajasthan also developed their SWP in between 2007 and 2010 Table 2 . Interestingly, most of the states which have developed the SWP are situated majorly in Ganga, Godavari and Indus river basin; both Ganga and Godavari are economically and Indus is physically water scarce. Ganga and Godavari river basins are also food deficit while Indus is food surplus (Figure7).

Both water scarcity and food scarcity drive the development and evolution of institutional norms at state level. The water rich eastern state of Orissa and north eastern states Assam and Meghalaya have also developed the SWP and Draft SWP (Figure 7 and Table 2). The persistent issues encompassing the institutional framework on water resource use in India at the regional scale are poor adoption and implementation of the water policies.

Table 2: States with State water policy and Draft State Water Policy

S.No.	**States**	State Water Policy (SWP) and Draft State Water Policy (Draft SWP), [Year]	State Action Plan on Climate Change (SAPCC) endorsed by the steering committee/ Draft State Action Plan on Climate Change (Draft SAPCC), considered by the expert committee [Year]
1.	Andhra Pradesh	SWP [2008]	SAPCC [2011]
2.	Arunachal Pradesh		SAPCC [2011]
3.	Assam	Draft SWP [2007]	Draft SAPCC 2012-2017 [2011]
4.	Himachal Pradesh	SWP [2005]	
5.	Karnataka	SWP [2002]	
6.	Kerala	SWP [2008]	
7.	Madhya Pradesh	SWP [2005]	SAPCC [2011]
8.	Maharashtra	SWP [2003]	
9.	Manipur		SAPCC [2013]
10.	Meghalaya	Draft SWP [2011]	Draft SAPCC [2011]
11.	Mizoram		Draft SAPCC 2010-15[2011]
12.	Orissa	SWP [1994; 2007]	Draft SAPCC [2011]
13.	Punjab	Draft SWP [2008]	
14.	Rajasthan	SWP [2010]	SAPCC [2010]
15.	Sikkim		SAPCC [2011]
16.	Tripura		SAPCC
17.	Uttar Pradesh	SWP [1999]	
18.	West Bengal		SAPCC

Source: Compiled from Amarasinghe, Sharma, Aloysius, Scott, Smakhtin, & Fraiture, 2004; and IELRC; MoEF http://moef.nic.in/ccd-sapcc

As the impact of climate change is being realized some of the states have been pro-active in developing the State Action Plan on Climate Change (SAPCC) endorsed by the steering committee or is being considered by the expert committee (Table 2). In order to mainstream water resources in sustainable production and consumption policies, the State Water Mission of the SAPCC is important. There are only three states which have a SWP as well as a SAPCC, indicating a relatively stronger institutional framework for governance of water resources to cope with water scarcity with the impacts of climate change at present.

Conclusion and future work

The discussion on the 'VWT' flows concept reveals its utility in introducing sustainability in water use. The concept is at the interface of environment, economy and policy discussions. The findings of the paper suggest that the concept is being internalized in the water policy discussions as it provides a helpful perspective for policies in water scarce areas. The 'VWT flows' concept is suitable for developing countries like India which are approaching water scarcity and face impacts of climate change on water resources. The concept is crucial as it aid in resolving issues associated with water availability and food security; water use efficiency; and conflict mitigation and water scarcity management.

The policy relevance of the VWT concept is evolving as it addresses the crucial and multifaceted development issues of food, water and energy securities, economic growth, employment creation, and poverty reduction. However, the policy relevance of the concept can be further enhanced by addressing concerns of dependency of a nation on food imports, integration of arable land, access to secure markets, and opportunity cost. The discussion emphasizes that there is a need for an institutional arrangement to enhance the effective use of the concept in policies other than the supply-side policies.

India is an interesting case for 'VWT flows' assessment because of its important role in the global economy and highest water use in the world. There is also an impetus from the National Water Policy and the National Water Mission, National Action Plan on Climate Change (NAPCC) for research on virtual water. The pro-active states of India have framed both the State Water Policy and State Action Plan on Climate Change; these are Andhra Pradesh, Madhya Pradesh and Rajasthan.

The review also emphasizes the need for future research on the quantitative assessment of the VWT flows to bridge the science and policy gap as well as identify sustainable use benchmarks. There is an initiation of discussion on the water footprint and virtual water strategy for India to identify the sustainable benchmarks. Further the discussion on virtual water in the context of India revolves around the large differences in the quantitative estimates of virtual water for IndiaThis indicates that for a diverse country like India average value of the virtual water trade flows need further research at a sub-national level.therefore, the future work that is proposed is carrying out of environmental input-output analysis using water as an input in the economy and wastewater as an output along with economic goods and services. The strength of input-output models lays in the ability to link inter-sectoral relationships. With the increase in water scarcity and interregional trade of goods and services it becomes necessary to account the sectoral interdependence. The input-output analysis is well established technique for the environmental studies and is being used for the water resources sustainability assessment. Furthermore, the methodology is able to capture the aspects like poor institutional arrangements, infrastructure, primitive technologies and adverse impacts of price fluctuations which are prominent on developing countries.

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