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Water Policy Research

Highlight

Virtual Water in Global Food and Water Policy Making:
Is there a Need for Rethinking?

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and
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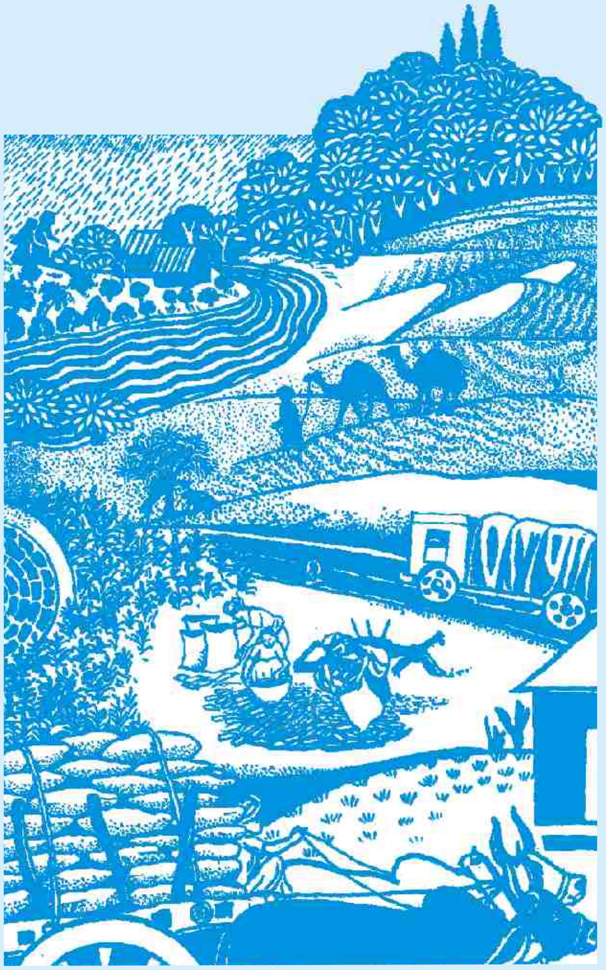

Analysis of country level data on renewable freshwater availability and net virtual water trade shows that a country's virtual water trade is not determined by its water situation, but by access to arable land. Virtual water trade increases with increase in gross cropped area. Many of the humid, water-rich countries will not be in a position to produce surplus food and feed water scarce nations. In fact virtual water often flows out of water-poor, land-rich countries to land-poor, water-rich countries. This means that the goals of "distribution of scarcity" and "global water use efficiency" are difficult to achieve through virtual water trade.

VIRTUAL WATER IN GLOBAL FOOD AND WATER POLICY MAKING: IS THERE A NEED FOR RETHINKING?[1]

RESEARCH HIGHLIGHT BASED ON A PAPER WITH THE SAME TITLE

GLOBAL WATER SCARCITY AND VIRTUAL WATER

The concept of "virtual water" was introduced in 1993 by Prof. Tony Allen as a powerful economic tool to ameliorate water scarcity problems of national economies. Later on several researchers argued on similar lines that water-scarce regions can achieve high global water use efficiency by importing products that have high virtual water content embedded in and exporting products that have very low water content. The argument has become dominant in the discussions on ways of facing global water challenges.

The rationale of "global water use efficiency" and "distribution of scarcity" in virtual water trade is based on the assumption that all the humid, water-rich countries are at an advantage in economic terms in producing foodgrains as compared to arid and semi-arid countries; and that the comparative advantage essentially comes from more favourable climatic conditions that reduce evapo-transpiration, and availability of water as the "free good" in the form of soil moisture. It is true that when a crop which has high embedded water is grown in a humid, water-rich country and traded with an arid or semi-arid country in return for a crop which has high economic efficiency (in Rs/m^3), there would be a "net water gain" for the water scarce country as virtual water flows out of the water-rich country. But the operational aspect of this concept needs to be looked into. Such an analysis would go far beyond mere agro-climatic variations and comparative water advantages, which scholars have already considered.

OBJECTIVES

The study involved analyses of linkage between virtual water trade and 1] renewable water availability; 2] agricultural water withdrawal; 3] net and gross cultivated land; 4] net and gross irrigated area; 5] gross domestic product; 6] human development index; and 7] per capita income in different countries. We ran regressions taking parameters such as agricultural land, gross cultivated land, gross irrigated land, per capita gross domestic product, and human development index as independent variables jointly or separately, against virtual water trade (dependent variable). The study also analyzed the linkage between cultivated land and apparent and effective agricultural water withdrawal (dependent variable); and "water richness" and access to agricultural land. The analyses were carried out using country level data on the above figures deduced for population unit. Here, countries having per capita renewable water availability exceeding 1700 m^3/annum are treated as "water-rich" and those having less than this are treated as "water scarce".

DOES RENEWABLE WATER AVAILABILITY INFLUENCE VIRTUAL WATER TRADE?

We started with the assumption that a country, which is rich in water resources in terms of per capita renewable water, would tend to produce food much in excess of its own domestic requirements and export to countries that face water deficits. The per capita renewable water availability ranged from 10.4m^3/annum in Kuwait

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to 481806 m^3/annum in Surinam. Out of the 131 countries, nine fall in the absolute water scarce category, four in the water scarce category, and 14 in the water stressed category. The rest 104 countries are water abundant according to Falkenmark's index of physical water scarcity.

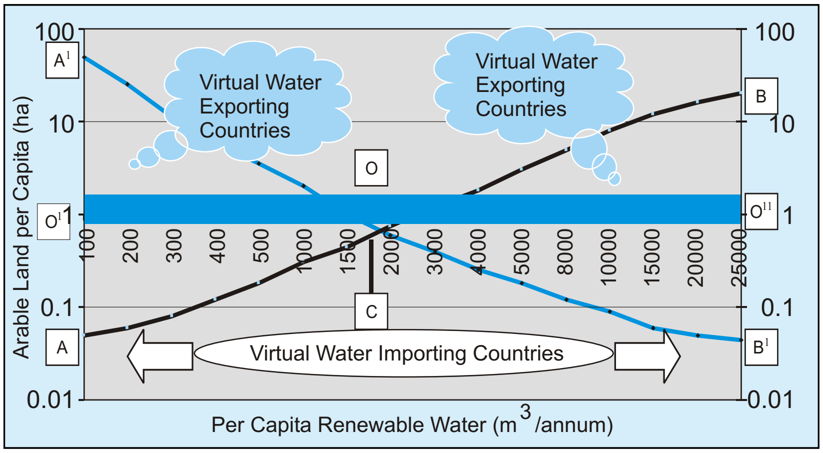
No correlation exists between relative water availability in country and virtual water trade. At least 65 water-rich countries resort to extensive food imports and have trade deficit in virtual water. The trade deficit ranges from 4.9m^3/capita/annum to 838m^3/capita/annum. On the contrary, there are several countries on the verge of approaching the water stress mark with renewable water availability below 3000 m^3/capita/annum that export foodgrains, livestock, poultry and livestock products.

The very fact that virtual water flows out of a relatively water scarce semi-arid country to a cold and humid country indicates that the goals of improved global water use efficiency and distribution of scarcity does not get realized through virtual water trade as it happens today in the global context. This does not mean that water availability does not act as a variable in the food production function in a country. It only means that total water sufficiency does not necessarily mean food self-sufficiency.

Figure 1 shows countries according per capita renewable water vs per capita arable land for a group of countries. The ideal situation is when per capita water availability is reasonably high to take care of food production requirements and sufficient arable land is available to use up the available water resources. This is shown by the point O in the graph, which is at the intersection of line AB and line A^1B^1. Now there could be several countries that have both low per capita renewable water and arable land (zone AO^1OC). They would have to resort to virtual water import. On the other hand, many countries will have more than the minimum per capita renewable water and arable land (zone BOO^{11}). These countries should be able to produce excess food and hence have a virtual water trade surplus.

Now there could be some countries which have very low per capita water availability but high arable land (zone A^1OO^1). They would also be in a position to produce surplus food irrespective of water deficit. This is because they could harness the soil moisture, a factor which is not considered in the assessment of country water deficits. The amount of water accounted for by soil moisture would increase with rise in per capita arable land. Exceptions are countries which have extreme climates, especially deserts. Such countries will have to resort to food import. They would fall in zone $O^{11}OCB^1$ in Figure 1. This is why no clear relationship exists between renewable water availability and virtual water trade. In a nutshell, most of the countries satisfy conditions that are more favourable for food imports. The line O^1O^{11} will be rather thick owing to the fact that quite a few countries with varying degree of per capita arable land and per capita renewable water resources would have trade balance in virtual water.

Figure 1: Renewable Water, Arable Land and Virtual Water Export



Does Arable Land Availability Control Virtual Water Trade Dynamic?

Our second assumption is that availability of arable land would be an important factor influencing the amount of water that countries would draw from man-made water resource systems and soil profile, provided they have sufficient water resources. If these assumptions are valid, access to arable land will be an important factor that would draw the contours of global food trade and hence define virtual water flow directions. But, in reality how far availability of arable land influences virtual water trade would depend on the relative positioning of different countries with respect to: 1] effective renewable water resources including soil moisture and 2] climatic conditions, mainly effective rainfall and potential evapo-transpiration.

Analysis shows that with increase in per capita gross cultivated land or net cultivated land, there is an increased possibility for a country to have surplus in virtual water trade.

Regression analyses carried out separately for analyzing the effect of: 1] net cultivated land; 2] gross cultivated land; 3] agricultural water withdrawal (blue water); 4] gross irrigation; 5] agricultural land, agricultural water withdrawal and gross irrigation; and 6] agricultural land and gross irrigation on virtual water trade show that none of the parameters as adequately explains virtual water trade of a country as the gross cropped area. Per capita gross agricultural land explains virtual water trade to an extent of 40.3 percent at one per cent level of significance. The second parameter which explained virtual water trade was net cultivated land in which case the R^2 was 0.40. The analyses showed that with increase in either per capita gross cultivated land or net cultivated land, there was increased possibility for a country to have surplus in virtual water trade.

The regression equation is estimated as follows:

$$Y = -18827 + 144.756 X$$

where Y = virtual water export (in m^3/capita/annum) and X = per capita gross cultivated land (in ha).

It is clear from the equation that a country's virtual water trade deficit will reduce by 144.756 m^3/capita/annum if the per capita gross agricultural land increases by one hectare, provided other factors that explain virtual water trade magnitude remain the same.

Many relatively water-rich countries, some of them extremely water-rich having very low per capita gross cultivated land, have significant virtual water trade deficits. Many countries having high per capita gross agricultural land have recorded virtual water trade surpluses. Some of these countries rank high in virtual water exports and are also water-rich (Canada and USA). But they use only a small fraction of their "blue water". A major share of their agricultural water use should be coming from soil moisture, which is determined by the area under crops.

There are several other variables that could influence the magnitude of virtual water trade, agro-climate being the most important among them. Variations in virtual water export of different countries with per capita gross cropped land (logarithmic values) are given in Figure 2. It is evident that there are only a few countries that have high per capita land availability, but they still import food. This could be because of the extreme climatic conditions prevailing in these countries, which act as negative externalities for crop production, poor adoption of crop technologies, and higher levels of consumption of meat and meat products that are higher up in the food chain.

The reason for this strong correlation between cultivated land and virtual water trade is increased ability to tap the water in the soil profile with increase in arable land. Also, increased per capita agricultural land increases the ability to utilize the harnessed water resources. The increased agricultural water withdrawal thus made leads to more virtual water trade. We ran the regression between gross cultivated land and effective

Figure 2: Gross Cropped Land Vs Virtual Water Export

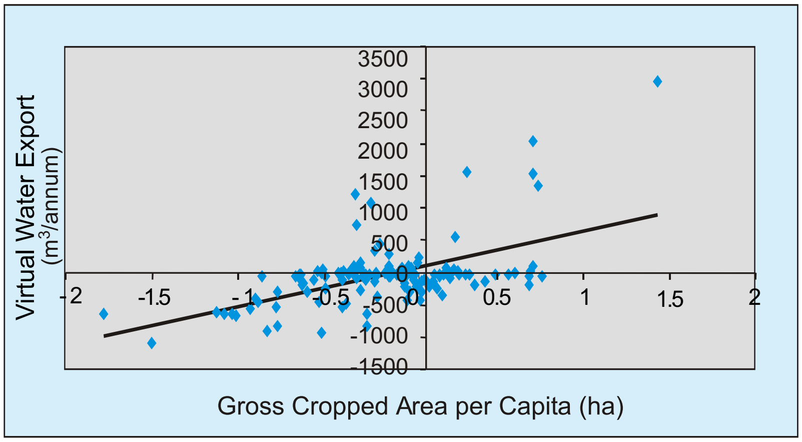
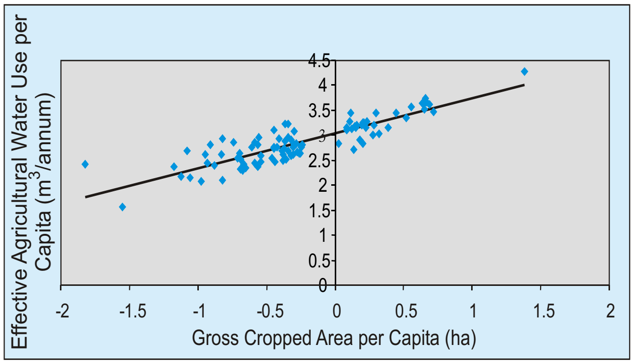


Figure 3: Gross Cropped Area Vs Effective Agricultural Water Use



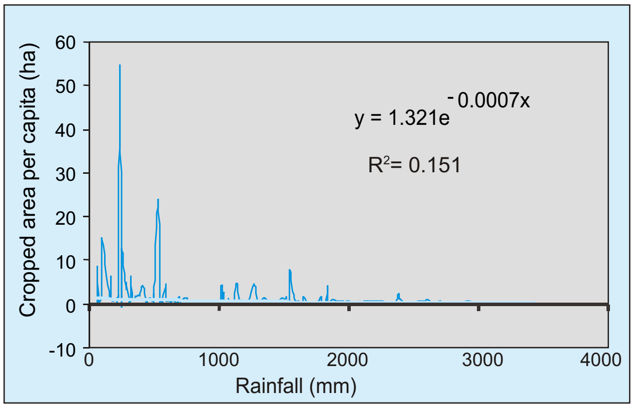
agricultural water use which included use of soil moisture from cultivated land. In fact, for many water scarce countries which are rich in arable land, soil moisture use is a significant component of the total water use for agriculture. The analysis showed a strong correlation. Gross cultivated land explained 94.6 percent of variation in effective agricultural water use ($R^2 = 0.946$) at 1 percent level of significance.

Effective Water Use in Agriculture (WUA) = 296.42 + 787* Gross Cultivated Land

Variation in effective water withdrawal with gross cultivated land (logarithmic values) is given in Figure 3. In the sample we have chosen for the analyses, only Australia has more than 5 ha of per capita arable land. But it was felt that Australia would be extremely important because of the extent of virtual water export it does annually.

There is a remarkably high level of correlation between gross cropped area and effective water withdrawal for agriculture, especially when we consider the following two facts: 1] irrigation has very little impact in terms of expanding the cropped area for many countries as only a small fraction of the cultivated land is under irrigation in most of the countries; and 2] there are major climatic factors that affect irrigation water withdrawal for a unit of irrigated land and they may vary across the 131 countries considered randomly. Therefore, one can assume that to a great extent agricultural land influences blue water use and water availability does not.

Figure 4: Water Richness Vs Access to Arable Land



IS THERE A LINK BETWEEN ACCESS TO ARABLE LAND AND WATER RICHNESS?

We did further analysis to investigate the strong direct relationship between agricultural water withdrawal and cropped area. The analysis showed an inverse exponential relationship between magnitude of rainfall and per capita agricultural land (Figure 4). Rainfall explained access to agricultural land in per capita terms to the extent of 15.1 percent ($R^2 = 0.151$). This only meant that there is a great probability for countries with larger per capita arable land to have poor rainfall conditions and vice versa. For example, even if this relationship is assumed to be robust, it would mean that a 100 mm increase in rainfall reduces per capita land availability by 0.092 ha. In fact, many countries with large per capita cropped areas had very low rainfalls, though several countries with smaller per capita cropped area are low rainfall countries. The per capita crop land in Australia is 24.02 ha while the mean annual rainfall in this largely drought-prone country is only 534 mm.

Such sharp differences in the availability of arable land between high and low rainfall regions in per capita terms could be partly explained by the historical movement of populations to regions endowed with better water resources over centuries. Low rainfall areas also experience droughts. Due to these factors, dependence on water in the soil profile and irrigation increases. Also, with widespread use of electrical and mechanical pumps over the past 100 years worldwide, rate of groundwater utilization has become unprecedented. When drought hits, dependence on groundwater increases to stabilize crop yields. Hence, effective water withdrawal is higher in regions with larger cropped area.

IS THERE A NEED FOR A RETHINKING ON GLOBAL FOOD AND WATER SECURITY?

The proponents of virtual water concept have tried to relate food self-sufficiency to "total water sufficiency" ("total water sufficiency" refers to the amount of water needed to produce the crops for consumption). Our analysis shows that "total water sufficiency" alone does not guarantee food self-sufficiency, but access to arable land would, except under extreme climatic conditions. It does not contradict the received wisdom that a minimum amount of water would be needed to meet the food production need, but suggests that the assessment of "minimum water availability" should also include water in the soil profile and therefore, the per capita arable land also should be factored in while assessing water sufficiency.

Our analysis shows that "total water sufficiency" alone does not guarantee food self-sufficiency, but access to arable land would, except under extreme climatic conditions.

There is a need to recognize the fact that many countries import food not because they lack "total water sufficiency", but because they do not have sufficient arable land to be put to cultivation. What matters more is how much land is available for utilizing that water for crop production.

Assessing water management challenges faced by nations purely from the point of view of renewable water availability and aggregate demands will be dangerous, because such an analysis would often end up suggesting allocation of available water to economically more efficient uses than agriculture when demand exceeds supply. Access to water in the soil profile, which is determined by access to arable land, would be an important determinant of effective water availability for food production.

These two arguments have major policy implications for water-scarce countries that are characterized by regional variations in water endowments. For this, we consider a food importing country. China, Southern African Development Community (SADC) countries, and Spain are some of the countries in the world that are characterized by major variations in water endowments within the country, and rely on food imports. From food self-sufficiency point of view, it might make sense for the country to transfer water from the "water-rich" region to the "water scarce region" even if it is at the cost of bringing down the net renewable water of the "water-rich" region below the acceptable levels defined by "total water sufficiency". This is because of two reasons: 1] water in the soil profile, which is not considered in assessing renewable water availability, would still be available; 2] water sufficiency for food production directly relates to availability of arable land, and water rich regions lack sufficient amount of arable land to utilize the water. Water transfer would increase utilization of water resources for crop production at the national level. With increased water availability for irrigation, area under cultivation might also go up significantly resulting from increased land use intensity. At the same time, the agricultural production potential in the water-rich region would remain unaffected.

If it is so, it could be advanced as a counter-argument against those who oppose inter-basin water transfer projects on the ground that they could deprive water-rich areas of their share of renewable water and therefore livelihoods. These projects would not merely attempt to reduce the major regional variations in natural water endowments; but would also address the issues of untapped potential of water for crop production and other economic activities, and the demand-supply balance.

Major water transfer projects will achieve the twin goals of improving the productivity of land in water scarce regions and equalizing "water richness".

For example, in India, the southern peninsula has vast amount of arable land that could be brought to intensive cultivation if water is provided. Similarly, northern Chinese provinces that are now facing severe water shortage have been practicing intensive irrigated agriculture. Major water transfer projects will achieve the twin goals of improving the productivity of land in water scarce regions and equalizing "water richness". It has been established that irrigation water use efficiencies in arid and semi-arid, water scarce regions are much higher than that in humid, water-rich regions. All these arguments build a strong case for physical water transfer.

We will now show that regional virtual water trade (both intra-national and inter-national) from the perspective of global water use efficiency and scarcity distribution will be of little practical relevance. It is revealing that many water-rich regions still remain importers of food, and naturally water scarce, semi-arid regions feed them. Bihar, a water-rich state in India in terms of per capita water availability, has been an importer of foodgrain for quite some time. The naturally water-scarce, semi-arid, and arid regions such as Indian and Pakistan Punjab and peninsular India are agriculturally more prosperous indicated by high productivity, primarily through irrigation, whereas the water-rich, semi-humid regions of eastern India have remained agriculturally backward. It has already been established that the "factor productivity of irrigation" has been high for all regions of India than the eastern parts. Another important reason for the food deficit of Bihar is the small per capita landholding of the order of 0.092 ha, which combined with agronomic factors limits the scope of using abundant water resources within the region.

This does not mean that water deficit regions should only embark on water transfer projects. Wherever possibilities exist virtual water trade should be encouraged. But for a region, which is well-endowed with good arable land, it would be the natural choice to bring in water from a water-rich region to improve the efficiency of use of land and water. But, this does not mean that on-farm water use efficiency can be ignored. In fact, physical efficiency of irrigation water use is extremely low in Third World countries resulting from absence of proper pricing leading to reduced water productivity.

POLICY IMPLICATIONS

The virtual water trade argument, to an extent, has influenced regional debates on setting policy priorities to deal with water shortages for food production that are likely to occur in future in the context of South Asia, some of the states of SADC, and China. Our analyses show that, while "global water use efficiency" and availability of blue water for food production could be important concerns that influence national water policies of water-poor nations, they cannot be the decisive factors. Availability of arable land and degree of dependence of a country on water for economic growth and its population for livelihood are important considerations.

Goals of "distribution of scarcity" and "global water use efficiency" are difficult to achieve through virtual water trade.

Regional virtual water (food) trade from a global water use efficiency perspective will have limited relevance. But, this constraint can be converted into an opportunity provided we change the rationale for virtual water trade from "water use efficiency" and "distribution of scarcity" to "land use efficiency"; adopt "productivity potential of water" as the water management goal, and consider regional water transport as a technically feasible option. The idea is to physically transfer water to naturally water scarce regions; put it to use; and then transfer foodgrains produced to "water-rich" and "land-poor" regions. The volume of virtual water embedded in food export can be treated as an exchange for taking water out of surplus areas. This will help avert any inter-state conflicts that could result from decisions to transfer water from water-rich states.

Another important merit in such transfer arrangements is that water-scarce regions that are used to intensive use of their endogenous water for livelihoods will continue to have their irrigation-based livelihoods, an important concern in virtual water trade. Massive transfer of water to these water-starved regions and its subsequent use for irrigation would also induce groundwater recharge. The impact will be double: first, water transfer will reduce groundwater pumping, and the return flows from irrigation would increase recharge thereby reducing the stress on groundwater.

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IWMI-Tata Water Policy Program

The IWMI-Tata Water Policy Program was launched in 2000 with the support of Sir Ratan Tata Trust, Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations.

Through this program, IWMI collaborates with a range of partners across India to identify, analyse and document relevant water-management approaches and current practices. These practices are assessed and synthesised for maximum policy impact in the series on Water Policy Research Highlights and IWMI-Tata Comments.

The policy program's website promotes the exchange of knowledge on water-resources management, within the research community and between researchers and policy makers in India.

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