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THE ROLE OF SCIENCE AND TECHNOLOGY IN THE SOFT PATH TO SOLVING CONFLICTS OVER WATER

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Abstract.

Today most water resources experts admit that water conflicts are not caused by the physical scarcity of water. They are mainly due to poor water management. However, scientific and technological advances that ocurred in the last fifty years open new paths to solving many water related conflicts, often with tools that a few decades ago seemed unthinkable. Four of them are discussed in this paper: a) salt water desalination; b) the concept of virtual water (i.e. food trade on a global scale due to low transport costs); c) the "silent revolution" in most arid and semiarid countries due to the low cost and ease in groundwater abstraction; d) how the use of remote sensing and GIS has allowed greater transparency and information on land use change and the corresponding water uses, coupled with the impact of the Internet can open up water governance to the public at large through participation and education. Together these advances are changing the concepts of water and food security that have been predominant during centuries in the minds of most water decision-makers.

Key-words: blue water, green water, virtual water, desalination, intensive use of groundwater, water footprint, water conflicts, remote sensing, GIS and Internet in water governance.

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1. Introduction

This paper aims to discuss how recent advances in science and technology and new concepts can shift our perceptions on the ‘looming water crisis’ repeatedly forecasted in the media and in academic circles. It tries to offer alternatives to doom and gloom scenarios by looking at facts on water use globally, and in particular by looking at cheap and feasible options which currently exist to address this water crisis.

This paper emphasizes that the current crisis is less due to water scarcity than to a crisis in water governance and management. Thus the solutions have to be found elsewhere. It proposes a shift away from pure technological fixes, predominant in the past or so called the hard path, which relied mainly on the construction of infrastructure like dams, pipelines or aqueducts (Wolff and Gleick 2002; Gleick 2003) towards a soft path in water governance.

As Gleick (2003) emphasizes: *A transition is underway to a "soft path" that complements centralized physical infrastructure with lower cost community-scale systems, decentralized and open decision-making, water markets and equitable pricing, application of efficient technology, and environmental protection*

The scope of this paper is to focus on four concrete and key options to address this water ‘crisis’, which are cheap, feasible and most important, already available; first, it looks at water use globally and, in particular the potential offered by yellow water or desalination, second, it looks at the silent revolution of groundwater use, third, it emphasizes the key strategic relevance –of virtual water particularly for arid countries and a country’s water footprint, and finally- although briefly- the potential of new technologies from the information age, like remote sensing, GIS and internet.

As a case study it focuses mostly on Spain because of the interesting lessons that this country can offer to other countries and regions in the world. This is for a number of reasons; first. Spain is now part of the European Union, and has a developed economy- yet only 50 years ago it was a relatively isolated country, with a predominantly rural economy. Spain therefore offers an interesting example to developing countries due to its recent economic transformation. Second, Spain is mainly an semiarid country, and other countries can learn from its both positive and negative experiences in relation to water governance.

The paper also focuses mainly in the agricultural sector, since irrigation is the main water user globally, accounting for more than 80% of the global water budget. Therefore, if we address key questions in relation to water use by irrigation, by definition we will be focusing on 80% of the world's water use. Any advances made in irrigation will translate in gains by other sectors – which often have higher economic returns or added value like industry, public water supply and sanitation or environmental services- which at present are not benefiting globally from water captured by irrigation.

There is increased agreement globally that the water crisis is not due to water scarcity but is a crisis of governance. The last UN report on Human Development clearly states this point of view (United Nations, 2006). This change in perception offers new opportunities in how to address this governance crisis. This paper revisits traditional concepts of water and food security by looking at new concepts and ideas, and how these are helping to re-shape old water paradigms. It particular it discusses the different water aspects, the opportunities provided by virtual water and its potential impact on softening the physical water scarcity of humanity at the global, regional and local level.

Traditionally, water played a key role throughout history in helping communities settle geographically, allowing civilization to develop from largely nomadic tribes towards communities centered on cities. This started, through water infrastructure for irrigation developed in Egypt and Mesopotamia, through to Roman aqueducts for public water supply, to canals for transport of goods and more recently for industrial development and hydroelectric power.

These first civilizations have been known as 'hydraulic civilizations' (Wittfogel 1957). These civilizations were born in the valleys of arid areas about 50 or 60 centuries ago. In these valleys hunter and gathering societies settled into the land thanks to small irrigation infrastructure that could guarantee the regularity of crops.

This required a collective effort, which facilitated the settlement of tribes, and led to the creation of 'civis' or small urban centers. This tradition of collective effort for the creation and operation of water infrastructure has continued. These so called 'hydraulic societies' relied heavily on 'hard infrastructure' and often economies of scale to re-organize land use planning, whilst facilitating the strengthening of the central state as funder and coordinator of infrastructure. With few exceptions, most of the large water infrastructure built in the last 100 yeas has been due to collective action on the part of the state, funded and controlled by the state administration.

However, this 'hard' path to water is now under duress and increasingly an alternative 'softer' path to water is being advocated. It partly coincides with the shift from government to governance and the fact that water policy is highly complex. To address water issues in the 21st century, the government alone will be unable to deliver. In the shift from government to governance, new power dynamics are being re-drawn and new concepts being developed to re-structure our understanding of the problem.

Old paradigms, based on the predominance of hydraulic societies, remain set in their obsession with both *water* and *food security*, and the key role of the central states in providing these, as a way of legitimizing their power vis-a-vis their citizens. Yet, the concept of water and food security are being re-defined by the concept of environmental security (Tuchman Mathews 1989), which by definition it is not state centered and rather turns on networks of governance, not the dominance of the sovereign state. The notion of environmental security challenges the foundations of water and food security, because in contrast to food and water security, it is inherently accepting that environmental problems know no frontiers and therefore solutions have to be global. This shift to water governance will be exemplified below by reference to aspects of water.

2. The different aspects of water

The basic functioning of the hydrological cycle is well known, and its quantitative evaluation calculated about forty years ago. In summary, total rainfall on land is calculated at 115,000 Mm^3, of which 45,000 make up the flow of rivers and aquifers, and 70,000 Mm^3 evaporate from soil or evapotranspirate from vegetation (United Nations 2003, pp 77 and 84)

Blue Water

Blue water is the water in the hydrological cycle from surface water runoff or groundwater recharge. It is also the part of the hydrological cycle that humans have used beneficially for their own use through the construction of water infrastructure, like canals and reservoirs . More recently blue water has also included the spectacular rise in the use of groundwater. According to the United Nations, the amount of water used for irrigation is about 2,000 to 2,500 Mm^3, to irrigate 250 million hectares. Shah (2005) estimates that out of the 2,000 to 2,500 Mm^3 of water used, 800 Mm^3 come from groundwater. In terms of efficiency of water use, irrigation - when efficient - is the prime example of a consumptive use, since 80-90% of water evapotranspirates. Yet, in most traditional irrigation (e.g. flood irrigation) water use efficiency is normally lower than 50%. Meanwhile in urban use, it is calculated that at least 20% is lost through leaky pipes. However, what increasingly has to be taken into account when discussing ‘blue’ water is the fact that there is a range of shades of blue, from pale blue of drinking water to dark blue of water polluted by sewage or industrial use. However, in theory water, if treated, is a renewable resource and will return to the water cycle.

Green Water

Two decades ago the term ‘green’ water started to be used. Green water is the name given to soil water. It is the water in the soil that allows the growth and development of natural vegetation (forests, pasture lands, tundra, bush land,…) as well as rain-fed agriculture. This water evaporates directly from the soil or through evapotranspiration from vegetation. Soil water has only recently started to be taken into account quantitatively, its measurement and monetary valuation is still highly complex. It is calculated at 70,000 Mm^3/year, of which about 3,000 to 4,000 Mm^3 are used by rain-fed agriculture. In most water and agricultural statistics green water is not included. This is the case of the FAO-AQUASTAT (FAO 2003), which only refers to blue water, even when in many countries – particularly in the developing world- most crops are rain-fed. Its analysis has led to the concept (discussed below) of water footprint.

3. The silent revolution: the intensive use of groundwater

Groundwater use until relatively recently was only undertaken on a small scale, with basic technology, generating low flows and irrigating small areas to supply small villages and urban centers, organized by small collectivities or individuals. Groundwater’s origin, location and movement were shrouded in secrecy, with little realization of cause and effect. This has changed dramatically in the last 50 years, mainly due to technological advances, like well drilling and the invention of the multistage or turbine pump. These have substantially reduced the cost and difficulty in accessing groundwater, which has led to a spectacular rise in intensive groundwater use (Llamas and Martinez-Santos, 2005b). In the last 50 years in practically all arid or semi-arid regions across the world, from California, to a large part of India, or Spain and Mexico, a silent revolution has taken place through the intensive use of groundwater (Llamas and Custodio 2003; Fornés et al. 2005a; Llamas and Martínez-Santos 2005b). It is called a revolution because it has led to dramatic changes in water use and food policy in these regions. It is also called ‘silent’ because it has been mainly undertaken by millions of small farmers, with little control and planning on the part of the government administration (Fornés et al. 2005; Llamas and Martínez-Santos 2005b; Llamas 2006b) The most spectacular example globally is the case of India, where population has more than doubled in the last 40 years, from 600 million to 1,100 million, and it has changed from being a net importer of cereals to becoming an important exporter in the global trade of cereals. This has been achieved mainly through the abstraction of 200 Mm^3/yr, from about 20 million wells to irrigate 60% of land, about 50 million hectares (Shah 2005). . In a recent report of the World Bank this situation has been described as a ‘quiet revolution’ (Briscoe 2005). These efforts have been mainly undertaken and financed by small farmers or small municipalities, and the pattern extends to most of South East Asia, including Pakistan and Bangladesh (Shah et al. 2006).

It is such a new social and technological phenomenon, that it is largely ignored or misunderstood by most international organizations that deal with water issues. More recently, groundwater has been raising in status in the global water agenda, first featuring in the 3rd World Water Forum in Osaka (18th march 2003), and in the World Water Week in Marseilles (March 2005), and more recently the World Water Forum in Mexico (March 2006) . The fact that the use of groundwater is so economically salient, yet politically difficult to address has led to some serious unintended consequences due to lack of groundwater planning and control. The monitoring of groundwater use globally has been minimal, with most government and water agencies taking little or no action to assess and control groundwater use. This attitude, which has tended to ignore or disregard groundwater use in water planning has been called ‘hydroschizophrenia’, where groundwater management was considered as totally separate from surface water, thus practically ignoring the concept of the hydrological cycle. The dominant view therefore extended amongst the majority of the public is the ‘hydromyth’ that groundwater is a fragile resource (López-Gunn and Llamas 2000; Custodio 2002).

In the case of Spain, the silent or quiet revolution is estimated involves hundreds of thousands of farmers, abstracting about 4 or 5 Mm^3/yr. However, increasingly these costs which until now were mainly external are now starting to impact directly on farmers due to the drastic lowering of water levels, to levels of 500 m in some small aquifers in Alicante and Murcia (Garrido et al, 2006). The main reason why groundwater has been so attractive to farmers has been its low cost, particularly as a fraction of the crop value. Additionally, except in the case of small or low-permeability aquifers, farmers are cushioned from drought, since aquifers provide a highly reliable source of water, particularly in times of scarce precipitation due to the time lag built into the system to provide a reliable supply of good quality water. Additionally, at present, as discussed above the cost does not include negative externalities like pollution or ecological impacts.

The first quantitative assessment of groundwater resources in Spain was undertaken in 1966 for the area of Rios Besos and Low Llobregat near Barcelona (Llamas 2006a). At the time, it was also suggested that similar studies should be undertaken for all basins in Spain, and particularly in the case of the Segura basin, where groundwater use was booming and there was already suggestions for an interbasin water transfer from the Ebro. There was a lack of control on groundwater use, and often the water authority would argue the difficulty in controlling groundwater use in the region due to the fact that water rights were private (Díaz Mora 2002). However, this is the case in many other countries across the world, in particular some states in the USA, where groundwater is private. Increasingly all the evidence points that it is not whether water rights are private or public, this is a political choice to be decided by society; the issue is whether water rights, either privately or publicly owned are properly regulated, though a clear programme of monitoring and sanctioning to ensure the sustainable management of a common good resource like groundwater

This lack of enforcement and implementation of the existing regulation has continued and has had some unintended side- effects on water planning for the whole of Spain. According to then Head of Groundwater Department in the Ministry of Environment, one of the main reasons the government pursued the Ebro water transfer was due to the uncontrolled groundwater over-exploitation in the Segura basin (Sánchez 2003).

In the case of the Segura basin, the answer of the Government to such a colossal chaos was to supply 1 km^3 per year via a water transfer from the Ebro to help recover these aquifers. It was politically easier to continue with a supply management policy, based on bringing additional resources to the Segura basin though an inter-basin transfer, than to pursue demand management and tackle the politically difficult question of controlling illegal abstractions. The Ebro River water transfer , approved by a Conservative government in 2001, was cancelled in 2004 by a socialist government. The new solution passed was to build about twenty large desalination plants. This solution was opposed by several members of the Spanish National Water Council, the highest consultative body for water planning in Spain (Sahuquillo et al. 2004;) since they considered that this was also a water supply approach based in "perverse subsidies" and against the water demand approach required by the EU Water Framework Directive.

In the case of the Guadiana basin, the Spanish parliament requested a Plan for the Upper Guadiana basin, when the Spanish National Water Plan was originally passed as law in 2001. The request for this plan was re-instated in the year 2005, in the new Law for the new Spanish water plan. There have been 20 draft versions of this Plan, although no formal Plan has as yet been presented to the Spanish Parliament[3]. The last draft proposal submitted or discussion in 2006 fall includes a budget of nearly four billion Euros but up to date has met a strong opposition from the farmer's lobby.

The situation described in Spain is similar to the arid and semiarid regions in the world. The intensive use of groundwater has triggered an economic revolution; however, government policy has not kept pace with this economic miracle. In many countries regulatory frameworks in relation to groundwater are either non existent or rarely implemented. This is due to two main reasons: the first is the fact that the implementation of these laws is often politically unpopular, the second is due to the power or hydrohegemony of the farmer lobby in most of these countries, which sometimes capture the water authorities or develop a clientelistic relationship. Two very different examples can be briefly discussed to highlight these issues. In Spain, in the year 2002 the Ministry of Environment initiated the ALBERCA Plan (Ferrer et al , 2004; Yagüe 2006). This plan aims to bring up to date the register on water uses and rights. This plan will end in the year 2008. However, some authors have argued that this plan will be insufficient to register even half of all the current abstractions. Two new initiatives have followed on the footsteps of the Plan ALBERCA. The first relates to a program of sanctions for illegal wells. The second is the modification of the Spanish Water Law to address the problem of illegal wells.

The initiative to sanction illegal wells could potentially be very effective since most academic literature and evidence points to the need to penalize free riders in healthy self governing systems to manage common property resources like groundwater (Ostrom 1990; Lopez-Gunn 2003). In October 2005 the administration initiated 2,000 legal fines to both illegal wells and illegal water abstraction above the water rights registered in either the Water Register of the Water Catalogue. However, it is estimated that currently there are about 2 million illegal water wells or wells abstracting more water than entitled to. This means that only about one per thousand of illegal wells are actually being sanctioned. However, two issues have developed that make the implementation of this sanctioning regime very difficult, first, many of these sanctions when they get to court have either prescribed or are cancelled by the

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[3] The latest evidence seems to pint out to a plan 1,000 pages long with a budget of 3 billion euros.

courts, since the legal system in Spain is currently overburdened with pending cases on water rights. Second, due to lobbying pressure from the farmer unions, the political will of the Ministry of Environment to 'name and shame' is wilting. A month after the announcement was made on the intention to issue 2,000 sanctions, the Minister for Environment announced an amnesty or delay with the enforcement for some farmers in the region of Castille- La Mancha- one of the regions with the largest number of illegal wells- due to 'social protection' due to the ongoing drought (Hispagua web 19-12-05; El Pais 19-1-06; 3-2-06 and 20-2-06; Llamas, 2006a).

The second initiative was based on a final law, which gave a last chance to water users to officially register their water right. However, it has been heavily criticized by environmental NGOs, and it was not included in the draft law presented in the summer of 2006 to the National Water Council by the Water Directorate of the Ministry of Environment. This draft law has also not been sent yet to the Spanish lower chamber *(Congreso de los Diputados*)(Llamas 2006c).

The silent revolution however, is now global in scale, and many of the problems discussed in Spain are similar in many countries across the world, particularly those related to the ineffective implementation of the regulatory framework to control and rationalize groundwater use. This fact is mainly due to the lack of educated participation in the process by the farmers who are the main stakeholders. One of the most spectacular case is happening in the United States of America, in the Ogalla aquifer.

The Ogallala aquifer, also known as the High Plains aquifer, has an surface area of more than 500,000 km^2, i.e. the size of Spain. Some areas of this aquifer, like in Texas, have been intensively used for the last 60 years. This Texan 'water mining' has meant that an annual volume of 6 km^3 per year has been taken out, which is 10 times the annual recharge. Therefore, water that was stored in this massive aquifer over millennia has now been reduced to 2/3 of its original volume (Terrell et al. 2002). This groundwater, abstracted relatively cheaply has been used mainly for the production of cotton, cereals and animal fodder, i.e. crops with little economic value. However, meat production and meat products generate more than 6 billion or million?? dollars per year, part of which has been exported as virtual water (see below), since the USA is the first global exporter of agricultural product, including meat. Groundwater in Texas is private property (Peck in press). Therefore, the state government of Texas has to persuade the powerful lobby of Texan farmers that this groundwater abstraction is not sustainable and that abstractions should be curtailed. However, it would be interesting to know to what extent the intensive massive use of non renewable groundwater has contributed to the hegemony of the US in the global food trade.

Grey water

The last color of water, and often the one most often overlooked is grey water. This water color is frequently used to describe water from urban and industrial water supplies. In this grey water, there are also different shades. The most obvious use of this treated grey water is its introduction in some parts of the water systems.. Adopting a ‘soft path to water’ would mean that what is being met are water needs, not demand (Wolff and Gleick 2002; Gleick 2003). For example, cities like Murcia and more recently in Madrid and Bardelona in Spain already operate on dual public water supply networks, one with drinking water and a second for watering gardens, cleaning streets, etc.

However, another much deeper understanding on grey water is that of the grey matter in our brain (Shamir 2000). The relative scarcity of water (blue or green) will sharpen human innovation (grey water)(Ramírez-Vallejo 2006), and will trigger positive technological change. The fact that Malthus’s catastrophic predictions never came to fruition is proof of the ingenuity of human kind and the fact that necessity is the mother of invention (Boserup 1965; Llamas 2006b).

4. Desalination’ potential and limitations

Shamir (2000) refers to water with either a high saline context or toxic load, which can be transformed into drinking water via chemical processes as yellow water. In recent years there have been relevant technological advances, due to progress in chemical engineering such as membrane technology (Reverse Osmosis), which has allowed the removal of all impurities from water at a reasonable (and decreasing) cost. The total cost of desalination by Reverse Osmosis has reduced substantially in the last few years. The cost for desalinating sea water is now estimated at 0.5 €/m^3. This is generally the case for large desalination plans, with no hidden subsidies. The price is lower if desalinating brackish groundwater. Desalination of water through thermal solar energy is maybe an important technology for the future (Blanco et al. 2006), although at present it is still not economically viable.

A recent study by the Pacific Institute (Cooley et al. 2006) gives an overview of desalination on a global scale, with special emphasis in California, a water scarce region but very wealthy. It is therefore significant that even in California only 1% of desalinated water is used for irrigation, even more telling is the fact that the desalination plant in the city of Santa Barbara is being decommissioned for economic reasons.

In Spain, some authors have estimated that there are 900 desalination plans, which could produce about 500 Mm^3 per year. (Llamas 2006c). However, the beneficial use of this desalinated water is less clear. For example, it is not clear whether desalinated water will be used for irrigation, since there is not much reliable data on the amount of desalinated water currently being used for irrigation. Olcina (2002) estimated that for the year 2001, 255 Mm^3 were desalinated in Spain, of which only 5 Mm^3 were used for irrigation. Meanwhile, Medina (2005) estimated that the total capacity of desalination plants for irrigation up to the year 2000 oscillated between approximately 8 to 15 Mm^3/yr, of which 60% was from brackish water and 40% from sea water. Medina (ibid) - gives more up to date figures for 2005, which estimates 600 Mm^3 were being desalinated, of which 55% came from sea water and 45% from brackish water, presumably from groundwater Agriculture used 210 Mm^3 of this total amount, mainly generated by small plants, with a capacity of 100 to 5,000 m^3/day, operated by private farmers. The cost per m^3 in the large plants operating with Revere Osmosis , is estimated at 0.45 to 0.71€/m^3.

Irrigation accounts for 25,000 Mm^3 per year of the water used in Spain (MIMAM 2000), -or 80% of total water use, Desalination from seawater only represented 5 to 10 Mm3 in the year 2000; desalination from groundwater brackish water may perhaps be in the order of 200 Mm^3 and is performed mainly by private farmers. In any case this would only represent less than 1% of the total water used for irrigation..

As previously mentioned, the Law on the National Water Plan of 2001 (*Plan Hidrologico Nacional*) included the Ebro River water transfer. A New Decree revoked the Ebro transfer in 2004 and a year later, in 2005, the Plan A.G.U.A. substituted the planned Ebro water transfer with about 20 new large seawater desalination plants. According to Albiac et al (2006), this project has a public investment budget of 1,200 million € to build the new seawater desalination plants, to generate 600 Mm^3, of which 50% or 300 Mm^3 are used for irrigation. The estimated cost will be 0.5 €/m^3. However, the real price would actually be more in the region of 1€/m^3. the price for this seawater desalinated offered by the government to farmers is I the order of .4 €/m^3 therefore, it will be necessary to give a subsidy covering 50% of the real cost. However, in the long term, this subsidy will probably have to be phased out due to the Water Framework Directive, and the fact that beneficiaries of any water infrastructure- due to the principle of full cost recovery- will have to pay the real cost. The farmers seem to be aware of this and are reluctant to accept the government conditions.

Therefore, it could be argued that the use of 300 Mm^3 of desalinated water for public water supply for new tourist resorts and for use in golf courses in the Mediterranean coast could be a sensible option. However, an economic analysis should be undertaken on the desalination plants in Marbella and Almeria. For example, according to an environmental NGO- the *Grupo Ecologista Mediterraneo* (2004) -, the Almeria desalination plant which was finished in 2002, is still not operational. The reason appears to be cost, since it is cheaper for the municipality to buy groundwater than to produce desalinated water in the existing plant. This is a despite the fact that the investment for the desalination plant was paid from central Spanish and European funds.

It is also not clear whether demand will exist from the farming population due a number of reasons (Llamas 2005a; Llamas 2006a). First, farmers at present are not paying for the externalities of groundwater abstraction (e.g. pollution, damage to wetlands, land subsidence); second, farmers are presently not paying for the use of groundwater, but only for the capital and of energy costs; third, at present there is little monitoring and sanctioning (as it will be discussed below) on the amount of water abstracted and how these correlate with their water rights. In many cases, farmers are either abstracting more water than entitled to in their water right –independent of whether this right is public or private- or are abstracting water illegally, with no entitlement to water abstraction. At present farmers are paying 0,1 y 0,2 €/m^3 for groundwater. Therefore the price of desalinated seawater water for irrigation offered by government in the A.G.U.A. programe will more than double than the formal or informal market price. This clearly explain the general reluctance of farmers towards the A.G:U.A programe..

In some coastal regions, -as will be discussed below- farmers could pay a higher price for the water, due to the high value of crops produced. However, farmers as rational economic agents will obviously prefer to pay the lowest possible price, free riding on the lack of action on the part of the authorities in relation to controlling groundwater abstractions. Therefore, in order for farmers to pay this new higher price two things have to take place; first, the administration must seize the opportunity provided by the concept of full cost recovery introduced by the new Water Framework Directive and second, the current water legislation (and limits on abstraction e.g. in over abstracted aquifers) must be enforced (Albiac et al, 2006). Similarly unless groundwater abstraction is regulated, farmers will find it easier and cheaper to continue groundwater abstraction- r than pay for new desalinated water, even if this is highly subsidized by government..

Therefore in both the case of desalinated water for irrigation and for public water supply and tourism, it appears that due to hidden subsidies and perverse incentives, desalination will only provide part of the answer. It is still part of the hard path to water, based on new infrastructure rather than tackling the softer path to water which requires tackling the much more politically difficult question of water allocation and re-allocation. i.e. who gets what, why and at what cost.

5. Virtual reality? Virtual water and water footprint

‘Virtual water’ is the water needed to produce a good or service (agricultural, industrial,…). It was a concept developed by in the late 1990s by Tony Allan (Allan 2003; Allan 2006; Allan in press). If a country exports a product that requires a high amount of water for its production, this country is effectively exporting virtual water, i.e. water embodied in the production of the corresponding good. However, this also means that due to opportunity costs, this water will not be available for other uses in the exporting country . Importing virtual water is allowing countries that are poor in water resources to achieve food and water security. Arid countries for example can use their limited water resources for a more profitable use, like tourism, public water supply, or the production of high value crops, instead of using this water to produce staple food that has high water consumption and yet has low economic value.

A country which exports a product that needs a lot of water to be produced is effectively exporting water, embodied in the product, and equally the country importing that good is saving water by not using its own water to produce that good.

There has been agricultural trade for centuries, even millennia, like the example in Chapter 42, in the Book of Genesis on the story of Joseph . Thus, virtual water trade is allowing water scarce countries, to achieve water and food security thanks to virtual water trade. However, what is new is its increase due to the increase in production thanks to technological advances and cheap transport – particularly by sea- which has facilitated trade. For instance, it is now possible to purchase kiwis in Spain produced in New Zealand. The cost per tonne of product transported by sea is about 1 euro per tonne or one 0.1 euro cent per kg. It is easier- and cheaper- to transport 1,000 tonnes of wheat, than the 1 million m^3 needed to produce that same wheat (see below Table 1). This, is different for poor countries, where the road infrastructure is not very developed. For example, in South Africa it is physically difficult and costly to transport goods imported by sea to the interior of the country (Hofwegen 2004).

In general trade in virtual water is often an implicit rather than an explicit choice, yet it has substantially ameliorated the problems of water and/or food scarcity in many arid and semi-arid countries. Thanks to virtual water many water scarce countries have avoided a crisis, particularly in politically unstable regions like North Africa and the Middle East. The only pre-requisite is that these countries are developed enough to have the purchasing power needed in international markets. If these countries are wealthy enough they are able to buy food embodying virtual water. As will be discussed below, most of these products are basic products like cereals, or fodder, whose value per tonne (or m^3 of virtual water) is relatively low (see Table 1 and 2 below). Most countries import and export virtual water, although the trade balance in virtual water can be very different depending on the individual country.

For example, Canada exports large amounts of virtual water when it exports cereals, yet imports virtual water when it imports flowers and fruit from Central America. Equally, Jordan imports virtual water when it buys cereals (of low economic value) yet exports virtual water in high value crops like citrus fruit and horticultural products, well suited to its climate.

Table 1: Comparative table on the amount of water (in ml) needed to produce 1 unit of specific products

Product	**Water (in 1000ml) necessary for production**
Bottle of Beer (250ml)	75
Glass of Milk (200ml)	200
Bread Slice (30 gr)	40
Cotton T-shirt (500 gr)	4,100
A4 sheet of paper (80gr/m^2)	10
Beef Hamburger (150gr)	2,400
Pair of leather shoes	8,000
Beef meat (1 kg)	15,000
Lamb Meat (1 kg)	10,000
Cereals (1 kg)	1,500
Chicken Meat	6,000

Source: (Llamas 2005a) from (Chapagain et al. 2005)

There is still some data however, which has to be analyzed further, because of its potential implications. First, it is important to explore further the geographical variations in the productivity of virtual water. For example, Chapagain and Hoekstra (2004) show that in Italy a tonne of wheat requires 2,400 m^3, yet in Spain it only needs 1,227 m^3, i.e. about half the amount of virtual water. This would imply that the productivity of virtual water in Spain is twice as much as Italy. Second, strategic choices have to be made by different countries on whether water is used to grow high value crops, or low value crops like cereals or alfalfa (see below Table 2).

Table 2: Average value of some vegetable produce (in $/tonne)

Product	Average value (in $/tonne)
Wheat	125-150
Barley	134
Corn	125
Tomatoes	856
Horticultural products	757
Sunflower	294
Virgin olive oil	2,036
Coffee	2,118
Fresh grapes	1,160

Source: after Appendix IV in Chapagain and Hoekstra (2004)

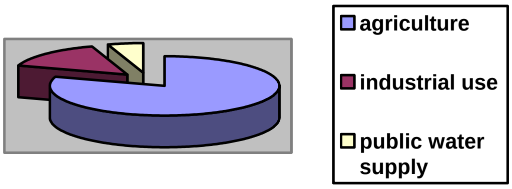
There is a growing realization that economic and social factors tend to be the drivers in virtual water trade, through trade in agricultural and processed food products. Estimates on the amount of water required for the production of each good are complex, and are being developed at the moment (Chapagain et al. 2005). Meanwhile estimates on virtual water for food or industrial products are still in its infancy. Zimmer and Renault (2003) have calculated that the total amount of water (blue and green) globally to produce food is 5,200 km^3. This is a similar amount in magnitude to the 6,000 km^3 estimated by the United Nations (United Nations 2003), as the water needed to produce food for 6,000 million people in the planet. Yet, it is important to remember that the total amount of water in the hydrological cycle is 115,000 Mm^3, and humankind at present uses below 10% of annual rainfall, i.e. of blue and green water.

According to Zimmer and Renault (2003), 29% of water is used to produce meat, 17% to produce meat products, and cereals only account for 23%. It has to be taken into account that the calculation for meat and processed livestock products includes animal feeds. However, from an energy point of view, the situation is quite different; cereals represent 51% of energy value and meat and livestock products only 15%

	Meat	Livestock	Cereals

Global Water Use	29%	17%	23%
Global energy use	15%		51%

In the case of Spain, Chapagain and Hoekstra (2003) calculate that the total green and blue water needs in Spain amount to 100 Mm^3/yr. Spain imports 45 Mm^3/yr in virtual water and export 31 Mm^3/yr, i.e. the balance is negative since Spain imports more virtual water than it exports. Yet 80% of the 100 Mm^3 of Spain's footprint is for food, 2/3 with water from Spain and 1/3 with imported virtual water, 15% for industrial water use (of which ½ corresponds to imported products) and 5% is for public water supply. This highlights the key importance that the agricultural sector represents for any arid country in calculating is water budget and demand, and therefore its water policy[4].



These figures are in line with those of the Spanish Ministry of Environment in relation to urban and industrial use (i.e. 5% and 15%), however, there is a marked difference in the case of agriculture. The Green Paper on Water or *Libro Blanco de las Aguas* (MIMAM 2000) calculates that the amount used by agriculture is 25 Mm^3/yr, whereas Chapagain and Hoekstra (2003) calculate it at 51 Mm^3 for national production and 17 Mm^3 for export. This difference might be explained by the fact that Chapagain and Hoekstra also include green water in the calculation, which might account for the 35 Mm^3/yr in green water (pastures, dryland agriculture, forests).

<u>Water footprint</u>

The sum of all water (blue and green) and all imported water (i.e. virtual water) required to meet the needs for goods and services for a specific area or collectivity is

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[4] Virtual water only affects indirectly energy consumption, mainly through its impact on transport, particularly by sea. However, at this stage more studies need to be undertaken in order to evaluate the primary energy consumption due to the import and export of virtual water. The impact is likely to be however, fairly high if goods are transported by air, as compared to by sea.

known as ‘water footprint’[5]. This concept was developed by Hoekstra and Hung (2002) and it is used as an indicator of water use by an individual, a collectivity or a country. It can be defined as the volume necessary for the production of goods and services that are used by one person or group of people. Obviously, this concept is intimately tied up with the concept of virtual water.

When the inhabitants of a region import goods and services from a different region, they are obviously importing virtual water that was needed to produce those goods and services. The total use of blue and green water that is used by a specific region for a social collectivity would be incomplete if imported and exported virtual water was not included.

The sum of national water (blue and green) and net imported water is defined as the ‘water footprint’ of that country or group. In the concept of virtual water used by Chapagain and Hoekstra (2004) virtual water that is exported in agricultural or industrial products are not subtracted. Possibly these authors consider that exports are not vital from the point of view of the country or group. Yet, exports can play a vital role for the economy of that country or group, amongst other reasons because it allows the generation of capital that allows this country or group to import virtual water as agricultural or industrial products.

Chapagain and Hoekstra (2004) calculate that the current total global water footprint for humanity is 7,500 Mm^3, although this figure is likely to increase in the coming years. This difference of about 1,500 Mm^3 –compared to the previously mentioned water used to produce food - because it includes public water supply and industrial use. In any case it is important to remember that the total amount of rainfall in the land surface, i.e. the sum of blue and green water is about 115,000 Mm^3. In other words, the water demand from the whole of humanity is well below 10% of annual precipitation. In Llamas (2005a) it was shown that the water footprint of Spain, Italy and the USA is similar – approximately 2,300 m^3/person/yr, whilst India’s water footprint is less than 1,000 m^3/person/yr. This is mainly due to the vegetarian diet in

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[5] This concept is linked conceptually to the concept of ecological footprint ((Rees 1996)

India[6] and its lower level of industrialization. Meanwhile China's water footprint currently is even lower, at 700 m^3/per capita/yr, although this is likely to increase substantially in the coming years.

Food trade is regulated by the World Trade organization (or WTO). Thus, trade in virtual water is much more dependent on global trade policy than national water policy. Authors like Garrido (2005) and Wilchems (2004) believe that the concept of virtual water is useful to help describe- and define- agricultural policy and to develop water and food security. However, the concept does not internalize shifts in technology and opportunity costs. Therefore the use of competitive advantage is necessary to define optimal trade and production policies. What is important however is to emphasize the need to integrate the agricultural Ministries in defining water policy since most water used globally is for agriculture and also the need to study key strategic decisions like whether it is best to irrigate or instead import virtual water.

Ramirez Vallejo (2006) argues that it is not sensible to apply pure economic theory to explain virtual water trade. Many factors influence water trade, like bilateral trade agreements, direct or indirect subsidies, technological innovation, or the macroeconomic polices of exporting and importing countries. It is crucial to remember that most trade in virtual water is not explicitly or directly motivated by lack of water or food security. For example, for the period 1993-1998, 75% of trade in virtual water was between OECD countries.

Trade in virtual water depends largely in WTO rules, which are in the process of being defined. These rules will have important geopolitical consequences, e.g. in terms of power shifts and some politicians- particularly in developing countries- are uneasy about trade in virtual water since it could lead to increased dependency towards exporting countries or large multinational companies, which could develop monopolies on global food trade.

The prices of agricultural products are largely dependent on climatic and technological conditions. However, these prices are probably influenced just as much

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[6] See Table 1 for amount of water needed to produce 1 kg of cereal vs. 1 tonne of meat.

or more by hidden subsidies and tariffs to farmers in the USA, the European Union and Japan. For example, Rogers and Ramirez Vallejo (2003) estimate subsidies to farmers in the OECD as 1,000 M $ per day, which has a substantial negative impact to farmers in developing countries . According to these authors, more than a third of the income of farmers from OECD countries comes from government subsidies. These subsidies are five times higher than all the aid received by developing countries, and twice higher than the agricultural export from developing countries. For example, a cow in the European Union receives a subsidy of two dollars per day, yet about 2,500 million people live on less than 2 dollars per day (United Nations 2005).

Rogers and Ramirez-Vallejo (2003) have made a forecast of the potential evolution of the virtual water market for the year 2020, in case of market liberalization under the WTO. The dominance of the USA would be even greater under market liberalization scenarios, whilst the role of Latin America would also increase substantially. A key element in all these future prediction will be the price of water, which at present is generally well below its real cost. Therefore reducing the gap between the price and real cost of water- as demanded by the concept of full cost recovery embodied in the European Water Framework Directive, could have a substantial impact on virtual water trade. However, it is difficult and a problem common to the whole world, to eliminate so called ‘perverse’ subsidies, i.e. those that are bad for the economy and the environment (Myers and Kent 1998).

6. The role of GIS and remote sensing in increasing transparency and participation

In this last section on key advances and science and technology to solve water conflicts, the role of remote sensing and GIS will be briefly discussed. These play an indirect- but crucial role in addressing water problems. (Chuvieco, 2002; Bosque, 1997; Schulz et al., 2000; Gurnell and Montgomery (2000). Remote sensing can help facilitate land use and land use change. Nowadays, the use of remote sensing is relatively cheap and allows us to measure with increased precision irrigated areas and the type of crop. This is essential in order to plan water policy for irrigation use, which as stated above, represents 80 to 90% of consumptive water use.

However, except in the region of Andalusia (Vives, 2000), most water authorities in Spain, and Water Departments in the Regional Governments on irrigation use data either does not exist or is not available. This is despite the fact that obtaining this data is relatively quick and cheap, as demonstrated by the Andalusia regional government 10 years ago. (Vives, 2003).

The other great technological advancement are Geographical Information Systems (or GIS), which greatly increase the potential transparency in information at a user level and in a user friendly format. Increasingly it is clear that the availability of good, sound information is basic for negotiations over water use in many conflictive areas. A good example is that currently implemented in the Manxcha region in Spain, where satellite information is being directly used by farmers though an Irrigation Advisory service , which integrates real time data to help farmers improve water use by different crops, whilst optimizing production (Calera et al, 1999; Calera et al 2005; Martin de Santa Olalla et al, 2003). Data and information transparency are the foundation stones on solving any potential water conflicts. Both GIS and remote sensing offer a relatively cheap and quick way of opening up decision making processes by allowing civic society to participate though transparency of information. In the case of water GIS is making huges strides in the range of ways it can be utilized to support and inform policy making (Gurnell and Montgomery, 2000; Chuvieco, 2002). Technologies like GIS and remote sensing can bring about transparency and participation, which in the information economy (Stiglitz 2006) foster innovation and adaptation essential to good management. Equally participation can prevent corruption, clientelism and inertia, whilst facilitating taking decisions that sometimes are politically difficult yet necessary. It brings about deliberative democracy in water management, essential to achieving sound water governance (Innes and Boother 2000; Lowndess et al. 2001; Bulkeley and Mol 2003).

7. Constructive realism in science and technology?

Often water has been portrayed in the tragedy of the global commons, (Hardin, 1968), where water is inescapably doomed to over-use, particularly in the case of groundwater. Only two options were offered, to centralize management under strong government control or to privatize resources allocating private water rights. Yet, more recently a third way is available, which has shown that contrary to predictions of over abstraction, self-governance by water users themselves, can help guarantee the sustainable management of the commons (Dietz et al. 2003).

Equally, there is a realization that neither optimism nor pessimism should dominate forecasts on water governance; instead the focus should be on constructive realism. For example, concern over population growth goes back a long time. For example, Guerra (Guerra 1989) discusses how Aristotle and other Greek philosophers in the IV century BC advised abortion in order to control population growth by slaves, since they outnumbered Athens citizens on a ratio of 1 x 20 in the year 313 BC; they also argued that such “overpopulaion” was threatening food security. Malthus, more than 200 years ago made predictions that now bear little resemblance to reality (Heap 2000; Heap and Comim 2007). World population is now six times larger than in Malthus‘s time, and most people have greater food availability and life expectancy than in Malthus’s time.

Julian Simon (1996) showed that predictions on the problem of overpopulation and exhaustion of resources have been proven wrong, thanks in great part to technological advances and human ingenuity.Aguirre(2006) has a similar point of view.. Instead of blaming the current ecological crisis on population overgrowth, more emphasis should be placed on sustainable consumption; since the ecological footprint of e.g. the UK in terms of CO^2 emissions is twice that of Bangladesh, yet the population growth in the UK is 120,000 per year compared to 2.4 million in Bangladesh.

It is increasingly clear that in order to solve the global water crisis simple scientific reasoning will not be sufficient. Many of the choices faced by society inherently imply key ethical questions, where increasingly a balance will have to be struck between pure utilitarian values on water e.g. as a market good, and other intangibles, like cultural, ecological and religious values (Llamas and Delli Priscoli 2000). Economic man as defined by the dominance of neo-classical economics and rational choice theory, where men are understood as self interested individuals and their bounded rationality, have to be expanded to view men and women as part of humanity and capable of altruistic behavior, with an expanded understanding on human rationality and self interested behavior. These new ethical issues and emphasis on the moral norms and value of water have increasingly been recognized, for example by international organizations like UNESCO, in its series on Water and Ethics (Delli Priscoli et al. 2004), and by the World Commission on The Ethics of Science and Technology (or COMEST)(Selborne 2001).

The starting point to current debates in water policy is that the crisis is not due to scarcity and water stress but to governance. That is, the diagnosis on the cause is different, and this leads to different solutions to those currently pursued by international organizations like the Food and Agricultural Organization (FAO) and the International Water management Institute (IWMI) which are still mainly focused on water and food security, by concentrating on the expansion of irrigated areas and greater use of both surface and groundwater. At present the solutions proposed are ‘hydrocentric’ based on the watershed (Brichieri-Colombi 2004). However, as it was discussed above decisions on the type of crop or on food trade would have a much higher impact than any decisions to build new large water infrastructure. This leads towards a re-definition on the unit of analysis away from a pure water shed towards the concept of the ‘problemshed’ – as defined by Allan (2006). That is, taking into account that globally approximately 70% of water is used for agriculture, the decisions on which crops are grown (and its embodied water use), and which foods are imported as virtual water, have a much substantial impact on the country’s or catchment’s water budget.

<u>The soft path to water</u>

The soft path to water requires innovative solutions to old problems, this translates in a portfolio of appropriate solutions to specific problems, instead of the old mentality where one size fits all, i.e. the hard path to water centered on water infrastructure as the only solution to the ‘problem’ of water scarcity’

Once again, as stated above, if the diagnosis of the water problem looks at the causes of the current water crisis –i.e. the lack of effective, efficient and equitable water governance, rather than the symptoms, i.e. physical water scarcity- then the course treatment will surely have to be re-assessed and modified on a case by case basis. The sections below re-visit some classic concepts and provide and alternative explanation in order to highlight that appropriate solutions are within reach in the soft path to water governance.

Many countries , particularly in the developing world still have to address questions related to food security, and particularly so in arid and semi arid regions, where droughts can trigger hunger and also potentially destabilize or even topple governments in power. However, often these mass starvations have more often a political origin than a physical cause, as highlighted by Brunel (1989). Food security can often be ensured either though self sufficiency in food production, or a mixture of own production and imports from other countries. This political choice, i.e. whether to opt for self sufficiency or an open trade approach has substantial implications in terms of need for water infrastructure, rainfed agriculture and trade in agricultural products. Often geography partly dictates the choice made, for example large countries like China or India can opt for self sufficiency, whereas arid countries prefer to guarantee enough income to be able to guarantee food imports. In very poor countries, food security is heavily compromised and conditioned by poverty. Their population tends to be mainly rural and relies on subsistence agriculture. Due to their lack of capital, authors like Hofwegen (2004) suggest that their safest bet to ensure food security is to improve the productivity of rain fed agriculture- or green water as discussed above-, since their poverty leaves the choice of building large irrigation infrastructure and/or agricultural trade beyond their reach. In other countries food security is slowly happening due to the silent revolution in groundwater use. In extremely poor countries, with less than 1$/per capita/per day, -where 500 million people live-, the NGO International Development Enterprise (or IDE) developed in the last 20 years a simple pedal operated pump (Polak 2005), which has allowed these areas to evolve in a relatively short space of time to a diesel or electric pump. Meanwhile, in mid range countries, a potential initial solution will be the intensive use of groundwater (Llamas 2005b; Allan in press).

Economies of scope and civic participation

Yet in many countries the idea still predominates that economies of scale of large water infrastructure is the suit that fits all, in order to guarantee food security. Yet the evidence cited above shows the key role of virtual water or the silent revolution of groundwater use, and offers the alternative concept of economies of scope, which looks for the most appropriate solution suited on a case by case basis.

In many countries there is a marked shift in the active population in different economic sectors. In general the shift is away from rural towards urban. For example, in the case of Spain, rural population -in the agricultural and livestock sectors - is less than 6%, when half a century ago it was 50%. This varies internally between less than 2% in the Balearic Islands to more than 10% in Andalusia or Extremadura. However, it is quite probable that the proportion of people employed by the agricultural sector will continue to reduce not only in Spain, but globally.

Some regions in the world live in conditions of extreme poverty, on less than 1 $ per day. In these countries the majority of the population tends to be rural and depends on subsistence farming. In these regions virtual water or importing food without giving due consideration to the staple diet of the country and to the potential impact on local agricultural markets could do more harm than good. The combination of high production costs due to lack of technology and the potential flooding by cheap- and often subsidized products from global trade could substantially harm local, subsistence markets.

Meanwhile, in developed countries, importing food could have impacts if certain protectionist tariffs and/ or subsidies are removed. For example this is the case of Spain and the current review of the European Union Common Agricultural Policy, which is likely to reduce both subsidies and tariffs for products like cereals, rice, sugar beet and many other products typical of continental style agriculture. In countries like Spain, these types of products often need to be irrigated in order to be able to compete, with other Northern European Union countries, with a wetter climate. Once subsidies for these products are removed, and even if water tariffs are not adjusted to account for the price of water many of these products may cease to be profitable in Spain.

Many authors consider that Spain should concentrate on typical agricultural products like horticulture, citric fruit, olive oil, and others, which at present have low subsidies from the European Union, and where Spain due to its climate has a competitive advantage. Many farmers are following this economic logic and are shifting away from agricultural products which are water intensive, like corn or alfalfa, towards Mediterranean products like vineyards or olive trees. Spain however will have to prove competitive once the WTO - or the EU itself through bilateral agreements - opens up the European markets to products from North Africa or Turkey.

Increasingly it is a vital question for Spain, and other arid countries to evaluate the value per type of crop and the use of green and blue water required to grow different crops. For example, Albiac et al (2006) (see below table 3) undertook a study on the different crops that would be irrigated by the planned Ebor transfer, and found that the value ranged from 900 euros per ha for cereals to more than 40,000 euros for greenhouse crops. These figures were similar to those generated by the Andalusia irrigation inventory produced ten years ago and updated three years ago (Vives 2003). Therefore the gross value per crop and m^3 from irrigation oscillates from 0.1 euro to 11 euros.

Table 3: Area, water use and income in the Spanish south east river basins (2001)

River Basins	**Total**	**Cereals, alfalfa and sunflower**	**Fruit trees**	**Horticultural product**	**Horticultural product (in green houses)**
Area (1.000 ha)	212,7	18,5	173,6	19,5	1,1
Irrigation water (Mm^3)	1.450	242	1.081	121	6
Income (millions €)	1.196	39	957	167	33
Segura basin					
Area (1.000 ha)	154,9	8,1	107,7	34,2	4,9
Irrigation Water (M	863	62	654	125	22
Income(millions €)	1.070	6	485	336	243
Sur basin					
Area (1.000 ha)	54,5	1,1	18,7	6,5	28,1
Irrigation Water (M	232	10	96	24	102
Income (millions €)	1.124	1	67	87	969

Source: Table 5 in Albiac et al 2005

Ecological impacts

Often the economic use of a natural resource has an ecological impact. It is a delicate question to achieve a balance between economic benefit and environmental costs. However, the valuation of these ecological costs is not straightforward, and is partly dependent on both the cultural and the economic situation in each country.

Environmental awareness is often conditioned by the so called Kuznets curve, which effectively links environmental awareness with income per capita. Poor countries are generally reliant on nature due to an agricultural subsistence economy. Their inhabitants are normally integrated in their local environment and have no means to over use or damage their local ecology. The main worry in these countries is to increase the standard of living, though economic growth, whether sustainable or not. Ecological or environmental awareness develops once the country reaches a certain level. Civil society seems to mature, environmental NGOS develop and in general environmental awareness grows. This awareness continues to develop as the standard of living increases. Mukherji (2006) has shown recently how the Kuznets curve also applies to many regions in the world in relation to water resources.

However, Hofwegen (2004) calculates that the liberalization of trade in agricultural products (and therefore virtual water) will have negative effects on the environment. This would happen if countries used- or overused - water resources in order to produce agricultural products in an unsustainable manner, in order to be able to sell these products to other countries. This seems to have already happened in one of the most developed countries in the world, in the USA, and one of the largest aquifers, the Texan Ogallala or High Plains aquifer (see above).

8. Conclusions

It seems clear that the introduction of key concepts like virtual water and water footprint have generated new ways of looking at old problems, like the traditional concept of food and water security, and the concern that humanity will shortly be ‘water stressed’.

Virtual water trade and the concept of water footprint are relatively new concepts, although their basis has been around for centuries, as agricultural trade, based on the law of competitive advantage. The quantitative data in relation to both concepts are at present a first approximation. It is therefore fundamental to improve methodologies to calculate the virtual water needed, not only to generate food products, but also industrial products and other services. It is therefore crucial to ensure that the basic data on green and blue water available is of the best quality. The concept of virtual water is helping to generate much more sophisticated water budgets, more thorough, and based on the water needs (and water footprint) of each country. In particular, it has also helped to highlight the key role played by green (or soil) water in the production of food products. The concept of water footprint emphasizes that in most arid and semi arid countries, water policy is heavily dependent and conditioned by agricultural policy. This is particularly true in a country like Spain where the sum of green and blue water to meet the demand of both agriculture and livestock represents almost 90% of the Spanish water footprint.

Trade in virtual water constitutes a key element in helping to eliminate or at least soften the global water crisis. However, it is not a panacea, methods have to be further developed, data has to be improved and the side effects or unintended consequences-economic, social, geopolitical and ecological, better studied.

In cases of extreme poverty, people with less than 1 dollar per day- normally reliant on subsistence agriculture, deserve a special mention. These countries represent 10% of the global population. According to the Johannesburg conference on Sustainable development, the great ecological crisis is extreme poverty. It is also an imperative ethical question, which requires fewer words and more imaginative, cheap and feasible solutions, like paying for environmental services offered by green water as e.g. green water credits (Grieg-Gran et al. 2006).

This paper has shown that there are already two politically silent events, which are helping to prevent the often quoted ‘water crisis’, these are virtual water and groundwater. Both are politically silent yet are allowing countries, particularly in arid and semi arid regions to sidestep the problem of water scarcity. However, this paper has also highlighted that these ‘revolutions’ generated thanks to scientific and technological advances should not occur in a vacuum and it is the responsibility of states to carefully assess their full potential and limitations. Science and technology have shown an alternative path, a soft path to water, where solutions are targeted to specific situations, supported by public participation and information transparency. This path offers an alternative to the traditional doom and gloom hard path, which concentrates on a one size fits all of new water infrastructure. There are currently cheap, feasible and real solutions to the current water crisis, but their Achilles heel once again is addressing pending- and politically difficult questions- on good water governance.

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