CHAPTER 6

Prioritising the processes beyond the water sector that will secure water for society – farmers, fair international trade and food consumption and waste

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ABSTRACT: Most of the water used in our economies is invisible. Invisible *green water* in soil profiles accounts for over 70% of the water used in food production. Also invisible is the water embedded in commodities traded internationally – know as *virtual water*. The role of farmers in achieving water security is also invisible. They manage all of the green water and with engineers most of the blue water worldwide. By doubling and trebling water productivity in both rainfed and irrigated agriculture farmers have met the water and food needs of the global population, which trebled in the second half of the 20th century. The international food commodity trading corporations are also pivotal in achieving global water security. It is argued that it is important that they exercise influence on the supply chain in proportion to this invisible pivotal role. There are other invisibles. Consumers unwittingly determine the volumes of water used worldwide. Diet is key. A non-vegetarian has a daily footprint of about 5 m^3 of water per day. The daily footprint of the vegetarian is only 2.5 m^3. Food waste is another invisible factor. Consumers in industrialized countries waste over 30% of the food –and embedded water– that they purchase. The same proportion is wasted between the farm gate and the market in developing countries. Reductions in these numbers are strategic and accounting for them will be essential in the achievement of water security.

Keywords: water security, green water, virtual water trade, consumers, trading corporations, food waste

> *It is on world's farms that the challenge must be faced and success achieved. Farmers are the world's major water managers*

1 INTRODUCTION

Water security is a vast topic. Scientists who deconstruct the topic find it daunting. Water professionals find it daunting because there is so much there that is beyond the water sector. The private sector finds it daunting because there is so much that is beyond the market that is of elemental importance. Even politicians who can think in a language of social and economic priorities find it daunting. They find it hard to allow water security onto the public agenda because the political price that has to be paid to change the approach of society to water use and management is so high. We all find it daunting because there are so many interacting uncertainties. Politics is the only trade that engages day in and day out with uncertainty and *wicked problems* (Conklin, 2006). And the ways of politics are very rough and ready. We must nevertheless learn to engage with this rough domain in which urgent and wicked problems are either addressed or ignored.

A wicked problem is not only urgent it is also extremely uncertain. Wicked problems are normally the outcome of previous attempts to deal with an earlier version of a similar problem (Conklin *et al.*, 2007). For example the big-oil/government nexus responded to the oil and gas crisis of the 1970s by racing to develop North Sea and North Slope oil and gas resources. In this they did the wrong thing extremely well. Oil prices stayed low for another three decades with devastating environmental consequences. An element of this rush to do the wrong thing extremely well was to crush precious and appropriate initiatives to mobilise renewable energy technologies[1]. There are less iconic examples in the water sector in the excesses of the era of the hydraulic mission in industrialised economies and still in train in the BRICS economies (Brazil, Russia, India, China) and in some other developing economies.

The purpose of the chapter is to focus on four elements of the intellectual challenges and of the water policy challenges associated with this vast topic. *First*, it will be shown that it is farming communities that manage the big water used and consumed by society. They manage about 80% of the water used in our economies – about 70% by volume of this water is green water and 30% is blue water. Unless society reduces its unnecessary food consumption we shall have to rely on farmers worldwide to raise the productivity of green and blue water to meet the food consumption of a future global population of about 9,000 millions. It will be shown that they have the propensity to do this. The *second* element of a more secure water managing scenario is one where the prices of food commodities send signals to farmers that they should produce crops with less water and with practices that do not impair the services of the water environment. A number of examples will show of how farmers have achieved spectacular increases in returns to water even in our own lifetimes. Price incentives work when they are reliable and long term and not misguided attempts to address wicked problems. The *third* element of fundamental importance is *international trade*. International food commodity trade has also been spectacularly successful in meeting the needs of at least 180 economies that have run out of water. But global trade is not fair. International trade in agricultural commodities has been severely distorted for decades. Its terms punish the weak economies of, for example, Africa. Food production is the major livelihood of most of the peoples of Sub-Saharan Africa. But the water productivity of Sub-Saharan farmers is the lowest worldwide. Millions of African farming families are repeatedly driven back into poverty by the level of international food prices kept low by the governments and food producing interests in Europe and the USA.

Fourthly, it will be emphasised that farmers compete on our behalf with the environment for water and tend to impair the water services of the environment. A joint effort is needed – both via increases in water productivity on the *farms* and *changed* patterns of *food consumption* by *society*. The latter will both *enhance human* and *environmental* health and reduce the consumptive use of water.

Farmers everywhere must be nurtured and encouraged to prosper by increasing – in some cases doubling or more– their water productivity. Doubled rainfed water productivity in Africa would be of global significance with respect to future global water security.

The issues of wasteful practices in the ways society handles the food supply chain in advanced economies is treated in another chapter (Lundqvist, this volume). Food transportation, storage and marketing –between the field and the market in developing countries accounts for even larger proportion of perishable food losses. In this case it is not the perverse behaviour of consumers. The waste of food, and therefore of consumptive water use, occurs because of the absence of effective transportation and food storage technologies (Biswas, 2009, pers. comm.).

The chapter will not address water security issues related to the small volumes of water needed for drinking, domestic use and for non-farming livelihoods. This form of water security is rarely constrained by the availability of water resources. Very few economies do not have the volumes of freshwater needed to supply enough water for their domestic water and water for non-agricultural jobs. Some economies in the Gulf and Yemen with its 23 million population living mainly between 1,200 and 2,000 metres above sea level, and many small island states are in difficulties with water

[1] The controversial example of energy is used because everyone can engage with this very topical issue. It especially highlights the dangers of *government/private sector alliances* where those at the heart of this political system are dependent for their continued exercise of power on very poorly informed *voters* or for their continued leadership of prosperous companies on badly informed *customers*. The *voters* and *customers* are very often manipulated to have appetites for types and levels of consumption that are lethal for society and its long term survival. The political economy is a wholly owned subsidiary of the environment.

security for industry and domestic uses. However, all those economies that have a sea coast or lie on major rivers can now desalinate water at costs that are similar to providing potable water by any other means.

2 GLOBAL WATER SECURITY

We have been trying for some decades to answer the question – *will there be enough water to meet the needs of a bigger population of between 8,000 and 9,000 million by mid-century in a warmer world with some different rainfall patterns?* The purpose of this study will be to show that the key factor relevant to answering this question and related policy issues is crop productivity on the farms of the world. On the subsistence farms of Africa, on the family farms of India and Europe, as well as on the corporate farms of North America and Brazil.

Since 1950 we have placed unprecedented pressures on our water resources – especially on our blue water. But we have also reached deeper and deeper into tracts with green soil water by turning natural vegetation into cropland. Over the past half century the response of farmers almost everywhere has been extraordinary[2]. Even more important than the mobilisation of new land and its green water and the expansion of irrigation has been the increase in crop and livestock yields. Increased yields on rainfed farms mean that the productivity of water has been increased. These increases in the yield of green water are easy to track. Increases in the returns to blue water have also been achieved but these are more difficult to evaluate.

These increases in returns to water have made it possible for the world to remain water and food secure. There will have to be further increases in the productivity of the big water deployed in food production if we are to remain water and food secure by the time we reach peak population in the second half of this century. At the same time society will have to re-think its food consumption habits and preferences if the water environment is to remain in good health and the health of society improved.

The second half of the 20th century has been a story of what we would now call *adaptiveness*. This *adaptiveness* has been unprecedented because it has been associated – in many parts of the world, particularly in the temperate latitudes – with the industrialisation of farming. The major feature of this industrialisation has been the unprecedented increases in the use of hydrocarbon-based energy in transport, cultivation, fertilizers and other inputs. The water/energy link is important but it is not the topic of this study.

Since 1950 the world's population has almost trebled. The use of freshwater has almost doubled. Food production has increased about fourfold and the only continent that now has a high proportion of persistently undernourished people is Africa. South Asia also has undernourished people but it

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[2] The farmer, whether a family farmer or a global corporation, has in their hands the decision making power to gain high or low returns to water by combining a vast array of endowments and inputs. These endowments include good or poor soils, which may be well watered or not. The climate may enable single or multiple crops and provide optimum growing temperatures of 30^{o}C or not. Droughts and floods have to be taken into account. The progressive and extraordinary increases in water productivity have mainly been the consequence of technological advances – equipment to transport and cultivate as well as fertilizer, herbicides and pesticides – since the beginning of the early industrial revolution in about 1800. The technological advances would have had little impact without a suite of economic and social adaptations. Technology helped the farmer to cope with the environmental circumstances and occasional extreme events. In parallel, urbanised industrial society evolved markets with demands for food commodities at prices that stimulated production and investment. Farmers could accumulate surpluses that enabled assets to be capitalised. A suite of other conditions have also evolved with complicated impacts. These include farm policies that protect and subsidise farmers. It will be shown that these range from those that are essential to protect the weak to those that wreak havoc internationally across over 100 poor mainly agricultural economies. The global market will be identified as the infrastructure that has both the capacity to remedy the water scarcity of most of the world's economies via virtual water *trade* as well as the potential means to ensure that the incentives for poor farmers in weak economies to have the incentives to improve their water productivity.

has managed to remain a net food exporter despite its very rapid rate of population increase. As a consequence India's groundwater resources have been very heavily overdrawn in some regions. But as in many regions water is still being moved via internal food trade from relatively water scarce regions such as Northwest India to the water rich regions of Eastern India (Verma, 2009). The same phenomenon occurs in China where the water scarce North China Plains are exporting food commodities to the water rich south of the country (Chapagain, 2007). California performs the same remarkable role in the USA and Andalucia in Spain. Industrialised irrigated farming achieves water miracles if the environmental costs are ignored.

This analysis will focus on food production because it is the demand for food which has exerted pressure on the world's water resources. Every additional individual, whether on a farm in a remote rural region of Africa, a new immigrant to the USA or another baby in a rich European city needs about 1,000 m^3/yr of water to provide its food. Food consumption accounts for about 80% of the water needs of a society. A 40% increase in the productivity of green and blue water used consumptively in crop and livestock production will meet the future water and food needs of the world. A lesser increase will meet the needs of a human population which might decide to consume food of types and in lower volumes and in different mixes that will be good for human and environmental health.

We also need to use and dispose of the water used for domestic and industrial purposes effectively as this water is costly to mobilise and dispose of. But any economies in these water-using sectors will be of minor significance with respect to the goal of achieving water security. It is the volume of water that is important for global water security and it is in food production that the big volumes are mobilised.

It is on world's farms that the challenge must be faced and success achieved. Farmers are the world's major water managers.

3 DEFINING WATER SECURITY

The important message is that water security is achieved outside the water sector in economies that are diverse and strong. A strong economy can afford to import water intensive commodities.

The important question is –is there enough water in the global system to meet the demands of the water scarce in a world with 25% more people?

To be water secure an individual needs about 1,200 m^3/yr. The volume of water needed for food per head appears to range from about 600 m^3/yr to 1,500 m^3/yr [3]. The water needed for the non-agricultural commodities consumed each year varies much more and these numbers are even more difficult to model than those for food consumption[4].

The current 6,800 million global population *consumes* about 8,000 Mm^3/yr of water in meeting its food needs. This volume happens to be equivalent to the annual flow of the biggest river in the world –the Amazon. The Amazon Basin's vast water resources are scarcely touched. Perversely the vast majority of the green and blue water *consumed* is in relatively water scarce regions and not in the regions of the world that have high levels of rainfall. Green and blue water in less well water endowed regions is used to produce food commodities that stay for the most part within the economies to feed their own populations.

By 2000 most of the 210 economies of the world had become net food importers. The volume of virtual water *trade* in food commodities is over 1,000 km^3/yr. This 15% or so of global green and blue water *consumption* is equivalent to the flow of any one of the next four biggest rivers – the Orinoco, the Congo, the Ganges or the Yangtse. Interestingly only one of these tropical/equatorial rivers – the Ganges – is utilised to provide significant volumes of consumptive use in food production. The

[3] These numbers are based on the modelling of Arjen Hoekstra.
[4] The assumptions used in the water footprint modelling to date.

vast blue water resources in these mighty tropical/equatorial surface water systems remain safely in the environment for the moment.

It is the blue water in the south to north and north to south flowing rivers – and their associated groundwaters – that have supported the majority of the crop production that has secured at least half of the extraordinary four-fold increase in food production in the second half of the 20th century. These are minor rivers in global terms normally with less than 10% of the flow of the major tropical rivers. These rivers – the Mississippi, the Nile, the Amu and Syr Darya, the Indus, the Irrawaddy, the Mekong and the wandering Yellow river have been raided for their blue water. As a consequence, some of them, the Nile, the Aral Basin rivers and the Yellow scarcely reach the sea.

When an economy runs out of water it will be evident in its inability to feed itself. The small volumes of water needed to provide potable water for drinking and high quality water for other domestic use and for industry and services account only for between 10% and 20% of the water utilised. High proportions of the water used at home and in industry returns to the environment and where treated this returning water can be re-used by society and the economy. Water used by farmers, by contrast, is utilised in a system where the water transpires to the atmosphere. There it is inaccessible to farmers and to the economy of which they are a part.

Moving food around the world in international trade is the main way that water security is achieved. It requires about 1,000 m^3 (tonnes) of water to produce a tonne of wheat [tonne (t) = 1,000 kg]. Economies that cannot find the 1,000 m^3 of water avoid all the economic and political stress of being unable to mobilise the water in their own economy by importing wheat and other water intensive commodities. The practice is as old as civilization as no city can survive without a rural hinterland able to provide embedded water in food. The embedded water is known as virtual water (Allan, 2001; 2003; Hoekstra & Chapagain, 2008). Most water – both green and blue water – stays in the economies where it is able to be used. Only about 15% of the water used to produce crops and livestock enters international trade. This proportion has been extremely successful in meeting the water needs of the water deficit economies. In practice about one third of the water traded is in exchanges between highly industrialised economies. The important message here is that water security is achieved outside the water sector in economies that have become diverse and strong. A strong economy can afford to import water intensive commodities. Strong and diverse economies are not dependent on water resource endowments. Strong and diverse economies evolve in well-governed political economies where human resources have been nurtured.

Understanding international crop and livestock trade is an important part of understanding current and future global water security. Some of big virtual water net *exporter* economies are advanced industrialised economies[5] – the USA, Canada and Australia. Other major net virtual water *exporters* are BRICS[6] economies – Brazil and India, or potential major food exporters such as Russia.

Almost all of the major virtual water *importers* are industrialised countries. In East Asia, Japan and Korea are in this group. Only France of Europe's 27 economies is a major net virtual water *exporter*. The Middle East and North African economies engage in virtual water *import trade* more than any other non-advanced economies and they will increase their participation in such *trade* as their populations will double by mid-century.

At least half of the additional food needed to meet the increased global demands of the second half of the 20th century has come from green water in temperate and semi-arid tracts in both the Northern and the Southern hemispheres; in North America and Europe and in South America and Australasia. Grain yields of such crops as wheat have been doubled or trebled since 1950 and amazingly they continue to increase in these regions. These globally strategic increases in

[5] There are about 35 advanced industrialised economies. They include the economies of the EU, the USA, Canada, the economies of Australasia and some of the economies of East Asia.

[6] BRICS – Brazil, Russia, India, China and South Africa. The BRICS economies comprise over 40% of the global population. They include the water tower of the world – Brazil and two pivotal economies: India and China that have either not come on to the world market at all (India), or only to a minor extent (China). Russia has vast underused water resources.

returns to water, mainly to green water, are the result of farmers combining their inputs – including water – ever more effectively.

They have been enabled to do this because they have been given incentives to produce food commodities in secure protected economies especially in the EU and the USA. In the process, rural societies have been transformed and it is this complex adaptiveness of advanced economies that has enabled the increases in returns to water. These advances in water productivity have brought us the version of global water security that we currently enjoy.

4 FARMERS, RURAL TRANSFORMATION AND FAIR INTERNATIONAL TRADE

4.1 *Farmers*

Farmers do not consciously address global water security but collectively they are key to its achievement.

What is water security in volumetric terms if water use efficiency can be increased almost tenfold?

Farmers have shown that it is possible to achieve tenfold increases in water productivity. In North-west Europe the yields of wheat per hectare in 1800 were about 1 t/ha. By 1900 they were 2 t. By 1950 they had reached 3 t/ha. Remarkably, by 1990 yields had reached 9 t/ha. All of these gains were achieved with the same water, as annual rainfall had not changed. It was not that three times the water had been mobilised between 1800 and 1950, nor three times more by 1990. After mobilising a range of inputs and enjoying – at least in recent history – reliable prices and helpful market circumstances water was being used nine times more effectively. What is water security in volumetric terms if water use efficiency can be increased almost tenfold?

The local impact of these changes on the farms of the UK was to transform the 60% dependence on imported food in the 1930s to a 40% dependence by the 1990s despite a 15% increase in population. A significant proportion of the global food exports have for the past four centuries been commodities exported from the tropics that could not be grown in Northern Europe. By the 1980s UK was even exporting grain for animal feed.

In Southeast Asia there has been another example of extraordinary increases in water productivity. In this case in the productivity of blue water. After the end of hostilities in Vietnam in 1975, farmers were able to operate in a secure environment. They could increase the rate of cropping from one to two, and in some cases, to three crops per year. Yields per crop also increased – they sometimes doubled. With double and treble cropping yields per hectare increased from 3 to 20 t/ha/yr in some regions. Vietnam changed within a decade from being a minor rice importer in 1975 to being a rice exporter by end of the 1980s (FAOSTAT, 2009). It became the second after Thailand in rice exports in the world by the mid-1990s. No one has completed any calculations of the increases in returns to green and blue water. One of the seasonal rice crops – that in the monsoon season – doubled yield to mainly green water. This increase reflected a significant increase in green water productivity. The calculation of the increased yield to blue water in the second and third rice crops are much more difficult to model. But in the firmament of the unknown unknowns on global water security this gap in knowledge is minor.

Farmers do not consciously address global water security but collectively they are key to its achievement. Every increment of improved yield, that is not just the consequence of increased blue water applications, contributes to local water security directly. And indirectly to global water security as water productivity increases can be fed through into the global system via *trade* in virtual water.

It is not being argued that the installation of water infrastructures created by engineers, and improved seeds, fertilizers, pesticides and herbicides are unimportant. They are important but the extent to which they are effectively combined with scarce water is in the hands of farmers.

It is being emphasised that if we are serious about addressing global water security one of the main ways we can promote this is by making the lives of farmers easier by protecting them from the uncertainties of markets and international trade. In the next section it will be emphasised that farmers combine available inputs most effectively if the rural economy and rural social infrastructures are favourable.

Farmers operate in pre-modern modes of food production with low levels of returns to water until political and economic processes allow them to operate modern systems with different options and the associated very much better returns to water. The importance of the transformative context will be considered next.

4.2 *Rural transformation*

> *Over the next half century, farmers will continue to adapt their capacities and will respond to the increased demand for food in all regions if they are given the economic and social circumstances in which to do so.*

Farmers have achieved doubled and even tenfold increases in crop productivity and returns to water over the past two centuries when their economic and social conditions changed and they were able to take advantage of new circumstances.

Environmental hazards have not varied much during the past two centuries. In the next century in some areas they will worsen with climate change and in other regions crop and livestock production might be easier. The calculus of the worsening and improving has yet to be completed. Two things are certain. First, farmers have delivered adaptive solutions to the increased demands for water to meet demographically imposed demands for food during the last century. These increased demands have been much greater than anything climate change will bring about in the current century in the availability of global water resources[7]. Secondly, over the next half century farmers will continue to adapt their capacities and will respond to the increased demand for food in all regions if they are given the economic and social incentives and favoured circumstances in which to operate.

They will do these things quickly or slowly to the extent that commodity prices are attractive and other incentives are intelligent and sound. If we are serious about global water security we need to bring in measures – *at the pace that is politically feasible* – to ensure a number of conditions. First, commodity prices should capture the value of water. Secondly, incentives put in place should take into account the needs of the farmers to be able to cope with environmental shocks. In addition, in advanced economies immediately, and at a politically feasible rate in less developed economies, incentives should also be introduced which promote practices that reduce the environmental impacts of intensified crop and livestock production on water and atmospheric services.

Rural transformation that enables farmers to achieve higher returns to water is not just about the economics of production and the adoption of sustainable practices. The past half century has shown that it is a complex mix of corporatisation at one extreme and a wide range of changes in the structure of rural family economies at the other. Financial services are essential. The features of rural transformation of fundamental importance to farmers in poor and non-diverse economies also include improvements in the material infrastructure. These improvements include village electrification, improved roads and bus services and reliable water services. And in the social infrastructure these improvements include education and health services. Just as important is the integration of the rural economies into regional, national and international economies in circumstances that are fair. Markets that favour the advanced economies will do just the reverse.

The integration of poor economies into global trade can be very dangerous and is only positive when the international terms of trade are fair. I guess there are many readers who at this point feel that fair international trade is a fanciful element of global water security. I would argue that it is amongst the top four factors preventing Sub-Sharan African farmers – the farming community that has been unable to keep pace with demographically driven demands – to match increased local

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[7] The comparison of the demographic and climate change impacts is deliberately stated in the way it is in the text at the level of hyperbole in order to get attention.

demand for food and water. The other three are unreliable rainfall, poor soil fertility and the socio-economic context. The next five decades will answer the question – have rainfall reliability and soil fertility been determining in sub-Saharan Africa? Or is it the political and economic contexts in which Sub-Saharan farmers operate?

Rural transformation has some other important features that help a farmer to survive environmental and market shocks and go on to increase crop and livestock productivity. Farmers across the world both survive and increase elements of their productivity by engaging in off-farm employment. Everywhere, as soon as rural transformation begins, the proportion of off-farm income that supports the farm enterprise increases. Subsistence farmers are full-time farmers. At the other extreme corporate farms employ full time professionals. At all points, in between these two extremes, the proportion of part-time and off-farm activity is universal although with different degrees of importance. A feature of off-farm employment of all or some of the farming family is that it hedges the farm enterprise against the brutal uncertainties of the environment and the market. This hedging is not trivial. It is a life and death issue. The suicide rate amongst farmers is above the society average on subsistence farms, as well as on farms in industrialised countries. We need farming communities to survive to be food and water secure.

Numerous conditions of industrialisation and of modernity have made it possible for farmers to increase their returns to water. Notwithstanding these advances farmers still have to cope with the environment. With rainfall variability, with multi-year droughts and seasons of excessive rainfall and flooding. But the extreme hazards of the market place which are just as lethal, and the deathly circumstances of no market at all, are nowhere experienced in the rural societies of advanced economies. Droughts are painful but survivable albeit with new patterns of farm ownership and adapted cropping.

A feature of modernising rural political economies is their juxtaposition with urbanising and industrialising economies. Rural depopulation is closely associated with a developing, industrialising and diversifying economy. I shall never be the same after spending an afternoon on a Canadian prairie farm at the height of the Saskatchewan harvest of lentils and durum wheat a few days before drafting this chapter. These commodities were all destined for the Mediterranean and the Middle East via the extraordinary global commodity trading corporations – such as Cargill. One could only be impressed by the way that the specific commodity needs of distant economies with very serious water deficits are supplied with their deeply preferred and essential food commodities grown on an almost completely depopulated landscape. The farm operations which achieve very high and increasing returns to only 500 mm of annual rainfall are dependent on *huge inputs of energy*. These energy inputs mobilise the tiny in number – but massively capitalized – human skills and equipment focused on the vital harvesting, transportation, storage and marketing infrastructures.

One was curious to know why the green water productivity had improved over the past decade. As usual it was a mix of agronomic and technological inputs and changes. Yields of the grain crops, and therefore returns to green water, had increased by about 20% in the past decade. The main reason for this increase was the adoption of low-till methods of cultivation and seeding with the parallel development of herbicide technologies. Low-till cultivation and seeding could have been adopted a century ago. But it was not adopted until over half a century ago in Australia and since then the approach has been widely adopted. The point being made is that even already high returns to green water can be improved with significant impacts on global water security.

4.3 *International trade and fair international trade*

The purpose of this section is to highlight the major forces associated with international trade that bring about global water and food security on the one hand and impair it on the other. Figure 1 illustrates the volumes of virtual water associated food commodity trade. It shows how the industrialised regions dominate the exports as they have in some cases substantial water resources – especially green water resources in North America, South America and Australasia. They are the *water losing* economies. The *water saving* economies are in East and South Asia. Figures 2 and 3 show that the majority of trade in food commodities is between the industrialised economies.

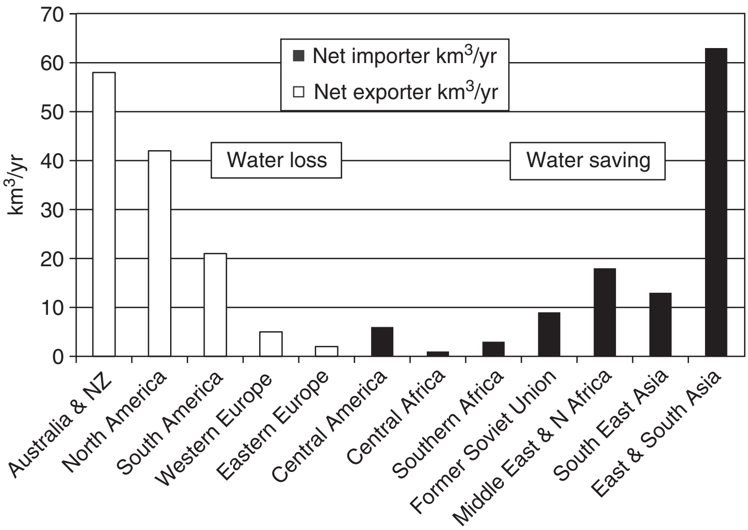

Figure 1. International virtual water *trade* showing the predominant *exporting* regions and the major *importing* regions.
Source: Hoekstra & Chapagain (2007)

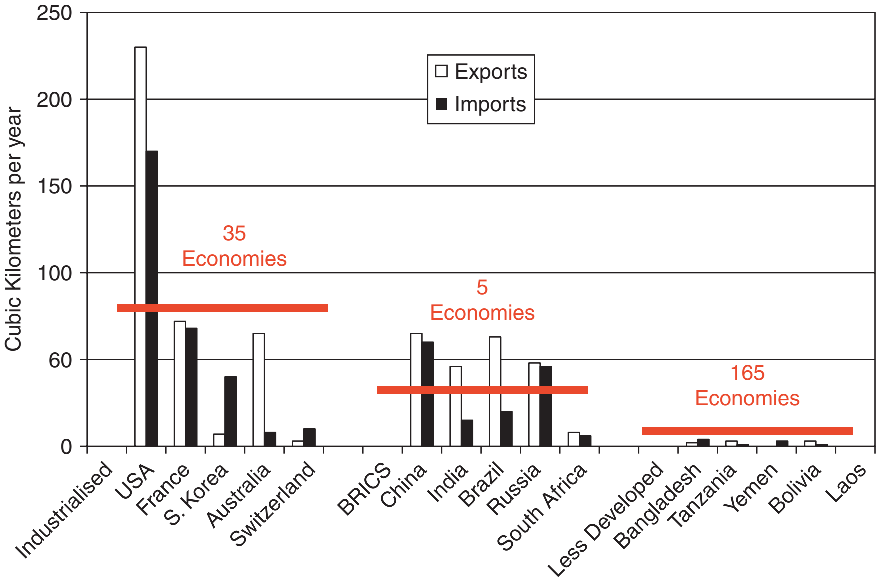

Figure 2. The volumes of virtual water *imports* and *exports* of some industrialised, BRICS and developing economies.
Source: Hoekstra & Chapagain (2007)

Trade in virtual water is accepted as the major means of remedying the water deficits of water scarce economies. Trade in food commodities is mainly between the industrialised economies. The BRICS economies are also significantly involved. The developing economies are scarcely involved and for the poorest developing economies, for example those of Sub-Saharan Africa, international food commodity trade can be very dangerously negative. For these economies virtual water *trade* associated with food commodity trade has a downside.

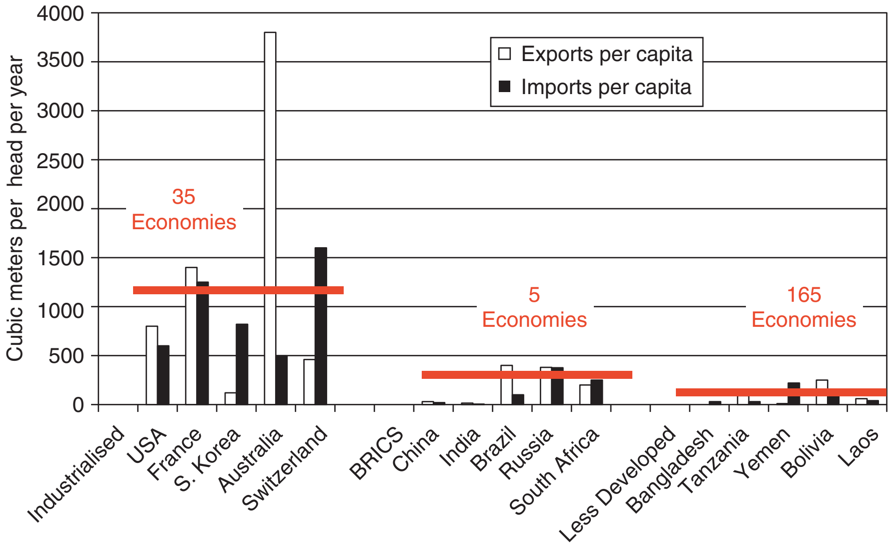

Figure 3. The volumes of virtual water *imports* and *exports per head* of some industrialised, BRICS and developing economies.
Source: Hoekstra & Chapagain (2007)

International trade in water intensive food commodities is mainly about meeting the food preferences of consumers in rich regions. But a substantial proportion of virtual water *trade* does address the water and food deficits of two BRICS and very many developing economies. Especially 20 or so economies in the Middle East where they are dependent for over one third of their water on imported food commodities. And when their populations double they will be 60% dependent.

The international food trade and emergency food assistance are currently important in Sub-Saharan Africa. The water intensive food imports are very necessary for humanitarian reasons during periods of drought. But at other times the terms of international food commodity trade have a very negative impact on the productivity of water in African economies. FAO data does show that there have been minor increases in crop yields in rainfed agriculture in East Africa. But crop yields of 1 t/ha or less are the norm in Sub-Saharan Africa. FAO agronomists argue that these levels of yield cannot be improved because rainfall is unreliable and soil fertility is low (Burke & Steduto, 2007, pers. comm.). The current drought in Kenya and the Southern Horn of Africa lend support to this argument. But there is other evidence that the yield gap – that is the difference between the yield achieved in experimental farm circumstances and that achieved by farmers who lack the technical, economic and social infrastructures of the experimental farm – can be reduced. Dorosh *et al*. (2008) have shown that there is strong relationship between crop production and crop productivity in rainfed tracts of Sub-Saharan Africa and the availability of transportation[8].

It is difficult to identify the relative impacts of the three factors determining crop yields: first, the environmental endowments; secondly the socio-economic infrastructures that can transform returns to water as demonstrated in industrialised economies; and thirdly, the terms of engagement in international markets.

[8] "In terms of agronomic potential, there is substantial scope for increasing agricultural production in sub-Saharan Africa, particularly in more remote areas. Total crop production relative to potential production is approximately 45% for areas within 4 hours travel time from a city of 100,000 population. In contrast, total crop production relative to potential production is only about 5% for areas more than 8 hours travel time from a city of 100,000 population. These differences in actual versus potential production arise mainly because of the relatively small share of land cultivated out of total arable land in more remote areas." (Dorosh *et al*. 2008).

The relative impacts of the third factor – the unfair terms of international trade – are especially hard to quantify. They are certainly a very significant factor in reducing the incentives for poor farmers on rainfed African farms to increase their crop yields and the returns to green water. The disincentives arise because the very productive farmers in the USA and Europe – enjoying powerful technical, market and social infrastructures as well as additional protection and close relations with USA based global trading corporations – have been putting staple grains on the world market for half a century at about half cost. There have been occasional price-spikes but the price of wheat has been falling for 1,000 years and especially since the 200 years of the industrial era. Staple food commodity prices have neither reflected the true costs of many inputs such as energy, nor the real costs of water –if environmental impacts were to be internalised.

The history of crop yield improvement in industrialised countries has been very long and arduous. The early advances were the result of agronomic improvements associated with investment. Farmers can only invest when they have financial surpluses and surpluses accumulate when prices are favourable. Prices tend to be favourable when there is scarcity associated with natural events such as droughts.

Sub-Saharan farmers endure droughts. But every time there is a drought and evident scarcity African governments with too many urgent problems including large and very poor urban populations – understandably – cannot resist the temptation of importing the under-priced grain on the world market. There has been an endless cycle of punishing rural poverty perpetuated by engagement of Sub-Saharan economies in international commodity trade during the second half of the 20th century. The experience has been damaging for the farmers and for Sub-Saharan economies. The current progress in the World Trade Organisation negotiations do not augur well.

It is suggested here that international trade in food commodities should be reformed to enable the farmers of Sub-Saharan Africa to be able to enjoy prices for their output that reflects their inputs and further enable them to invest in improved cultivation and harvesting systems and in modern and sustainable agronomic practices.

The visit to Saskatchewan at the height of record breaking harvest made one aware of what can be achieved in an environment that is *extremely hostile* most of the year. Farming has evolved from a life of non-mechanised poverty and cycles of failure (Waiser, 2005) to one where extreme environmental and market shocks can be accommodated. Last year's productive vigour on the grain farms of North America is a consequence of reasonable although late rains and the vital stimulus of two years of high commodity prices. The previous year's price spikes came after over a decade since the last spikes in 1995. In 2008 grain prices were exceptionally high as they tend to be when there is an unwelcome spike in global energy prices.

Canadian farmers – like African farmers – have to survive in a global market dominated by the distortions of EU and USDA subsidies. For decades the EU and the USA have competed down the global price for some of the main grain staples. The potential of the Canadian farm sector has been revealed by the price spike of 2008 when it was briefly released from the numerous disincentives and the lack of investment associated with low commodity prices. One does not have to go very far back, however, to encounter a period when the farmers of the prairies of Canada faced the inevitable crisis which follows a number of years of low rainfall. The recent extreme year was 2002 when some farms did not take their combine harvesters on to the fields in August or September. Canadian farms do fail but the whole industry is kept in place by the vast suite of hedging processes which relatively prosperous farmers can engage in themselves as well as those of the banks and in extremis of government.

5 COMPETING WITH THE ENVIRONMENTAL SERVICES OF WATER

Farmers compete on our behalf for water resources with the environmental services of water. We have a voice. The environment can only be given a voice.

Sustainable intensification is sound. Unsustainable intensification is not.

Farmers are also key players with reference to the environmental services of water. In delivering food and water security to society they compete – on our behalf – more significantly than any other water resources users with the environment for water. Agriculture tends to impair the water services of the environment. In many hotspots world-wide irrigation has made extensive tracts of land unusable.

When incentives are being put in place to bring about increased returns to water, measures should be put in place that incentivise consideration of the environmental services of water.

6 CONSUMPTION – WASTE, DIET AND DEMOGRAPHIC POLICY

A joint effort is needed – both via increases in water productivity on the farms and changed patterns of food consumption by society.

China has taken 5% out of global water demand. Their population policy is the biggest water demand management measure in modern history.

The analysis so far has shown that global water security has been achieved by increasing the productivity of green and blue water in food production. Where the intensification is sustainable there is a virtuous circle.

Water consumption for food production is such a dominant and pivotal use that many ways of reducing levels of agricultural demand for water resources must be deployed. Levels of food consumption are determined by consumers. Consumers in rich economies tend to overconsume food and associated embedded water. And they also waste food. Other chapters draw attention to the waste of water associated with the waste of food by society from harvest to table and beyond.

The relationship between the water consumption of individuals and societies and their diet has been emphasised by a number of water scientists (Hoekstra & Chapagain, 2008; Waterwise, 2008; Allan 2010). The water demand of the individual vegetarian South Asian has a light daily water footprint of 2.5 m^3/day of water. The heavy beef consumers of Europe and the USA require about 5.0 m^3/day of water. Since the consumption of a lot of red meat is bad for human health we have the remarkable situation in the industrialised world that people are eating their way to poor health and at the same time unnecessarily depleting and misusing scarce water resources. About one in five of the world's population live in industrialised countries and tend to have these bad consumption habits. If some were prepared to abandon these bad diets and others were prepared to eat more sensibly the demand for water in industrialised economies could be reduced by up to 30%. The challenge in the BRICS and developing economies is that the majority vegetarians in the 1,000 million population of India should remain vegetarian. The Chinese should remain committed to their fine cuisine and resist the industrialisation of their food consumption. And those in developing economies should not emulate blindly the bad consumption habits of the industrialised world. The difference between the water demand of a sensible food consumption scenario and one similar to that of the industrialised world will make at least a 20% difference to the level of future global water demand.

Global water demand is not only driven by diet. China has shown that it is possible to gain a substantial demographic dividend for the water environment by addressing the problem of rising demands on natural resources by introducing a population policy. The one-child policy has taken 300 millions out of China's and the global economy. Global water resource demands have been reduced by a volume equivalent to the water demand of the USA, or Old Europe or the Middle East. While the populations of the USA and Europe will not rise significantly, the population of the Middle East will double. The global calculus of water security has been impacted positively by China and will be impacted negatively by the Middle East. China has taken 5% out of global water demand. Their population policy is the biggest water demand management measure in modern history.

A joint effort is needed –both via increases in water productivity on the *farms* and *changed* patterns of *food consumption* by *society*. The latter will have the dual benefit of enhancing human and environmental health and reducing the consumptive use of water.

7 CONCLUDING COMMENTS

Water security has been shown to be an elusive concept. Most of the key factors have been addressed – invisible water resources, invisible solutions to water security beyond the water sector, virtual water and international commodity *trade*, water productivity, socio-economic contexts consumption and waste. But there are some others that compound the problem of conceptualizing water security. Water provides many services from food production to environmental amenity. New demands on water resources come along. Brazil has been producing bio-ethanol since the oil price shocks of the 1970s. Many other economies, notably the USA, have followed suit in the recent era of unstable global energy prices. Both Brazil and USA use food crops – mainly sugar cane, soya and maize – to produce bio-ethanol. The volumes of green water associated with this supposedly renewable energy production are very negatively significant with respect to global water security. Brazil is the only economy that is so well endowed with water that it can engage in bio-energy production without much reflection. Using food crops for energy production has a very large water footprint of strategic significance with respect to global water security. This example of society's latest way of testing the capacity of the global water environment is just another complicating factor in any attempt to conceptualise the already elusive concept of global water security.

It has been emphasised in this chapter that the volume of water is important but what we do with water is more important. Farmers do more with water than any other agent and have the potential to increase the productivity more than any other user because they handle 80% of water resources. Societies must nurture farmers and incentivise them to gain even higher returns – sustainably – from green and blue water. They can achieve such higher returns, in some cases much higher returns, if society enables them to operate in conditions that protect them from environmental and especially market uncertainties. They must be incentivized to achieve sustainable intensification of water resource use.

Mobilising new water has been important in achieving the contemporary version of global water security. But managing water, and especially allocating it effectively and *trading* a crucial proportion of it embedded in water intensive commodities have been other means that have been just as important. They will be even more important in future.

Global water security will be achieved with a wide variety of improved engineering, improved water management on farms and with an even wider variety of improved economic and social infrastructures. New blue water could increase food production by between 20 and 40% but with significant negative environmental costs. Increased green and blue water productivity could achieve even higher increases in global food production. The ways we consume food could have even bigger impacts. Diets of the one in five who live in industrialized economies could be changed to advance human health and reduce their water consumption by at least 20%. Future demand for water in the BRICS economies and the developing economies is very hard to predict and will be determined by demographic trends and even by demographic policies. The latter have been shown to be very significant in reducing water demand in China. In addition society itself has the solution in its own hands as it can modify its demands for water resources by reducing waste, by modifying diets and by levelling off the rate of population increase either as a consequence of socio-economic advancement or demographic policy.

We need to look beyond the water sector to achieve water security.

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