

Water security and related issues in Sri Lanka : the need for integrated water resource management (IWRM)

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Abstract: Water is the least regulated natural resource in the world. Water security implies accessibility to cheap and clean water to achieve acceptable standards of food and goods production, sanitation and health, which in turn require cheap energy. Water security should also entail an equitable distribution of water for all stakeholders in the country to prevent social, political and civil unrest. In Sri Lanka, almost 96% of available water from the hydrological cycle is used up in agriculture and food production, contributing just 13% to the Gross Domestic Product (GDP, 2007). With the demise of cheap energy water, food and energy security issues become closely interlinked. Domestic and industrial per capita water use has increased with (GDP) growth. With per capita water availability expected to decrease over time, water security should become a key element in national planning in Sri Lanka. This entails the physical protection of all water related infrastructure from potential disruptions and the efficient allocation and utilization of our limited water resources in all sectors of the economy, with a well executed programme of integrated water resources management (IWRM) backed by quantitative hydrological-modelling. Nations can be characterized by their water footprints and virtual water flows across their borders through the medium of international trade in commodities whose volumes change over time. This is also a mechanism to transfer water from regions of surplus to those of scarcity so that some balance in water security is achieved. With envisaged shortages due to increasing demand arising from population growth, rising living standards and even predicted climate changes on short time scales, water cannot be considered an inalienable right by its users. In a globalizing market economy, intra- and international virtual water flows require that a fair price be levied on water extraction and use.

Keywords: IWMD, virtual water flows, water availability, water footprints and scarcity, water security.

INTRODUCTION

The entire basis of life on earth with all its infinite biodiversity is unimaginable without water. More so than the depleting oil and gas reserves, which are essential to run our complex industrial and transport systems and for which viable alternatives will eventually be found, water will be the defining crisis of the future. Water is the ultimate renewable resource, but the available quantities of freshwater will be determined by the climatically controlled global hydrological cycle and its spatial-temporal variations¹. It is also a resource constantly on the move from the sky to the ground to the rivers and lakes, moving slowly in underground reservoirs and much of it ending up in the oceans. Consequently, rather than being considered a static resource, the flow of water is the main emphasis today in water resources assessments. More than 2 billion people live in highly water stressed regions. Climate change is expected to accelerate water cycles and thereby increase the recoverable freshwater resources (RFWR), thus reducing the numbers in water stressed areas^{2,3}. However, changing seasonal patterns and increasing likelihood of extreme events such as floods and droughts may offset this effect. Integrated water resources management (IWRM), which is essential for future water and food security, can reduce the vulnerability of communities. This will be a challenging task for governments and policy makers, especially due to the ongoing debate on privatization of water rights and distributions. It is a matter of time before a price will have to be put on water extracted from the ground.

Water economists estimate that by 2025 water scarcities will cut global food production by more than the current U.S. grain harvest⁴. Why water scarcity? As populations increase and economic growth and standards of living improve, this is immediately reflected in the per capita use of water. Humans need a staggering amount of water to feed and clothe them in a lifetime. Exports of food, grain, cotton, sugar, textiles, paper etc., are actually an indirect trade in large amounts of water (designated virtual water) as these items are water based products (Table 2). In the future, there is a real danger of water being diverted to grow bio-fuel crops at the expense of food crops. The average urban house in Asia uses about 200 litres/day; Australia and the USA consume almost 450 litres/day⁵. Consequently, producing countries are mainly responsible for reducing the flow of rivers and even emptying them in some areas, while at the same time depleting groundwater resources. A recent book⁵ documents the hydrological anarchy prevailing in the world today with dire consequences predicted in the coming decades and warns that future food security could be impaired if water shortages become critical (already happening in India and Pakistan).

Water security refers to the accessibility of communities to adequate amounts of clean and affordable water to maintain acceptable standards of food, drinks and goods production, sanitation and health (World Health Organization recommended minimum water quality standards). By definition this also includes availability of water for irrigation and industrial processes. Growing water shortages in many parts of the world are forcing governments to treat water security as a priority in national planning. To ensure water security it is also essential that cheap energy is available to extract the underground water from deep aquifers, when available surface water is inadequate; transport the water through canals and pipes; manage and recycle waste water and in the extreme situation to desalinate brackish and saline waters. Globally, the amount of energy needed for these services exceeds 26 Quads (7% of total world consumption of energy; 1 quad=1 quadrillion btu). Consequently, water security is inextricably linked with energy security. Since most water demands are in agriculture and food, it has a major bearing on food security too. In a global sense, there is no shortage of either water or energy today. What is in short supply is cheap and clean water that is accessible to communities. The era of cheap energy is over for good and in the developing world rising energy costs are a major constraint to water security⁶. Nations should strive to formulate viable water and energy policies where the efficient (not wasteful) and

wise use of available water (and energy) is enforced. This is important as it has a bearing on environmental and sustainability requirements. Water security can be improved by affordable infrastructure investments and better management, which in turn improve public health and sanitation, food security and industrial development. The United Nations Millenium Development goal is to reduce by half the number of people without sustainable access to safe drinking water⁷.

Globally, annual human and animal water consumption is only about 0.3% of the total water availability¹. Most critically, lack of minimum water security is also a fundamental cause for the prevalence of ubiquitous poverty across much of the developing world. Poverty alleviation and the accompanying national developmental paradigms must have water security as a cornerstone of their programmes. A major part of current international trade directly or indirectly involves water, energy and food or their derivatives and by-products. In Sri Lanka (and in many other countries) there are no reliable estimates of groundwater extraction, which compounds the problem. Like all natural resources, society will eventually have to pay a market price for the largesse. This is why certain soft measures (legislation, regulation, water policies and pricing mechanisms) and technological applications need to be considered to manage supply and demand wisely and ensure water security in Sri Lanka.

Water budgets ^{1,2,3,7,8}

The earth's total water supply is estimated to be about 1300 million km³. About 96% (1250 million km³) is in the oceans and is undrinkable; ~28 million km³ of fresh water are locked up in ice caps and glaciers; the earth's atmosphere contains 12.5 million km³; rivers, freshwater lakes and groundwater contain ~8 million km³. Consequently, > 99.7% of all water is not available for human/animal consumption. The remaining 0.3 per cent freshwater is not easily accessible due to location and depth. Much less than 1% of the total supply is available in stored groundwater. The global demand for water has increased by 300% during the past 50 years. Almost 70% of available freshwater is withdrawn for agriculture (in Africa it is ~90%; in Sri Lanka it is 95%; in the USA 39%, but almost 40% of its water is used up in cooling thermal/nuclear power plants). Global water extraction in 2005 was ~4000 km³ (= ~30% of the World's total freshwater supply; this is projected to rise to 70% by 2025). Overpumping of groundwater by farmers now exceeds natural replenishment by > 160 km³ (= 4% of total extractions).

If the above figures are placed in context, it is estimated that 1.1 billion people worldwide lack access to clean water and 2.4 billion lack access to basic sanitation and live in areas of high water-stress^{7,8}. The WHO sets the minimum amounts of water required to satisfy basic human needs at $\sim 1,000 \text{ m}^3$ per capita per year. Today, over 200 million people in about 20 countries live much below that level and by 2050 will go up to 1.7 billion in 40 countries². There are health impacts of these shortages. Water borne diseases account for 80% of all infections in developing countries, with 4 billion cases of diarrhoea annually, 200 million with schistosomiasis and several millions infected with malaria and dengue, 6 million suffering from trachoma etc. Consequently, health security is also called into question.

Throughout human history, rivers have been our foremost source of fresh water, both for agriculture and domestic consumption. The amount of water stored in all the world's rivers is $\sim 2000 \text{ km}^3$, much less than the current water withdrawals of $\sim 4000 \text{ km}^3/\text{year}$. However, their annual discharge is $\sim 45,500 \text{ km}^3$, which flows mainly to the oceans. This is the amount considered to be the potential maximum recoverable freshwater resource (RFWR) if all upstream water is used². But RFWR are also required for water demands of ecosystems and river navigation. Water withdrawn from rivers (and underground water) is called 'blue' water and water

evapotranspiration from non-irrigated cropland is called 'green' water⁹. Only $\sim 10\%$ of blue water and 30% green water resources are used globally and there should be no water scarcity. The problem is the high variability of its availability in time and space. Thus, all of the available RFWR are not available to society. Flow during floods and wet seasons cannot be used during dry phases if not for the millions of storage systems (reservoirs, lakes, etc.) in place by regulating the flow of major rivers. This stored water is estimated to be about 7200 km^3 globally^{10,11}. Pioneering country studies of water withdrawals and global water balance estimations with future projections have been carried out, which are an invaluable compilation for water scientists and water economists¹².

Sri Lanka

Rainfall accounts for a major share of precipitation in Sri Lanka where average annual rainfall varies spatially from $< 1000 \text{ mm}$ in the dry zone to over 5000 mm in the wet zone (Figure 1). Estimates of average annual rainfall in Sri Lanka ($65,610 \text{ km}^2$ area) varies from $1800\text{--}2000 \text{ mm}$ ^{13,14,15,16} giving a total volume ranging from $\sim 118,000\text{--}131,220 \text{ Gm}^3$. Evapotranspiration (ET) measurements in 70 drainage basins¹⁷ (out of a total of 103 basins) registered values of $900\text{--}1550 \text{ mm yr}^{-1}$ for the wet zone (with the low end values at the highest elevations) and measurements of $1200\text{--}1550 \text{ mm yr}^{-1}$ in the dry zone. Consequently, substantial water surpluses and deficits occur across the climatic zones, which are seasonally determined. Spatial and temporal variations of ET have also been discussed¹⁷.

The average annual volume of surface water in Sri Lanka is estimated to be $\sim 51,300 \text{ Gm}^3$. The flow and storage of this volume is in 103 drainage basins ranging in size from $\sim 10,000 \text{ km}^2$ (the Mahaveli Basin) to $< 10 \text{ km}^2$ in coastal rivulets. Only 18 of the country's rivers have basin areas exceeding 1000 km^2 . River discharges show a wide range of spatial and seasonal variability caused mainly by rainfall variations^{18,19}. In the high rainfall areas, river discharges amount to 50-70 % of rainfall. In the catchments of the central highlands, tree or forest cover curtails stream flow significantly. In the dry zone areas, river flows account for $< 30\%$ of rainfall even during rainy seasons; infiltration is high and surface runoff is minimal or absent. In the Precambrian hard rock metamorphic terrain of Sri Lanka ($\sim 90\%$ of the area), rainfall is the determining factor of surface drainage and river discharge variations. Wet zone drainage basins ($\sim 27\%$ of the area) account for almost 50% of total river discharge^{19,20}.

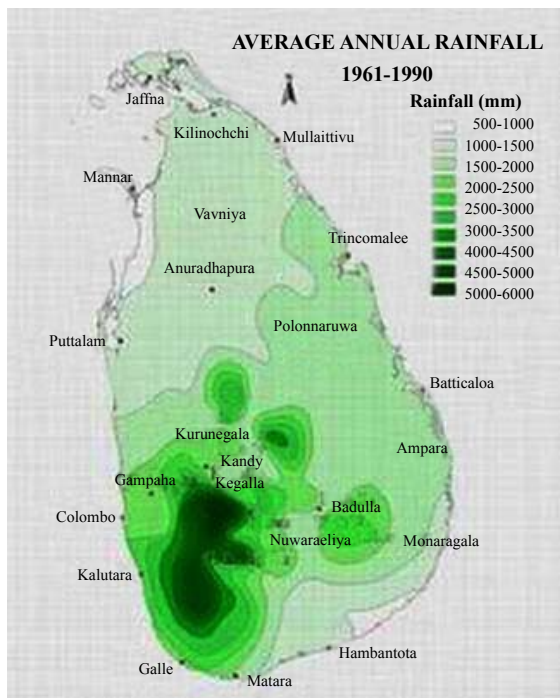


Figure 1 : Average annual rainfall in Sri Lanka (1960-1991)
Source: <http://iri.columbia.edu/~mahaveli>

The total groundwater (from surface infiltration, percolation and sub-surface circulation) potential of Sri Lanka is estimated to be $\sim 78,000 \text{ Gm}^3$ (UNEP)²¹. Due to the lithologic character and low porosity of the rocks and the absence of deep aquifers, about 50% of the country is poorly endowed with groundwater^{22,23}. The aquifers are shallow and small (occurring within the weathered mantle, coastal sand aquifers and freshwater lenses in dune areas and as fracture porosity within hard rocks at depth). Large amounts of extractable water are found in the coastal strip of Miocene limestone in the north, northwest and northeast of the country ($\sim 5,000$ to $20,000 \text{ G litres yr}^{-1}$). These soft rock/sediment aquifers are $\sim 10\%$ of the total surface area. Since most rural communities depend upon well water for drinking and other domestic requirements, it is this fraction that is most vulnerable to over-exploitation in the future. A paradigm shift from unregulated groundwater extraction to groundwater management and governance holds the key to its equitable use and sustainability. Additionally, groundwater is being increasingly extracted for agriculture. All issues related to groundwater extraction, overexploitation, optimal utilization, water pollution, conservation of drinking water sources, water rights and water pricing are addressed by IWRM practice.

Basically, these three components constitute the water resources capacity of Sri Lanka. The construction of large storage reservoirs over the past 60 years has resulted in an overall irrigation capacity of $\sim 540,000$ hectares of which 63% are served by major irrigation systems¹⁶. With the completion of the Mahaweli Project, further expansions are subject to much uncertainty in the use of water resources and appropriate and efficient water management practice. Structural and administrative mechanisms to regulate efficient water use and distribution are much to be desired. Wastage is high and farmers simply do not pay for the water they use. There is an absence of consensus, cooperation, reciprocity and much selfishness when it comes to sharing water for the benefit of the entire community. A levy or price on the volume of water used, both to reduce waste and earn revenue for local infrastructure maintenance would create another inefficient bureaucracy and controls. The free access to irrigation water is considered (irrationally) an inalienable right by farmers. The available water is inadequate and double-cropping of rice is a problem. Cropping intensity can be maximized only by improving IWRM practice, which would lower costs, rather than doing so by increasing arable land extent and new irrigation projects.

Sri Lanka is fortunate in that her three main plantation crops (tea, rubber and coconut) are almost totally rain fed.

Today, agriculture and forestry accounts for only 16% of Sri Lanka's GDP, which includes the use of underground water. Total water withdrawals have been estimated at 10 km^3 in 1996. Most of the water withdrawals are used for growing rice with $\sim 85\%$ of the irrigated area and 44% of the population being in the dry zone²⁴. Yet, an enormous irrigation infrastructure has to be maintained for just one crop, which is essential for food security in the country as it is the staple diet. The irrigation efficiency (i.e. the ratio of irrigation requirements to the irrigation withdrawals) at present is about 20%, which could double by 2025. By any measure, water use in agriculture is a very inefficient practice with poor returns.

Water is also a hydropower resource in Sri Lanka with a potential generating capacity of about 2100 MW^{13} . Today, the installed hydropower capacity is about 1230 MW , which fluctuates through the year due to changing reservoir capacities brought about by variable weather patterns. The current hydroelectricity output is around $3,100 \text{ Gwh}$, which is about 12% of Sri Lanka's power requirements and the limits to hydropower generation may be not too far away. With increasing dependence on thermal power generation round the year and in the future, the high cost of energy will also be a constraint to water security. Thermal power generation also requires large volumes of water for cooling thermal plants, water that can be recycled as and when needed (in the USA, power plant cooling uses $\sim 40\%$ of its total fresh water resources, the same as that for agriculture).

With average per capita water availability (of internal renewable freshwater resources) in Sri Lanka of $2500 \text{ m}^3 \text{ yr}^{-1}$, there is no great water inadequacy in the country at present²⁴. However, the total available water resources at district levels are cause for concern in the coming years. In the districts of Colombo, Puttalam, and Jaffna, the average drops below 1000 m^3 , which is significantly below the recommend levels for human health and quality of life. A figure of 50 litres/day/person (globally) has been suggested as a basic requirement for domestic needs²⁵. With the projected levels of population increase by 2025, the national average will drop to $\sim 1900 \text{ m}^3$ and way below 1000 m^3 in 6 districts (+ Gampaha, Kandy and Kurunegala). The per capita water availability in Sri Lanka is highly variable at district level, with effective steps needed for water conservation and management if severe scarcities are to be avoided in many parts of the country. A per capita availability of $1750 \text{ m}^3 \text{ yr}^{-1}$ is the water-stress threshold for a country²⁶. Levels below this are indicative of regular or seasonal water-stress conditions. If so, the 6 districts above will soon be under permanent water-stress conditions (with 44% of the 2025 population in 20% of the land area).

These estimates have not taken into account possible impacts of future climate change.

Long term rainfall records covering some 277 stations in Sri Lanka, highlight a clear long term trend of increase or decrease of rainfall (Table 1). Rainfall variability studies^{27,28} are of critical importance as they impact on spatial and temporal water availability (for domestic, agricultural and industrial use), natural hazards such as floods and droughts and hydropower generation. The impacts on agriculture have been discussed, again implying the linkage between water and food security in Sri Lanka^{24,16}. The lack of an IWRM-hydrological model has a bearing on costs and prices of commodities. Water, energy and food security are interlinked through the prices we pay for these commodities. If the high costs are due to poor management (and corruption?), then a time will soon come when a price will have to be levied for extracting a natural resource, especially if the water resources required for domestic, agricultural and industrial use are depleted due to population growth, rising living standards and envisaged future climate change.

Virtual water and water footprints ⁴

Economists have long theorized that it is unwise for countries that depend on irrigated water to grow low value food crops with high water needs. The value of the water used to irrigate crops such as rice, wheat, sugar cane, cotton etc., could be much higher than the value of the product. Irrigated crops cannot compete with crops that depend on rainfall. In 1995, Professor J.A. Allan of the University of London put forward the idea that countries with severe water deficits should import food grown with cheap water from regions with a water surplus, instead of using their scarce (hence expensive) reserves to grow their food needs. This gave rise to the concept of Virtual

Water (Wv). Virtual water is the water used in producing countries to produce the goods that another country imports. That is the water that a country would require to produce the goods that it now imports. This is a difficult concept to analyze and even rationalize. Sri Lanka (a water rich country), once gained a rather questionable reputation as the largest net Wv importer in the world (at $\sim 86.10^9 \text{ m}^3 \text{ yr}^{-1}$ between 1995 and 1999); Japan has an abundance of water for all its needs; yet it imports $\sim 65\%$ of its food and 80% of its timber requirements, which amounted to net Wv imports of $\sim 60.10^9 \text{ m}^3 \text{ yr}^{-1}$ (data for 1995-2001)⁴. By 2001, Sri Lanka had reversed the trend and had become a net Wv exporter. Table 2 summarizes the amounts of Wv embedded in some common products of the modern world. The per capita use of Wv varies from country to country according to their diets, life styles, economic wealth etc. With the international trade in food, clothing and other commodities, there is a virtual flow of water from the producing to the consuming countries⁴. Water deficit regions are thus able to achieve real water savings, conserve their limited reserves or divert them to other more critical areas of the economy. At the regional or global level, Wv trading can either result in cooperation, dependence, economic disruption and political or diplomatic conflict, thus affecting water security and geopolitical relations. More than any other single commodity, water signifies the interdependence of the modern world.

The concept of Water Footprints (Wf) was introduced in 2002 by Arjun Hoekstra and T.Y. Hung of the University of Twente in the Netherlands⁴. The water footprint of a nation refers to the total volume of freshwater used to produce the goods and services consumed by the people of that nation. The Wf consists of the use of indigenous freshwater resources and the use of water resources originating outside the borders of a country. That is:

Table 1 : Long-term rainfall trends at selected stations in Sri Lanka

Station	Period	*r ²	From (mm)	To (mm)	Change (mm)
Anuradhapura	1880-1993	0.092	1,480	1,260	-220
Avissawella	1880-1981	0.010	3,888	4,025	+137
Badulla	1880-1993	0.107	1,950	1,688	-262
Colombo	1880-1993	0.137	2,042	2,520	+478
Hambantota	1880-1993	0.016	1,078	1,040	-38
Jaffna	1889-1989	0.036	1,326	1,204	-122
Kandy	1880-1993	0.298	2,234	1,860	-374
Watawala	1910-1993	0.200	5,644	4,940	-704

* Three-year moving averages trend-line values based on data from Nakagawa *et al.*^{16,19}

$$\text{Wf} = \frac{\text{total use of domestic water}}{\text{water}} + \frac{\text{gross Wv imports}}{\text{imports}} - \frac{\text{gross Wv exports}}{\text{exports}}$$

The Wv contents of the common crops grown in Sri Lanka and the total used up for industrial goods and products are summarized in Appendix 1. This information is required for calculating Wv flows and Wf in the equation above. Note the very high water requirements for spices, cashew, cocoa, rice and coffee.

It is clear that part of the Wf of a nation originates from within the country (internal) and part of it outside (external Wf). The total Wf is composed of three components (blue, green and gray)⁹. Wf (blue) is the volume of freshwater evaporated from the global blue water resources (i.e. surface and groundwater) to produce the goods and services of a nation; Wf (green) is the volume of water evaporated from the global green water resources (i.e. rainwater stored as soil moisture); Wf (gray) is the polluted fraction resulting from the production of goods and services (this water is always below acceptable water quality standards). The Wf includes extraction and use of both surface and groundwater and soil water (in agriculture).

The above concepts are the basis for determining water self-sufficiency (Wss) and water dependency (Wd) of a nation; They are also a measure of the water scarcity (Wsc) of a nation. Wsc is the ratio of the internal Wf to the total Wf of a nation (Appendix 1). A water scarcity index can be defined as $Rws = (W-S)/Q$, where W, S and Q are annual water withdrawals by all sectors of the economy and the annual RFWR. A region is highly water stressed if Rws is > 0.4 ^{2,10}. The per capita stress threshold ($\sim 1750 \text{ m}^3 \text{ yr}^{-1}$) is derived from this index. Wss is 100% if all the water needed to produce goods and services is available within the country (93 % for Sri Lanka) and Wss is zero if all the water requirements are met with Wv imports. The Wv import dependency of a country is the ratio of the external Wf to the total Wf of that country (7% for Sri Lanka). In the past, water statistics emphasized the supply side for each sector (domestic, agriculture, industrial water use) and was producer oriented. The Wf concept includes demand and consumer oriented indicators as well (i.e. an indicator of water use in relation to consumption).

When goods and services are traded internationally, there is no physical transfer of water (except what is present

Table 2 : Estimates of the amount of water used to produce some common items of modern industrial societies *

Product	Water Used (litres)	One full meal chosen from items below (litres)
Rice (1kg)	2700-3400	Plate of rice 120
Wheat (1 kg)	1200	Sandwich 400
Maize (1 kg)	450	Eggs (1 kg) 3,700
Potatoes (1 kg)	180	Orange juice (200 ml) 170
Beef (1 kg)	15,000	Mixed salad 60
Milk (1 lit)	900	Cheese (1 kg) 5,300
Poultry (1kg)	2800	Eggs (1 kg) 3700
Pork chops (1 kg)	5900	Potato chips (200 g) 185
Sugar (1 kg)	4,000	Coffee (1 kg) 26,500
Cotton shirt	2000	Sugar in coffee (1 sp) 50 cups
Apple (1)	70	Coffee in cup 140
Grapes (100 g)	120	Beer (glass) 75
Jeans (1 kg)	10,850	Wine (glass) 120
Bed sheet (900g)	9750	Hamburger (150) 2400
A-5 paper (sheet)	10	Tea (250 ml) 35
Diaper (75 g)	810	Bread slice 40
Leather shoes	8000	
Pair of jeans	10,950	Milk (200 ml glass) 200
Motor car	400,000	
House (1)	6,000,000	
Computer chip	3200	Brandy (glass) 2,300

* These values can change from country to country and over time and is probably representative of the USA, Australia, Japan and Western Europe. Data extracted from Hoekstra and Chapagain 2007³¹.

in the goods, which is a negligible volume), but there is a significant transfer of W_v amounting to over 1650 Gm^3 per year⁴ ($G=10^9$). The end result is that high water deficit countries can reduce the pressure on domestic water resources by W_v imports (i.e. Kuwait, which has a W_v import dependency of 85%). Interestingly, countries and regions with very high per capita incomes and GNP (Western Europe, UK, Scandinavia, Singapore, Japan, Gulf States and Taiwan etc.) have a very high W_v import dependency (W_d is generally over 70%). It is simply more practical (and affordable) for these countries to import some or most of their requirements, thus conserving their water resources. It is clear how the ramifications of these concepts are eventually related to the water security of a country.

The W_f also varies from country to country. It is calculated at 700 m^3 per capita per year for China (with 7% outside its borders); Japan is 1150 m^3 (with 65% outside the country); 2500 m^3 for the USA (with a 19 % external W_f) and Sri Lanka 1293 m^3 (with an external W_f of ~7%). The global average is 1243 $m^3/c/yr$. See Appendix 1 for a summary.

Water economists have calculated that to produce a kilogram of rice requires between 1200 to almost 6000 litres of water, dwarfing drinking and domestic water usages (Table 2). When grain is used to feed livestock to produce the meat and milk products we consume, the figures become mind-boggling. It requires about 4,000 litres of water to ultimately produce enough beef for a 114 gram (quarter pound) hamburger and anything between 900-1300 litres for it to produce a litre of milk. Next time gourmets eat just a 100 g of cheese, they would have used up ~500 litres of water. People of affluent classes (wherever they may be from Albania to Zanzibar), when they next visit their favourite supermarket and fill up their trolleys with whatever (meat, sausages, ice cream, cheese, coffee, sugar and their favourite alcoholic beverages) should refer to Table 2 and compute the amount of water it took to produce those goodies and reflect upon their conspicuous consumption per capita per unit time (say one year). It becomes a tragedy and bordering on obscenity, when they compare themselves with less fortunate human beings who are a majority in this world and many surviving on just one-dollar per day and all the time helping to run our rivers dry and lower groundwater tables. To the above must be added the cosmetics, lotions etc. that are widely used to satisfy our vanity. When we add the number of toilet flushings per capita per unit time and the daily showers and baths, the figures become surreal. And then Coke and Pepsi and other beverages.....But this is the world we live in

(whether we like it or not) where market forces dominate. Reducing these needs would be going backwards in time for many. The question is how we can restore a balance based on need, moderation and comfort, rather than ego, greed, luxury and waste. If biofuels, a viable alternative to oil and gas become a reality, then more water will be diverted from food crops to fuel-crops in the future, thus creating further imbalances in the water-cycle and affecting water and food security. Also, books, newspapers, magazines, stationary etc. which use huge amounts of water are essential for civilized living and are not luxuries. Most of these paper based products, packaging materials etc., are ultimately discarded, if not recycled, which again requires large amounts of water. However, things must be seen in perspective. All of what has been discussed above is perhaps not applicable for over 80 per cent of humanity. Yet, they contribute to most of the basic value added items listed above.

Lessons from India⁵

The Green Revolution (GR) has produced high yielding crops of rice, wheat, corn etc., that has fed her population, which is now over 1 billion. Widespread irrigation made this possible. But GR crops also require large amounts of water to keep productivity high. River flows are just not adequate to meet water demands for agriculture. However, unlike other Asian countries, which achieved agricultural self-sufficiency by diverting rivers to irrigation canals, India did it by not only draining the rivers into canals, but also by tapping its vast underground water reserves.

Today, over 20 million farmers depend on tapping underground aquifers to farm their fields. Part of this water goes to the rapidly growing private water business. In the last 20 years, farmers have invested about US\$ 12 billion on rigs, pumps and boreholes. However, underground water is a dwindling resource. This water grows thirsty crops like rice, alfalfa, cotton and sugarcane. This is a "free-for-all" activity according to an Indian water expert who calls it hydrological anarchy. There is no regulation; no statistics on who own pumps and how many pumps (with subsidized electricity) are in operation. The International Water Management Institute (IWMI) estimates that about 200 million acre feet (maf) of water per year is extracted for irrigation in India. The rains bring only 120 maf and underground water irrigates about 60-70% of India's crops. Over one million pumps are bought each year. Most hand dug wells and over a million tube wells have run dry. Today, tube-wells at 400 metres depth are running dry. The mudflats of the Cauvery delta in Tamil Nadu were a rice paddy of some 2500 km^2 extent. In Tamil Nadu, only half as much land

is irrigated compared to 12 years ago⁶. Today, there is a hydrological conflict between the states of Karnataka and Tamil Nadu over sharing the flow of the Cauvery River.

As the water tables fall, more subsidized electricity is used to pump water to the surface (= US\$ 5 billion per year energy equivalent or 1 per cent of GDP). If charged at market rates, agriculture would be abandoned and only rainfall will provide water, which is insufficient. Today, the grids cannot take the strain and blackouts are common (the effective limit to pumping according to IWMI experts). In Gujerat, mostly an arid state, a dairy farmer uses 2000-5000 litres of underground water to produce every litre of milk. Water tables are about 150 m deep and lowering by about 6 m per year. This is making milk in the desert. The “white revolution” according to politicians. No underground water, no milk. The dairy industry is the main reason for the water crisis in Gujerat. Just two districts here export 1.2 maf of virtual water as milk. India is the leader in world milk production- but at what cost?

Farming water in India is cheaper than dairy or crop farming. Just pump the water from depth, fill up the bowsers (thousands of trips each day) and send them on their way to the cities for sale. This is where the bottled water comes from. Add to this the factories producing goods, dyeing and bleaching of textiles, bottled beverages like Pepsi and Coke etc. Eventually, the wells will run dry due to over-extraction, unless a regulatory mechanism is in place. The environmentalists call it “the tragedy of the commons”, where everybody is after short term wealth at the expense of protecting their longer term future. Everybody must get a share of the boom times and then perish together. The examples above can be multiplied across the world in China, USA, Russia, Libya, Mexico, South America etc., and the looming crisis widens.

Water security in Sri Lanka

Fortunately, the situation in Sri Lanka is not alarming at all, but there are serious lapses in water security if we go by the definition given above. The World Bank estimates that, of the 85% of Sri Lanka’s population living in rural areas, only 10% have access to treated tap water and every fifth person relies on unprotected water sources for drinking and ~30% of those living in rural areas and small towns do not have access to sanitary latrines²⁹. Again, this reiterates the fact that there are problems of accessibility of rural communities to clean water and sanitation. When the water availability drops below

1000 m³ per capita, there is a serious threat to human well being and health. This is despite an average water availability of 2500 m³ per capita per year²⁴. IWRM practice should strive to keep annual per capita water availability above the recommended stress threshold of 1700 m³. More worrying is the longer term predictions of decreasing water availability in some districts²⁴. Sri Lanka could avoid these problems if we heed the lessons learnt from neighbouring India. Some form of regulation is required for preventing over-exploitation and over pumping of the highly vulnerable shallow underground aquifers, whose recharge capacity is naturally low due to the prevailing geology.

In the longer term, an aggressive programme of waste water (and sewage?) recycling is required in the main cities and towns, as practiced in water-stressed Australia, whose well tested technology could be appropriate for Sri Lanka if and when the need arises, but requires capital investments. Japan recycles ~80 per cent of her industrial waste waters. Additionally, rainfall harvesting and artificial groundwater recharge programmes in the water-stressed districts should be explored for feasibility and viability (as in India). All these inputs should improve the water security situation in the country. So, what price water? Can these programmes be brought on stream without the consumers paying their share?

The drinking and domestic water problems were recently highlighted by several unexpected events, both local and regional, which made severe demands on governments. In Sri Lanka, two events occurred, which tested to the limits the resolve of government institutions. The first was the December 2004 tsunami, which inundated a coastal zone of ~800 km length up to 2 km inland and in the process destroyed over 50,000 drinking water wells and affected over 500,000 people in the coastal communities³⁰. The Water Supply and Drainage Board had the difficult task of providing free drinking water to these communities at great cost to the state as the tsunami was a totally unexpected event. The NWSDB continued to perform this task to the best of its ability. The health authorities were able to move in quickly and take control of the situation. Amazingly, following the disaster, not a single death was reported from water borne diseases despite widespread cross-contamination from broken water pipes and damaged lavatories and cess-pits. Providing adequate supplies of bottled water from voluntary organizations in the initial stages and aftermath were also instrumental in alleviating the drinking water shortages. Three years after the tsunami, some wells are still saline and the water undrinkable. The second was the Mavil Aru

incident in the eastern province, which prevented water from reaching farmers for several weeks, resulting in the destruction of around 30,000 acres of rice harvests and aggravating the civil conflict in eastern Sri Lanka. The first was a natural disaster, which could not be prevented and the second was a totally uncalled for incident, which was the use of water as a weapon in a civil conflict.

It could be argued that Sri Lanka's "hidden" or virtual water trade with other countries is essential for her economic well being. However, the water savings from Wv imports have not been translated into substantial improvements in the water security situation in the country. Sri Lanka is more than 90% self-sufficient in her water requirements, yet faces a water scarcity of 47% due to the trade in Wv. It needs to be emphasized that the variables Wv, Wf, Wsc and Ws are not constant factors but change over time due to export/import trends, economic growth or recession, climatic changes with disruptions to the normal hydrological cycle in the short term and with the frequency of extreme events such as droughts and floods increasing. Also, major shifts to thermal power generation will require large volumes of water for cooling thermal plants and so on. The system must be kept in check to prevent imbalances in the water budget.

An important aspect of our water security is the protection of the hydropower reservoirs and dam sites, water tanks, main intake and pump stations (such as Ambatale on the River Kelani) and dry zone cascading reservoirs from natural as well as human and terrorism induced disasters. Recently, a US\$ 100 million contract was awarded by the government of Sri Lanka to a Swedish company to supply a much needed and reliable drinking water facility for the eastern coastal towns of the Ampara District. It includes the supply, construction, installation and commissioning of two high-tech water treatment plants, eleven pump stations and associated electro-mechanical equipment, 115 km of treated water transmission mains and 655 km of distribution piping and related infrastructure. This is an area of recent civil conflict and the question arises about plant and domestic water security in the district. This applies to all such installations across the country dealing with water and power supplies. A vulnerability assessment must be made by the utilities according to acceptable standards with certification of adequacy by an independent body. Security practices must be incorporated into a utility's regular functions, which should include prevention of natural or intentional contamination of drinking water sources and distribution systems. The arsenic and fluoride poisoning disasters in Bangladesh and India (called the largest "mass poisoning" event in the world) is a case

in point⁵. Fluorosis is also common in some parts of Sri Lanka and especially in the north-central region where kidney diseases are prevalent.

In a regional context, the monsoonal flooding of much of South Asia in 2007, the worst in recorded history, displaced ~19 million people in India, Bangladesh and Pakistan (= population of Sri Lanka). In all cases, drinking water sources and supply networks were destroyed with several million wells contaminated, and alternate supplies had to be provided for the displaced millions to avoid epidemiological disasters that follow the floods. A major cyclone in November 2007 affected the water supplies of over 2 million people.

The price of water

This is a highly controversial topic in Sri Lanka with political, economic and sociological implications. Domestic and industrial water delivered at site in the urban areas is metered and billed at the prescribed rate of the NWSDB. Irrigated water used in agriculture and farming, which accounts for about 95% of available water usage is supplied free to farmers and there is also no regulatory regime or a charge for withdrawing water from wells anywhere in the country and in both suburban and rural areas, despite the profusion of water pumps and tube wells. There are no deep aquifers due to basement metamorphic rocks exposed over much of the country. The water storage capacities are very limited in the brackish, shallow coastal sand aquifers and weathered lateritic profiles further inland (generally > 50 m thick) and are very vulnerable to over-exploitation. The potable water layer in the coastal areas is very thin and fluctuates with the seasons. Its potential for contamination is high during monsoonal recharge when water tables are close to the surface or during excessive drawdown when salt water intrusion occurs. Water quality is generally poor and rarely monitored. It would be far more practical to improve infrastructure facilities and supply piped water to the coastal communities and make a charge for this service, rather than a licensing mechanism for withdrawing what is poor quality groundwater. In the inland areas, a permit system for extracting underground water is more appropriate. It is an unacceptable state of affairs when the state does not get any revenue for almost 80% of the water used.

The data presented in Appendix 1 gives us a measure of the water requirements (and costs) of the various primary crops in Sri Lanka. Coffee, spices, rubber, cocoa, cashew and rice are very thirsty crops. In terms of water use it is preferable to drink tea rather than coffee. Eating meat products entail high water requirements and

greater land area (16,000 litres of water are required for 1 kg of beef). Milk and alcoholic beverages also require high amounts of water. A standard cup of coffee would have used up 140 litres of water and an apple 70 litres. International trade in coffee accounts for over 7% of Wv flows amounting to over 50 billion m³/year. The global trade in coffee is worth US\$ 70 billion/year. Only about ten commodities make up 50% of Wv flows. Sri Lanka accounts for 0.38% share in global average use of water for crop production.

This brings into contention the pricing of water in Sri Lanka. Today, a significant number of urban dwellers have resorted to drinking bottled water priced at Rs. 35 per litre. This is a good starting point to discuss prices. If cents.....per litre are charged for withdrawing underground water (albeit difficult to monitor) or an annual charge of Rs.....per well is made through a license or permit system across the country, the provincial council or the local authority (*Pradeshiya Sabha*) could be entrusted the task of collecting the revenue through its existing administrative system. A *Grama Sevaka* division should be able to audit the number of wells in use in its jurisdiction. The government is unlikely to “earn” very much from this exercise. However, if sufficient revenue accrues to monitor water quality regularly and maintain small scale infrastructure in the rural areas and suburbs, it would still be a success. The water rates in the urban areas are paid for by the residents and larger volume users without any protests. The NWSDB delivers tap water at a base rate of just Rs. 1.25 per unit (1000 litres) with a block increase for higher volumes. Hopefully, the drawers of groundwater from wells will not protest if and when a levy is made or if water delivered on tap is charged at say Rs. 2.50 per unit (still very reasonable). There are several advantages of such a system; it could also be a way to prevent wastage and conserve water if the pricing mechanism is right. With the packaging industry playing a major role at product marketing, it would be appropriate to print the amount of water used to produce a consumer item in its label, in addition to the nutritional content (a good educational and awareness technique). These ideas are only points for discussion in the public domain at this juncture.

DISCUSSION

There are several aspects to water security in Sri Lanka. While the present status of water availability per capita per year at 2500 m³ is a comfortable one, there is the related problem of water shortages at district level today and the worrying prospect of this figure coming down to <2000 m³ within the next 20 years due to

increasing demand and even possible short term climate change. The responsibility of the government at the highest levels is to ensure per capita clean water availability at around the recommended threshold of 1750 m³. This requirement should be an essential goal of the national planners responsible for water affairs. Natural hazards such as floods, droughts and tsunami can temporarily affect water availability and security for which, alternate back up programmes to supply water to the affected areas should be in place. With predicted water shortages in the future, rainfall harvesting and artificial recharge in the drought prone and water deficit districts of the country should be explored, with feasibility studies starting now. The best additional source of freshwater (like oil) in all countries is conservation. In many countries conservation measures are achieved through pricing mechanisms, which have worked well for both water and oil. In the UK today, gasoline is sold at the pump at ~ Rs. 230 per litre, which is twice the cost in Sri Lanka. In oil-rich, water short desert countries where cheap energy is abundant, much of the domestic water is desalinated, brackish or seawater. In the Maldives, desalinated water is used for drinking and at great cost.

It is important that conflicts over riparian water rights, which affect water security, are avoided. In Sri Lanka most of the major rivers flow west from the central highland source areas. The largest river, the Mahaweli (with a basinal area of 18% of the total) ends up in the dry zone in the East. Water shortages for agriculture are a recurring problem in the North-Central and Eastern Provinces, especially during times of drought. In Pakistan, where the Indus River provides most of the water for agriculture, there is almost a state of war between the desert states of Punjab and Sindh for water rights, with upstream Punjab at a distinct advantage over downstream Sindh. So much water is being extracted that there is no flow today for the last 140 km of the Indus. It is no surprise that the Indus River Authority is the largest government employer in Pakistan. Similarly, for the Cauvery River flow between Karnataka and Tamil Nadu. This was ultimately decided after almost 20 years, by a ruling of the Supreme Court of India. If growing food crops becomes too expensive due to water shortages and then just as in India (cited above), farming water and retailing will become attractive, thus reducing food security. This has to be avoided at all costs in Sri Lanka.

The third aspect of water security has to do with political and civil unrest as was the case with the Mavil Aru incident. The need to protect our engineered reservoirs and dam sites, pump stations, distribution

networks, hydropower plants and related infrastructure, contamination problems of drinking water due to natural hazards such as tsunamis need no elaboration. IWRM includes all these aspects where wastage and profligacy is curtailed and water sources protected. The aim should be for all citizens to have equitable access to cheap and clean water, which is their fundamental right.

Virtual water flows are an essential requirement for water security and economic well being in Sri Lanka and across the world. It could also be an effective concept in IWRM. However, over dependency on food imports is a cause for concern and food security. There is a relationship between the impact of international trade and the structure of the global economy and local water depletion and pollution, bringing into focus the link between the globalization process and sustainable water management. Further, it is essential to explore whether the international trade in virtual water flows leads to global water use efficiency or whether it simply shifts the environmental burden to other locations. The Wv savings by Sri Lanka have not been utilized to improve water quality or security in the country. Generally, water scientists are unaware of what kind of information is required by the policy makers. Like in most developed countries, water data in Sri Lanka should be on an open file and easily accessible to scientists. It is clear that there should be improved cross-communication between scientists and policy makers to ensure that new developments, findings and expertise in the hydrological sciences are translated into concrete actions that address water security issues.

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Appendix 1

Some Relevant data for calculating the Wf for Sri Lanka.

Population = ~18.5 million
 Gross National Income = US\$ 1200 per capita (current)
 Arable Land Area = 883,000 ha
 Total Renewable Water Resources (actual) = 50.00 Gm³/year (G= one billion)
 Agricultural Water Extraction = 11.87 Gm³/yr
 Domestic Water Extraction = 0.25 Gm³/yr
 Industrial Water Extraction = 0.25 Gm³/yr
 Total Water Use = 12.37 Gm³/yr
 Evapotranspiration = 3.98 mm/day

Domestic Water Withdrawal = 0.25 Gm³/yr
 Crop Evapotranspiration = 21.72 Gm³/yr (internal);
 2.29 Gm³/yr (external)
 Industrial Water Withdrawal = 0.165 (internal) +
 0.009 (external) Gm³/yr

Use of foreign or imported water (Gm³/yr)
 a) agricultural products = 1.32; b) industrial goods = 0.24;
 c) re-exports of imported products = 0.26
 Consumption of Domestic Water (internal Wf) = 14m³/cap/yr
 Consumption of Agricultural Products
 (internal Wf) = 1185 m³/cap/yr
 (external Wf) = 72 m³/cap/yr

Consumption of Industrial Water
 (internal Wf) = 9 m³/cap/yr
 (external Wf) = 13 m³/cap/yr
 Average Wf = 1293 m³/cap/yr

Total Renewable Water = 50.00 Gm³/yr (~2,592 m³/capita/yr).
 Total Internal Wf = 22.13 Gm³/yr
 Total External Wf = 1.56 Gm³/yr
 Total Wf = 23.69 Gm³/yr
 Water Scarcity (Wsc) = 47 %;
 Water Self-Sufficiency (Wss) = 93 %
 Water Import Deficiency (Wdf) = 7 %

Water Footprint (Wf) for Sri Lanka

Water Footprint (Wf) = Volume of goods and services consumed by a nation x Virtual Water (Wv) content of all consumed goods and services
 Total Wf (SL) = 23.69 Gm³/year;
 Average Wf = 1293 m³/capita/year;
 Global Average = 1243 m³/capita/year.
 Note: Data at end of 2001

Wsc = Total water footprint : Total renewable resources in SL.
 Scarcity can be > 100 % if a country consumes more than what is domestically available

Virtual Water Flows (Sri Lanka (1997-2001)

Gross Wv flows (exports) = 2640 Gm³/yr
 (crops 2381 + livestock 46 + industrial 213)
 Net Wv flows (imports) = 1822 Gm³/yr
 (crops 1373 + livestock 83 + industrial 366)
 Net Wv imports = - 818 Gm³/yr (net volume out of SL).

Wv content of some primary crops in Sri Lanka in m³/tonne (2001)³¹

tea	10,829	sorghum	4878
cabbage	422	rubber	23794
mustard	2320	tomato	740
coconut	2991	chillies	1624
banana	1363	coffee	20543
sugar cane	234	cucumber	382
rice	3168	manioc	848
aubergene	594	cashew	45557
potatoes	437	carrots	426
cardamoms	41438	soya	3268
mango	4210	cloves	45025
onions	937	pineapples	540
cinnamon	28546	ginger	1486
lemons	3344	cocoa	20435
oranges	7334	sesame	6049
tobacco Leaf	3363	pepper	7536
groundnuts	7120		

Total crop water use in Sri Lanka is ~ 2.40E +10, which is ~ 0.38% of the total share in global average water use for crop production.

The above Wv contents change from country to country for a given crop, giving a measure of water use efficiency.

International Wv flows of some major agricultural products related to trade : coffee (7%); rice (6%); wheat (9%); soybean (11%); Cotton (4 %); cocoa (9%); meat (13%); others (41%)
Total international “virtual water trade” is about $1625.10^9.m^3.yr^{-1}$

Wv content of industrial products in Sri Lanka (1997-2001):
Average industrial water withdrawal = 252G m³/year
Average value addition = US\$ 4283 M/year
Average water withdrawal/unit added value = 0.06m³ per US dollar

Exports of industrial products = US\$ 3623 M/year
Average Wv exports related to industrial products = 213 Gm³/year
Average Wv imports related to industrial products = US\$ 5256 M/year = 366 Gm³/year
Wf due to consumption of local industrial products = 165 Gm³/year
Wf due to consumption of imported industrial products = 240 Gm³/year
Total Wf (industrial) = 405 Gm³/year
Average Wf per capita /year = 22
Data extracted from Chapagain and Hoekstra (2004)⁴.