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Water Insecurity and the Poor:

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Summary

Household water insecurity is a pressing problem in developing countries. Unsustainable water withdrawal is increasing due to population growth, industrialization, urbanization, and increasing agricultural production which leads to various problems. The number of countries facing problems of water scarcity and insufficient water supply is rising. Already there are 1.2 billion people without access to clean water, many of whom live in 20 developing countries classified as ‘water scarce’. Typically it is found in these countries, that the poor pay particularly high prices for water and are most water insecure.

Progress towards water security can be made only if there is a more comprehensive understanding of the interactions among waters’ various characteristics and functions. Water is not only a natural resource, but also an economic commodity, *and* a human consumption good or entitlement. The problems of water insecurity can be grouped under three main headings: availability, access and usage. In the framework of a multidisciplinary approach to the analysis of water problems, the paper elaborates on these three elements, defining sectoral and cross-sectoral knowledge gaps. The paper concludes with a research agenda in support of improved policy design and action.

Zusammenfassung

Die Probleme der Trinkwassersicherung bei der armen Bevölkerung in Entwicklungsländern werden immer vordringlicher. Die weltweit jährlich entnommene Wassermenge steigt kontinuierlich durch die rapide wachsende Bevölkerung, die zunehmende Industrialisierung und Verstädterung sowie durch eine wachsende landwirtschaftliche Produktion an. Die Anzahl der Länder mit Wasserversorgungsproblemen und –engpässen nimmt stetig zu. Bereits jetzt haben rund 1,2 Mrd. Menschen keinen Zugang zu sauberem Trinkwasser. Viele davon leben in den 20 Entwicklungsländern, die zu den Ländern mit Wasserknappheit zählen. In diesen Ländern zahlen die Armen typischerweise die höchsten Wasserpreise und sind von besonders hoher „Wasserunsicherheit“ betroffen.

Fortschritte bei der Erzielung einer nachhaltigen Trinkwassersicherung sind nur möglich durch ein umfassenden Einblick in die Wechselwirkungen der verschiedenen Wasserfunktionen und –eigenschaften. Wasser ist nicht nur eine natürliche Ressource, sondern auch ein wirtschaftliches Gut wie auch menschliches Grundbedürfnis und Konsumgut. Die Probleme der Trinkwassersicherung fallen unter drei Hauptbereiche der Trinkwasserversorgung: Verfügbarkeit, Zugang und Nutzung. In dem vorliegenden Report werden im Rahmen eines interdiziplinären Ansatzes diese drei Elemente zur Analyse der Problemzusammenhänge der Trinkwassersicherung herangezogen und sektorale und intersektorale Kenntnissdefizite identifiziert. Zudem werden in Hinblick auf die Verbesserung des Wassermanagements Bereiche herausgearbeitet, in denen noch Forschungsbedarf besteht.

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1. Introduction

The world's population is projected to reach 8 billion people by the year 2020 (UNFPA1997). This expected increase has raised considerable debate about the world's ability to meet future food needs (Brown 1994; Pinstrup-Andersen 1995). However, food is only one of the concerns. Until recently there has been surprisingly little debate on the implications of population growth for household water security in developing countries. Since 1970, global demand for water has risen at roughly 2.4 percent per annum (Clarke 1993). Today, rapid urbanisation in developing countries and continued expansion of irrigation (albeit at a slower rate than in the past), are causing demand for water to rise, often where supplies are the most constrained. Already there are 1.2 billion people without access to clean water, many of whom live in the 20 developing countries classified as 'water scarce' (WHO 1998)[1]. Extrapolating from recent trends, the number of water-scarce countries will rise to 30 by the year 2020, of which 21 will be low-income, food-deficit nations (Rosegrant 1997). The task of ensuring adequate access to safe water for the poorest households in LIFDCs will be one of the severest challenges to development professionals of the 21st century, at least as hard as providing them with access to food.

This paper provides an overview of key issues in household water security and their implications for policy and research in the coming decades. Water is not only a commodity, but also a natural resource and a perceived human entitlement. Much is known already about policy and program design for *food security* and about policy frameworks required for more effective *environmental security*. However, little is known about how appropriate mixes of policies, institutions and market mechanisms could help achieve household water security in water-stressed environments. At a time when the privatisation of water allocation responsibilities and the creation of markets in water rights are offering gains in economic efficiency, there is increasing attention to the non-market dimensions of water. Can the demands of economic efficiency, ecosystem integrity, agricultural growth and household usage be met simultaneously, especially where supplies for more than one of these demands have to be provided at one time?

The paper has 3 sections. The first provides an overview of key issues in water security and offers a conceptual framework for a multidisciplinary approach to the analysis of water problems. The second section elaborates on the main elements of water supply, access and usage, defining sectoral and cross-sectoral knowledge gaps. The concluding section elaborates on areas that require further research in support of improved policy design and action.

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[1] Defined as countries with internal renewable water resources <1,000 cubic meters per capita per annum.

2. Water Security: Issues and Concepts

Water security can be defined as access by all individuals at all times to sufficient safe water for a healthy and productive life. Unlike the definition of household food security, the concept of “safe” water requires more than one standard — clinical safety, cultural and taste requirements for potable water, minimum pollutant standards for ecological and agricultural uses, and lesser standards for industrial and waste management. Achieving each of these standards remains a challenge even for industrialised nations. In the late 1990s, only 35 countries provide safe water to more than 95 percent of their inhabitants (World Bank 1998). Even fewer countries have full sewerage coverage. In addition, withdrawals in some industrial (and even in many developing) countries are excessive. In the United States, for example, the water withdrawn for public supplies (for drinking, but also for fire-fighting, watering of municipal parks, filling public swimming pools, as well as other domestic and commercial purposes), exceeded 175 million litres per day in 1990--a per capita average of 830 litres per day (MSU 1997). This rate is projected to increase a further 32 percent by the year 2000 (MSU 1997).

As a result, many industrialised countries are beginning to experience scarcity. This is illustrated by the fact that some countries, or (semi)arid regions within countries, find it hard to ensure adequate waste water disposal: parts of Texas in the USA send their sewage untreated into the Rio Grande; some cities have difficulties maintaining drinking water quality (*Cryptosporidium* outbreaks continue to threaten hundreds of thousands of consumers in major cities like Milwaukee and Sydney); some are struggling with supply shortages due to long-term depletion of ancient aquifers (such as Mexico City), and most have only recently begun to tackle industrial and agricultural pollution control aimed at ecosystem integrity (Gleick 1993; World Bank 1993; Carter et al. 1994; HMSO 1995).

At a global level, withdrawals are expected to increase by 35 percent by the year 2020, with growth in demand rising fastest in developing countries (Rosegrant et al. 1997). Between 1950 and 1980, per capita water availability declined by around 40 percent in Asia and by 50 percent in Africa (Ayibotele 1992). Figure 1 shows that there are currently 31 countries in which fewer than half of the inhabitants have access to safe water. These are not only found on the African continent, but also across Asia and Latin America. Major gains were made during the 1980s (the International Drinking Water Supply and Sanitation Decade), when 1.6 billion people were provided with safe water and about 750 million with adequate excreta-disposal facilities at an estimated cost in excess of $134 billion for the decade (WHO 1996). Even though aggregate spending on water and sanitation continues at around $30 billion per year, the number of people facing water insecurity remains above 1 billion--and is set to grow (The Economist 1998; WHO 1998).

Why? The problems can be grouped under three main headings: Availability, Access and Usage. Consider the conceptual diagram in Figure 2. This framework draws upon recent theoretical and methodological developments made with respect to the concept of 'food security' — an evolution in thinking that has yet to be matched where water is concerned (see Webb and von Braun 1994; FAO 1998a). The framework makes water availability the central focus, but the physical presence of hydrogen and oxygen atoms is clearly not all that matters. The idea of water security allows for water to be considered as a natural resource, as a commodity, *and* as an entitlement. These are complementary perspectives, not contradictory ones.

For example, if one considers the second and third rows in Figure 2, <u>water availability</u> is a function of supply (largely dependent on ecological factors, some of which can be degraded or enhanced by human action), and distribution (which represents the mechanisms by which water is made useful to human (and ecosystem) activities). (In order for water to be available as an input to household water security, the stock and flow of water must be both adequate (geographically) and reliable (temporally).

<u>Water access</u> refers to household control of water as a commodity. This is partly determined by modes of distribution (with national policies and investment priorities playing important roles), and partly by effective demand; that is, how much a household can actually 'take home' (to the kitchen, farm or trough). The latter depends on income, physical location (in relation to distribution channels), and sometimes on status (in communities with traditional allocation mechanisms — discussed further below).

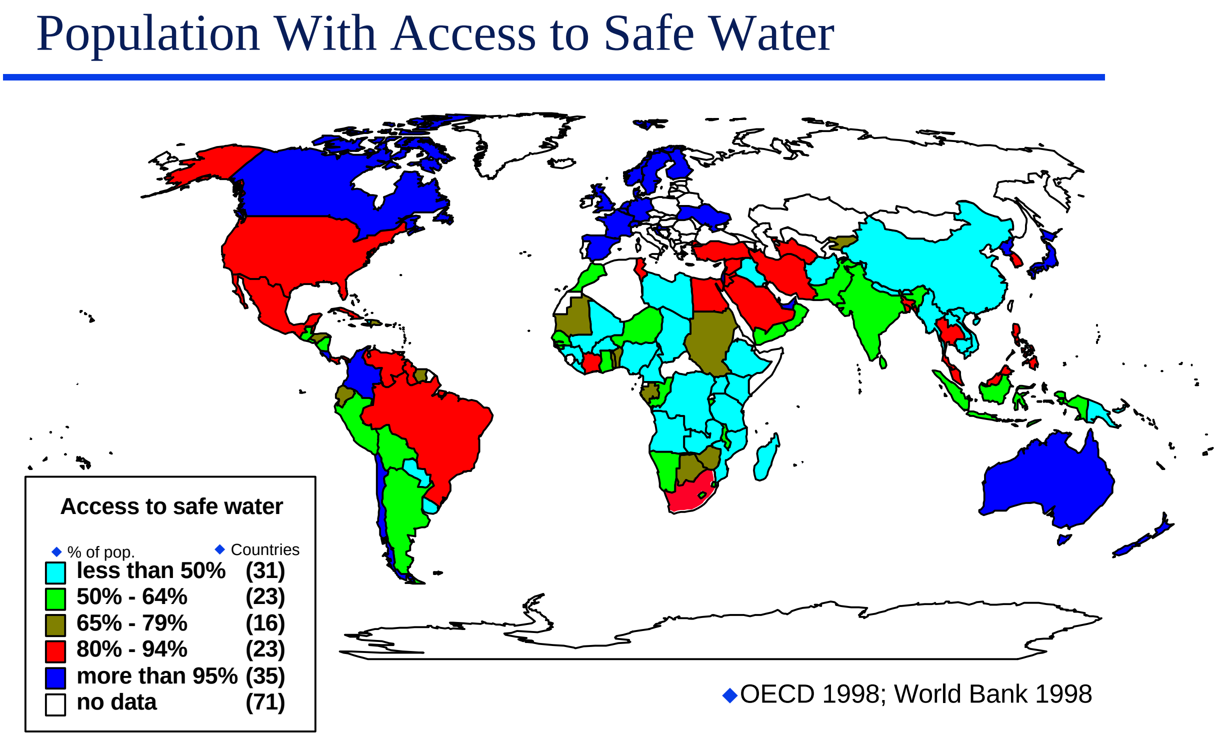
<u>Water use</u> relates to individual entitlements, i.e. water as a public and private good. Whether available water is appropriately absorbed in the body depends on how much water can actually be consumed by the individual (according to need), water safety (quality), perceived entitlements (personal status), environmental constraints (non-water-borne diseases), opportunity costs (especially with regard to women's time), and knowledge (human capital formation in relation to hygiene, sanitation, water consumption, and disease control).

This same framework for understanding household water security allows for two cross-cutting notions: 'risk', that is the reality that individuals may not be able to secure water when and where they need it, and 'multi-tasking', that is the fact that unlike food, the same water can be used for more than one purpose). For example, the risk of water availability failure can de driven from the supply side through widespread and prolonged drought. Alternatively, access failure can be caused on the income side by an economic shock that sharply alters prices, thereby making poor urban dwellers reduce their water consumption rather than pay more. Again, access failure may result from the usage side as a result of sickness or death through Aids of the adult women in a household, sharply increasing the opportunity costs of fetching and carrying water for the remaining adult male. In other words, consideration of the risks to water security demands multidimensional attention beyond a single sector and beyond single usage.

Public action (government policies, donor or NGO interventions) may have a positive or negative impact on private initiatives at any point in the conceptual framework. Interventions can be long-term or short-term and can be directed at different levels. Actions can take the form of long-term investments, including national watershed action plans, ecosystem conservation, and reforestation policies. A country's development strategy and use of macroeconomic policies - including fiscal, monetary and trade policies - can directly and indirectly affect demand and investment in water-related activities, the clearest example being public investments in irrigation, flood control or dams (Bhatia and Falkenmark 1993). Even macroeconomic policies and sectoral policies not focused on water can have a strategic impact on resource allocation and aggregate demand in the economy. The same applies to more micro-level actions, such as digging boreholes or making investments in primary health care that are aimed at controlling seasonal waterborne disease.

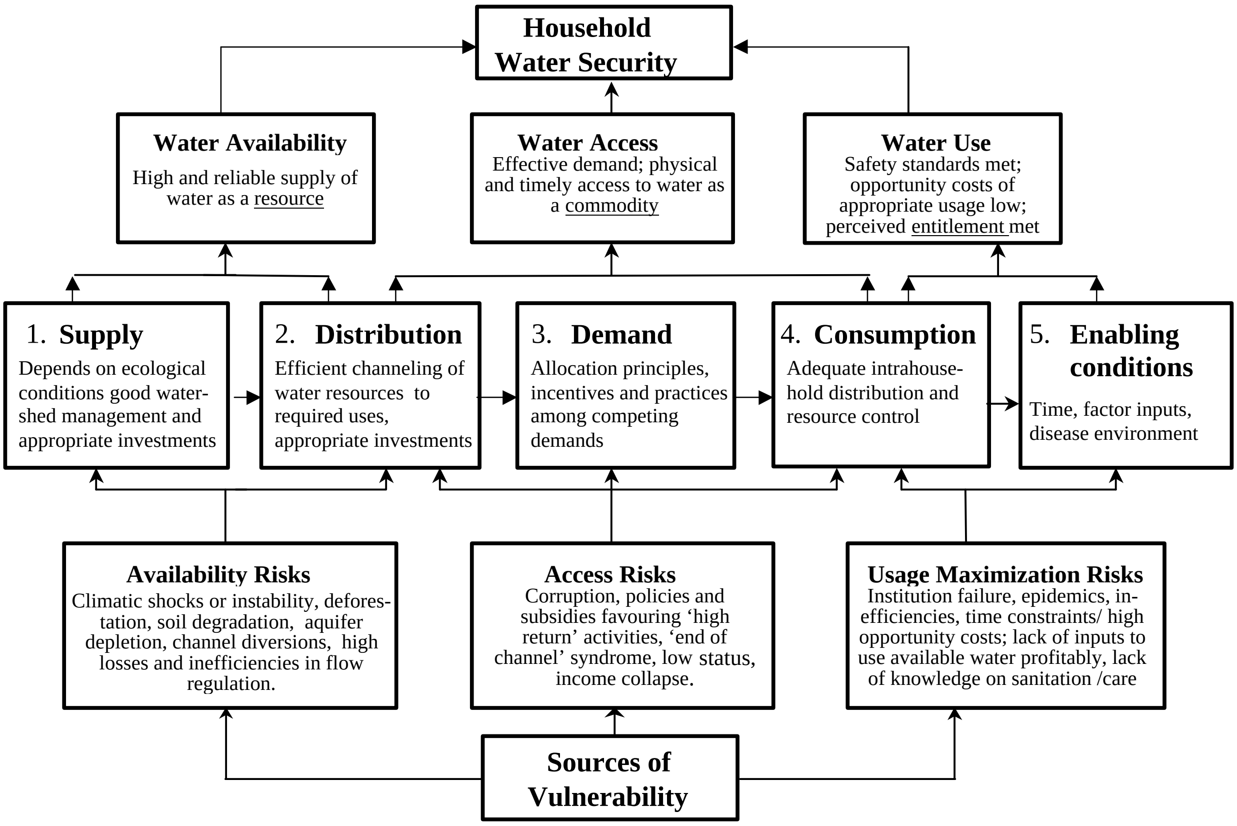
The meso-level is occupied by interventions such as employment generation programs and other income transfer activities aimed at raising effective demand among targeted population categories, or equity-focused projects, such as irrigation investments targeted at women farmers. These kinds of action have both ‘upstream’ and/or ‘downstream’ linkages with actions taken elsewhere. Thus, if one public intervention (say, investment in a large dam that reduces downstream flow to poorer farmers) has a negative impact, there is a danger that potentially positive effects of other interventions (like a policy change in water allocation principles that improve access rights to water flows) could be cancelled out.

Figure 1: Global Access to Safe Water



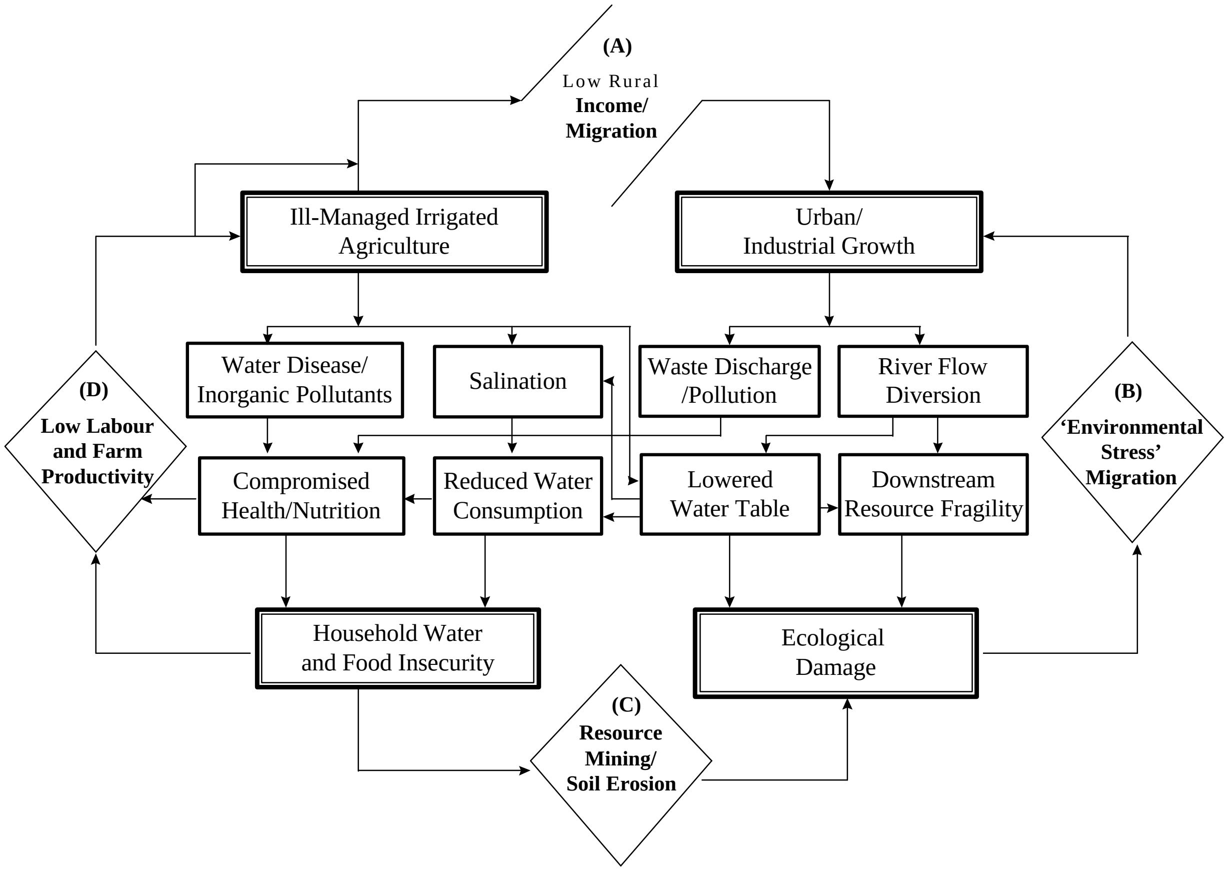
◆OECD 1998; World Bank 1998

Figure 2: Conceptual Diagram of Household Water Security



A theoretical example of potentially negative multisectoral interactions among urban growth, irrigated agriculture, ecology and food security in terms of water use (and abuse) is illustrated in Figure 3. This figure shows that urban growth can require river diversion (for urban consumers and industry), which may negatively affect downstream ecology through reduced recharge and loss of fauna/flora. Such is Botswana's fear for its Okavango Delta — a big tourist attraction — if Namibia diverts 100 million m^3/year from the river by pipeline to Windhoek. There is also danger of uncontrolled waste and pollution from urban centres.

Figure 3: Selected interactions among irrigated agriculture, urban growth, environment and household water security.



The rivers of El Salvador downstream of San Salvador are, according to a 1995 study by the Salvadoran Program of Investigation of Development and the Environment: “fouled. by unregulated dumping of industrial waste and garbage, often toxic. San Salvador .. generates 1,255 tons of garbage a day, of which only 37 percent is collected. The garbage that is collected is thrown on porous, volcanic soil, where it decomposes and filters into the water table.” (Farah 1997). Such negative outpourings from urban growth can have several effects, including direct damage to fauna, flora and soils, lowered water tables (resulting in increased work for women in collecting household water requirements, which typically reduces consumption), and both direct and indirect impacts on human health and nutrition.

Nutrition can also be affected in negative ways by poorly-managed irrigated agriculture, water pollution, increased water-related diseases and destruction of the soils through salination. Impaired nutrition in turn results in lower agricultural productivity (D), contributing to low rural incomes (A), as well as natural resource mining (C), which can cause ‘environmental stress migration’ (B) or simply poverty-driven rural-urban migration (A). The interactions are complex, and can lead to a negative spiral of ill-effects.

Analysis of water security issues must therefore pay more attention to the multisectoral linkages among the roles of water as a natural resource, commodity and human entitlement. Until recently, much research on water was framed in a uni-disciplinary or uni-sectoral context. For example, research already exists on the modelling of renewable aquatic resources at a global level — work conducted mainly by environmental specialists concerned with world ecosystem requirements (FAO 1996; Postel et al. 1996; WRI 1997). There is also considerable work on technical issues relating to irrigation management efficiencies (Hillel 1996; Plusquellec et al. 1994). Furthermore, a valuable body of literature has emerged during the 1990s on water market efficiency, water rights and water pricing models (Rosegrant and Binswanger 1994; Meinzen-Dick 1996; Easter, Rosegrant and Dinar 1998).

However, far less research has been focused on cross-sectoral relationships in water usage and competition (including the environment and human welfare as ‘sectors’), on the realities of household-level competition for community-based water resources, or on alternative policy and institutional options to address equity problems in water access and usage. As noted by Bhatia and Falkenmark (1993), “Economic policy-makers tend to confront policy issues one at a time, stating policy objectives in single dimensional terms. This approach presents difficulties because a policy aimed at achieving a single objective usually has unintended and unrecognised consequences. Water managers and policy-makers need to assess the entire range of government interventions to understand fully the economic, social and environmental impacts on a given sector, region or group of people.”

Improving water security (not just management or technical efficiency) requires us to consider how water (as resource, commodity and entitlement) is linked to the national (and international) economy in different ways. Equally important is an understanding of how alternative policy instruments influence water security among different economic sectors and across different scales of activity. The following sections elaborate on these linkages while identifying areas where further research is required.

3. A Scarcity of Liquid Assets: Water Availability Issues

As with food, the world still has sufficient water at an aggregate level to meet everyone's minimum needs. Against estimated annual renewable freshwater supplies of between 9 and 14 trillion cubic meters, current global usage stands at less than 4 trillion cubic meters (Rosegrant 1997). As is the case with food, however, the global availability of water is *not* matched by adequate local access. Freshwater is unevenly distributed geographically and temporally, resulting in surpluses for some people and a threat of severe water insecurity for others.

Table 1 shows regional changes in per capita water supplies since 1950, with forecasts for the year 2000. Per capita supply is highest in Latin America and lowest in North Africa and the Near East. Supply in Europe and North America is not expected to change greatly by 2000 due to low population growth rates, but many developing countries face escalating shortages as their populations grow and withdrawals increase.

Table 1: Water availability (1000 m^3 per capita, per annum) by region

Region	1950	1980	2000
Africa	20.6	9.4	5.1
Asia	9.6	5.1	3.3
Latin America	105.0	48.8	28.3
Europe	5.9	4.4	4.1
North America	37.2	21.3	17.5

Source: Ayibotele (1992)

From 1940 to 1990, withdrawals of fresh water from rivers, lakes, reservoirs, underground aquifers, and other sources increased by more than a factor of four (Shiklomanov 1993). Asia as a whole already accounts for the largest share of the developing world's water withdrawals. Table 2 shows that in 1995 Asia withdrew almost as much water per capita as Europe (western and eastern combined, plus the Commonwealth of Independent States). But projections up to the year 2020 suggest that Asia will overtake both Europe and the USA in per capita withdrawals and by then account for 60 percent of the world's water withdrawal. China and India drive this demand growth, supported by strong income growth, continued expansion of irrigated area, and industrial growth. Demand in China, for example, is expected to triple between 1995 and 2020, while in India an increase of around 270 percent is anticipated (Rosegrant et al. 1997).

Table 2: Per capita domestic water withdrawals, 1995 and 2020

	1995	2020
	(m^3 per capita/)	
Sub-Saharan Africa	11	15
Asia		
China	25	71
India	20	54
Other East Asia	77	98
Other South Asia	21	41
South-East Asia	56	87
Latin America	65	82
W.Asia/N.Africa	56	70
Europe/CIS		
Western Europe	94	94
Eastern Europe & CIS	89	103
USA	240	240
World	56	75

Source: Adapted from Rosegrant et. al. (1997)

But not all countries will fare so well. Using the *'water stress index'* (which defines national *water stress* in terms of internal renewable fresh water availability between 1,000-1,667 cubic metres per capita per annum and *water scarcity* in terms of internal renewable fresh water availability lower than 1,000 cubic metres per capita per annum), the number of people living in water-scarce countries will rise from 132 million in 1990 to 653 million (under the low UN population growth projection) in 2025 (WRI 1996). By 2050, this figure would rise to between 1 billion and 2.4 billion (depending on the projection variant), representing 13 to 20 percent of the projected global population. The index is a useful signal of potential danger. When the 1,000 cubic metre level is breached, water shortage is considered to be a severe constraint on socio-economic development and environmental protection. Certain continents, Africa and parts of western Asia in particular, are already highly vulnerable to increasing water scarcity, and things look like getting worse.

However, such projections have to be interpreted carefully since they are based on past trends (for water supply) and estimates of future usage based largely on demographic dynamics. They do not incorporate possible changes in water use efficiency. Burundi, for example, is potentially a water-scarce country according to the water stress index, but it uses little water for irrigation at present and so has abundant supplies for other purposes (see Table 3). What is more, national averages mask diversity at the sub-national level. While scarcity may not always appear at the national level, serious water shortages are apparent in certain regions and watersheds. Notable examples include northern China, western and southern India and parts of Mexico. For example, although India as a whole has adequate average water supplies of 2,500 cubic metres per capita, the state of Rajasthan has access to only 550 cubic metres (Rosegrant et. al. 1997). Similarly, while China has only 7 percent of the world's renewable freshwater supplies (for 22 percent of the world's population), water stresses are not uniform across the country (Ryan and Flavin 1995). They are felt acutely in the northern and western arid regions, while the coastal south-east consumes ever more water for its industrial and urban development (Smil and Yushi 1998).

Table 3: Countries facing potential water insecurity in 2000 according to the water stress index [1/]

Country [2/]	Population in 2000	Water Availability	
		Internal renewable fresh water availability	Water resources including river flows from other countries
	(millions)	(m^3 per capita)	
Egypt	62.4	29	934
Saudi Arabia	21.3	103	103
Libyan Arab Jamahiriya	6.5	108	108
United Arab Emirates	2.0	152	152
Jordan	4.6	153	240
Mauritania	2.6	154	2843
Yemen	16.2	155	155
Israel	6.4	260	335
Tunisia	9.8	384	445
Syrian Arab Republic	17.7	430	2008
Kenya	34.0	436	436
Burundi	7.4	487	487
Algeria	33.1	570	576
Hungary	10.1	591	11326
Rwanda	10.4	604	604
Botswana	1.6	622	11187
Malawi	11.8	760	760
Oman	33.3	880	880
Sudan	33.1	905	3923
Morocco	31.8	943	943
Somalia	10.6	1086	1086

[1/] Water stress: internal renewable fresh water availability between 1,000-1,667 cubic meters/capita/annum, water scarcity: internal renewable fresh water availability <1,000 cubic meters/capita/annum.

[2/] A number of other countries with smaller populations, e.g. Barbados, Cape Verde, Djibouti, Malta, Qatar and Singapore are also included in the water-scarce category.

Source: Adapted from Bhatia and Falkenmark (1993)

In other words, constraints on water availability are not uniform across localities, nor across population groups. Nevertheless, while considerable attention has been paid by the scientific community to demand management and efficiency enhancement where water demand is already high, much less attention has been paid to problems associated with sub-national disparities in water insecurity, either at the watershed or the household level. For example, countries like Ethiopia, Sudan and Uganda share the waters of one of the world's most important rivers (the Nile), but each provides fewer than 50 percent of their inhabitants with access to safe water (World Bank 1998). Mali and Niger, through which the River Niger flows, also manage to offer safe water to fewer than two thirds of their inhabitants. The same is true for the Congo river basin, parts of the Mekong in Cambodia and Laos, and the Red River basin of northern Vietnam. In each case there is plentiful water flow, but investment decisions by public authorities (in what are very poor countries) have been directed more to dam-building for large-scale irrigation and/or hydro-electricity generation than towards community-level water storage or clean water supplies.

Is it possible in such countries to identify the 50 percent or more of the population who do *not* have access to safe water? This in itself remains to be documented. Just as not all poor households are food insecure, not all households facing food insecurity are water insecure. However, it is likely that they are mostly poor and often food insecure people living in one of four different contexts:

i) Dry marginal lands. Semi-arid rural areas typically far-removed from principal water supplies (as in the case of parts of north-western China and the Sahelian countries);
ii) Areas of high risk of drought or flood. These are places in which productivity potential is sometimes high (as in parts of Bangladesh or Brazil), but vulnerability to extreme weather phenomena generates high risks for water insecure households.
iii) Fragile watershed hillsides, that are major water sources but which tend to be 'upstream' of major benefit flows (as in the case of Laos and Vietnam); or
iv) Urban slums. Neighbourhoods bi-passed by most urban development.

In all four contexts, household water insecurity is a major element in interactions among poverty, malnutrition and resource degradation. Each context is dealt with briefly below with particular attention to the risk factors mentioned above.

3.1 Dry Marginal Lands

Watersheds located in arid and semi-arid regions are home to more than 1 billion people (Revenga et. al. 1998). These water-stressed regions account for 70 percent of the world's poorest people (Broca and Oram 1991). They also account for a disproportionate share of child malnutrition; that is, although semi-arid regions account for only 27 percent of the population of the dry and sub-humid tropics as a whole, they contain 44 percent of the total number of stunted children (low height for age) (Sharma et. al. 1996a).

Of course there are many factors involved in determining the geographic distribution of poverty and malnutrition, including variations in income-earning opportunities, climatic endowments/risks, varying levels of agricultural productivity, and a lack of public development investments (Ravallion and Wodon 1997; Krugman 1998). However, water insecurity plays a part in all of these through the limits it places on non-farm processing industries, constraints on health and sanitation improvements, and of course constraints on agriculture.

Where agriculture is concerned, all farmers in semi-arid environments face limits to crop and animal productivity. Yet, the use of fertiliser, labour and other inputs can still make a difference for farmers wealthy enough to secure such inputs. For example, it has been found in marginal regions of Burkina Faso and Ethiopia that average grain output from wealthier farmers can be twice that of poorer farmers cultivating adjacent fields in the same communities (Webb and Reardon 1992). Poverty, combined with a lack of water, makes the difference. However, even irrigation is not exempt from problems. Salinity is a significant and widespread form of freshwater pollution in arid and semi-arid regions, caused by over-pumping of aquifers, poor drainage and high evaporation rates which concentrate salts on irrigated land, thereby reducing productivity over the longer term.

What is more, livestock productivity is also constrained by water stress. Inhabitants of dry-land areas rely perhaps more than other smallholders on the milk of large and small ruminants (Webb and Coppock 1997). Calves require around 9 litres of water per day during their faster growing periods, sheep around 5 litres per day (McDonald et. al. 1990). A cow yielding 10 litres of milk per day under semi-arid conditions needs around 100 litres of water, but to raise that milk yield by one third requires a more than one third increase in the volume of water available to the animal. During major droughts, it is the poorest households who lose the largest share of their herds due to their inability to secure adequate water and feed (von Braun et. al. 1998).

These many factors combine at the sub-national level to cause water insecurity in sub-regions of countries like Benin, Indonesia, Brazil and Zimbabwe, which do provide more than 70 percent of their total population with access to safe water. In these sub-regions, the concentration of risks associated with both food and water insecurity can make the impact of even minor exogenous shocks (droughts, floods or market failures) more severe than they would otherwise be for the vulnerable households concerned.

3.2 Catastrophic Supply Failure through Drought or Flood

Flooding and drought remain the two biggest ‘natural’ threats to life, as well as to food security and water security world-wide. Between April 1997 and April 1998, floods were reported in over 40 countries, while droughts were a problem for 22 countries (FAO 1998b). Some nations suffered both, including Brazil, Guyana and Indonesia. These extreme weather anomalies (linked to the El Niño/La Niña phenomena) took a heavy toll on human life and property in many parts of the world. Floods claimed more than 3,000 victims, left more than 250 million people without shelter in Asia alone, and caused severe damage to infrastructure (roads, bridges, rail links). There were widespread threats to water security due to drinking water contamination and increased water-borne diseases. Local food production was also severely disrupted.

For example, vast areas of cultivated lands were submerged across Asia, affecting approximately 45 percent of global cereal output and over 90 percent of paddy production. While there were substantial problems in the Democratic Republic of Korea, India and Nepal, it was China, Indonesia and Bangladesh that were perhaps hardest hit (FAO 1998b). Indonesia faced the dual impact of droughts and flooding. Once self-sufficient in rice, Indonesia has already become one of the world’s largest importers of rice, and faces the prospect of reduced domestic production due to drought, disruption of commodity markets in parts of the country due to floods, and high import prices due to its financial crisis.

In Bangladesh, heavy monsoon rains caused extensive flooding in two-thirds of the country’s 64 districts. Flooding resulted in the death of around 400 people, and was responsible for “a significant increase in the incidence of water-borne diseases” (FAO 1998b). Around 25 million people are reported to have been affected by the floods, with many thousands left homeless. Some 7,000 livestock were reported killed. More than 750,000 hectares of farmland were affected, with almost 500,000 hectares of rice and other crops being totally destroyed. Food grain imports exceeding 1 million tonnes were required to stabilise the country’s food security situation.

Identical problems were found in China. In mid-1998, there was extensive flooding in central, south-eastern and north-eastern parts of the country. The level of the Yangtze River surpassed its record height set in 1954 and it burst its banks in countless areas.

More than 3,000 people are thought to have been killed, while some 240 million people have been directly affected. The direct cost of the flooding (including the total lost of harvest from 1.3 million hectares of farmland) is expected to be more than $20 billion (OCHA 1998a).

In some regions, drought remains more of a pernicious threat than flooding. Droughts (periods during which water availability is below minimum human requirements for a given locality), can become a way of life based on coping mechanisms and societal adaptations which help most people survive all but the worst crises. Nonetheless, extended droughts still represent a catastrophic supply failure that affects water-insecure households the most.

Between January 1963 and January 1995, USAID calculates that there were 284 major droughts world-wide, directly resulting in the deaths of over 885,000 people and seriously affecting the livelihoods of a cumulative total of 2.4 billion people over the 22 years (USAID 1995). Most of these droughts occurred in semi-arid regions of very poor countries, including (but not restricted to) China, India, Pakistan, north-east Brazil, the land-locked Sahel, the eastern African Rift Valley, and southern Africa. For example, the drought in southern Africa in 1991/92 caused harvest shortfalls of 50 to 75 percent in 8 countries, as well as livestock mortality, a collapse of export agriculture, and a large drain on foreign exchange as large amounts of food had to be imported.

Natural disasters such as droughts and floods are no longer the principal source of humanitarian crises, as their relative importance has been superseded during the 1990s by armed conflict. The number of conflict emergencies grew from 20 in 1990 to 50 by 1996, and the resulting number of refugees and other displaced people leapt from around 30 to 50 million over the same period (Webb 1996). This post-Cold War explosion of conflict emergencies has arguably resulted in a refocusing of operational and research attention away from droughts and floods. Under-funding of early warning systems, as well as of targeting mechanisms and intervention policies, has become an increasing problem in many countries as analytical attention has shifted away from water to war (IFRCRCS 1995; FIVIMS 1998). Dis-investment in EWSs and drought/flood planning is dangerous since it makes response time to the next climatic disaster even slower.[2]

Therefore, two important points need to be made in this regard. First, while attention has moved away from natural disasters, water itself remains a central element of crisis mitigation and rehabilitation. At the refugee camp in Goma, which received tens of thousands of Rwandan refugees in a matter of days at the height of the genocide, relief organisations were heavily burdened by the task of bringing truck loads of plastic containers for distribution to the refugees.

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[2] This applies to many transition economies as well as developing countries. Romania, for example, was severely affected in 1998 by flooding in two-thirds of its 41 districts, which caused 21 deaths, the destruction of 2,000 homes, 590 km of roads, 279 bridges, 35 hydroelectric buildings, over 103,000 hectares of crop land, and the contamination of over 200 sources of drinking water (OCHA 1998b). The transition from public to private sector dominance of market operations often leads to a weakening of public agencies that still play an important role in predicting/mitigating crises.

The containers held not food aid, but purified water, an essential ingredient of every diet, especially since the pre-existing water supplies in Goma were hopelessly inadequate to meet the new demand.

The second point is that while there is a chance that post-Cold War (and other long-standing neo-colonial conflicts) may in time be resolved, instances of flooding and drought may be expected to occur more or less regularly. Their occurrence can be predicted and their impact mitigated, but not prevented. Even if one were to disregard the most pessimistic predictions associated with climate change, global warming and environmental destabilisation, there is a real danger that the human and economic impacts of drought may become more, rather than less, severe in coming decades. As population grows, food insecurity becomes geographically concentrated in the poorest continents, and national governments pay less attention to the design, implementation and funding of early warning systems (WFP 1996; Turton and Bottrall 1997).

It might be pointed out that most drought-prone and/or water-stressed countries still do not have coherent and fully operational water-needs-planning systems able to act at a national level (Frederiksen 1992; Ohlsson 1995). Countries that have been prone to famine, as opposed to drought, have shown a lead in the formulation of disaster planning and preparedness systems (including Ethiopia, India, Sudan and Botswana). However, these systems relate more to crisis response than to the planning and investment required in ‘normal’ years to prevent disasters from becoming humanitarian crises (von Braun et. al. 1998).

Crises do not allow for a debate on the relative responsibilities of public and private agents. Plans and institutional capacities are required to safeguard the needs of the most water insecure households, not just large-scale irrigation schemes and city reservoirs. As the World Bank has argued, “tolerable conditions can only be sustained in drought management if government policies support a program of conscientious maintenance of supplies to a substantial cushion of non-critical use under conditions of normal precipitation. Any infringement on the cushion assures economic and human disaster.” (Frederiksen 1992) The questions are, i) how big should a cushion be?, ii) who should decide (technicians, policy planners, politicians)?, and iii) how would it be managed where governments are pulling out of the water allocation business?

Even the United States only recently submitted to Congress a bill called the ‘National Drought Policy Act of 1997’. Although the United States often suffers serious economic, environmental (and sometimes human) losses from regional droughts, there is still no co-ordinated Federal strategy for dealing with the underlying problems or with the emergencies themselves. State, local, and tribal governments have had to deal individually and separately with the problem. Therefore, the Drought Policy Act was introduced as a first step in establishing an integrated Federal policy designed to prepare for and respond to serious drought emergencies.

Similarly, in 1995 the European Commission's Directorate General of Research and Development (DG XII) organised an expert workshop to discuss the state –of –the art in, and research needs for, flood management issues. It concluded that despite major advances in forecasting systems since the 1980s, "important issues remain in both the detailed understanding and simulation of processes involved in flood propagation and also in the best practice for management of the river and its catchment." (Krzysztofowicz 1995; HR Wallingford 1996). As a result, the EU's Fourth Framework Research Programme continued to focus on long-term research issues related to flooding (within a framework of integrated river management), with a view to identifying difficulties arising from past management practices and current best practices. Reviews and research of this kind *world-wide* would be a useful contribution to water-stress planning in many developing countries.

3.3 Fragile Watersheds

The problem of covariate risks of water insecurity where poverty, malnutrition and environmental degradation are concentrated also applies to fragile watershed environments that are, paradoxically, principal sources of freshwater[3]. For example, water availability is not yet a major problem in most northern regions of SE Asia. Although cities such as Bangkok and Jakarta are subsiding due to the exhaustion of the deep aquifers, which have been pumped almost dry, the humid mountain watersheds remain water-surplus areas. Yet, poverty and water insecurity are often high among populations living in steep watersheds of the poorest developing countries (Belsky 1994; Templeton and Scherr 1996).

There are three main reasons for this. First, such areas often attract little government investment due to their remoteness and inaccessibility -other than investments in dams to support large-scale irrigation and/or hydroelectricity generation, from which the benefits are mostly drawn downstream of the watershed itself (Webb 1998).

Second, such watersheds are often inhabited by indigenous minorities neglected by central authorities and/or displaced by dams. For example, Vietnam's Hoa Binh dam, which supplies energy as far as Ho Chi Minh City, caused the displacement of more than 30,000 Muong minority people in 1979. They received no compensation and "simply moved their houses up onto steep slopes above the reservoir where they now scratch out a bare subsistence from swidden cultivation" (Rambo et al. 1995). The clearing of the steep slopes has so dramatically increased soil erosion in the basin around the dam that it has been estimated that the life-span of the reservoir has already been reduced from over one hundred years to perhaps 30 years.

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[3] This should not be taken to mean that there are no water insecure households in fragile coastal mangrove and estuarine ecosystems; there are. What happens at the coast, however, is determined in large part by what happens upstream. Overall ecosystem integrity is determined to a large extent by processes occurring at the head of the watershed.

Nevertheless, plans are being made for a much bigger dam for Son La province to be built in the coming years. If built, this new 'Ta Bu' dam would force resettlement of more than 100,000 Black Thai minority people.

Unfortunately, such displacement is sometimes justified in ecological terms. Some dam projects receive support from conservation groups because it is claimed that the projects "will save the area from slash-and-burn farmers." (Kasetsart University 1994). For example, in Thailand, a local NGO called the Dhammanart Foundation supports the displacement of people who cause 'damage' to existing ecosystems. According to this Foundation, "local wisdom could not protect the forests from the lifestyles of some hill tribes, for example, the Hmong, who at first clear-cut the forest to plant poppies for opium" (Rajesh 1997). Similarly, the Asian Development Bank has supported large dams projects in the regions by claiming that "upland ethnic groups are destroying forest as a result of their shifting cultivation practices." (Watershed 1997).

The third reason is that deforestation, associated with displacement or chronic poverty, affects the ability of watersheds to maintain their flow, affecting smallholder productivity after a few years and affecting the integrity of local ecosystems almost immediately. Apart from human use, water is also needed to sustain the natural ecosystem not only of wetlands, rivers, and the coastal waters into which they flow, but also of the source water basin itself. The clearing of land for agriculture in high watersheds often leads to water contamination. When the soil is stripped of dense vegetative covering it is prone to erosion. This results in water turbidity because of increased amounts of suspended matter, nutrient leaching, and a decreased water-retention capacity of the soil, which in turn affects the cultivators who cleared the land.

According to Revenga et. al. (1998), 42 of the world's most important 145 watersheds have lost more than 75 percent of their original forest cover, and 15 have lost more than 95 percent. Table 4 indicates that associated soil erosion has been severe in many watersheds, particularly in China, south-east Asia, parts of central America, southern Africa and Madagascar, all of which are characterised by fragile highland ecologies.

3.4 Urban Slums

The third concentration of water insecure people can be found in urban slums. Of the $134 billion invested in water supply and sanitation during the 1980s to 1990, urban areas are estimated to have received 74% of the total and rural areas only 26%, despite the fact that it costs an average of $105 per capita to provide water supplies in urban areas versus only US$ 50 in rural areas (WHO 1996). It can be argued that this urban bias resulted from a concentration of political pressures close to the seat of power, and represented an attempt to respond to explosive rates of urbanisation during recent decades.

Nevertheless, by 1994, about 30 percent of all urban residents in sub-Saharan Africa were not served by municipal water services of any kind (Watters, cit. WRI 1996). Coverage of water services is only little better in most Latin American and Asian cities, and the stresses are increasing in most countries.

Table 4: Number of major water basins affected by serious soil erosion, by region

Region	Area Eroded <5%	Area Eroded 5 - 15%	Area Eroded >15%	Total Basins in Region (a)
Africa	8	5	4	17
Asia	15	6	10	31
Latin + Central America	11	2	1	14

Source: Adapted from Revenga et. al. (1998). Map 13.

Note (a): Identified as ‘major’ watersheds by the authors

Between 1990 and 2025, the number of urban residents is expected to double to more than 5 billion people (UN 1995). Around 90 percent of this projected growth will occur in developing countries. The Latin American/Caribbean region is already the most urbanised part of the developing world, with more than 70 percent of its population living in towns and cities in 1990 (Table 5). Indeed, in Latin America, the absolute number of urban poor already surpasses the number of rural poor (ECLAC 1994). Between 1970 and 1990, the number of urban poor increased from 44 million to 115 million, while the number of rural poor increased from 75 million to 80 million.

Table 5: Trends and projections of urban population shares for developing country regions, 1950-2025

Region	1950	Urban Population Shares 1970	1990	2000	2025
			(percent)		
Africa	14.5	22.9	33.9	40.7	57.1
Latin America	41.5	57.3	71.5	76.4	84.2
Southeast Asia	14.8	20.2	29.9	36.9	55.4
Southern Asia	16.0	19.5	27.3	32.8	51.5
Western Asia	23.9	43.2	62.7	70.3	79.8

Source: United Nations, 1990 Revision of Estimates and Projections of Urban Populations (New York, 1990).

Note: Because of the geographical demarcation used by the United Nations, the data on growth rates for the Asian regions *exclude* China, the Koreas, Mongolia, and Hong Kong, but include Turkey and Israel.

Although Africa and Asia are currently only around one third urban, it is in these regions that the most explosive growth is already under way, at an average of between 4 and 5 percent per year. Between 1990 and 1995, some countries in these two regions, including low-income food-deficit countries such as Burkina Faso, Mozambique, Nepal, Niger and Afghanistan, were experiencing even higher urban growth rates of more than 7 percent per year. Such rates of growth are expected to continue for several decades, such that both Asia and Africa are expected to be more than 50 percent urban by 2025. More importantly, the number of underweight pre-school children is rising so fast in urban areas around the world that the problem of urban undernutrition is catching up with rural conditions (Haddad et. al. 1998).

The malnourished poor bear the greatest burden of urban environmental risks because sub-standard housing, overcrowding (increasing the risk of airborne infections and accidents), air pollution, and a lack of clean water and sanitation serve to compound existing deficiencies in food consumption. Calorie consumption in many low-income urban households is already so low that poor water quality and sanitation make nutrient absorption difficult, especially for vulnerable individuals. For example, there is evidence that per capita energy consumption in many parts of sub-Saharan Africa is generally higher in rural than in urban areas, regardless of income or expenditure levels (von Braun and Pandya-Lorch 1991). For the urban poor with already sub-optimal calorie consumption, exposure to polluted water and a lack of sanitation raise the risks of morbidity, malnutrition and (early) mortality considerably.

Consider Abidjan in Cote d'Ivoire. The number of people without access to piped water grew from 800,000 in 1988 to almost 1 million in 1993, roughly 38 percent of the population (Leitman 1995). Less than 30 percent of Abidjan's population is served by sewers, and 15 percent resort to open defecation. Most wastewater finds its way to the city's lagoons, which are highly polluted. Municipal, industrial, and hazardous wastes also combine to increase the risks of diarrhoeal and other diseases in the city's slums. It is no surprise, therefore, to find that there is no statistical difference in rates of acute malnutrition (wasting) between Cote d'Ivoire's urban and rural areas, despite the fact that other measures of chronic nutritional deficiency (stunting and underweight) are much higher for rural areas (MII 1995a).

Similar health and nutrition risks are found elsewhere. In the Philippines, the Tondo squatter settlement of Manila has an infant mortality rate three times higher than the rest of the city, the rate of tuberculosis is nine times higher, and three times as many children suffer from malnutrition (WHO 1992). In Bangladesh, infant mortality rates in the early 1990s were higher in urban slums (for both girls and boys) than in other urban locations or in rural areas (WRI 1996). Indeed, some of the most rapid urbanisation is occurring precisely in neighbourhoods that can least cope with the growth. For example, the urban fringe of Jakarta (Indonesia) is growing much faster - at a rate of nearly 18 percent per year - than the city as a whole (World Bank 1994). It is the poor in such areas who receive the least services. Around 31 percent of households classified among Jakarta's 'poor' have neither a piped water connection nor access to a private well, compared with 12 percent for the city as a whole (Surjadi et al. 1994). The main structure of Jakarta's sanitation system is an open ditch system that serves as a conduit for all wastewater. Planned as a city of 500,000 people, it cannot cope with the wastes of around 12 million residents, many of whom are packed into peripheral slums that are subjected to industrial as well as domestic waste (Sivaramakrishnan 1986). In 1989, an estimated 200,000 cubic meters of wastewater per day, largely untreated, was released into the city's waterways (World Bank 1994). Because of these conditions, diarrhoea is found to be responsible for 20 percent of deaths among children less than five years old in Jakarta (Clarke et al. 1991).

Of course, these conditions also make any exogenous shocks more likely to affect urban slums than is the case elsewhere. During the drought in southern Africa of the early 1990s, Zimbabwe's second largest city (Bulawayo) ran out of water. The reservoirs ran dry, and although some households were able to pay the high prices demanded by street vendors who brought in brackish water from up to 100 km away, the poorest could not. The city's urban and economic life came to a virtual standstill. Urban schools in another of Zimbabwe's provinces (Manicaland) were also forced to close because the shortage of drinking water was leading pupils to faint in class (Herald 1992).

The issues of water supply, and availability of that supply, are therefore crucial for insecure households, both in terms of normal access and in relation to exogenous shocks. This raises the question of how access can best be ensured for the poor in both contexts.

4. Who Turns the Taps?: Gaining Access to Scarce Water

Given the geographic and temporal scarcities of *water as a resource*, there has been much discussion in recent years on how to improve the efficiency and equity *of the use of water as a commodity*. When food insecurity becomes a national or global concern, there are calls for more investments in the means to raise agricultural productivity, that is, for improved supply management aimed at increasing the volume of food available. With water, this is not possible. When water insecurity looms, the calls are in the direction of demand management aimed at rationalising and conserving water usage. It remains an open question as to how this can best be achieved.

Technical innovations that allow usage of alternative sources or multiple re-usage of water from an existing source do hold some promise, but mainly for situations where water-stresses are already high. For example, the very cheapest desalination technologies (producing drinkable water at more than $1 per cubic meter) are still too costly to contemplate outside of wealthy countries with relatively low population densities (Gleick 1996). Where large volumes of water are needed at low cost on a regular basis, affordable technology has yet to be invented.

Pumping from deep groundwater sources has become more feasible thanks to lessons from the oil industry, but such reserves are finite, there are environmental externalities attached, and the costs of pumping are high. For example, Mexico City formerly relied on the Mexico Valley aquifer until supply from the latter became insufficient. The city now pumps water into the Mexico valley from the Cutzamala River over a ridge 1,000 meters high and through a pipeline 180 kms long — at a cost of $0.82 per cubic meter, which is at least 50 percent more than the cost of water from the aquifer. Similarly, in Amman, Jordan, the average incremental cost of groundwater is $0.41 per cubic meter, but since demands are so great, water is being pumped up from a depth of 1.2 km (40km away from the city) at a cost of $1.33 per cubic metre (World Bank 1993).[4]

Re-cycling of water is another area offering potential gains. For example, closing the cycle of water-coolant systems for some industries would help since the same water would be used multiple times. The problem is that making the required system changes costs money, and manufacturing industries in developed countries have little incentive to make such investments since they pay only a fraction of the actual cost of water (Postel 1984; Oodit and Simonis 1990). Multiple usage of water does of course already occur in that ecosystems make use of upstream

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[4] The authorities in Mexico City may have left off pumping from their aquifer a little too late since much of the city located above the aquifer is visibly subsiding. The same is true of Bangkok and Jakarta. In the latter case, parts of the city have sunk 30 to 70 centimetres in the past 15 years due to over-pumping (WRI 1996).

water flow prior to human extraction. The extracted water may be used in an urban setting before later being diverted again for hydroelectricity generation or for agricultural use (as Egypt already does in re-channelling urban waste water to desert-based irrigation schemes west of the Nile and in the Sinai (The Times 1997). With luck, the resultant water will be neither too polluted nor depleted before returning to esturine and marine environments — a problem of quality management that has yet to be fully addressed in most countries[5].

Technological improvements in efficiency are also proposed for the single largest consumer of water world-wide; namely, irrigated agriculture. Irrigation accounts for around two-thirds of total use of the world’s freshwater, but its intensity of use allows for 40 percent of global grain production to be grown on just 17 percent of the world’s arable land (FAO 1996; Faures 1998). Because of this productive intensity, irrigation provides direct employment, food and income for an estimated 2.4 billion people (Bhatia and Falkenmark 1993). In India, for example, 55 percent of agricultural output derives from irrigated land. Moreover, average farm incomes have increased up to 100 percent as a result of irrigation, while yields have doubled compared with rain-fed perimeters. Similarly, in Mexico half the value of agricultural production and two-thirds of the value of agricultural exports is from the one-third of the arable land that is irrigated (Bhatia and Falkenmark 1993). In each case, managed water distribution through irrigation is the linchpin of a technical package (including fertiliser, new seeds, and access to credit) that is required to maximise productivity gains. Indeed, it is expected that between 50 and 70 percent of all new food production that is required to meet new food demands up to the year 2025 will have to be met through irrigation (FAO 1996).

The problem is that water use efficiency in irrigation in most developing countries is as low as 25 to 40 percent (Rosegrant 1997). That is, 60 to 75 percent of the water diverted or pumped for irrigation is ‘lost’ from the system via evaporation, leakage of canals, seepage or inefficient management (FAO 1996; Rosegrant et al. 1997). Seepage can cause water-logging and salinity. It is calculated that around 25 percent of all irrigated land in developing countries suffers from varying degrees of salinisation (Bhatia and Falkenmark 1993). Moreover, stagnant water and poor irrigation drainage can escalate the incidence of water-related diseases, resulting in human suffering and increased health costs. More efficient technologies, including drip-irrigation systems, lining of irrigation canals, more efficient sprinklers, and better irrigation timing and volume control, could lead to savings and contribute to enhanced water availability (Oodit and Simonis 1990)[6].

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[5] To dilute and transport (flush out) a volume of 450m3 of waste water entering the world’s rivers after ‘first usage’ already requires 6,000 km3 of unpolluted water (WRI 1996). As urban and industrial areas grow, so will the quantity of waste water produced, thereby raising demand for more unpolluted water for the flushing process. Without substantial investments in waste-water treatment and more effective quality regulation, much more water will need to be diverted to the flushing process in future.

[6] According to Radwan (1998), the savings for Egypt’s Delta region could be on the order of 30 percent.

The same is true of many municipal supply systems where leaking distribution systems also plague urban water utilities. In Manila (the Philippines), more than 50 percent of treated water distributed through public systems goes unaccounted for, compared with a level of 8 percent in Singapore (Bhatia and Falkenmark 1993). For Latin America as a whole, such water losses cost between $1 billion and $1.5 billion in forgone revenue each year (Schmid 1987). Some of the loss is due to ‘theft’ in the form of unregistered taps, but much is simply ‘lost’ because of inadequate metering, poor flow control systems or pipe breakages.

Yet technological solutions to enhance efficiency are only part of the solution. More attention is being paid these days to a) the economic management of water commodities, b) the institutional requirements for sustainability and equity, and c) how best to combine them in different contexts.

4.1 Commodity Markets

Concern about the economic management of water as a commodity has led to increased attention to water pricing and to markets. This trend has been accelerated by pressures mounting on governments to withdraw long-standing subsidies, impose fees for water provided, or even to divest themselves of responsibilities for water supply and allocation altogether.

Governments have historically subsidised much of the cost of water. For example, subsidies paid in Mexico to operate and maintain water systems (excluding capital investment costs) amounted to 0.5 percent of GDP until recently (Rosegrant 1997). In India, about 30 percent of all public investment has gone into establishing irrigation systems, for which water was then supplied almost without cost to the users (Bhatia and Falkenmark 1993). In the mid-1980s, it was estimated that average subsidies to irrigation in six Asian countries covered 90 percent of the total operating and maintenance costs (Repetto 1986). And a recent survey of water projects financed by the World Bank found that the average price charged for water covered only one third of the cost of supplying the commodity (The Economist 1998).

The rigours of implementing macroeconomic reform programmes since the 1980s have forced many developing countries to re-assess their role in water provision — neither an easy role to fulfil for many public authorities, nor an easy role to abdicate. The economic efficiency gains of allocating water through markets and prices as opposed to state-controlled mechanisms is already well-documented, at least for countries that have reasonably well-functioning regulatory institutions and markets (Holden and Thobani 1997). Today, the privatisation of water utilities is proceeding in some developing countries, with management of water systems being transferred to private firms, autonomous utilities, and/or water user associations in the hope of improving management, reducing costs and saving water.

Countries like Chile and Mexico have been replacing large-scale water subsidy programmes with various systems of tradable water rights, privatised infrastructure, and cost-recovery (Hearne and Easter 1995). Chile's 1981 water law granted water users (farmers, industrial firms, water and power utilities) property rights to water without charge. In addition, the state auctioned new water rights. Subject to certain public regulations, these rights can be sold to anyone for any purpose at freely negotiated prices. They may also be used as loan collateral. Mexico has also established property rights to water during the 1990s, although restrictions were initially put on inter-sectoral trading.

Early evaluations of experiences in such countries lend tentative support to the idea that the economic benefits can outweigh the potential political fall-out (Gazmuri 1995; Bauer 1997). There is evidence of water savings as well as increased inter-sectoral and household trade, with economic gains in all areas (Gazmuri, Schleyer and Rosegrant 1996). In the Philippines, for instance, moves towards water pricing by the National Irrigation Administration since the 1970s and 1980s led to a decline in water usage of 13 percent, although crop area and yields held constant (Bhatia and Falkenmark 1992). And in Chile, water charges actually *fell* after tradable water rights were introduced because the new regime facilitated the transfer to user groups of the responsibility for carrying out operations and maintenance (O&M) activities and for setting water charges. Because the users were able to carry out O&M activities more cheaply than the government could, charges were lowered (Thobani 1995).

However, there are two caveats to the generally positive press that water markets tend to receive. On the one hand, most evidence collected thus far has been from countries which received considerable support in/for changing their management system from donor agencies, that is, countries with already high levels of infrastructural development, foreign direct investment, and large export capabilities (Brehm and Castro 1995; Bauer 1997).

On the other hand, it remains unclear what the equity outcomes have been even in such ‘positive’ cases. Chile, Mexico and Peru are countries with fairly well-developed factor markets and reliable institutions. Market imperfections can of course be addressed through appropriately formulated laws, regulations, and taxes; well-functioning private markets are not cost-free to the state (Holden and Thobani 1997; Binswanger and Deininger 1997). In many countries facing severe water stress and inhabited by many water insecure households, however, institutional capacity is often weak both in regulatory terms and (importantly) in terms of protecting the interests of the poor — an equity issue.

Subsidies have rarely benefited the poorest households simply because they tend to live away from piped services or irrigation perimeters. Thus, the removal of a subsidy or codification of tradable rights may have limited impact on the water insecure as they have few water assets to trade. Indeed, the poor often pay more for water than wealthier households do. Numerous studies document that large numbers of urban poor pay higher prices and a much larger share of their income for drinking water than families with access to a city water system. (Bhatia and

Falkenmark 1992). For example, urban slum dwellers who depend on street water vendors may pay up to 100 times more for their water than if they had access to conventional public utilities (see Table 6). As a result, slum dwellers may spend as much as 30 percent of their income on water compared with the only 2 percent spent by wealthier urban households (WRI 1996).

Table 6: Income elasticities for domestic withdrawal and the ratio of water prices charged by street vendors to public utilities, selected regions, countries and cities

Region, country, or city	Price ratio (private to public)	Income elasticity of demand
North Africa		
Egypt		0.37
(Imbaba/Cairo)	40:1	
(Tunis)	10:1	
Sub-Saharan Africa	..	1.2
(Abidjan)	5:1	..
(Nairobi)	11:1	..
(Lagos)	10:1	..
(Nouakchot)	100:1	..
South + East Asia		
India	..	1.0
China	..	0.8
(Dacca)	25:1	..
(Karachi)	83:1	..
Southeast Asia	..	0.4
Myanmar	..	0.8
Vietnam	..	0.5
Thailand	..	0.4
Indonesia		
(Jakarta)	60:1	0.4
Latin + Central America	..	0.6
(Cali)	10:1	..
(Guayaquil)	20:1	..
(Lima)	17:1	..
(Port-au-Prince)	100:1	..

Source: Adapted from Rosegrant (1997), Bhatia and Falkenmark (1993), Cestti (1995), McPhail (1994)

Note: “..“ means ‘not available’.

Furthermore, water from vendors not only costs more, but may also be of poorer quality. Households in Jakarta, Indonesia, have been estimated to spend up to $50 million per year to boil water for drinking - an amount equal to 1 percent of the city's gross domestic product (UNDP 1992). These are, of course, the households that *can* afford to use fuel for this purpose. Those who cannot afford to boil all their water will consume an unsafe resource and/or consume less of the inferior commodity they have available, which in itself carries serious hygiene and health risks.

Yet, there is evidence (from Mozambique, India, Ghana and Ethiopia) that poor rural as well as urban residents would be willing to pay more for safe water delivered reliably near to their home or farm (Coppock 1994; Saywell 1998). For example, surveys of surface water systems in Pakistan found active trading for irrigation water among smallholders in most watercourses studied (Meinzen-Dick 1996). In India, roughly 50 percent of the area irrigated by tube wells is thought to belong to farmers who purchase their water (Thobani 1995). And researchers in Tamil Nadu, India, conclude that although water is seen as a free public good in rural areas, many villagers would pay for better (cleaner and more reliable) individual supplies: “preparedness to pay is far more common than ... previously assumed” argues Gnanadesikan (1998). But how much? And to whom?

Three sets of characteristics jointly influence a household’s willingness to pay for improved water supply (World Bank Water Demand Research Team 1993):

- Socioeconomic and demographic characteristics: education, occupation, size and composition of family, income, expenditure and assets;
- The nature of existing (traditional) water systems versus those of improved supply systems on offer: *cost* (both financial and time required to collect water), *quality* and *reliability* of supply;
- Household attitudes toward government water policies and their sense of entitlement to government services.

Household response to a new, possibly ’improved‘ water supply is not due to one set of determinants alone, but to their joint effect. This suggests a need for careful consideration of the potential correspondence between public sector concerns for an appropriate water supply policy and local peoples’ wishes as reflected in their willingness-to-pay.[7] For instance, some villages may have a high willingness to pay for private connections, but a low willingness to pay for public taps. Or, it may be the case that only a minority is willing to pay the full costs of a private connection, while the majority is willing to pay the full costs for access to water from public taps.

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[7] The reader is referred to the Appendix for an overview of the methods used to estimate consumers’ willingness to pay.

In arid areas, a relatively high proportion of households is likely to be willing to pay a lot for water from public taps, while the real costs are in fact so high that they exceed the beneficiaries' willingness to pay. The cost may be higher because of distance to regular supplies, low population density, or the lack of related infrastructure, such as electricity. In these cases, improved systems can only be built and operated with subsidies. [8]

It has been suggested that households usually pay, or are willing to pay, *3 to 5 percent* of their income for an improved water supply (World Bank Water Demand Research Team 1993). Yet since income is not the only or even principal determinant of water demand, the share of income that a household is willing to pay varies widely according to local context. Studies conducted in different developing countries illustrate that:

- In Parana State, southern Brazil, many households are not willing to pay for public taps, but will pay 2% of their household income for yard taps (World Bank Water Demand Research Team 1993).
- In Imbaba (a community near Cairo, Egypt), there are some households that spend about 8.5% of their income on water (Cestti 1995).
- In Ukunda, Kenya, it was found that on average households were spending about 9% of their income on water from water vendors (Whittington, Lauria, Okun, and Mu 1989).
- In Onitsha, Nigeria, poor households were estimated to be spending 18% of their income on water during the dry season versus 2-3% spent by upper-income households (Whittington, Lauria, Mu 1991).

Furthermore, the reliability of water supply, one of the elements influencing people's willingness to pay for improved water supply service, should not be underestimated. Unreliable service can discourage people from having their household connected to a piped water system. In Punjab, Pakistan, it was found that households were willing to pay as much as 40% more per month for reliable service than for the existing (unreliable) service (Altaf, Whittington, Jamal, Smith 1993), while in Jakarta, Indonesia, one survey showed that households currently connected to the piped water system are willing to pay 30 percent more than they are currently paying if piped water is made more reliable (Cestti 1993).

At the same time, one should keep in mind that the *willingness to pay* may differ from the *ability to pay*. It cannot always be assumed that individuals who are willing to pay for a basic service will be able to do so. On the one hand, research in particular regions has shown that women have a higher willingness to pay for improved water supply than men (Green and Baden 1995). It is the lack of control over household income, patriarchal decision-making structures and/or biases in intrahousehold resource allocation processes that may hinder women from committing resources to such an investment (Nigam, Rasheed 1998 and Green and Baden 1995).

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[8] Some villages will have a low willingness to pay for improved water service because local households have other, more pressing needs (see Appendix).

On the other hand, Reddy and Vandemoortele (1996) argue that although most evaluations of willingness to pay are based on partial enquiries of the value that individuals place on one particular need, the ability to pay is actually related to broader decisions on the use of the total household budget, taking all other needs and outlays into account.

Per capita demand for freshwater is a function of the growth in per capita real income and the income elasticity of water demand. Information on income elasticities of demand for water is extremely scarce for low income countries. Knowledge of income and price elasticities is important for modelling changes in demand resulting from alternative demand management alternatives (Barrett 1996). Since one of the key tools of demand management is water pricing (be it via public authorities or the market), predicted responsiveness of water consumption to changes in water price is needed to inform effective decision making. The reported water price elasticities for residential water demand range from –0.11 to –0.70, with an average value of –0.45 (see also Table 6). That means that a 10 percent increase in the piped water price would reduce residential water demand by 4.5 %. These values represent long-run elasticities. The literature also reports short-run price elasticities obtained from time series records. These price elasticities range from –0.10 to –0.36 with an average value of –0.21. The effect on water use brought about by a price increase is greater in the long-run than in the short-run (Cestti 1995 and Cestti et. al. 1997). Similarly, the household income elasticity for urban water demand in developing countries ranges between +0,04 and +0,60 with an average value of +0.30 (Cestti 1995).

A study conducted in the Jabotabek region of Indonesia shows that there are different price elasticities for the various water sources (piped water, groundwater, water from vendors). The price elasticity for piped water demand calculated from a cross-sectional survey is estimated to be –0.68, whereas the price elasticity for vendor water demand was found to be –0.80. Furthermore, it was found that consumers do not react to changes in the price of groundwater, as there is only very little variation in the water price. This is because groundwater demand in the Jabotabek region is determined by its quality (Cestti 1993). Unfortunately, information on water prices and changes in water consumption resulting from changes in price is lacking for most developing countries, and especially for different income categories within those countries. The limited evidence available suggests that demand for water is highly elastic for low income countries (which tend to have low water withdrawals currently), but that the income elasticities decline in response to rising income and water usage (Rosegrant et. al. 1997). According to the second column of Table 6, sub-Saharan Africa (with its low income levels and low usage) has the highest elasticity of demand, followed by China and India, which also have high elasticities due to their high incidence of poverty. The (former) ‘Tiger’ economies of eastern Asia, on the other hand, have very low demand elasticities comparable to those of industrialised nations, which tend to fall at (or below) 0.0. For example, demand elasticities within the United States are reported to range from -0.1 to -0.7 (Barrett 1996).

These data suggest that there is considerable scope in many developing countries to explore pricing mechanisms for water delivery even among the very poor, a point that was acknowledged at the International Conference on Water and the Environment (ICWE) of 1992. As an input to the Rio summit (UNCED), the ICWE assembled a group of 114 developing and developed nations (plus 28 UN organisations) to examine the role of water in development. The meeting agreed on several major principles for action, one of which was that “water has an economic value in all its competing uses and should be recognised as an economic good.” (FAO 1993) As a result of that decision, agencies such as the World Health Organisation quickly took up that theme in their own work, proclaiming that “water has a price that should always be paid for by consumers” (WHO 1994).

However, this remains a contentious stand. There are religions (for example Islam) that prohibit water allocation by market forces, and others that treat water as a sacred good. For instance, the Navajo people of the south-western United States have a word for ‘water’ that is the same as the word ‘prayer’ (Shoumatoff 1997). According to Boulding (1980), the special status of water “as a symbol of ritual purity” exempts it in many people’s view from the “somewhat dirty rationality of the market." This is an extreme position, but it is one which continues to carry weight. Indeed by 1997, both WHO and UNICEF modified their earlier position, stating that they now recognise the need to see water also as a social resource, not only as an economic good (WHO 1997).

Similarly, there are some contexts in which households, even those willing to pay and trade water, are obliged to deal with water less as a commercial commodity than as a public good, something akin to an entitlement, albeit with certain responsibilities attached. This (culturally prescribed) perspective also requires attention beyond the market into realms of community relations and the traditional institutions that govern the sharing of scarce resources.

4.2 Indigenous Institutions

Elaborate indigenous institutions have existed for centuries in many water-scarce environments. Such institutions are embedded in cultural and societal structures that at times operate differently from trade mechanisms based on price. According to Radwan (1998), water systems must be understood in terms of the cultural setting within which they operate: “the formal and informal power structures which govern social behaviour ... interact to create the functioning village.” There is growing professional acknowledgement of the point that non-state institutions (indigenous, traditional, informal) sometimes exert a major influence on the success or failure of development interventions in general, and water interventions in particular (Miller et al. 1996; Kholn and Wolter 1998; Saywell 1998).

‘Institutions’ in this sense should not be confused with organisations. Non-state institutions are social systems that structure human (and therefore economic) interaction. They enforce sets of publicly recognised constraints on behaviour, such as rules regarding individual tenure or access rights, and conventions regarding participation in community norms or the definition of contexts in which community needs outweigh those of the individual (North 1994; Miller et. al. 1996).

For example, water rights among the Sonjo people of northern Tanzania are regulated by an institutionalised group of elders (the *wenamiji*) who have long controlled the management of water for hill-furrow irrigation (Potkanski 1987). Failure to co-operate in communal duties of irrigation maintenance or the ‘theft’ of water can result in the *wenamiji’s* imposing fines (e.g. a number of goats), or even lead to the expulsion of the culprit from the community (Adams et. al. 1994). It is impossible, at least for the present, for individual Sonjo households to operate outside of the institutional norms of the locality. No move towards pricing or tradable rights should be taken before carefully examining the issues of infrastructure maintenance responsibilities and the cultural impact of either a gain or loss of power by the *wenamiji.*

Similarly, in southern Ethiopia, Borana semi-nomadic pastoralists depend on a series of deep wells (*tula*) to water their livestock once every 3 to 4 days. These wells are several hundred years old and have given rise to a complex system of collective maintenance and management (Cossins and Upton 1985; Webb and Coppock 1997). The Borana rangelands are divided by the elders into 75 demarcated districts (*meda*). Each has one or more water points and a core population divided into several dozen encampments with their herds. Although the *meda* are communally controlled, individual access to grazing zones, and more importantly to water, is controlled by clan authorities. The Borana, like the Fulani and WoDaaBe of Niger, appoint well-keepers whose responsibility it is to schedule the timing and duration of watering periods for each encampment. When it is their turn, the men of an encampment bring their herd to the *tula* and climb down as much as 20m into the well shaft. They form a human chain, lifting goat-skin buckets to the surface, where they are emptied into water troughs for the animals. Where surface ponds and shallow wells exist, similar principles of organised access and common participation are observed. Households not contributing labour, time or capital to the digging or maintenance of wells are either excluded from using the water or charged a fee. It is instructive that when diesel pumps were installed in some *tula* in the 1980s with a view to reducing the time and drudgery involved in lifting the water, the system broke down. The poorest households traditionally help wealthier households in a long-standing client-patron relationship. The poor contribute extra labour on behalf of the wealthy in the arduous (and sometimes dangerous) tasks in the deep wells in return for food and breeding stock. With the advent of pumps, well-keepers and other wealthier households no longer needed to coerce and remunerate the poor for work that was superfluous. The wealthiest elders gained monopolistic control over well management (Coppock 1994), but some pumps were vandalised and others quickly fell into disrepair. Today, the traditional well institutions have regained their former place, and NGOs and government agencies are looking at ways to build on traditional social structures rather than circumvent them.

It can be argued that the pursuit of equity in development requires that more attention be paid to indigenous water institutions that play a role well beyond water or even agriculture *per se*. As Radwan (1998) has noted for Egypt, “formal structures created to replace informal traditional structures have been less successful than envisaged and are themselves the sources of many... problems.” This is not to suggest that all indigenous institutions always protect the needs of the poor — that much is clear from the above example from Ethiopia. Malnourished, water insecure households are often marginalised by informal, culture-bound norms that may protect the interests of the community, but also benefit the interests of an influential elite.[9] The challenge is to marry technical and economic concerns with the realities of social controls in new ways that are directly and measurably beneficial to the poor. Obtaining a broader and deeper understanding of traditional institutions, particularly of the principles and mechanisms employed by those that actively protect the interests of the poorest water insecure households, is urgently needed.

So is a better understanding of how water insecure households *themselves* perceive their own condition and potential solutions. There is accumulating evidence that planners’ assumptions about water demand or usage behaviour among the poorest households may be far removed from reality. According to Saywell (1998), fieldwork in cities in India (Vijayawada), Mozambique (Maputo) and Ghana (Accra, Cape Coast and Tamale) indicates that “there exists a significant gulf between perceptions among professionals and those of the community in respect of the appropriateness of on-plot sanitation systems” and that “all too often, assessments and judgements regarding effectiveness and appropriateness are made from a technologically biased and purely external perspective.” Supply-driven approaches typically translate into technical preferences for waterborne sewerage systems, despite their history of poor performance, management, operation and sustainability. The conclusion is that professionals planning water interventions “must be sensitive to the social and cultural context in which decisions about sanitation are made, if widespread community adoption of programmes is to follow” (Saywell 1998).

A typical example of differences in needs perception is offered by Chinautla, a slum of Guatemala City. A community group requested the installation of a single water tank in their neighbourhood rather than conventional piped access, although such a tank was typically used only temporarily (Espinosa and Lopez Rivera 1994). In the absence of many other options, it was felt that this was the best solution to its water supply needs since each household could built its own pipe to the central source. This was done although the municipality had assumed the community would prefer to wait for full access to piped supplies. The association receives a single bill from the water company, and one resident selected by the community manages the billing and the collection of fees from each household. While the cost of the single-source water tank per family is more than a direct connection to the municipal water network, it is far less than what they had been paying for water from private vendors.

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[9] The equally important issue of gender-specific impacts of water projects is dealt with in the next section.

Similar examples of differences in perception can be found in rural environments. In Ethiopia, a country which during the 1980s and early 1990s hosted the largest food-for-work programme in Africa, consultation between project implementing agencies and participants was minimal (Webb and von Braun 1994). For example, while most projects were focused on soil conservation and reforestation (in 1985, some 70 percent of total labour was applied to soil-bunding work), these activities were seen by most participants as having limited personal utility. Many villagers would have preferred (had they been asked) activities relating to health and sanitation, including clinic construction, latrines and clean water supplies.

These various examples confirm that households in many different environments may see water-related benefits as outweighing other interventions, including some related to agricultural productivity enhancement. Access to sufficient water has a premium for the poor. The next problem is that even if water is available and accessible in sufficient quantities, water *usage* may not be adequate to generate required human benefits.

5. Not All s Well that Ends in Wells: Problems in Water Usage

The Nobel Laureate Robert Fogel has shown that there was a dramatic decline in mortality in European countries (France and the United Kingdom) between 1780 and 1830 (Fogel 1997). The principal mechanisms leading to an improvement in survival rates were: i) the elimination of malnutrition, ii) advances in public health, iii) improvements in housing, and iv) reduced consumption of toxic substances. The elimination of malnutrition, he ascribes less to health policies than to advances in the decontamination of water and food and improvements in sanitation, as well as to gains in agricultural productivity. Improvements in nutrition and health in themselves accounted for as much as 30 percent of total per capita income growth in western Europe during the 200 years between 1780 and 1980 (Fogel 1994).

Fogel’s research underscores the fact that making water clean (not just available), encouraging appropriate consumption (not just access), and ensuring appropriate disposal after usage are distinct elements in both human and economic growth. Thus, ‘usage’ (the third category of the water security diagram in Figure 2 above) relates not only to consumption as an *input*, but also to consumption as an *outcome* of various social, economic and environmental interactions. These interactions are manifest in a negative sense wherever water security is compromised by: a) inadequate quality, b) inadequate knowledge (about use), and/or c) insufficient time to improve use (high opportunity costs).

5.1 Water Quality

There are still 1.2 billion people without safe drinking water and almost 3 billion lacking adequate excreta disposal facilities (WHO 1997). Without access to a minimum of 15 (pastoral) to 20 litres (sedentary) of safe water per person per day, a household faces serious water insecurity risks (Teka 1977; Gleick 1996). WHO (1996) estimates that 5 million people (*all ages*) die each year from illnesses due to unsafe water and the lack of sanitation.

Some water is actually poisonous. Large numbers of Bangladeshis have recently been seriously affected by water containing high concentrations of arsenic, derived from wells sited over geologic deposits of arsenic (Ghosh 1998). India provides another case where deep boreholes sunk in the state of Madhya Pradesh during the 1980s were inappropriately sited. Some of the boreholes were tested and found to be free of harmful bacteria, but the water was never tested for natural chemicals. In this case, high geologic concentrations of fluoride have resulted in serious fluorosis (fluoride poisoning) for at least 60 million people, of which 6 million were children (Pearce 1998). The symptoms include massive limb deformity, stillbirths, and rickets. These human tragedies could have been avoided if more attention had been paid to water safety in all its aspects. Drilling deep wells to get below contaminated or saline water courses may seem logical, but it may instead be a much more expensive, and potentially dangerous, solution.

Other sources of water are merely harmful. Industry uses large amounts of water, of which 85 percent is typically recycled as waste water. The major problem is that much of this water is returned polluted with wastes, chemicals and heavy metals (Gupta 1992). The city of Shanghai, China, for instance, recently had to invest $300 million to move its municipal water intake many kilometres further from the city because the adjacent river sources had become too fouled by industrial waste (The Economist 1998). Much of the water derived as agricultural ‘waste’ is also polluted with nitrates, pesticide chemicals and salts. And there is also water affected by upstream contamination with faecal matter. Each of these forms of pollution is widespread and dangerous.

There are five main categories of diseases related to water: i) water-borne diseases (typhoid, cholera, dysentery, gastro-enteritis and infectious hepatitis); ii) water-washed infections of the skin and eyes (trachoma, scabies, yaws, leprosy, conjunctivitis and ulcers); iii) water-based diseases (schistosomiasis and guinea-worm); iv) diseases from water-related insect vectors such as mosquitoes and blackflies; and v) infections caused by defective sanitation (hookworm) (WHO 1998). Unfortunately, there is considerable uncertainty about the relative importance of each of these transmission paths (Kjellén and McGranahan 1997).

Some of these diseases are coming under control, but others remain global scourges. For example, increasing population densities and declining public investment in water have led to the spread of schistosomiasis to areas of the world where it was previously either not endemic or only minimally endemic , with the result that there are now 74 developing countries, mostly in Africa, in which schistosomiasis is a major problem (WHO 1998). Typhoid and cholera remain global concerns, particularly in the context of crises such as mass refugee movements resulting from armed conflict, or in the case of major flooding which contaminates supplies of drinking water. Of course, diarrhoea remains the world’s biggest water-related problem. Diarrhoeal diseases linked to unsafe water are responsible for 3 million deaths each year among children under age 5 in the developing world (WHO 1995). Africa is the worst-affected, with an average diarrhoea-related mortality rate of 17 per 1,000 (Sharma 1996b).

Various regional studies have been undertaken to determine the impact of improved water supply on health. Without doubt, improved water access has a positive influence on people’s health. However, a review of various studies has shown that a hierarchy of interventions, ordered from most to least effective, becomes apparent. In a first stage, the highest positive effects derive from improvements in household sanitation and hygiene practice, followed by improvements in both quality and quantity of water supplies, increasing quantity of water consumed and improving water quality (Hoddinott 1997). However, improvements in only one of these aspects is unlikely to lead to an extreme fall in morbidity. Integrating all interventions is certainly most effective. Besides, it must be emphasised that to some extent it is the water quantity, not the quality, that is of greater importance (Hoddinott 1997). There is a need of sufficient quantities of water for personal and domestic hygiene to reduce infections.

In addition to mortality and morbidity, the risks of water insecurity can also be measured in terms of nutritional status outcomes. In countries as diverse as Kenya, Pakistan, Guatemala and Ethiopia, it has been documented that access to sufficient clean water (preferably from pipes or private wells) is strongly correlated with household food insecurity, which itself is strongly correlated with poor nutritional outcomes among pre-school children (Haddad et al. 1996). For example, an analysis of water and sanitation in 15 sub-Saharan countries indicates that while the mean rate of stunting of pre-schoolers living in households *with* access to sanitary excreta disposal facilities is 19 percent, the rate of stunting in households *without* sanitation is close to 50 percent.[10] Similarly, the average rate of stunting in households with access to clean, piped water is 17 percent in these countries compared with a rate of 36 percent for households that collect drinking water from unprotected surface streams or open wells. The difference in wasting levels (weight for age) in relation to the source of drinking water was 7 percent and 16 percent, respectively. This confirms how crucial it is to have not only access to, but also knowledge of the importance of, safe water and waste water disposal.

5.2 Adequate Knowledge

Knowledge of water uses and abuses implies education, both formal and informal. People must use the water supply and waste facilities properly in order to obtain the health benefits inherent in them; the physical presence of a water pipe does not in itself guarantee hygiene. This means that is crucial for households to know how to protect and store water safely, how to maintain personal and domestic cleanliness, how to dispose of excreta and how to eliminate or minimise unsanitary environmental conditions. Knowledge transfer, behaviour change and personal care are the key factors. For example, female literacy is strongly, positively correlated with lower levels of both stunting and wasting (Frongillo et. al. 1997).

Of course, schooling has not only a direct effect on hygiene and sanitation; its impact on nutrition relates to income earning potential, productivity, food consumption patterns, health care patterns and other aspects of the overall habitat. However, some direct and indirect knowledge about the importance of water to human growth is associated with formal education.

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[10] Based on own analysis of individual country data from the Demographic and Health Surveys published by Macro International Inc. (see MII 1996). The countries included here were: Benin, Burkina Faso, Burundi, Cameroon, Ghana, Kenya, Malawi, Mali, Namibia, Niger, Nigeria, Rwanda, Senegal, Uganda, and Zimbabwe.

Where informal education is concerned, indigenous wisdom is certainly important. For example, the slums of Indore, India, are located either on the banks of canals and rivers or on the city's lower-lying flood plain. The monsoon frequently causes flooding and most slum residents are aware that there are health risks associated with this flooding. Despite an absence of knowledge about the epidemiology of contagion, they have names for different flood conditions that relate to associated symptoms (Baare and Patnaik 1996). Water clearly contaminated with faeces is known as *Gander pain*, the worst kind of water since it is believed to bring *kitanuh* (small unseen insects) responsible for causing stomach problems and diarrhoea even through contact (not having drunk the water). On the other hand, *Maila pain* (dirty water without excreta) is unpleasant to walk through, but not considered to be dangerous, while *Pineh ka pain* is water clean enough for drinking.

Another form of informal knowledge transfer is that provided by public education campaigns on radio and television. In countries like Kenya and Ghana, there is a statistically significant correlation between the absence of stunting (low height-for-age) and the use of television and radio (MII 1995b, 1996). Again, it is not necessarily only the transmission of messages regarding water that matters since there are important synergies among most of the ‘development’ messages transmitted to the public via such media. What is more, obtaining the knowledge and understanding how to act differently is not a guarantee that the knowledge *can and will* be acted upon. There are serious constraints on water-stressed households, and particularly on women in most households, which may hinder their ability to act on knowledge and make adequate usage of available water.

5.3 Time (Opportunity Costs)

Gender constraints are an issue in water as in most other aspects of development. Problems appear mainly in terms of *time constraints* on women, who are responsible for mostwater hauling, carrying and domestic water chores, and in terms of *access rights* to water for productive use (particularly irrigation and home gardening).

Women in water-stressed environments spend a lot of time fetching water. This in itself can constrain how much water is used. The installation of a village-based stand-pipe or pump can increase water usage four-fold simply because it reduces the time required to obtain water (Cairncross 1987). Some women in Burkina Faso have to travel such long distances for water that they seek to optimise time by choosing water sources lying in the direction of their farms, where they can stop and work for an hour or two before completing the fetching and carrying (Zwarteveen 1997a). In the Sidamo regions of Ethiopia, women spend around 12 percent of their waking time collecting water to meet household needs (Coppock 1994). Their source is usually a well or spring that lies an average of 14 kilometres from home.

However, water for agricultural production is an equally important concern for these same women. For example, a project aimed at reducing the distance and time required for fetching water among the Boran pastoralists of Ethiopia decided to install cement cisterns that would fill with rain and captured surface run-off. Married Borana women manage most livestock operations and dairy marketing (Webb and von Braun 1994). The siting of cisterns near encampments cut the time required by many women for a round-trip to the water source from 3 hours to 15 minutes (Coppock 1994). The result, despite clan rules that restricted water use by each household, was a 74 percent increase in water consumption, 90 percent of which came from the new cisterns.

And yet, there were two quite unexpected side-effects. On the one hand, women's time spent fetching water changed little; although they travelled less distance, they went to get water more often, making an average of 10 trips per week versus 5 trips per week previously. So the expected effect on women's time was not forthcoming. On the other hand, even though total household consumption rose from an average of 78 litres per week to 134 litres per week once the cisterns had been built, water for drinking, personal hygiene and washing clothes only rose from 16 litres per week to 20 litres per week (Coppock 1994). The bulk of the increased water use was accounted for by a more than 3-fold increase in consumption by livestock. In other words, the women, offered better water access but faced with constraints on withdrawals, decided that they would rather use the gain to invest further in their livestock. Their time constraints were not lessened by these interventions, but they did make gains in productivity.

Productivity concerns also loom large in the context of women's participation in irrigation management. There is a well-established literature dealing with the relative rights and responsibilities of male and female farmers in agriculture, and with the positive or negative impacts of technological change on the gender balance of those responsibilities (Agarwal 1994; Cleaver and Elson 1995; Jackson 1996). On the whole, a consensus emerges from this broad literature on two central points: first, women are often side-lined by the introduction of new technologies or techniques (including the establishment of tradable water rights or new irrigation schemes), and so distributional and equity concerns need to have a high priority in the assessment of perceived water needs. Second, net productivity gains from system changes are greater if women are involved as partners in the design and introduction of technologies and/or at least given access to water and land in their own right (Zwarteveen 1997b).

An example of both problems can be found in Gambia, where the introduction of large-scale pump irrigation disturbed the traditional pattern of responsibilities whereby rice was mainly farmed by women, while rain-fed cereals and groundnuts were farmed by men (von Braun and Webb 1989). Despite plans to make this a 'women's project', it was discovered that men took over the management of the irrigation to such an extent that irrigated rice became a 'man's crop', and women assumed control of rain-fed cereal and groundnut fields.

Many attempts were made to restructure the design and administration of the irrigation tenure rights, but little progress was made in changing the new pattern of responsibilities. Women did not gain substantial additional access to the improved water technology (Pena et. al. 1997).

However, this does not mean that women are always absolute losers in the change. The households most involved in the Gambian project did gain substantially in income, food consumption and nutrition terms (von Braun et al. 1989). This occurred because men used most of the additional rice output to raise household consumption, while most women gained alternative income (outside of traditional rice), by cultivating a rain-fed cash-crop and/or working for payment on the new 'men's' fields. Yet, in cases where women did obtain their own irrigated plots, their productivity was as high as the men's, and the households gains were proportionately higher.

Similar findings emerge from Burkina Faso and Nepal. An evaluation of the Dakiri irrigation scheme in north-east Burkina Faso showed that 9 percent of individual plot holders of a 120 hectare project were women. The income of these women rose sharply once they gained control of their own irrigated plots, and net gains to household social and economic welfare increased if both husband and wife had plots (Zwarteveen 1997a).

In Nepal, numerous studies have highlighted the 'success' of the Chhattis Mauja irrigation scheme, where the infrastructure was built by the users and "all users are involved in the irrigation organisation" (Yoder 1994). The project has been productive and appears to support the case for management by users' associations. However, it has also been found that there is a large group of users involved neither in the management of the scheme nor in its maintenance; namely, women farmers. Not consulted because they do not belong to the users' associations, women farmers help themselves to the water they need and avoid participation in infrastructure maintenance. Since they are not members, the users' association cannot easily enforce its rules on the women, who in effect have become free-riders of the system by default (Zwarteveen and Neupane 1996). While the women are not unduly disadvantaged in economic terms (while they retain access to their own means of production), this arrangement is already creating "performance weaknesses" in the scheme because of a lack of control over water withdrawal and a lack of labour mobilisation at the 'head end' of the canal system.

These examples suggest that women should be involved in users' associations and be producers in their own right. Indeed, a study conducted in Indonesia (Schrevel 1989) concluded that the major cause for the poor functioning of that country's water users' associations was a lack of female representation. Yet, in the absence of formal representation in associations, women's entitlements can at least be partially met if they have direct access to the improved water management systems that they need. The point is that women's time in agriculture, just like men's time, is more valuable in cases where water management is improved. Finding ways to enhance the productivity of women's time through water projects is one of the challenges facing food and water policy-makers.

6. Conclusions on Research Needs

In recent decades, food policy analysis has developed a conceptual structure that unites agriculture, soil science, economics, climatology, geography and nutrition in a common understanding of issues and goals. It remains for water policy analysis to develop similar conceptual and scientific synergies across hydrology, environmental sciences, health, and food policy (among other disciplines). For this to happen, linkages among environmental, economic and social processes need to be better elaborated.

Running through this review has been a recurrent tension between a need for analytical differentiation of water's multiple facets, on the one hand, and the need for a multifunctional synthesis of water's functions on the other. Progress towards water security can be made only if there is a fuller understanding of the interactions among waters' various characteristics and functions. It is not only a natural resource, but also an economic commodity, *and* a human consumption good or entitlement. There are many gaps in our knowledge about each of these functions, especially where the demands for each are simultaneous rather than sequential. The challenge to water research in the coming century will be not only to fill in the gaps in our knowledge of each individual function, but also to integrate such findings across individual sectors.

Yet the search for solutions to competing demands continues to be based too extensively on the analysis of each function separately: market solutions for competition for a commodity, technical solutions for problems of supply, policy and regulation solutions for competing societal entitlements. Competition and/or consensus occur at all levels, within households, within communities, among sectors, institutions, and countries. Environmental research which does not consider social and economic factors simultaneously risks reiterating environmental orthodoxies of the past. Physical analyses of 'erosion', for example, are not always divorced from socio-political forces in society since the purely 'scientific' agenda is often driven by prevailing policy agendas (Satterthwaite 1997). However, the same may be said in regard to economic research that denies the relevance of entitlement or heritage concerns, and for social research that ignores the intergenerational relevance of ecological integrity concerns. Water security policy must be fully advised of positive and negative interactions at all levels if multiple (often non-commensurate) environmental, economic and social objectives are to be met in a sustainable fashion (Revenga et. al. 1998).

Water has been the focus of numerous recent international conferences (including Dublin in 1992, Stockholm in 1996, Washington, D.C., Petersberg/Bonn and Paris in 1998). Within the Programme for Priority Actions formulated at the Paris conference, it was emphasised that the priorities for official development assistance should include actions to meet basic needs (drinking water supply, sanitation, control of water-related diseases, etc.). It was agreed that ”rapid action is necessary to reach progressively approved international standards in order to meet quantitative and qualitative basic needs in rural and underprivileged urban areas. Special attention should be paid to the means of achieving the eradication of water-borne diseases. Special consideration should be given to gender and equality issues; including programs to improve the status of women and increase their meaningful participation in decision-making.” Further priorities include the strengthening of mechanisms for regional consultations on drought and flood preparedness, such as early warning systems and mitigation plans at local and national levels, and the establishment of economic incentives to enhance irrigation efficiency in order to increase the quantity and regularity of food production.

The OECD also agreed in 1996 that two of the indicators for measuring success in meeting poverty alleviation targets by 2015 should be i) raising the share of people with access to safe water, and b) controlling the intensity of freshwater usage (with environmental sustainability in mind) (OECD 1998). But, at the turn of the 21st century, we are still far from agreement on the most appropriate methods for identifying households facing water-stresses or for ensuring adequate supply, availability and usage of clean water to such households. We do know that certain technical advances in forecasting and modelling, and economic advances in pricing and the design of user rights have brought us closer to understanding how ecosystems work and how supplies might be allocated more efficiently than in the past. Yet much remains to be understood of the spatial, temporal, and scalar dynamics that emerge when ecological, economic and social demands compete in conditions of scarcity. This implies an integrated research agenda that considers key aspects of water functions linked at different scales.

Beginning with water availability, there is a need for better assessment of the relative condition and trends of major water systems of ecological and/or human importance. This requires the establishment of more rigorous and sensitive status indicators for watershed heads, river and stream channels, estuaries and coast. At present, there are few quantifiable standards other than indices of so-called ‘biotic integrity’ or ‘trophic conditions’, which focus more on water quality than overall systems. What is required are links between changes in quantity and quality of water to habitat changes (be they ‘improvements’ or ‘degradation’), land-use changes and entitlement outcomes.

Such assessments need to go beyond a mere cataloguing of indicators, and beyond an arbitrary indexing of available indicators and macro-level modelling without a confirmatory process on the ground. For example, Revenga et. al. (1998) refer to four separate variables in their assessment of 'watershed vulnerability', namely, population pressure (urban growth rates, in fact), soil erosion, rates of deforestation, and the share of watershed accorded ‘protected’ status. While each of these four variables is important in its own right, it remains unclear how these (or any alternative) variables can be combined, ranked or merged to generate a valid assessment of relative *risk* of failure of water availability in relation to all sectors of water demand. This calls for more effort to be expended in assessing the explanatory power and ‘sensitivity’ of a wider range of variables, including non-ecological ones. Participatory approaches toward gaining indigenous perceptions of status, trend and risk would need to be explored, as well as the potential for using remote sensing technologies as aids in monitoring the movement of pollutants through entire watersheds and in identifying vulnerability hot-spots.

Second, there is a need for research on the temporal and spatial dimensions of water insecurity, especially where risks of major disruptions to availability are concerned (including droughts and floods). Arid regions are not uniformly arid. Although 9 of the 14 watersheds expected to face the greatest increases in population pressure in coming years are located in dry-land regions of Africa, this does not mean that all such regions, or all people in those regions, have an equally high risk of water insecurity. Combinations of surface, groundwater and aquifer access, different soil and geological substrata conditions, varying levels of technological adoption, differences in food security status (for example the degree of reliance on irrigation), result in diverse conditions that affect the nature of household water security in both ‘normal’ years and during crises. For example, during the drought in Zimbabwe of 1992, harvests were down by 75 percent over the previous year, and pipes in some towns ran dry. But not all parts of the country were equally devastated and smallholders were not uniformly affected even in places where drought was severe. Why not? Analysts routinely consider falling income and food consumption in such crises, but few data exist on household or community-level water consumption coping strategies. As Faures (1998) points out, “The current state of ... rural water use ... is largely unknown.” Whose consumption declines more than others, and how are dwindling supplies allocated by households across the demands of family, livestock, crops and ecological integrity?

This does not imply a need for more studies of drought prevalence and precipitation trends. Rather, closer scrutiny of the diversity of impacts of single events is required, as well as research into up-stream/down-stream effects of management changes. A study of transects of large water basins facing substantial future population pressures (such as the Congo, Volta, or Uruguay) would provide crucial information on how economic, institutional or ecological change in one part of a system affect the others. Only with a detailed understanding of the interaction of the factors affecting management changes and the shock impacts will it be possible to mitigate temporal and spatial variations through improved policy and project design.

It should perhaps be noted here that the United States Environmental Protection Agency and National Science Foundation initiated a watershed research program in the late 1990s aimed at improving “understanding of the natural and human-induced processes that affect the quantity, quality and availability of water resources in both natural and human-dominated systems” (NSF 1997). Although such understanding is still lacking in the context of the United States, such knowledge is much more deficient in developing countries where water stresses are far greater (Naiman 1995).

The same is true where water access is concerned. During ‘normal’ years, water has different economic values across time and space. But these values remain practically unknown apart from a few studies relating to urban supply projects and irrigation schemes. What is the ‘real’ price of water and the opportunity cost of access to that water at 1km, 5km, 50 km from a city (going upstream on the Nile or the Volta rivers, for example)? At what point do price and cost boundaries intersect, like ripples on a pond, as other sources and/or major users come into view? Coppock (1994) found that pastoralists were willing to sell 8 bulls and contribute many weeks’ of labour to build a single water cistern. Does that ‘value’ change as one moves into semi-arid regions or the closer one comes to potential urban markets for dairy products?

Part of any understanding of the topography and timing of price relationships to water has to be a better quantification of demand elasticities relating to income and usage, i.e. the willingness and ability to pay. This is useful for more appropriate planning of water supply projects and the calculation of potential costs and revenues. Furthermore, there is growing interest in seeking ways of meeting regional supply deficiencies (due to institutional deficits and constraints on government capabilities), through private sector channels, and determining what the distributional and equity effects might be.

The potential roles of water markets, tradable access rights, and primary use conversions can be adequately assessed only if attention is also focused on the net effects, and not merely on economic efficiencies. This includes a need for assessments of equity and of the distributional effects of reforms in countries such as Chile, Mexico and India. Recent changes in incentive structures for water allocation and usage along with the decentralisation and privatisation of water management functions have already generated efficiencies and water savings. That is not all that matters, however. For households already lacking effective demand for food and public services, we need to know the impact on their demand for, and use of, water. The household economics of water consumption and potential trade-offs against food consumption, asset investment, and investments in future natural resource productivity, remain poorly understood in water-stressed environments.

Public action requires effective identification of people ‘in need’. We need to understand how well (or poorly) indigenous institutions protect the interests of vulnerable households. How are such institutions affected by price, market or other policy reforms at a national level? Can public assistance be effectively targeted through the medium of traditional water institutions? Can traditional institutions play a wider role in managing public externalities, such as water safety regulation, infrastructure investment in common access lands, and the resolution of inter-ethnic and cross-frontier disputes? Widespread political rhetoric in favour of decentralising power has yet to be matched in practice in all but a few countries. However, the principle, as it relates to water, has already encountered problems in countries like Ethiopia, where competing ethnic interests in access to resources affect the development of political entities at regional and national levels.

In cases where indigenous systems can cope only with local situations, modern policy instruments and institutions must be tailored to cope with growing needs among water insecure households. The United Nations recognised the “serious deteriorating conditions of household water security [in Africa], which includes household drinking water and sanitation”, and made special reference to the need for “targeting of the populations in greatest need” (UN/ACC 1995). The difficulty is that some of the most urgent needs for improved water access are found in contexts where existing political and technical institutions are weakest (Faures 1998; The Economist 1998). Establishing appropriate designs and roles for institutions concerned with water equity is an urgent priority.

A further aspect of institutional responsibilities relates to ‘knowledge’ transmission. What kinds of public investment are required to ensure appropriate education among households about the positive aspects of clean water usage and negative aspects of poor sanitation? Education on water use (and synergies with appropriate food use and sanitation) is as important as making more clean water available. At present, vulnerable households tend to be those with the least access to formal education or literacy training. What, then, are the investment priorities needed to overcome such deficiencies?

As for water usage, much research remains to be done on how actual consumption levels among poorest households can be raised. How do patterns of family usage vary across seasons? Who are the beneficiaries of improved water access? Women, men, or children? The wealthy or the poor? And to what extent do various age, gender, status and income categories benefit or lose out in the change?

Indeed, to what extent can we identify patterns of intrahousehold discrimination in water use as sometimes exist with regard to food? If patterns of control and discrimination do exist (as is often the case in relation to food and other resources), does their existence affect nutritional outcomes aside from the impact of food and disease? How much fuel wood and charcoal might be saved (to be measured as positive ecological externalities) if cleaner water were to be made available to the millions of people who are forced to boil the unclean water that they receive today?

Additional research is also necessary in the field of water-related diseases. There are not only great uncertainties about the transmission paths of water-related diseases, but there is also no final proof of the relative importance of water quality standards versus improved access to sufficient water quantities for human health, labour productivity and food security.

Such basic research is important in its own right, but applied analysis is also needed to determine how physical and economic savings/efficiencies can be secured in regions of water stress. Are water insecure households already more efficient in their use of water than households facing easier water access? What improved patterns of usage would maximise gains to water, food and ecological security simultaneously? For instance, as urbanisation proceeds at unprecedented rates, it remains to be adequately assessed whether large amounts of water can be diverted out of agriculture to urban consumption without detrimental effects on household and national food security goals Similarly, the expected global demand for livestock products in coming decades has implications beyond human competition for feed grain. Livestock require important amounts of unpolluted drinking water in order to make significant productivity gains. Projections of growth in feed-grain requirements have yet to be matched by detailed projections of animal water requirements, or how to meet them.

Finally, a point on water ‘usage’ relating to the physical property of water — its liquidity. As noted in the case of water poisoning, there are important links among the mineral status of soils, water, crops, livestock and people that have been neglected. One area where research could yield high returns is the role of water in nutrient cycling. Human micronutrient deficiencies are often linked to mineral deficiencies in soils and water (rather than the result of specific dietary patterns). If rock and soil are deficient, the consumer may also be. Human iodine and selenium deficiencies are endemic in areas of China, central Asia, and the Sahel where those minerals are environmentally scarce (Calloway 1995; Goudge 1997).

Water is a major transmitter of nutrients from bedrock and soil through cultivars and livestock to human consumers. The natural role of water in nutrient cycling could be exploited if water were used as a vehicle for addressing human deficiencies in remoter developing regions. There are well-established methods of tackling pernicious deficiencies of Vitamin A, iron, or zinc, which together affect many hundreds of millions of women and children around the world. Conventional methods (including consumer education, pharmaceutical supplements, food fortification) have had varying degrees of success. However, many people still live far from the markets and institutions required to make such approaches effective and cost-efficient, and the scale of remaining problems spurs demand for new ideas. One that may be considered is ‘fortification’ of drinking and/or irrigation waters with soluble trace mineral supplements such as fluoride, iodine and selenium where such elements are severely deficient from all other sources. This approach is in its infancy, but could offer useful data on the processes (human and ecological) that relate directly to water safety (Oldfield 1990; Gutknecht 1996).

Appendix:
Methods of estimating the economic benefits of improved water supply to households

The approaches described in the following are current methods of improving the practice of economic appraisals of water supply services. They can be used as tools for planning and designing rural water supply projects in developing countries, and are particularly concerned with the consumers' responses to new service options (Whittington and Swarna 1994).

1. Estimated Cost Savings

The simplest way to calculate economic benefits is to measure cost savings to households from the improved water source:

a. Cost savings based on water not purchased from vendors

The data requirements for the calculation are:

(1) the average quantity of water a household purchases from vendors,
(2) the price vendors charge for water,
(3) the price charged by the water utility.

However, cost savings are only a portion of the total economic benefits and include neither the consumer surplus (see section 2 of the appendix) nor the economic benefits of those households in the community which are not connected to the new water system, such as households with private connections.

b. Cost savings based on value of time saved by not having to fetch water

In many communities in developing countries, households obtain their water by walking to traditional sources (wells and public taps) and carrying water home. If a water supply system reduces the amount of time households spend fetching water, an estimate of the cost savings could be calculated by multiplying the amount of time saved by an estimate of the money value of that time.

The data requirements for the calculation are:

(1) the amount of time the household spends fetching water per day,
(2) the amount of water collected,
(3) the monetary value of time spent fetching water.

Generally, it is assumed that the value of time spent collecting water should be valued at one-half of the wage rate for an unskilled labourer in the project area.

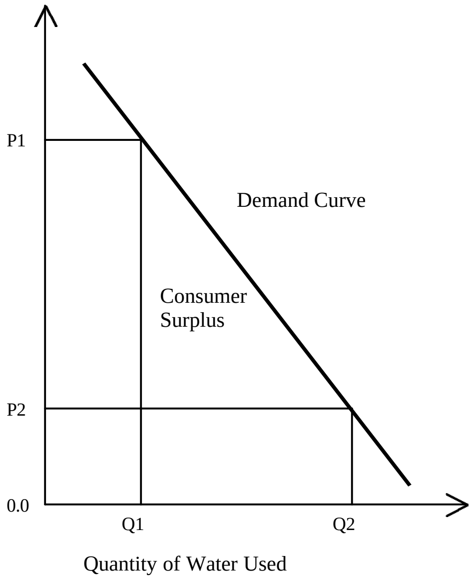
c. Cost savings based on not having to boil water

In some countries, households commonly boil their drinking water. Introducing an improved water system will, to some extent, save time, fuel and/or any additives used to purify the water, such as alum.

2. Estimates of the consumer surplus of the increased quantity of water used

Another part of the benefits of improved water supply is the *consumer surplus* of the increased quantity of water used as a result of the fall in the shadow price of water[11]. If the relevant demand function for water were known, it would be easy to calculate the consumer surplus associated with an increased supply of water (Q_2–Q_1)[12]. However, the difficulty is to estimate the appropriate demand function for the various water sources and uses. Whittington and Swarna (1994) recommend assuming a functional form for the water demand relationship (e.g. linear or log-linear) and estimating the quantity of water that is likely to be consumed (Q_2) at the price (P_2) to be charged. They point out that by having the two points (P_1Q_1) and (P_2Q_2), and assuming the functional form, the demand function can be defined over the relevant range of values of Q_2, and the consumer surplus can be determined.

Figure 4: Household s Willingness to Pay for Water: Cost Savings and Consumer Surplus



Source: Adapted from Whittington and Swarna 1994.

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[11] Real resource cost includes the monetary price of water and the real resource cost of collecting water (the time spent hauling water and the cost of equipment such as a rope or bucket).

[12] Q_1= Quantity of water households are using before a new water system is built; Q_2= Quantity of water that households will use after the new water system is constructed; P_1= Shadow price (or real resource cost) of a unit of water to households before the new water system is constructed; P_2= Shadow price of water to households after the project is constructed

3. The Hedonic Property Value Approach

The hedonic pricing approach is a method of deriving benefit estimates based on revealed choices about related goods. It relies on the notion that the price of marketed goods can be decomposed into its attributes, and that an implicit price exists for each of these attributes.

A sub-method of the hedonic pricing approach is the hedonic property value approach, which can be used as a method of determining how household rental values in an area reflect households' willingness to pay for a specific type of water supply and distance to the source. In other words, the hedonic model is based on the idea that households choose to rent or purchase a house based on dwelling and community characteristics such as a specific water supply type or the proximity to the water source (North and Griffin 1994).

Using the hedonic property value approach to estimate households' willingness to pay for improved water services involves two steps. First, it is necessary to estimate empirically the hedonic price function $r(z_{1,}\ z_2,\ z_3,\ldots,\ z_{water},\ldots z_m)$[13]. Furthermore, the household's marginal willingness to pay for the housing attribute of improved water service, Z_{water}, must be equal to the implicit price of z_{water}, given by the partial derivative of the hedonic price function with respect to z_{water}, i.e., $\partial r/\partial z_{water}$ In the second step, the implicit price of z_{water}, $\partial r/\partial z_{water}$, can be used to estimate an inverse demand curve for this housing attribute, and to estimate the economic benefits of improved water services to households (Whittington, Swarna 1994 according to Palmquist 1991).

North and Griffin (1993) have applied the hedonic property value method in their study. Using data from a sample of rural households in one region of the Philippines, they estimate the determinants of the rental value of dwellings using the bid-rent approach to the hedonic price model. In particular, they did research on the relative valuation these households place on owning a private source of water and distance to a public or communal source. They therefore formulated a bid-rent function that characterises the trade-offs each household is willing to make between housing characteristics (e.g. distance to water source) and paying more rent.

They found that households in all income ranges are willing to pay about half of their monthly imputed rent to have piped water in the house. But there was lower willingness to pay for water in the yard. At this time, the poor households were more willing to pay for proximity to a town or improved housing materials than for a closer shared water source.

The study shows that the housing market in this particular rural area does place a value on water sources and that it is capitalised in the price (or rental value) of the house. However, one would expect that as soon as connections to water systems become more common, the relative value of that characteristic will fall as a determinant of housing value.

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[13] The hedonic price function relates the market prices (or rental value) of the housing unit to its attributes.

4. Contingent Valuation Surveys for estimating Willingness to Pay (WTP)

The contingent valuation approach has become a standard method of estimating the benefits of non-market commodities. It also has been successfully applied in many studies on household water supply in developing countries, where it has been used as a direct method to estimate the economic benefits of an improved water supply (see Altlaf, Whittington, Jamal, Smith, 1993; Briscoe et. al. 1990; Whittington, Lauria, Mu 1991; Whittington, Briscoe, Mu, William 1990). Within this method households are simply asked individually how much they are willing to pay for an improved service. The respondents may be asked a direct, open ended question such as: “What is the maximum amount of money you would be willing to pay (for a specified good or service)?” Or, respondents are given a specific choice requiring a yes/no answer. The questionnaires are designed in the form of a bidding game with several options of combining open-ended and yes/no questions (Whittington and Swarna 1994).

In the context of the WTP approach, W. Musser, L. Musser, Laughland and Shortle (1995) introduce the term *averting costs* as a lower bound of the willingness to pay. Averting costs are costs that are incurred in order to prevent harm. These could be expenses such as those incurred to prevent people from drinking contaminated water, for example for boiling water or hauling water from an alternative source. Musser et.al. (1995) point out that the calculation of averting costs is based on actual market behaviour, in contrast to the individual statements of willingness to pay, which are hypothetical.

Compared with deducing WTP from market behaviour such as averting costs, using contingent valuation surveys to estimate WTP provides the particular advantage that contingent valuation can be used in situations in which related market behaviour is unavailable.

5. Discrete-Continuous Water Demand Model

The discrete-continuous model can be applied to characterise how a household decides which water source to use for different purposes and how much water to use from particular sources. It therefore fails to fit neatly into the range of methods presented above, but is nevertheless useful for acquiring a better understanding of household water demand behaviour.

The model consists of two parts:
(1) a discrete choice model that describes the probability that a household will choose a particular water source and
(2) a continuous demand model that describes the quantity of water used by the household from that chosen source.
Thus far, the application of this method has been very limited, the major problem being the availability of the required data (Whittington and Swarna 1994).

Mu, X., Whittington, D. and Briscoe, J. (1990) attempted to develop a model for household water source decision-making through a discrete choice approach in Ukunda, Kenya. Their analysis indicates that households' source decisions are influenced by the price of water and collection time, as is suggested by economic theory. It was found that the time it takes for a household to collect water from a particular source and the number of women in a household significantly affect a household's decision on which source of water to use, while income appears to be relatively unimportant.

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