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Research in Progress 16

WATER AND THIRD WORLD CITIES: THE EXPANDING PUZZLE

Olli Varis

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UNU World Institute for Development Economics Research (UNU/WIDER)
A research and training centre of the United Nations University

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ABSTRACT

Water and food scarcity are among the major problems that mankind faces today and will increasingly face in the coming decades. They are likely to have ecological effects on a global scale, are probably sources of social and political instability, and will create humanitarian disasters.

Water and land resource problems are growing rapidly. As Frederiksen (1996) points out: *Perhaps the most important constraint on solving the water resources crisis is time. There is very little time to do all that needs to be done to accommodate the 1 billion new people to be born in the next 10 years. Very few actions of the magnitude needed can be completed in this period.* What these actions and what their magnitude should be, is an urgent and important matter of dispute.

This paper discusses the water problems induced by urbanization and cities of the third world in particular. First, the causes, history, present state, and future outlook of the global urbanization development are presented with a summary of the global freshwater situation and infrastructure issues. Then, possible solutions are discussed. Finally, the paper highlights challenges to the water sector with respect to the demand for increased food production, alternative solutions to coping with the urban water pollution problems, suggestions for water resources management principles, and human resources development issues.

I INTRODUCTION

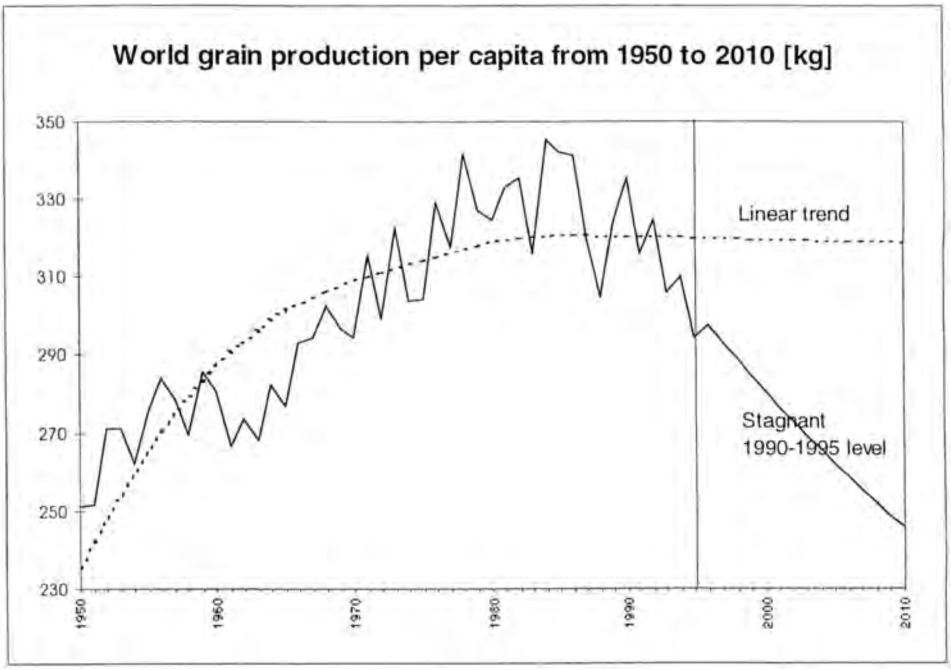
Water and food scarcity are among the major problems that mankind faces today and will increasingly face in the coming decades. They are likely to have ecological effects on a global scale, are probably sources of social and political instability, and will create humanitarian disasters.

Water and land resource problems are growing rapidly. As Frederiksen (1996) points out: *Perhaps the most important constraint on solving the water resources crisis is time. There is very little time to do all that needs to be done to accommodate the 1 billion new people to be born in the next 10 years. Very few actions of the magnitude needed can be completed in this period.* What these actions and what their magnitude should be, is an urgent and important matter of dispute.

Four-fifths of the global population growth is in urban areas. Growing cities need rapidly escalating quantities of food and water. Mounting aspirations related to urban lifestyles typically mean more water use than is the case in rural communities. Rural areas must produce more and more food and other biotic products to meet the demand of the cities. However, food production on our planet does not appear to grow any longer. According to Worldwatch (1996), it has stagnated to the level it was in 1990 (Figure 1). Not only food, but also the closely related water is a scarce resource. The growing demand both in urban and rural areas call for increasing level of exploitation of water resources. Together with intensifying need to develop and implement water saving techniques, storage requirements and interbasin transfer demands escalate. Making the issue still more complicated, the criticism to hydraulic constructions has grown rapidly during the last couple of years, and many financing organizations including the World Bank are increasingly sensitive to such projects.

The present type of development in urbanization in the Third World puts heavy pressure on water resources, food production and the environment, and raises problems that need more interdisciplinary solving patterns than we are used to at present. Cities and water problems are still often understood to just include water supply, sanitation, and wastewater treatment issues. Relation to agricultural production and other competing resource uses, nutrient and organic matter cycles, etc., are however, issues of growing concern and importance. The contemporary trends of liberalization of world trade, belief on market mechanisms, privatization, decreasing public sectors, growth of informal sectors, and other related issues evoke an increasing need to handle water and land, not just as economic externalities of marginal importance, but as key resources for sustainable development.

FIGURE 1
WILL THERE BE ENOUGH FOOD TO FEED THE MANKIND IN THE COMING FEW DECADES? WATER IS THE CRITICAL FACTOR UNDERLYING THIS DEVELOPMENT



The growth in many of the cities in the Third World is so rapid that present infrastructure is simply unable to handle the growing needs and infrastructure development often cannot keep up with growth rates. In many cases, the infrastructure dates back to colonial times and the deterioration problems are usually added to the capacity issue. The same type of problems but in much smaller extent are also frequent in industrialized countries, in former centrally planned economies in particular. Much of the population, particularly those living in squatter settlements have no access to safe drinking water and proper sanitation. Waste management including waste water treatment is often underdeveloped. There is an evident and urgent need for urban areas to develop their infrastructure. However, there is a potential danger that the uncontrolled urbanization is given another boost, and the infrastructure development is outpaced very rapidly.

With the escalating pressure for water and land resources, examples of unsustainable water resources management are getting more and more frequent. Among many, the two most drastic examples include overexploitation of groundwater and salinization of irrigated land. Already one-third of all irrigated land has been spoiled by salinization. While one-third of all agricultural production is from irrigated fields, the extent of this problem is enormous. Moreover, transport and transfer of food and water to congested areas that are apart from food production on one hand, and do not allow natural ecosystems to process the wastes on the other hand, make the recycling of resources such as nutrients and organic matter increasingly difficult. This yields the loss of productive capacity of ecosystems at one end, and in gigantic waste and pollution problems at the other end.

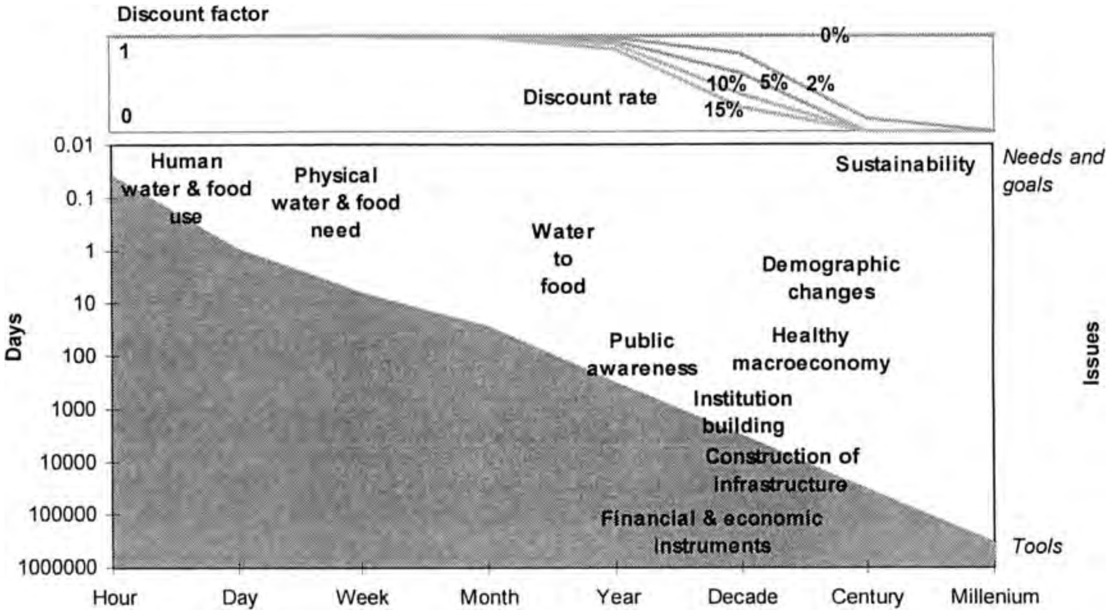
The facts that the world is getting rapidly more urban, and the rural areas are increasingly influenced by various changes due to the growth of cities and vice versa, has been growingly acknowledged by international organizations. The 1992 UN Conference on Environment and Development (UNCED) defined the goal of sustaining economic growth while maintaining the essential integrity of the Earth's ecosystem. The Agenda 21 specified the practical implementation of these ideas to head towards sustainable cities and urbanization development. The 2nd Human Settlements Conference (HABITAT II) in 1996 was largely built to these achievements, emphasizing the comprehension of rural and urban connections in the development of sustainable future. The responding voices can be heard from many directions; e.g., the World Bank has launched, on top of their "old agenda", providing household water and sanitation services, the "new agenda", taking the goal towards sustainable development in the spirit of the Agenda 21 (Serageldin 1994, 1995). In addition to the environment, the sustainability criteria should incorporate also the exploitation of natural resources, development of human resources (health and education) and offering an efficient macroeconomy.

In this framework, the water sector should be able to provide solutions that develop societies to sustainable direction. Sustainability is an inter-generation concept; but for example till 2025, just one generation ahead, the world population will grow with over 2.5 billion people, 80% being urban growth as was mentioned before. It is clear, that there is no way back to a society which could produce its own energy from renewable sources, recycle all the waste produced, and would not violate any other basics of the earth's ecosystem. Indeed, the development is just towards the opposite direction with a very fast rate. The problems that the next generation – or just the University students of today – must solve within the water sector appear huge.

Implementation of any sustainable policy should be affordable. The fastest urbanization rates are in areas where there are very limited possibilities to design systems within a longer time perspective. In low-income economies, is it realistic or even justified to say that sustainability should be a water sector issue? Definitely not always realistic but still justified. It is indeed there where the issue touches the highest number of people. Whereas the governments, cities, and other social units will be heavily involved to provide services to meet the immediate needs – a task for which many technical, economic, financial, and institutional solutions exist but may not be easily realizable due to various constraints including time (Figure 2) – it appears that there is an urgent need of the international community to react with action plans, guidelines, and measures to combat excess and rapid congestion of people to urban areas with no prerequisites to proper services, and unsustainable pathways in urban development. Urban models in which material cycles are closed – e.g., by mixing agricultural areas to congested areas – are needed. Technology options with low capital costs are also crucial. Nothing can, however, compare in importance to pollution prevention actions; wastes should be returned to the (food) production cycle as much as possible. These all are heavy requirements, but without them we just fall into fruitless and non-constructive scepticism.

This paper discusses the water problems induced by urbanization and cities of the third world in particular. First, the causes, history, present state, and future outlook of the global urbanization development are presented with a summary of the global freshwater situation and infrastructure issues. Then, possible solutions are discussed. Finally, the paper highlights challenges to the water sector with respect to the demand for increased food production, alternative solutions to coping with the urban water pollution problems, suggestions for water resources management principles, and human resources development issues.

FIGURE 2
SUSTAINABILITY IS A LONG TERM CONCEPT, STAYING OFTEN IN CONFLICT WITH MORE IMMEDIATE NEEDS AND FINANCIAL REALITIES (THE FIGURE SHOWS THAT A FINANCIALLY RATIONAL SOLUTION DOES NOT INCLUDE THE SUSTAINABILITY CRITERIA, AND MANY CRUCIAL TOOLS FOR BALANCED INFRASTRUCTURE DEVELOPMENT ARE ALSO DISCOUNTED AWAY). SOLUTIONS THAT MEET THESE BOTH ENDS ARE NEEDED, BUT THE MORE SHORT THE ECONOMY IS OF RESOURCES, CONTROL, AND PUBLIC AWARENESS, THE LESS SOPHISTICATED TOOLS CAN BE USED, AND THE MORE THE FOCUS IS ON THE IMMEDIATE NEEDS



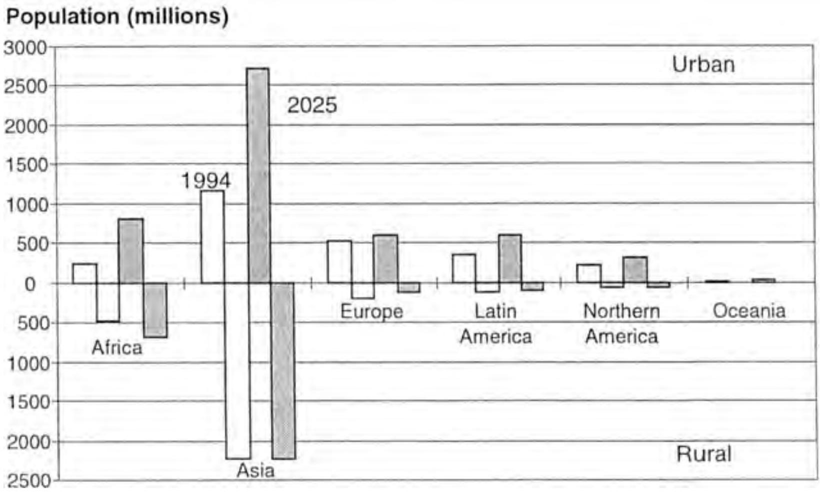
Source: modified from Varis and Somlyódy (1997)

II GLOBAL FRESHWATER CONCERN: A URBAN-RURAL CONTINUUM

2.1 Population growth is four-fifths in urban areas

The world population grew by 91 million in 1992 (Brown et al. 1993). The growth in urban areas — due to both migration and natural growth — accounts for roughly four fifths of this figure. The growth rate of the global human population is approximately 1.9%, while in Africa it is around 2.9%. The rate of Third World cities with over one million inhabitants was approximately 5.6% during the period 1980-1990 (Drakakis-Smith 1987). This growth rate implies a 72% population within a decade. Some cities, Africa in particular (e.g., Addis Ababa, Kinshasa, Lagos), have more than doubled their population within the last decade. Urbanization in the Third World is remarkably faster than that experienced in industrialized countries, moreover, the biggest cities appear to grow at the highest rates. Much of the urban growth in the Third World occurs uncontrolled, with only a minor impact felt from government controls.

FIGURE 3
RURAL AND URBAN POPULATION BY CONTINENT



Data from United Nations (1994).

In Africa and in Asia, the proportion of urban population is around one third while in all the other continents it is over two thirds (Figure 3). Therefore, the most massive urbanization development is to be expected in Asia and in Africa. According to the estimates by the United Nations (1994), the percentage of urban population in less developed regions of Latin America will grow from 57% (162 million) in 1970 and 72% (315 million) to 84% (592 million) in 2025. Corresponding figures for less developed regions in Asia are 20% (407 million) in 1970, 29% (879 million) in 1990) and 54%

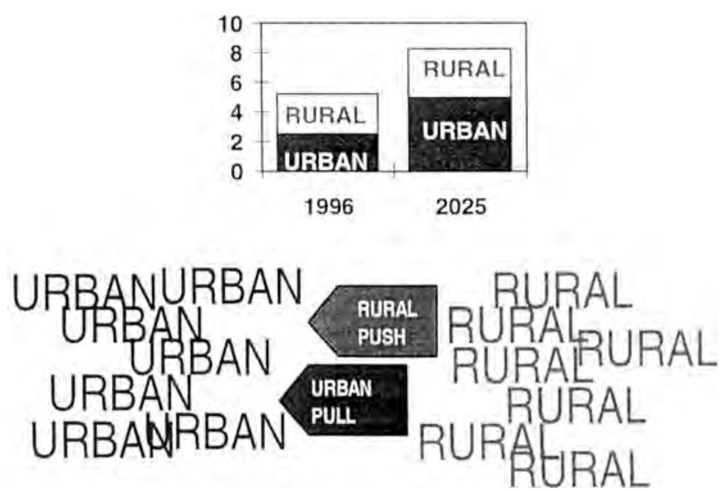
(2556 million) in 2025; and those in Africa are 23% (83 million) in 1970, 32% (206 million) in 1990) and 54% (857 million) in 2025. The world total UN estimates are 37% (1352 million) in 1970, 43% (2282 million) in 1990) and 61% (5187 million) in 2025.

2.2 Why urban growth?

Why is there an alarming number of people leaving their rural settlements, with their sound social relations, and moving into hectic urban centers, where there is a high probability of living in very poor and overcrowded circumstances? Most migrants to many Third World cities build their homes on any available land without adequate infrastructure, and often live on a formally illegal basis. In Ankara, Turkey, two thirds of the population live in squatter settlements, because former urban plans have proven incapable of meeting the demands of the population explosion (Drakakis-Smith 1987). The situation is not too different in many other cities; two thirds of the population of Calcutta, India, and three quarters of that of Ibadan, Nigeria, live in squatter conditions.

The fundamental reasons to urbanization are twofold (Figure 4), called often the rural push and the urban pull (see Haggett 1979). Rural areas often have high birth rates, and they do not offer work for the growing number of young people (even improving technology often reduces the need for labor).

FIGURE 4
WATER MANAGEMENT AND INFRASTRUCTURE DECISIONS ARE AMONG THE MANY COMPONENTS OF RURAL PUSH AND URBAN PULL FORCES



Urban pull factors are manifold. Discrepancies in living conditions between rural and urban areas are marked in many countries; In Brazil, Iran, and Argentina, the ratio of Gross Regional Product between the richest and poorest regions is around 10. Although this by no means represents an expected growth in income when migrating to a city, it shows the possibility of a better life. However, the differences between the economic elite and the migrant are typically huge. On the top of these two reasons is international migration, which is of considerable volume in many big cities.

Most Third World cities have a colonial background. Colonialism varied enormously from region to region, but some general features can be seen. Drakakis-Smith (1987) presents a seven-step model for colonial urbanization (see also King 1991). It relates primarily to Asia, but the succession is mostly likely to be valid across Africa and Latin America as well. The time scales may differ from city to city. A brief summary of the model with an example (Delhi, India, summarized from Drakakis-Smith 1987) is given in Box 1.

BOX 1. THE DELHI CASE

Pre-contact phase (pre-1500). Small towns with organical pattern predominate. In Delhi, phases 1 and 2 are difficult to separate.

Mercantile colonialism (1500-1800). Limited colonial presence in ports. Trade in natural products of local region. At the end of the 18th Century, Delhi was the Mogul capital with 150 000 inhabitants. The center was dominated by the Royal Palace, the Jama Mosque and the Chadni Chowk, as political, religious, and commercial foci, respectively. The remainder consisted of narrow lanes and organically patterned mixed land uses.

Transitional phase (1800-1850). Reduced investments overseas. Industrial revolution facilitated greater profits. Between 1803 and 1857 Delhi was a district military post to Punjab — not a major administrational or commercial center — with a few hundred European inhabitants. The British were living in an area next to the Royal Palace, where the Mogul aristocracy used to live. Their living was very similar to that of the local elite. Very little conflict took place.

Industrial colonialism (1850-1920). Cheap raw materials from colonies. Territorial patterns, new settlements. In Delhi, the puppet emperor was dethroned in 1857. The British military control sharpened, and the indigenous people were forced to move out of the civil lines. Isolation increased. Many imposing buildings for symbolizing institutional power were constructed. Around 230 000 Indians were living in the old city of 4 km^2 while a few thousand British lived in the open spaces of their district.

Late colonialism (1920-1950). Growth of European influence. Extension to smaller towns in hierarchy. Delhi was chosen as the capital of India in 1911 due to good railway connections. A decade later, New Delhi was planned on a vast scale. Spatial categorization was very rigid. There was no manufacturing growth except some food industry. Old Delhi received some improvements to water supply and drainage, but major water infrastructure efforts were focused on the foreigners' districts. There was massive immigration to Old Delhi, which amplified the contrasts.

Early independence (1950-1970). Rapid population growth by immigration of indigenous people in search for jobs. Expansion of slum and squatter settlements. Delhi's population increased rapidly. It was an attractive opportunity, although most immigrants lived in very poor circumstances. Around 1960, Old Delhi contained 60% of the city's population in with a density of 41 300 per km^2.

New international division of labor (1970 onwards). Appearance of the factories of multinational corporations. Further migration. Since 1960, Delhi's population has grown fourfold, up to 6 million. Squatter settlements without proper water related infrastructure have expanded and multinational companies do not employ a notable part of Delhi's population, unlike some Third World big cities.

In most Third World countries the biggest urban centers often grow at the highest rate, being the most attractive one. In Thailand, for instance, Bangkok is fifty times bigger than the next biggest town, and its growth rate greatly outpaces that of other Thai cities. The concentration of manufacturing centers within the capital is strong in comparison with other cities. Manila contains 79% of the Philippines manufacturing employment. As a result, many Third World capitals have become under direct government administration, almost to the point of being quasi-independent (e.g., DKI Jakarta, Bangkok Metropolitan Area, Metro Manila, Federal Territory of Kuala Lumpur). These cities evidently want to be among the ones that raise from peripheral to semi-peripheral or even core socio-economic units in the global scale (cf. King 1991). Such centers are pressingly needed, especially in Sub-Saharan Africa and in many parts of Asia.

2.3 The informal power

In many Third World countries, the authorities have only a limited control over the economic and the social systems in their nation. The low level of control is a boundary condition to any policy measures to combat undesired development pathways and side effects of urbanization.

During the early independence period (although in some cities even before the 1930s), the split of the economy became evident. A huge population with no adequate housing, health care, and education lived in very poor circumstances. They created their own economic system that consisted of various illegal and semi-illegal activities. This informal, or 'petty-commodity' sector has grown, and in many cities almost 90% of the population are linked to the informal sector (Drakakis-Smith 1987).

The informal sector is often of high economic importance to the city. It runs with low administrational costs, it is rather self-contained, it recycles many materials, and it is in many respects very productive and innovative (e.g., economics). Authorities are often apathetic towards this sector (e.g., politics), as it provides potential, inexpensive labor and product supply to the formal sector, as well as other assets. Attempts to control this sector are not always as strong as they could be. Freshwater problems as well as other infrastructure shortcomings, with nutritional shortcomings and environmental issues are very pronounced in the informal sector.

The formal sector prefers experienced and educated labor. Many, often strategically important, cities have attracted foreign investments and industries in marked amounts since 1970. Such cities include São Paulo, Rio de Janeiro, Mexico City, Hong Kong, Singapore, Soul, Taipei, Bangkok, Kuala Lumpur and many others. Infrastructure may develop rapidly, but not necessarily in a balanced way. Environment, e.g., waste water, does usually not have a high priority.

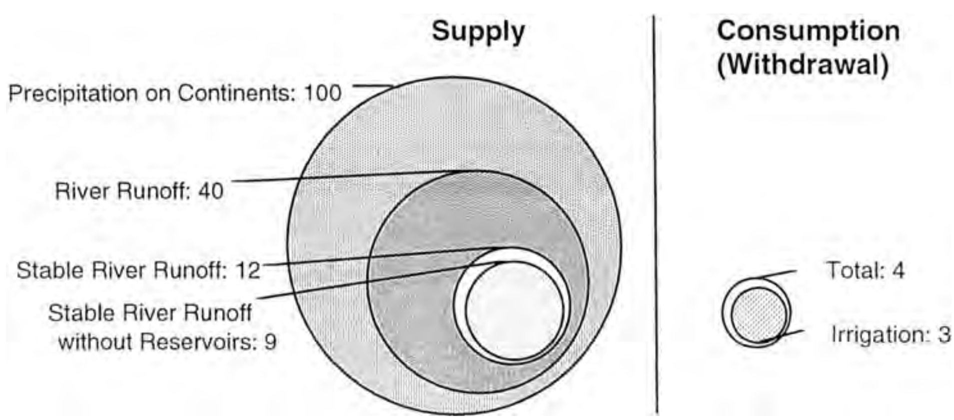
Some cities have been able (and willing) to break the dual system and get the informal sector under control. This has happened by launching massive social programs, by constructing low-cost housing for the poor, by introducing birth and immigration control, and by demolishing the slum districts. An example of such a city is Singapore, which has stabilized its economy and has been able to attract investments. A strict environmental policy including water and sanitation has been implemented. More than two thirds now live in 'new towns' which are a result of low cost housing programs. It is yet to be seen whether this kind of development will become a trend in Third World cities. It definitely requires plenty of political power and capital, and therefore it is likely to only reach the so-called newly industrialized countries. Yet there are a plenty of cities (Asia in particular) that could take this route, but in very many less wealthy cities with weaker institutional arrangements, this path appears difficult if not impossible to achieve.

2.4 Cities need food and water which both become increasingly scarce

Cities need food, which must be produced with rapidly increasing efficiency to meet the escalating demand. In terms of water infrastructure, the urban issues are increasingly linked by rural water uses, due to the allocation problems of this growingly scarce and increasingly polluted resource. When allocating more and more water to urban centers, the other water uses — not the least food production — are increasingly subjected to water shortage. Major local and regional problems are also due to groundwater mining and pollution due to unsustainable water use in rural and urban areas. Water quality and quantity problems must be seen as two sides of the same coin.

It is crucial to understand that water is a limited valuable resource. Freshwater resources form less than 1% of the total water on the Globe. Figure 5 is a general account of the global freshwater situation, showing that stable river runoff (portion of freshwater that can be made available for human use) is approximately 25% of the water discharged by the rivers. It does not reveal more complex problems like spatial and temporal variability and quality issues which make the problem more complicated and difficult.

FIGURE 5
GLOBAL FRESHWATER BALANCE (1000 KM^3 PER YEAR)

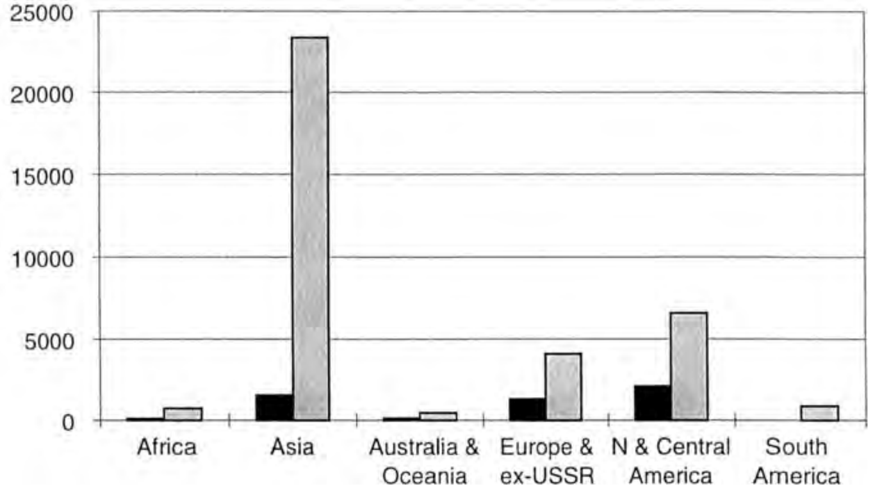


Data from Golubev (1993)

A growing population, searching for an improved quality of life, will require more freshwater to meet their increased needs. It is projected that by 2000, water withdrawals could increase by almost 60% over 1980 values (Shiklomanov 1993). Coping with spatial and temporal mismatches of water demand and water use, more and more hydraulic constructions are needed (e.g. dams; Figure 6). This need is coming at a time when many are demanding that water remain within the natural ecosystem and policy changes to that direction take place (Postel 1992, Pearce 1992, Serageldin 1995). One can observe, that Africa and Latin America have still very few large dams, taking into account their sizes and population projections; at least when compared to other continents. Asia, in contrast, has constructed and is constructing most of the world's dams.

FIGURE 6

NUMBER OF LARGE DAMS (> 15 M HEAD) BY CONTINENT



Data from Veltrop (1993)

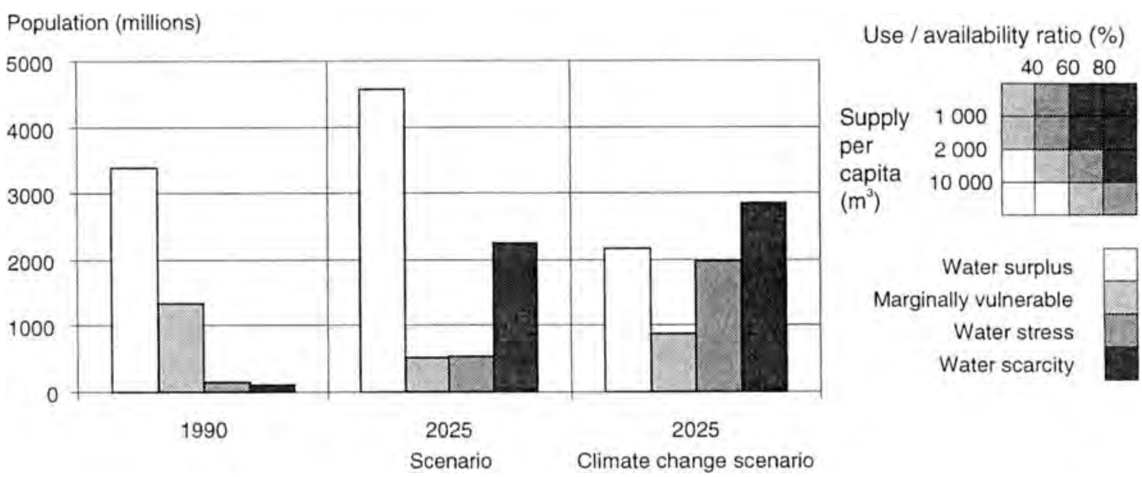
According to current estimates, agriculture contributes to more than two thirds of global freshwater use. In arid areas, the figure is much higher. For instance, in Egypt, it is 98% (Biswas 1993). Agriculture uses water for many purposes, and produces numerous side effects to water resources, including erosion, leaching of nutrients, accumulation and washoff of pesticides and heavy metals, increased salinity due to evaporation losses, and spreading of various diseases such as schistosomiasis and malaria.

Irrigation-fed agriculture has become a backbone of human nutrition, as well as cotton production. In this century, the area of irrigated land has increased to five or six fold, being at present about 250 million hectares. That area, being about 15% of total arable land, contributes to roughly one-third of total agricultural production (Golubev 1993), and a still higher proportion of tradable cash crops. The growth rate of irrigated areas is now decreasing (Yudelman 1985, FAO 1990). This is due to increasing marginal costs of new areas, and to growing emphasis on negative side effects of irrigation. At present, soil salinization covers about 60 million hectares, which is close to quarter of the total irrigated area (Rydzewski 1992). According to Worldwatch (1996), global food production has not increased since 1990. This is an alarming symptom, also on the global freshwater situation.

Large-scale irrigation typically requires changes in water supply, both in space and in time. This means either more storage capacity or/and interregional water transfer. The construction of almost one million man-made lakes with total volume of 6000 km^3 has increased the secured water supply by 25% (Golubev 1993). As a consequence, the mean renewal time of river systems has dropped from 20 days to 100 days causing major ecological changes. Of particular importance is the drastic reduction in self purification of fresh waters. Gross changes in material transport and sedimentation have thus also occurred. The extent of water transfer projects has also grown remarkably. At the beginning of this century, the largest schemes were between 0.5 and 1 km^3 per year. Current schemes are of the next order of magnitude, and projects of yet another order of magnitude have been proposed (Golubev 1993). Yet, their acceptability has increasingly been questioned (e.g. Serageldin 1995).

Figure 7 shows that the share and the number of the world population that will be suffering from the shortage of water is in an expanding phase. It should be mentioned that this analysis only includes water quantity based on national, aggregate values and it is likely that including quality information or disaggregating spatially and temporally could drastically change the results. Incorporation of water quality problems would reveal that the water scarcity issue still an essentially more severe problem than shown in Figure 5. The possible climatic changes are likely to add to these problems.

FIGURE 7
VULNERABILITY OF THE GLOBAL POPULATION TO WATER SUPPLY DEFICITS



Data from Kulshreshtha (1993)

2.5 Open material cycles should be closed to work towards sustainability

Agenda 21 of the Earth Summit '92 in Rio de Janeiro postulates the concern and urgent need to plan and implement environmentally sustainable development strategies. Evidently, in addition to the environment, the sustainability criteria should incorporate also the exploitation of natural resources, development of human resources (health and education) and offering an efficient macroeconomy.

When exploring the current development pathways of human demographic development, and particularly that of urbanization and mega-cities, one easily ends up with a conclusion that any level of sustainability in their future development is a distant dream with no possibilities to be managed in foreseeable future but in minor details. However, this is where we simply must start from, but keeping in mind the entire problem setting with the population pressure, resource scarcity, environmental problems and socio-economic realities.

Without making an attempt to contribute to the rapidly growing literature on the definitions of sustainability (see Varis and Somlyódy 1997), one basic point deserves mentioning here, which is not sufficiently emphasized in mainstream discussion on urban water infrastructure, nor in rural water resources development. Evidently, water management should attempt to close material and energy cycles as much as possible (e.g. Niemczynowicz 1993). This requirement is in fundamental contradiction with the present type of urbanization process, in developing countries in particular. Instead, the high population densities should be avoided, unless the waste produced in cities can be recycled to the production of food or other mass products. The wastes, if discharged to water courses and aquifers, contribute essentially to the water scarcity through pollution (Figure 8). Overexploitation (mining) of aquifers, is a rapidly growing, which clearly is an unsustainable tendency.

FIGURE 8
CLOSING MATERIAL CYCLES IS ONE OF THE BASIC PREREQUISITES FOR SUSTAINABLE WATER RESOURCES MANAGEMENT

2.6 Infrastructure, growth, and unbalance

Developments of infrastructure and technology are among the key factors which have contributed to the growth of present day cities. We mentioned above that Delhi was chosen as the capital of Imperial India because of good railway connections. Its growth in area and population in the 1920s and 1930s was greatly enhanced by the spreading of cars, telephones, etc. Other examples include Jakarta, Indonesia (Box 2) and Bangkok, Thailand (Box 3). They both are subject to the typical dichotomy; the present infrastructure has not been able to respond to the growth of the city, but any improvement in infrastructure potentially speeds the growth of the city. We must emphasize that these cities are not among the poorest nor the most problematic ones in the world.

BOX 2. THE JAKARTA CASE

Indonesia is one of the world's most populated countries. It has a territory of over 1.9 million km^2 for its 200 million inhabitants (the population currently grows at 3 million a year). Yet, around 110 million live on the island of Java which is only 127 000 km^2, making Java one of the most densely populated areas in the world (870 inhabitants per km^2). The biggest of the three Javanese cities is Jakarta, with an official population of 10 million inhabitants (Figure 9), but an actual population which is probably higher. The number of seasonal residents and commuters was 1.15 million in 1985. The case study is summarized from the study by United Nations (1989).

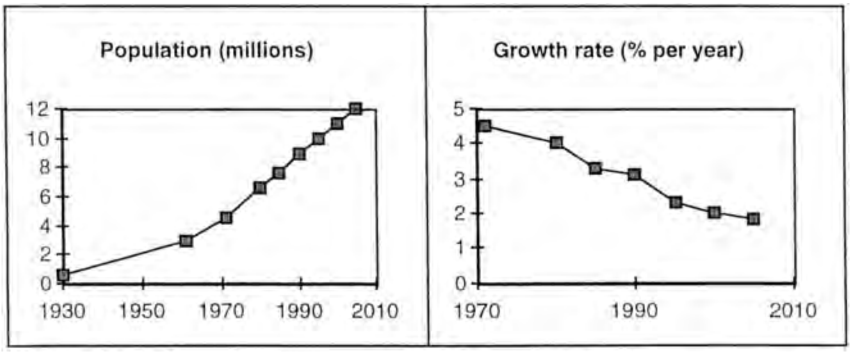
More than 20% of the housing in Jakarta is on a temporary basis and 40% is considered semi-permanent. This yields a rough figure of 60% living in settlements called kampungs, which now have a semi-legitimate status. Housing programs divide kampungs into two classes: never-to-be-improved and those to-be-improved categories. Residents of the first category are encouraged to return to their villages, move outside Java, or select some housing area in Jakarta. The to-be-improved category kampungs is improved by introducing basic services such as rubbish collection sites and hydrants. By 1984 the housing improvement programs had reached 3.8 million inhabitants, yet it has been estimated that 50% of the population within these settlements has yet to be served.

The water distribution network of Jakarta was originally built by the Dutch to supply water for 0.5 million inhabitants. Although extended, it cannot cover the whole city area. Due to rapid population growth, growth in new industries, and large scale real estate construction, there is a rapid increase in water demand. Around 14% of the population (generally the most wealthy households) have piped water. Wells are used by more than half, and water vendors by 32% of the population (Serageldin 1994). Highly polluted canals and rivers are used widely as a water source for cooking and washing.

The extension of water supply faces severe problems. Groundwater use has already caused remarkable saltwater intrusion into main aquifers. Surface waters which are utilized are often so polluted that they are considered worse than the water running through sewage treatment systems in many countries. Network leakages are huge. The water supply company is an independent corporation that must make profit, so it focuses extensions of the network to households which can pay. Standpipes on kampungs have received less attention. Where there are standpipes, there are often illegitimate vendors selling water to the poorest urban households at roughly 13 times the official price.

The city has no sewerage system for the 700 000 m^3 of sewage produced daily. Part of the sewage runs through septic tanks; most of it goes directly to dikes, canals, and rivers. The area is prone to seasonal floods that raise water to the streets. Wide-reaching groundwater pollution has been observed due to poor waste management. As a response, existing drains have been re-directed in some locations to provide a faster passage of the water into the sea. Pilot scale studies for the construction of a sewer system have been made.

FIGURE 9
OBSERVED AND PROJECTED POPULATION GROWTH RATES OF JAKARTA



Data from United Nations (1989).

BOX 3. THE BANGKOK CASE

The population of the Bangkok Metropolitan Area, Thailand, has grown drastically in the last two decades and is currently pressing 10 million. Infrastructure is developing rapidly but desperately behind the needs. One example among many of the situations facing Bangkok is given. Food cost is one of the many factors which limits migration to the city. Food has to be transported from great distances, often during the night, which increases its selling price. Highways into Bangkok are an incredible sight, often choked with small trucks transporting vegetables and live animals to the city in an endless queue.

A new expressway to the North as been partially completed, with the aim of reducing the traffic jams. One of the greatest impacts of this development has been the increased distance that small trucks are able to transport food, sometimes over 700 km away on a daily basis. This has caused a better and cheaper supply of food, but has also brought more immigration and problems. In spite of the ambitious objective of reducing congested area, the Northern expressway remains problematic.

Water is transferred from Northern reservoirs in growing amounts to meet increased needs (although Bangkok is almost floating on water), and the big irrigation systems were already partly dry in 1993 (Thailand is the world's biggest rice exporter). There are plans to transfer water from the Mekong River to the Northern reservoirs to compensate the increased urban use (partly due to tourism industry that apparently brings more cash than rice export or is prioritized for some other reason, each of the tens of thousands of daily visits to a massage parlor consumes roughly 500 liters of water).

The Vietnamese, being downstream, strongly oppose the water transfer, and the Mekong Commission is in an uncomfortable position. The Thai government is not willing to set restrictions on city water use and they are frantically trying to get foreign investments (with success). If water price and other costs were higher in Thailand, then the big investments (textile, machinery, rubber, electronics, oil refinery...) would perhaps go to Saigon, Kuala Lumpur, Taipei, Manila, Guangzhou, Jakarta, or somewhere else. That would be a heavy price for water (with modest exaggeration, many other things may pay even a bigger role).

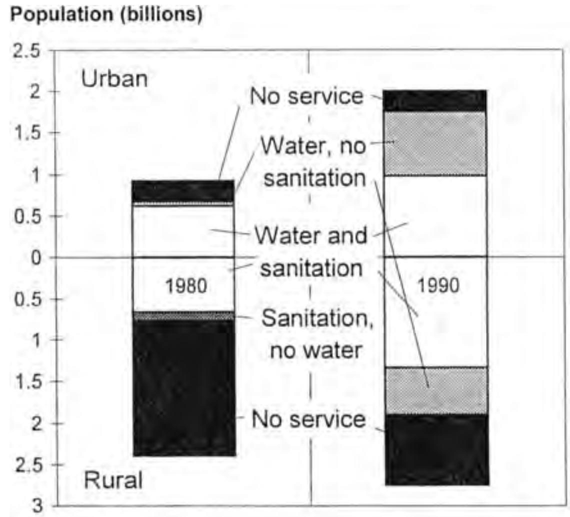
In Bangkok, there is no waste water treatment or even proper sewerage system. The klongs (open canals) receive the waste of almost any consistency in increasing amounts, being largely anaerobic. During floods, the water comes to streets. Pescod (1993) gives a summary of the present state of the water infrastructure in the Metropolitan Area. The pollution has dramatically increased in the last three decades. More than ten studies have been made to support several master plans which all failed. They suggested conventional sewerage networks connected to large treatment plants. Yet, at present, strongly neglected purification systems such as septic tanks and institutional treatment systems barely reduce organic load.

King Bhumipol made a personal intervention over the situation of the rivers in the region, and the city's waste water treatment was sharply increased in national priority in 1990. Public awareness is rising. The present strategy has divided the area into 24 zones. Each zone will have a secondary treatment plan. The focus has shifted from individual dischargers to purification of the water in klongs. Institutional arrangements have been developed to facilitate the construction, management and monitoring of the 24 systems. Economic incentives to discharge into sewers instead of klongs and rivers are under preparation.

Bangkok is one example of a city that is growing in an almost uncontrolled fashion. Water problems are huge, many-sided, and deeply linked with other economical, social and infrastructure issues. Quality problems are closely related to quantity problems. What will happen within Bangkok is open to question. There are many possible tracks that development may take. One possibility is that the government will be successful in intensifying investments in water quality capital and programs and the environment as a whole (perhaps to attract tourists and investments from new technologies, cf. Singapore). But are such changes to be realized in practice? Will there be political will and the power to accomplish? Will improved infrastructure only attract even more migrants to the city? Already, immigration from surrounding countries happens (Vietnam, Cambodia, Myanmar, Laos...).

Global experience has shown that the first part of water infrastructure development is the water supply (Figure 10). Sanitation eventually comes along, in one form or another, yet waste water treatment is often greatly delayed. This mismatch causes an open material flow which leads to large-scale water pollution. The delay in industrialized countries has been from years to decades. A question arises; can the formation of this gap be slowed, particularly within big cities, where it is still manageable? In many Third World countries, the urban water infrastructure does not reach the majority of urban dwellers. Another question is how the already existing, often huge gap could be closed? Somewhat astonishingly, the World Bank does not consider this gap a big problem, but rather as a natural evolution path of infrastructure development (Serageldin 1994).

FIGURE 10
ACCESS TO SAFE DRINKING WATER AND ADEQUATE SANITATION IN URBAN AND RURAL AREAS IN DEVELOPING COUNTRIES, 1980 AND 1990



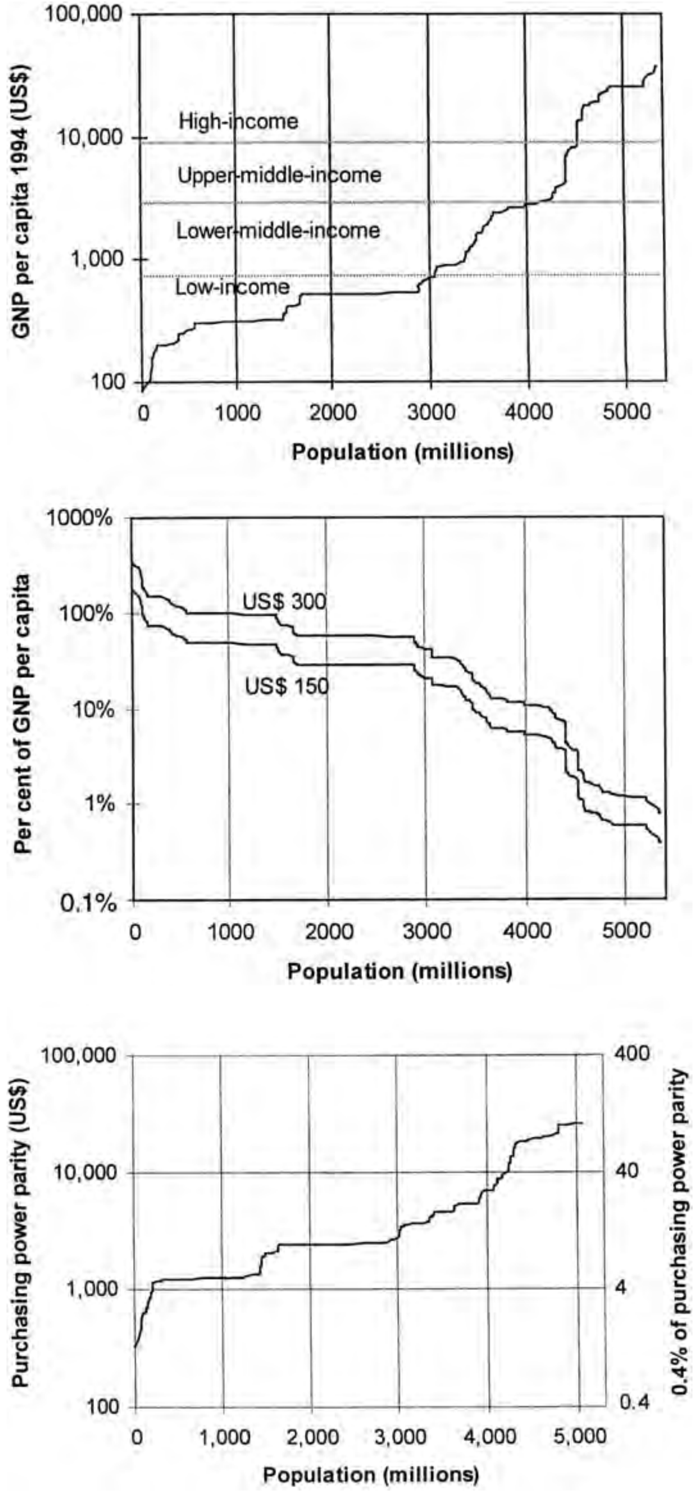
Data from World Bank (1992a)

Water transfer systems that connect reservoirs, rivers, irrigation systems, cities, and other components of the water infrastructure facilitate improved possibilities for allocation of water among different water users. This development that can be argued as unavoidable, is again a potential source of many types of conflicts and problematic development pathways. Few examples among many include increased urban bias, less pressing need to manage water quality (waste, salinization etc.) problems locally, and even international conflicts. All in all, the urban and water infrastructures are no longer as separate entities as they often are considered to be.

2.7 The affordability issue: the case of urban infrastructure

The world economies present a high variety of economic potential. Figure 11 shows the GNP per capita and population of 133 countries with over 95% of the world's

FIGURE 11
TOP: WORLD'S POPULATION AGAINST GNP PER CAPITA. *MIDDLE:* THE EXEMPLARY SHARE OF URBAN WATER INFRASTRUCTURE COSTS OF GNP IN DIFFERENT ECONOMIES. *BOTTOM:* WORLD'S POPULATION AGAINST PPP

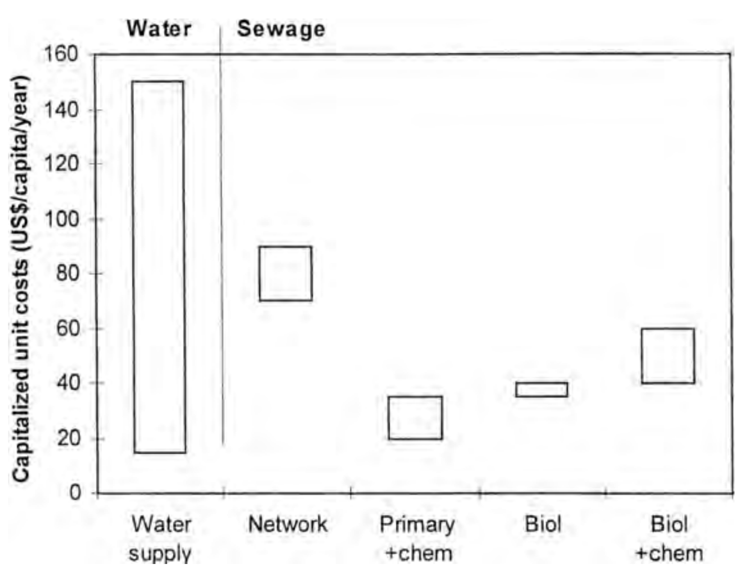


Data from World Bank (1996) except middle.

population as a cumulative plot of country averages. Note, that the vertical axis is logarithmic, smoothing remarkably out the disparities. The income level classification used by the World Bank (1996) is also shown: Low-income economies (most Sub-Saharan Africa, South Asia, China, some SE Asian countries), low-middle-income ones (some Latin America, most of former USSR, some African countries), high-middle-income countries (most former socialist countries in Europe, most of Latin America, some SE/E Asian and a few African countries), and the high-income economies (OECD countries and a few others). The numbers of inhabitants were 3.2, 1.1, 0.5, and 0.9 billions in 1996, and the urbanization rates in 1990-1994 were 3.8%, 2.3%, 2.6%, and 0.3%, respectively.

The high variety in the costs of urban water infrastructure does not allow the use of exact figures, but we produced an exemplary cost envelope of US$ 150 to 300 as a minimum level of western type of solutions (Figure 12), capital costs per year per person (cf. Serageldin 1994). The GNP and cost data can now be compared (Figure 11). With these figures the situation appears hopeless; there seems no economic realism in attempting to provide proper water infrastructure for the most humans, at least when considering western types of solutions.

FIGURE 12
EXEMPLARY COST RANGES OF DIFFERENT COMPONENTS OF URBAN WATER INFRASTRUCTURE



Now, take the other view: How much would economies be capable of spending on water infrastructure? The World Bank (Serageldin 1994) gives a percentage of 0.4% of GDP as an investment rate typically used in water supply and sanitation. This estimate is based on the examination of over 120 urban water projects realized 1967-1989, in 29 developing countries. Again, a hopeless view: what the sum of US$ 1 to 3 a year for most people would make when improving water and sanitation services? The study revealed, that the rate of total public investment of the GDP has declined somewhat over the study period, being around 8.7% in 1987. That makes US$ 10 to 65 per capita. Taking even the world average GDP per capita, US$ 4470 in mid-1994, the above percentages would yield US$ 18 for water and sanitation, and US$ 390 for total public investment. The level of investments on environmental protection range globally between 0.5% and 3% of the total GDP, being typically higher in countries with higher GNP. In a low-income country with GNP per capita around US$ 80 to 725, the spending to environmental protection is bound to be below US$ 10 or even US$ 1 a year.

The situation is not that hopeless due to at least the following reasons. First, it is well known that in many big urban centers in the Third World, the Gross Regional Product per capita is much above the country average (up to 10 times, Drakakis-Smith 1987). Second, the income distribution is often very wide; even the middle class may be pretty well off if measured with any economic criteria. The income inequality is highest in middle-income countries (Nafziger 1997); not in the poorest ones as one could think. Third point is the informal sector. The poor and the informal sector are a big question mark and an enormous diversity exists. GNP data do not cover the economic activity of the informal sector. Besides an economic issue, it is typically a political question of priority setting how to provide services for those very poor and those living on an illegal basis.

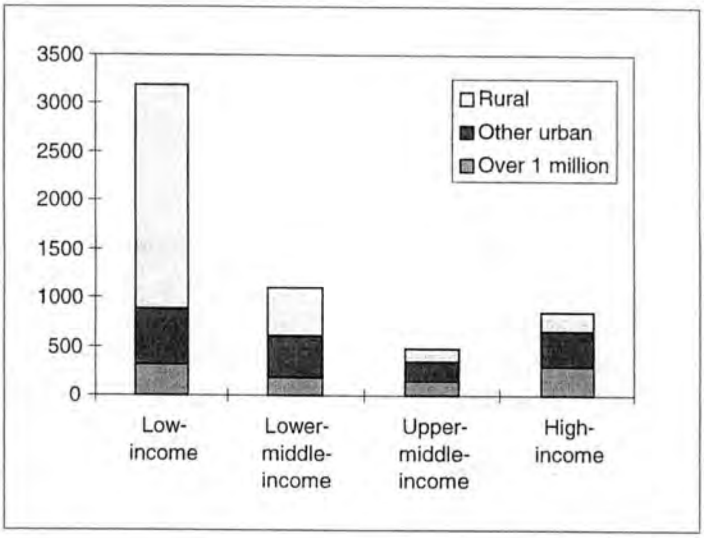
Perhaps most importantly though, many local expenses in low-income countries are much lower than in high-income economies. The GNP generally overestimates the difference between rich and poor countries (e.g. Nafziger 1997). A number of alternative indices have been proposed to allow more realistic comparisons. The World Bank uses the purchasing power parity index (PPP). It exceeds the GNP per capita typically 5 to 10 fold in low-income and lower-middle-income economies (Figure 11). Recalling the investment rate in water and sanitation of about 0.4% of the GDP, we again face an excessively low economic capability of most humans this respect: about 4/5 of the mankind lie in the range of being able to spend between US$ 4 and 40 per person in a year in water and wastewater. Recalling that the Gross Regional Product in many megacities exceeds up to tenfold the country average helps us to get rid of much of the excess pessimism.

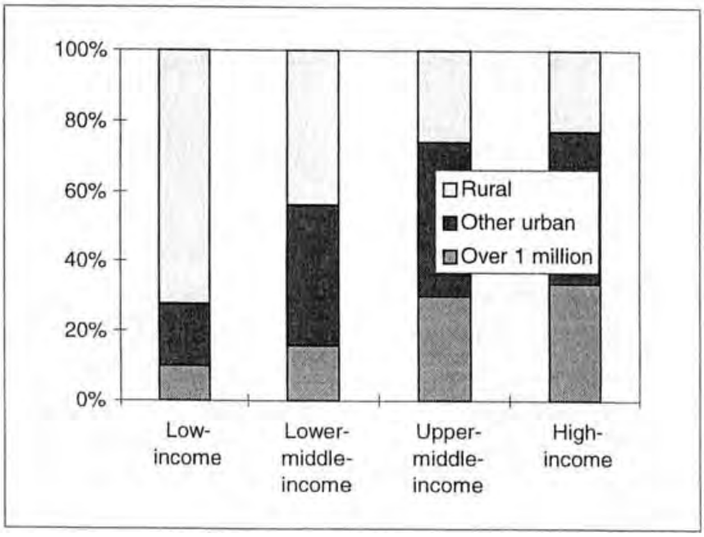
In light of the recent development of the low-income economies (World Bank 1996), it would be overoptimistic to expect rapid economic growth in their near future; a notable economic growth appears rather rare, whereas a remarkable economic decline is much more frequent. Moreover, many poor countries are heavily and increasingly indebted and therefore very averse to invest on foreign technology. The observation that the disparities between economies are growing rather than diminishing suggests that the poorest economies will face the affordability question in a sharply increasing way, because the unit costs of water and sanitation service grows rapidly with congestion. Urban water infrastructure is typically far more expensive to construct and maintain than a rural one. The World Bank (1992a, b) has estimated, that the difference is typically one order of magnitude. As a city grows, the unit costs tend to grow sharply: traditional low-cost systems become unfeasible in congested areas; water has to be transferred from larger distances, and waste accumulation and pollution problems emerge; and aspirations due to urban lifestyle tend to increase water demand per capita.

It seems that much can be done even in lower-middle income economies, but what to do with the low-income ones, in most of which urbanization is very fast and will continue long (cf. Figures 3 and 13)? In terms of population share, India and China are in the key position; they have roughly 2/3 of the low-income category population, and both have showed positive economic indicators over many years. But still, for many of the remaining 1.1 billion people, such a cautious economic (and social) optimism is unjustified in our view.

FIGURE 13

POPULATION AND POPULATION SHARE IN URBAN AGGLOMERATIONS OVER 1 MILLION INHABITANTS, IN OTHER URBAN CENTERS, AND IN RURAL AREAS. THE URBANIZATION RATES IN 1990-1994 WERE 3.8% FOR LOW-INCOME, 2.3% FOR LOWER-MIDDLE-INCOME, 2.6% FOR HIGHER-MIDDLE-INCOME, AND 0.3% FOR HIGH-INCOME ECONOMIES.





Data from World Bank (1996).

III PRESENT AND FUTURE PROBLEMS: IS THERE A WAY OUT?

3.1 Introduction

The answer to the question presented in the title of this section is not simple, nor it is a single one. Water in the poor, hungry, and urbanizing world is interconnected to so many issues in so profound manner that solutions targeted to improve the situation in one single sub-sector of a society may easily produce more problems in total than it solves, if the interconnectedness of the water issue is not taken in proper consideration.

In the following, two views are presented to the water issue: the rural one emphasizing the significance to increase markedly the food production in coming decades. As was sketched out, now around one-half of the human population is still in rural areas. After one generation, in 2025, the rural population is only one-third. This one-third should feed themselves, plus an urban population, which is double the size of the present one. The another view to the water issue taken here is the urban one. The rapidly growing cities in developing countries are challenged by providing basic needs to their inhabitants, a gross proportion of whom are living very poor and on an illegal basis.

3.2 Rural view: cities are hungry for food and they attract the best people

3.21 Food production needs rapidly growing amounts of water

For balanced water resources development, it is not enough that there is water available. The supply should meet the demand, but this cannot be realized without the appropriate capacity—including human, institutional, technological, and economic—to put the resource in use. This all should be managed so that the resource itself is not damaged, i.e. in a sustainable way (Figure 14). In practice, the sustainability concept includes, besides the ecological dimension, also economic, social, and political aspects.

Over two-thirds of all water withdrawals go for food production. The crucial role of water as an agricultural input, and as a major factor in the rapidly grown food production in 1970-90, is unarguable. The arable land area did not grow in that period, but the irrigated area went up 40%. In conjunction with the developments in the application of other inputs, the world's grain production grew 72%. This yielded a notable improvement in the global food situation: the population growth did not exceed 40%. This positive development trend has been replaced by a more stagnant one in this decade. Both the arable land area and the fertilizer use have decreased. The irrigated area grows still, but much more slowly than before. Consequently, food production has not grown, whereas population has with 14%, with 720 millions. This trend has recently evoked wide concern in various directions. Much of the achievements of the past decades has already been lost; the per capita grain production has returned to the mid-1970s level (Figure 15).

FIGURE 14
SUPPLY, DEMAND, CAPACITY, AND SUSTAINABILITY: THE CHALLENGES TO MEET THE WATER DEMAND ARE TOUGH ENOUGH WITHOUT THE UNAVOIDABLE QUEST FOR SUSTAINABILITY

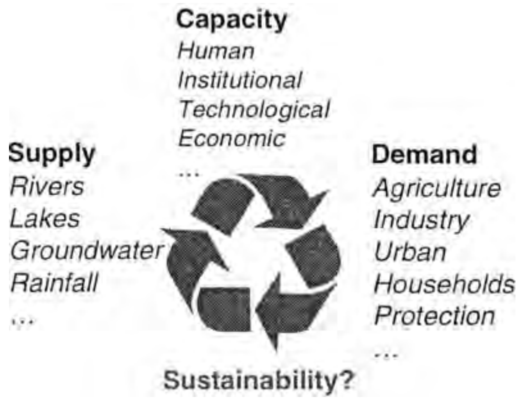
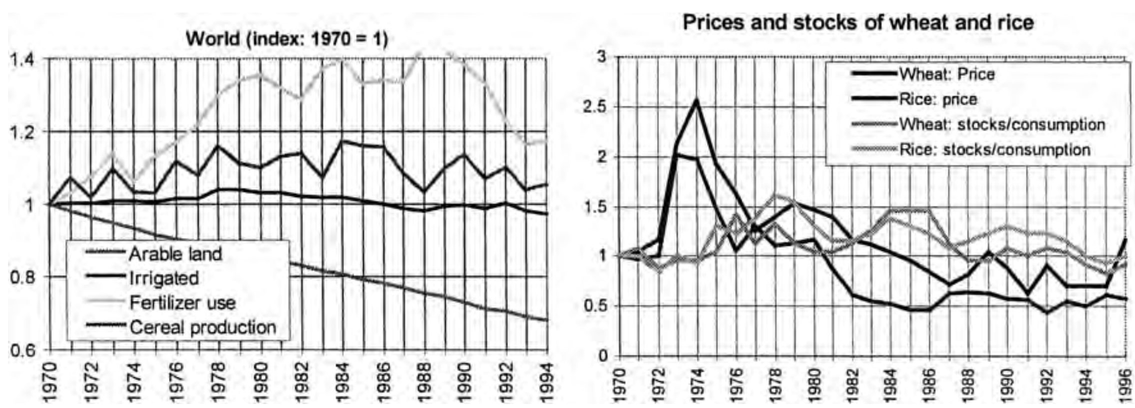


FIGURE 15
WHO WILL INVEST IN FOOD PRODUCTION? THE PER CAPITA INDEXED DEVELOPMENT OF ARABLE LAND, IRRIGATED LAND, FERTILIZER USE, CEREAL PRODUCTION, CEREAL PRICES, AND CEREAL STOCKS



Data: World Bank (1997).

There must be several reasons to this development shift. The most important three reasons are first, the rapid urbanization development, and second, the collapse of the former centrally planned economies, which had a highly input-intensive agriculture. Third, partly as a consequence of the collapse, the free trade paradigm has been prevalent, forcing agricultural investments to compete more with other investments (manufacturing industry, urban services, tourism), on the basis of revenues per invested sum of money.

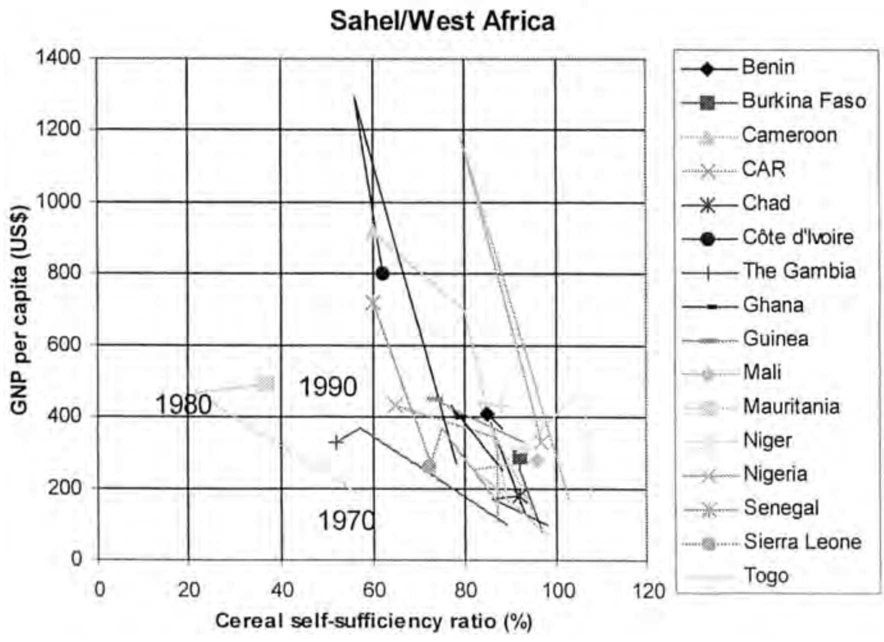
Water is a basic need in many ways; as drinking water, in sanitation, in public health, and in food production. In economic development its role is crucial: most developing countries depend on local food supplies and export income from agricultural products to allow the import of manufactured goods and primary products they cannot produce themselves.

Globally, food availability and security are among the mankind's major threats. The expansion of agricultural production has to take place, and the food must be produced somewhere. The individuals that suffer most from food and water scarcity tend to have the weakest voices in local and global policy-making. Typically, the successful export of foodstuffs from a low-income country hits worst the domestic poor whose food becomes less accessible, given their lacking cash. Foreign trade benefits go to others.

This brings in mind the fairness issue of global trade liberalization, advocated by rich, highly urbanized economies such as USA, EU, and Japan. From the world market, Japan alone imports 4 times the amount of grain than the whole Sub-Saharan Africa (Alexandratos 1995). Is it because there is no demand for food there? Demand certainly exists; the per capita calorie consumption in Sub-Saharan Africa is only around 60% of that in developed countries. They simply do not have enough cash (Figure 16).

Similarly, many other sub-sectors of water development are heavily constrained by human, institutional, economic, and technological capacities (Varis and Somlyódy 1997), and hinder the development of the societies as a whole.

FIGURE 16
THE POOR ECONOMIES IN SAHEL/WEST AFRICA ARE ABLE TO IMPORT FOOD ONCE THEY HAVE CASH FOR IT



Source: Vakkilainen and Varis (1998a,b) based on the GNP data of the World Bank (1997) and the self-sufficiency data by FAO (Alexandratos 1995).

3.22 Driving factors to development are highly uncertain and unstable

It is definitely an anecdote to say that the future of the mankind is governed by various uncertainties. However, this fact does not seem to be properly acknowledged in today's global change and development studies. It is a commonplace to present a 'forecast', which gives a single value for the item in concern, given a specific time slot in the future. Another approach is to present a set of scenarios, e.g., low, medium, and high ones, with varying assumptions of some critical parameters in the model used.

It is, however, crucial to fully appreciate the complexity of global-scale issues, and their deeply interwoven interconnections. We demonstrate the inaccuracies of global assessments with two examples (Figures 17 and 18); water and food availabilities in the world. Depending on the study approach, data used, and other factors, different people end up to very diverse views on the state of these issues now and in the future.

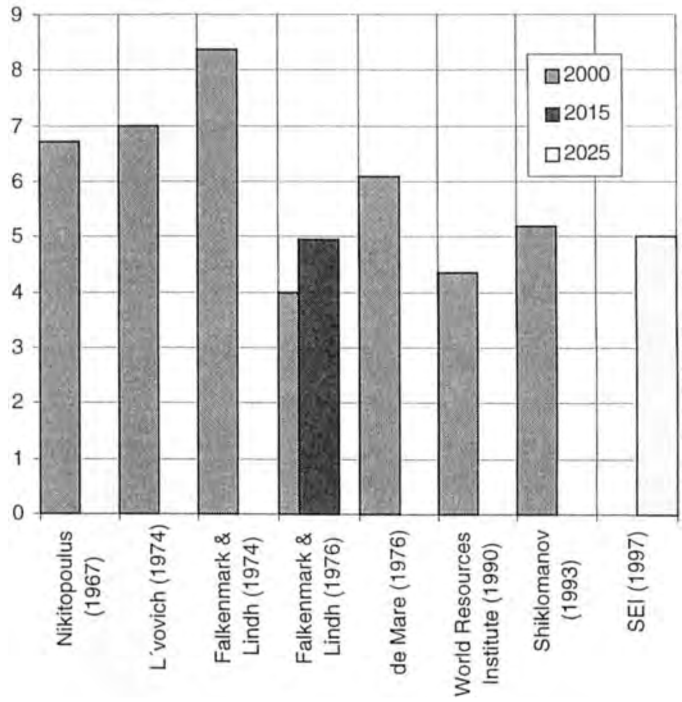
We cannot avoid the thought and the overall feeling, that the studies—or perhaps rather the approaches used—tend to overlook the various interconnections and uncertainties, and give therefore an overly deterministic view of development of very complex issues. The world itself is subject to high uncertainties and unpredictable variations. This applies not only to natural resources such as water, land and food, but also to the nature itself, to the development of economies, and that of the whole human societies. The climatic change projections show locally and globally huge mismatches, and *the most important signal for policy makers is simply the increased uncertainty* (Varis and Somlyódy 1996). Other environment-related issues such as land degradation, increased pollution, the loss of forests and biodiversity share many of these same features.

When considering the economy, the highly unstable development witnessed by numerous countries immediately influences the pressure set to natural resources, but is not properly included in global assessments. E.g., in the IPCC and World Bank scenarios for GDP used by SEI (1997), for S and SE Asia, the annual growth rate used was 4.5%. Now, a few months later, the rupee has gone down with over 80% of its value at that occasion, which was not long ago in comparison to the time frame of the study itself: till 2025. Indonesia with its over 200 million people is not alone. Most SE Asia, with many other Asian, African, and Latin American countries suffer from similar instabilities, that are reflected throughout today's globalizing world.

What comes to political uncertainties, it is still easy to recall the development in former centrally planned economies in Europe and some other continents. The developments in the last 10 years were highly unpredictable, and affected deeply the whole global economy. Many other examples can be given. In the countries that lie in the basin of the Nile, only Egypt has not been suffering from major political instabilities or civil wars during the past 25 years. Burundi, Ethiopia, Kenya, Rwanda, the Sudan, Tanzania, Uganda, and the ex-Zaïre, have each appeared in our TV-screens over a while due to sad reasons. In fact, political instabilities have been rather a rule than an exception in many parts of the world that are most affected by the developments that will become effective in the global water, food, poverty, and urbanization arena.

FIGURE 17

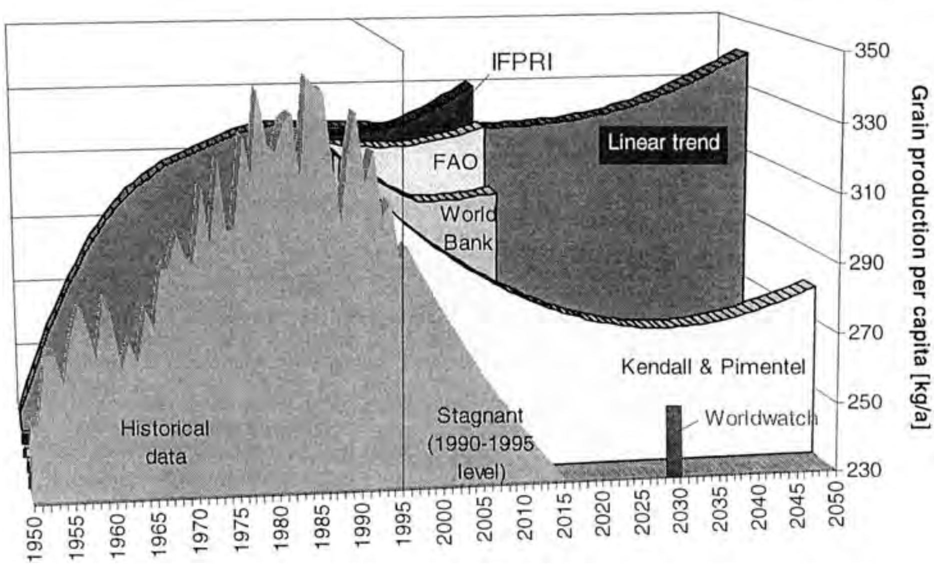
WATER WITHDRAWAL (1000 KM^3/A) PROJECTIONS ARE HIGHLY UNCERTAIN, SHOWING NOTABLE MISMATCHES



Data: SEI (1997).

FIGURE 18

FOOD PROJECTIONS ALSO SHOW MARKED MISMATCHES

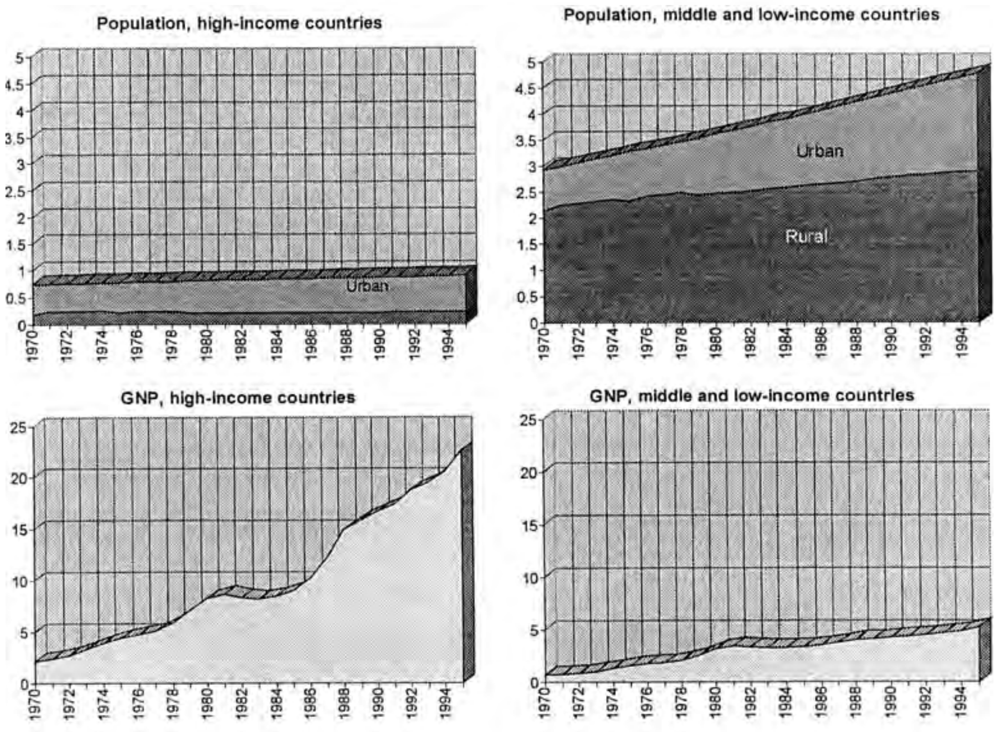


Sources: IFPRI (Agcaoili and Rosegrant 1995), FAO (Alexandratos 1995), World Bank (Mitchell and Ingco 1993), Kendall and Pimentel (1994), and Worldwatch (Brown 1996).

3.23 Underlying disparities feed the instability

The world is rich with contrasts and disparities with respect to aspects discussed here. Clear is it, though they present such a magnitude, appearance, and character, that they deserve a special concern. We have collected some examples including economic capacity and population in rural and urban areas (Figure 19), urbanization rates (Figure 5), and water use vs. availability (Figures 3, 11 and 20). They destabilize the world development in a number of ways. In addition, they constitute deep-going problems of equity within the mankind, with respect to access of the basic needs such as water, food, housing, education, and good livelihood.

FIGURE 19
THE HIGH-INCOME, MAINLY URBAN, PEOPLE DO NOT PUT THEIR MONEY TO AGRICULTURE OF DEVELOPING COUNTRIES. MOST CASH IN DEVELOPING COUNTRIES IS IN URBAN HANDS. GNP UNIT IS US$ 10^{12} PER YEAR

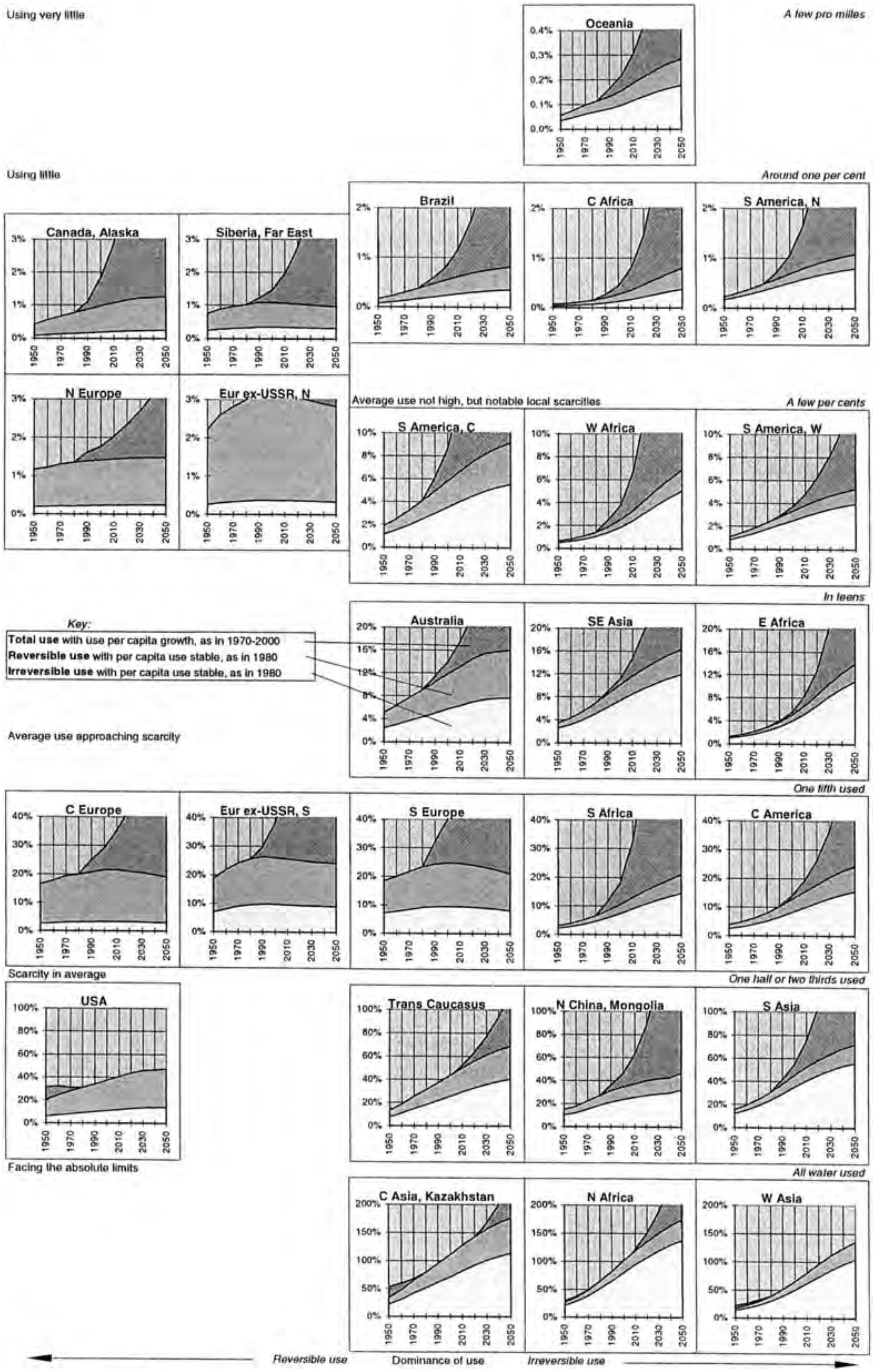


Data: World Bank (1997).

3.24 Food and water are basic needs, subjected to high uncertainties

The importance of various uncertainties around global water, in a hungry, poor, and urbanizing world are underlined. There exists very diverse views on the present state of the world's resources, and the future projections are subject to huge mismatches. Political instability and unpredictability, hydrologic and climatic variations and their likely shifts from the observed behavior, economic development, ecological and environmental threats including land and watershed degradation being the foremost issues.

FIGURE 20
GROWTH OF WATER USE RELATED TO AVAILABILITY



Source: Shiklomanov (1993). Water use data is from 1980, 1990, and 2000, and water availability data from 1950, 1960, 1970, 1980, and 2000. Other values extrapolated by us.

There should be more focus on real interdisciplinarity and integration. Water should be considered in closer connection with social, economic, financial, environmental, political, and institutional issues to bring the analyses closer to policy making. A methodological challenge to cope with interdisciplinarities and extreme uncertainties and complexities is evident. One attempt in progress is documented later, in section V.

Water and food are too precious and basic issues to be forwarded under control by market mechanisms and business cycles only. The poorest 85% account only for 18% of global cash flows. They are not equitable partners in the world market. A major stabilizing factor is to produce food close to the users, by not forgetting the self-sufficiency paradigm, both in developing and developed countries. This underlines the many-sided, stabilizing role of rural development in a society. The significance of education at all levels should not be underestimated, so that economies would be increasingly capable to take responsible care of their own sustainable development. Much more stable frames than today are needed in many parts of the world.

Most of the negative consequences of unbalanced and unstable development are felt by developing countries; by the poor and hungry. From there, they reflect increasingly over the whole globe. In the rapidly globalizing world, the responsibility of industrialized countries is growing as the economies get more open and trade barriers lower.

When targeting towards sustainable and equitable development at the global level, the policies in high-income countries are more crucial than many think. Water has many very basic and deep-going roles behind the development process, and its many facets should be appreciated and realized in development co-operation policies of developed countries, and in the policies of international organizations.

3.3 Urban view: cities are thirsty for clean water but they die to pollution

3.31 Sanitation in the industrialized world

Let us first recall the way the industrialized countries have solved urban water problems. There is long, diverse history in the construction of water and sanitation systems within industrialized cities. Copenhagen, Denmark in Northern Europe is a good example, because it has the typical features of European development trends within the sanitation and waste water treatment sectors of major urban areas (Box 4, from Hansen and Therkelsen 1978).

In the industrialized world, the trend is towards further development and improvement of these systems (cf., Niemczynowicz 1993). Treatment processes will be produced to remove more and more of the impurities in waste water. In many cities, the sewerage and treatment systems are centrally controlled, with real-time monitoring and computerized control. Sophisticated integration of the system components with external data — such as weather data and analysis — yields increased efficiency and improved treatment results. But such systems require highly skilled labor, large amounts of capital, and steady socio-economic conditions (both finance, chemical supplies, etc.).

BOX 4. THE COPENHAGEN CASE

The excreta disposal system in Copenhagen in the 18th century was a hole in the ground which was emptied from time to time. Some holes were simply covered when tagged as inadequate and new one was dug as needed. The next step was a privy inside a house, usually under a staircase, which was regularly emptied and often caused severe odor problems. From 1756, ground tanks with brick walls were introduced and became the only allowed system until 1795. Methods for emptying the tanks advanced gradually, and around 1880 vacuum trucks were used. In parallel, various portable, pail latrine systems were developed, where urine and faeces were usually separated.

A sewage system was first proposed in Copenhagen 1853 which consisted of two different lines; one for household waste and stormwater, and the other for toilet sewage. Ironically in 1853, the first cholera outbreak occurred Copenhagen. Despite the quite evident need to improve sanitation conditions throughout the city, the sewage system proposal was turned down.

The change from the pail system and ground tanks to sewer system and the flush toilet finally arrived during the 1890s. The earlier system failed because it was poorly managed (health related risks) and it was labor intensive. The new system caused less direct nuisance and inconvenience and had fewer hygienic problems. However, the new system was not without its difficulties as it was expensive to construct, especially to areas at great distances. Consumption of the high quality water was considerable which made operating the system quite expensive to run. Also, the sewage discharged from the network caused pollution problems, as there was a several decade utility gap between the sewage system and the purification system in Copenhagen. Eventually, waste water treatment was a complete system, as the transport and purification systems were combined to create a well controlled, semi-closed system.

TABLE 1.
INDUSTRIALIZED WORLD: THE MAJOR FEATURES OF URBAN WATER INFRASTRUCTURE

Water supply	High coverage required, safety is a major concern, a part of living standard, willingness to pay is there Inherited systems from past decades: no separation (high quality water is used for all the purposes) Limited flexibility: infrastructure is given, a change would need 15-20 years (reconstruction period)
Sewerage	Systems often, and philosophy originate from the 19th Century Public health and water borne/transmitted diseases original driving force Long planning horizon and life time - difficult planning due to uncertainties in future flow estimates Very expensive, investment and money driven (decisive element of the infrastructure) Functions: transport of pollutants (liquids); originally domestic wastewaters; industrial ones (at a later stage); stormwater; linkage to road construction; an incremental part of city planning; change in its function along time (19th Century - very little industrial wastes, etc.); future changes are also anticipated
Treatment	Central plants dominate Activated sludge mostly and its advanced versions Increasing sophistication (operation etc.) Sludge management is often overlooked

Source: Varis and Somlyódy (1997).

The major problems arise when these requirements are not fulfilled. They may appear risky if proper maintenance is not there, and many unsustainable features are inherent (water and pollutant transfer via the entire infrastructure, need for continuous operation, sensitivity to under- and overloads, implementation failure risk is an inherent feature, energy loss, material loss etc.). In other words, they may be sustainable if implemented/operated perfectly, but they have not been realized, and are apparently not realizable in the majority of cities in the world due to economic, political, technological, and institutional reasons.

3.32 *Third world cities in comparison*

In many Third World cities, sewage systems exist, yet they often date back to colonial times. Therefore, they are typically too small and include no proper end-of-pipe treatment, and are often in a state of disrepair due to improper management. In Alexandria, Egypt, a sewage system for one million citizens has to deal with wastes from more than four million people. There are much worse cases such as Jakarta and Bangkok (mentioned above), where there are open sewage canal systems.

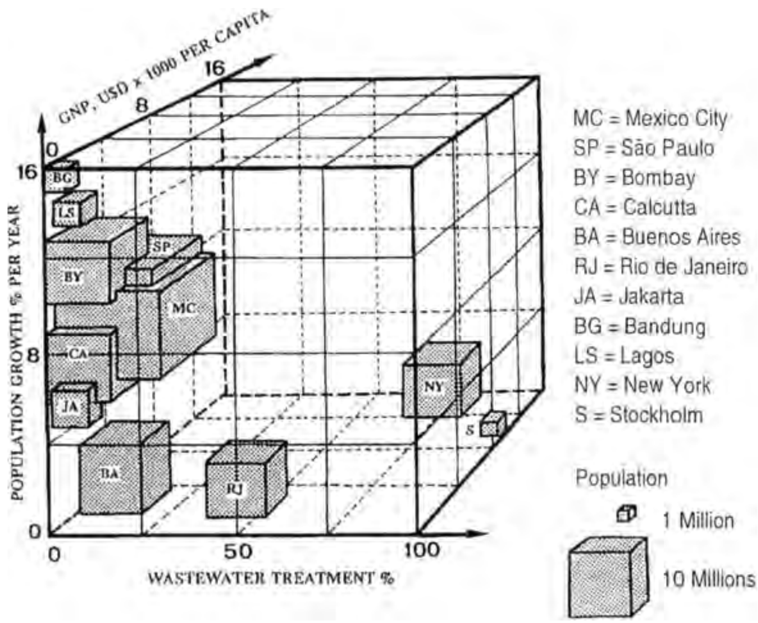
For those with no proper sanitation, realistic solutions should be found. For those with sanitation, improvement is often needed. Evidently, the problems with the flush toilet and sewerage systems are considerable, especially in the big cities of the Third World. Large portions of the housing sector are formed on an illegal basis with no proper waste water treatment even considered much less constructed. Water might be in short supply due to seasonal variations, inadequate infrastructure or technical inadequacies within the supply system. Money, political will and power are often lacking. It is likely to be a long before the development of highly sophisticated treatment systems within the mega-cities of the developing world.

3.33 *Technical alternatives and affordability*

A much argued issue is the type of technology that should be implemented in the urban water infrastructure — water treatment in particular — in the Third World. Apparently, the technology should fit, again, with the other parts of the infrastructure puzzle. Figure 21 shows selected cities in the industrialized countries and in the Third World, with respect to the level of wastewater treatment, population growth rate and GNP per capita. There should be alternative development pathways for those areas suffering from problems that are much bigger in comparison to available capital. Many regions do not have the resources for fast development, which is often unlike their counterparts in the industrialized world.

The level of investments on environmental protection range globally between 0.5% and 3% of the total GNP, being typically higher in countries with higher GNP. In a poor country with GNP per capita around US$ 200 to 400, the spending to environmental protection is bound to be well below US$ 5 a year. Alternative, less capital intensive solutions, which simultaneously fit together with available human resources and infrastructure are desperately needed. Many ecological and biological low-input solutions, plus labor-intensive approaches instead of capital and equipment intensive ones enter often the discussion.

FIGURE 21
RELATION BETWEEN WASTEWATER TREATMENT CAPACITY, GNP AND RATE OF POPULATION GROWTH IN SELECTED LARGE CITIES



Source: Niemczynowicz (1993).

The literature is rich in alternative solutions to the sanitation problem and several principles for solving the problems illustrated above have been proposed. A short summary is given below, clustered along side a set of widely used buzzwords.

i) *Save Water.* There are many ways to reduce water consumption by increased efficiency. Those include technical measures such as reducing leakages, economical incentives such as proper pricing, restrictions such as limiting water use for certain purposes, and increased public awareness. Many positive results from developed and developing cities have been reported (Worldwatch 1993).

ii) *Recycling of organic matter.* In traditional farming systems, manure is returned to fields as organic fertilizer. Composting is widely used. In many traditional integrated aquaculture, livestock and farming systems, especially in Asia, sophisticated and efficient production systems with low emission rates have been sustained for hundreds if not thousands of years (e.g. Edwards 1992, Chan 1993). Although these are primarily rural issues, there are many lessons to be learned from these systems to build cities which can achieve an increased ecological balance. At another level, sludge from waste water treatment plant is relatively widely returned to terrestrial ecosystems.

iii) *Recycling of water.* Various options to industrial and municipal water recycling have been proposed. The industrial production per used unit of water has steadily increased in Japan, being now threefold to the level in 1965. In the developed world, there are many examples; and there are also examples (although fewer in number) from the developing countries (Worldwatch 1993). In municipal water supplies, the use of lower quality water for flush toilets and other uses that require a lower standard have been applied.

iv) *Sanitation without water.* Many parts of the world have found solutions for sanitation through various types of latrines. Winblad and Kilama (1985) present a survey of such installations from 18 countries around the world. Many new solutions have also been suggested (see also Hansen and Therkelsen 1977, McGarry 1982). Water consumption is non-existent or much lower than in flush toilets and the waste can be returned to terrestrial ecosystems, but proper management is required.

v) *Appropriate technologies.* It has widely been emphasized that the technological level chosen should be in balance with the available infrastructure and economic conditions. Technology should allow for proper management and extensions of the installations in accordance with the prevailing conditions and within available human resources. There is a wide range of appropriate technology literature. Examples include water extraction to purification, water distribution to sanitation, and waste water treatment (cf. Eikum and Seabloom 1981, Schiller and Droste 1982, Ho and Matthew 1993, Grau 1996, Mara 1996).

vi) *Solution to pollution is dilution.* This principle unfortunately often leads to open mass flows and should be avoided when possible. However, it is used very widely. The pollutant is transported away and/or diluted to a lower concentration. Such systems operate in many ways. One example is the practice in Jakarta: an improvement was due to speeding the passage of waste water into the sea by re-directing open canals. Another, more sophisticated example is on coastal discharge of waste waters. Once a sewerage network has been constructed, the site of discharge can be chosen such that dilution is sufficient to prevent problems (e.g., Gunnerson 1988).

Niemczynowicz (1993) sees the water pollution abatement process consisting of six principal steps. They are:

i) *Preventive actions.* First, one should try to prevent the formation of pollution at its sources. This applies to industrial processes, to transportation, mining, agriculture, and to many more sources of pollution.

ii) *On-site treatment and reuse close to production.* Wastes (nutrients, minerals, chemicals...) should be recovered and reused as close to the production as possible.

iii) *Off-site treatment and reuse.* If the above is not feasible, recovery can be organized outside the site.

iv) *On-site, or off-site concentration and storage.* A temporary solution to residues that cannot be directly re-used.

v) *Treatment at small-scale plants using low technology.* Various biological and ecological systems (terrestrial, wetlands, aquaculture, livestock...) can be effectively used in small-scale plants.

vi) *High technological treatment at the end of pipe.* If the above options are not successful, the approach should follow that of highly developed countries using high technology and capital intensive methods.

We want to pay special notice on the flush toilet, which is more or less self evident issue in industrialized countries. Many points made above would very strongly push the water sector to find alternative solutions to it, for the Third World mega-cities in particular. Box 4 described the urine separation approach when using dry latrines from the 19th Century on. Approaches of similar type have been proposed recently as a realistic practice for large urban areas with limited water infrastructure (cf. Beck and Cummings 1996, Gujer and Larsen 1996). It would save water in comparison to the flush toilet, and produce both liquid and solid, natural nutrient-rich matter, that should be used as a fertilizer in food production in order to close the material cycles.

3.34 Water: social or economic good?

Ways to make and maintain the urban water infrastructure efficient are many. Along with the globally prevailing trends of deregulation and privatization, a.o., the World Bank's "New Agenda" (Serageldin 1994, 1995, see also the critical comments of Frederiksen 1996) is in favor of making water from a social good to an economic one. It has been shown in many cases (yet not in all) that governments are unable to tackle the issue. Public awareness and community involvement, together with higher involvement of the private sector are believed to facilitate a more successful development than the patronizing public sector approach of the past. With better checks and balances, particularly in terms of enhanced cost recovery, the water infrastructure should have better possibilities for capacity building, and therewith to meet its requirements, and to run without subsidies (Figure 22). Subsidies are often considered of being most beneficial to those with tap water supply, i.e. the rich and the middle class.

Many studies show that if the money used by the poor to buy water from usually informal sector water vendors would be used for water infrastructure installations the funds would be enough. Also the willingness to pay would be there since the piped water infrastructure would in long term save reasonable sums of money. What is missing ? The bigger the urban center is, the more complicated and far-reaching solutions for supplying water and taking care of waste are needed. The control over the informal sector which dominates the economy in many cases is missing. The priorities of water and sanitation, especially for the poor, are not always too high, both in the government and in the individual level. The avenue from water vendors to piped water for everybody is long and it requires commitments from so many stakeholders that it just hasn't always, and too often, taken place. Perhaps the solution to this is not as simple as many agendas suggest.

The financial performance of the water infrastructure sector is often very poor. While it typically has a cost recovery rate of one-third, implying that the majority of running costs has to be covered by public funds, sectors such as power and gas are much closer to financial autonomy. Some sectors such as telecommunications even make profits. Water utilities should have a better financial performance. With better checks and particularly with enhanced cost recovery and 'proper' pricing of water, the sector should be better off for capacity building, and therewith to meet its requirements, and to run without subsidies. Subsidies are often considered of being most beneficial to those with tap water, i.e. the rich and the middle class.

FIGURE 22
THE PRESENT TENDENCY OF CONSIDERING WATER AS AN ECONOMIC GOOD, DESPITE ITS MANY MERITS, INCLUDES SEVERE PITFALLS, ESPECIALLY IN TERMS OF INABILITY TO COPE WITH THE POOR, THE ENVIRONMENT AND THE INFORMAL SECTOR

"Money makes the water go round"

The responsibility issues, the fate of the secure, affordable water to the urban poor, the subsequent public health problems, the equity issue, among other things, have evoked wide concern. we share this concern. A trap in thinking may yet be the belief that all the poor are willing to pay the real price for water. The creativity in digging own wells (with often very low quality), boring holes to water pipes and many other ways to get water without expenses has been great also thus far. Consecutively, we raise the following questions:

i) How the above scheme can be realized within the informal sector without strengthening the positions of those having the informal power (making weak governments still weaker)?

ii) How it will impact the public health and the urban poor in particular (less social function for water)?

iii) How does this scheme handle with the sustainability issue as discussed above (the nature does not charge for water, nor does it pay for it, even if its needs were crucial, also for our survival)?

These hardly are easy questions to answer, yet a sceptic might say that the result may not be that different from those of strengthening the governments. After all, the importance of the externalities of this scheme is in our view not comprehended properly.

3.4 A holistic view is needed to freshwater management

3.41 What should change?

Fresh water management including urban water infrastructure witnesses a number of trends or at least it should witness them in the close future in order to work towards sustainability. Somlyódy et al. (1995) have collected and broadly discussed the most significant of them (Table 2).

The sectorial, fragmented and narrow comprehension of these very broad and widely interconnected issues are one of the major causes to the unbalanced development in many ways, not at least in the urban-rural disequilibrium and disparity, and extensive urbanization in the Third World. In the water sector, the voices calling for integrated approaches and holistic views become ever louder and the argumentation gets increasingly rigorous (Falkenmark and Lindh 1976, Biswas 1976, Kinnersley 1988, El-Ashry 1993, Somlyódy 1995, Somlyódy et al. 1995). Still, strictly sectorial, even jealous approaches tend to dominate. The same applies to infrastructure issues.

3.42 Vicious circles under control

A particular challenge is to make any attempt — through balanced and integrated water management including infrastructure issues — to try to avoid uncontrolled growth of mega-cities by tackling both the urban pull forces and rural push forces that are behind the process. There should be incentives for the rural people to stay in provinces. Here again, water (with education, other infrastructure etc.) is crucial. Decreasing the urban pull and rural push forces should still be a high priority topic in development programs.

Urban-rural interactions should be realized, they partly have the same infrastructure (energy, transport, telecommunication, water, etc.). Their close connections are particularly clear in the water and agricultural sectors. Urban primacy is a reality in many countries. The Bangkok example of prioritization of the tourist industry over rice farming shows a clear urban bias. However, rural primacy might neither work very easily, as the experience from, e.g., Pakistan shows. Rural push is particularly important in developing countries with a shift of agricultural production to cash crops using intensive irrigation with decreasing labor force. If a city infrastructure is very developed in comparison to the rural one, it will in turn enhance urban pull.

One should evidently make any attempts to try to cut the vicious circles in urban development, and to make the urbanization and infrastructure development more controlled processes (Varis 1997b; Figure 23). This, however, requires huge amounts of political and economic power and will, especially over the informal sector. These are often lacking. Recent developments in former centrally planned economies are vivid examples of collapsing formal sectors that tried to keep a strong control over the opening societies. How the success stories of today — e.g., Singapore, Western Europe — will develop further, remains to be seen.

TABLE 2
TRENDS IN FRESHWATER MANAGEMENT

PAST	PRESENT	FUTURE (Expected and/or desired*)
(1) General		
Local problems		Increasing scale
Fast response, reversibility		Delayed responses and irreversibility
Limited number of pollutants		Multiple, sophisticated interacting pollutants
Point sources		Diffuse sources
Single media (water)		Multi media (water, soil, air)
Static, deterministic, foreseeable		Dynamic, stochastic, uncertain
Regional independence		Importance of global interdependency
(2) Control type		
"End of the pipe"		Source control, closing material cycles, land use management, concern on large scale projects*
Technical		Non-technical elements*
Discharge standard - rigid		Use attainability - flexible
(3) Infrastructure and treatment systems		
"Traditional technology"		Special treatment methods (biol-chem treatment, high-tech processes, upgrading, appropriate technology, natural treatment, small-scale treatment). Emerging new traditions and technologies
Landfilling of solid wastes		Increased reuse and recycling*
Large scale control and exploitation		Regional and small scale development management and conservation. Flood plains, wetlands, and other ecosystems as valuable resources.
Massive, capital intensive urban infrastructure		Localized, small scale, creative infrastructure development*
(4) Monitoring		
Local measurements		Networks, remote sensing, continuous measurements
Conventional parameters		Special parameters (micropollutants, eco-toxicology, biomonitoring, etc.)
Monitoring of water		Integration of effluent and ambient monitoring and aquatic ecosystem monitoring
Poor data availability		Improved availability (data bases, digital maps, telecommunication), integrated information systems
Hands off "my" data policies		Open information flow
(5) Modeling		
Individual issues (processes, control, operations, planning, etc.)		Integration (model library, DSS, GIS, etc.)
Limited, numerically based results		Scenario based and visual. Use of multi-media to explain complex ideas
Use by experts		Use in administration, meetings, etc.
One correct paradigm - single discipline		Many paradigms known and accepted within and between disciplines
(6) Planning and project evaluation		
Poor/narrow definition of objectives		Clear goals and objectives*
Short-term view		Long-term view*
Cost evaluation		EIA, risk and multiobjective evaluation, social and political impacts*
Little concern on failures and adjustment needs		The future is never certain: reliability, resiliency, robustness, and vulnerability*
Positive and negative impacts separately		Positive and negative impacts together
(7) Science and engineering		
Science does not drive actions		"Science for Action" and combination of broad, emerging scientific concepts with engineering*
Problem isolation and engineering solutions		Improved planning*
Interdisciplinary gaps and barriers		Integration of quantity, quality, hydrology, economics, politics, social science and management*
Expert produces the optimal solution		Expert is a facilitator for communication and learning

TABLE 2
TRENDS IN FRESHWATER MANAGEMENT (CONTINUED)

PAST PRESENT	FUTURE (Expected and/or Desired*)
(8) Legislation, decision making institutions and development	
General rules and rigidity	Specific rules and flexibility*
Undivided implementation	Process view*
Little enforcement	Improved enforcement
Command and control	Polluter/user pays, improved policy instruments
Confusing institutional settings	Clearer structures and responsibilities, less barriers and mismanagement*
Decisions by politicians and administration	Public awareness and participation, NGOs, and enhanced communication (scientists, planners, community, government, etc.)*
National policies	International policies*

Source: Somlyódy et al. (1995).

FIGURE 23
CITY GROWTH APPEARS TO OUTPACE INFRASTRUCTURE DEVELOPMENT IN MANY THIRD WORLD CITIES

3.43 *Integrated management: the horizontal dimension*

There are many ways to work towards a sustainable water infrastructure. However, none of the sectors or subsectors — e.g., water supply and sanitation or irrigation — can manage it alone. All the pieces of puzzle should fit together, the system components should be more or less in balance, including different sectors, political, economic and financial realities, social issues, human resources, institutionalization and operations management such as pricing, and not to forget the constraints due to most simple things, water and food availability and the importance of education.

The integration concept can include integration over different service sectors. A challenge is to foster, e.g., the water, the energy, and the telecommunications sectors to provide solutions that work together and with the rest of the society. Telecommunications can benefit the water sector in many ways, e.g., by enhancing public awareness, education, decentralization possibilities, better resource allocation in time and space (better forecasts, data sharing), sharing of expertise, transparency of policies, and many more. The connections of water and energy sectors are very tight, e.g., through hydropower, water convey systems, energy supply and treatment processes.

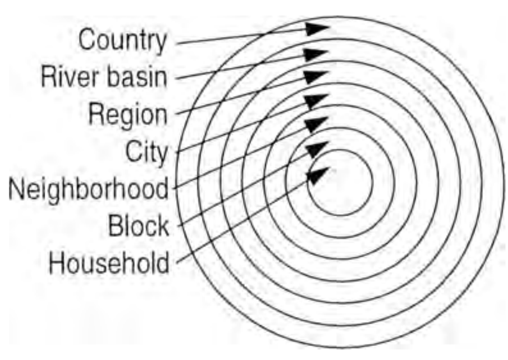
In municipal water infrastructure development, water and sanitation should be seen as one entity and they should be developed together (Figure 24). This is not often the case. Most of the public health effects of water supply, if performed without proper sanitation, will be drained off. Moreover, water and sanitation projects should be accompanied with education, public awareness and community involvement. These issues are also crucial when increasing the efficiency of water supply systems.

FIGURE 24
PUBLIC HEALTH AND WATER: IMPERATIVES

3.44 Integrated management: the vertical dimension

Another challenge is to further develop solutions that allow the integration of the top-down (governmental) and bottom-up (localized markets with public awareness) implementation and control of water infrastructure. The decision units concerning water at different vertical levels of the society (Figure 25) should be closely linked, not only from government level down to households but also to the opposite direction. The participatory approach, based on public awareness, boosting the transfer of decision making to the lowest appropriate level appears to be high in many agendas, in comparison to sectoral, central planning model that has dominated previously. This is a great challenge to institutional building, especially in many developing countries; informal institutions such as NGOs, neighborhood associations, private enterprises and even households should make commitments and be incorporated in the decision making processes.

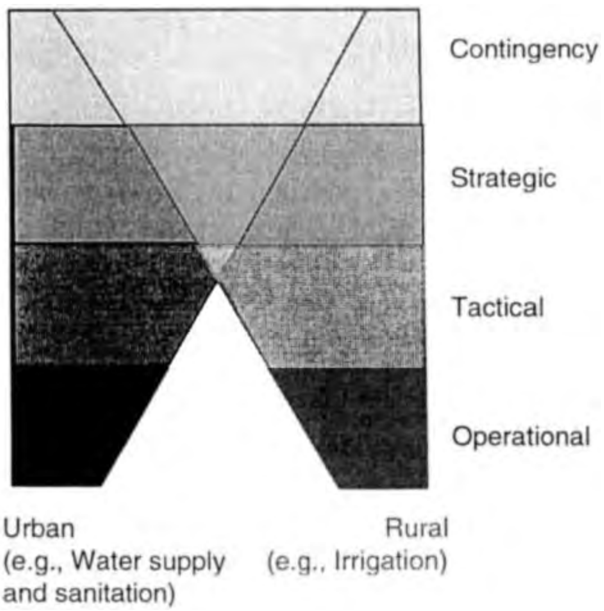
FIGURE 25
SOCIAL UNITS (LEVELS OF DECISION MAKING) IN THE WATER SECTOR



According to Serageldin (1994).

Evidently, with increasing temporal and spatial dimension of the planning process, more integration to other sectors is needed (Figure 26). At the contingency level (e.g., international commitments), all sectors are thoroughly interwoven. These overlaps gradually fade in importance when going through strategic planning (policies, plans, programs), tactical level (annual water allocation etc.) to operational level (plant or reservoir operation, or short term remedy, etc.). The growing recognition that the different aspects of water management form a continuum (e.g. Serageldin 1994, 1995) appears to reveal that the concern of water is no longer only on operational or tactical issues as has been typical to the past.

FIGURE 26
WITH INCREASING SCALES, THE ISSUES BECOME MORE INTEGRATED



3.5 Human resources development

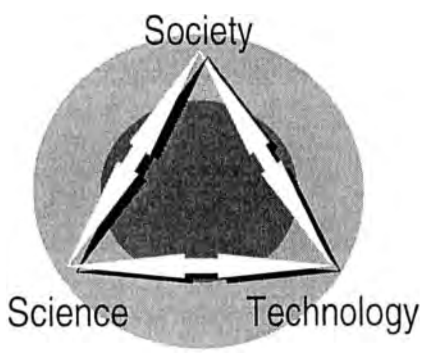
The academic world has undergone and is perhaps increasingly experiencing a tendency of specialization. The education is splitting into more and more specific, narrow, and profound disciplines. This process is usually, though very unfortunately, followed by the erosion of generalistic views over the society and the nature. Academic incentives, resource constraints and many other factors contribute to this development. Societies and other levels of education come along; sectorial approaches to development have dominated, too much in many ways.

It is not difficult to find examples, where too narrowly comprehended development schemes have created more problems than they have solved. For instance, in the water sector, such cases include boring of deeper wells that has led to overexploitation of groundwater resources and enhanced desertification; creation of water markets with "proper" pricing aimed at better cost recovery and capacity building but causing creativity in digging private low-quality wells and making holes to water pipes to extract water at no cost; improved water supply without proper wastewater treatment or even sanitation that has caused environmental deterioration and health problems; building of dams without proper analysis and remediation of adverse environmental and social effects, just a few examples to give a flavor. Evidently, highly educated people should possess a generalistic view to avoid such undesired development paths, because much of the development is in their hands anyway.

When discussing the present challenges to human resource development to support sustainable infrastructure development, with special reference to higher education in the water sector, we argue that profound changes in paradigms of water management, education, infrastructure, etc., are needed to meet these challenges with success. The issue is discussed, with emphasis on the importance of holistic views to the social, political, natural, economic, and technical complexity and interactions. Education — at the university level in particular — should take these views into account much more than is done at present.

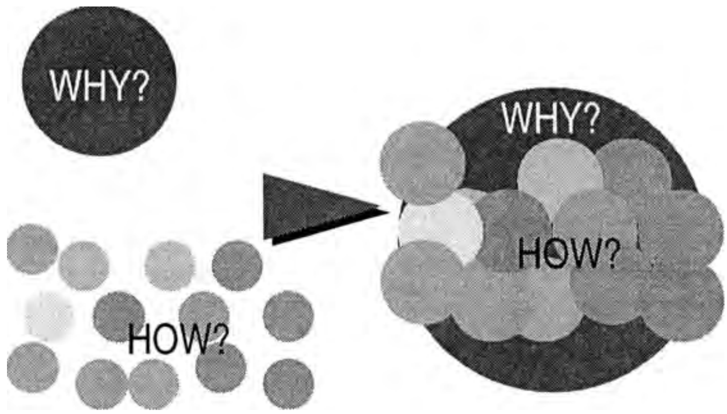
The two focal issues to be considered in higher education to better cope with the water issue in cities are (1) each individual with higher education should possess a generalistic view to the society, science and technology, and feel responsibility which should go hand in hand with the power and privilege due to education (Figure 27), (2) the educational system should encourage and teach the individuals to include the question *why* in their personal agenda, besides the question *how*, which is too dominant, and even dangerous without the concern of the question *why* (Figure 28).

FIGURE 27
HIGHER EDUCATION SHOULD PROVIDE, IN ADDITION TO DISCIPLINE-SPECIFIC EXPERTISE, A GENERALISTIC VIEW OVER SOCIETY, TECHNOLOGICAL POSSIBILITIES AND OPTIONS, AS WELL AS SCIENTIFIC FACTS AND APPROACHES



Higher education is just one part of human resources development. As was emphasized in the case of urban infrastructure, also the higher education should fit the rest of the society, yet being hopefully somewhat ahead of the overall development. All levels of education needed, and the primary education is clearly the prerequisite for balanced development. Public awareness and participation which is increasingly emphasized today, requires education at very principal level. Yet, organization of primary education is impossible without universities.

FIGURE 28
HIGHER EDUCATION SHOULD PROVIDE, IN ADDITION TO DISCIPLINE-SPECIFIC EXPERTISE ("KNOW-HOW"), ALSO ENOUGH BACKGROUND TO COMPREHEND THE DRIVING FORCES AND CONSEQUENCES OF THE DEVELOPMENT ("KNOW-WHY")



Water related education at higher levels has traditionally been split into several disciplines including several engineering subjects (hydraulic engineering, water resources engineering, water supply and sanitation, etc.), a number of subjects in applied sciences (limnology, hydrogeology, etc.), and in pure science (hydrobiology (botany, zoology, etc.), hydrophysics, aquatic chemistry, etc.). Though it is mandatory to go further and further into details in these important fields, the overly reductionist approach should be balanced by providing more of general topics to individuals. In engineering education, for instance, this means more education in science (natural, social and political) and in pragmatic issues such as institutions and law. This would change the approach from one profound technological focus (vertical) to include another, horizontal dimension, not as a by-product as is typical today, but as a field of strong expertise, not a most profound one, but rather a holistic view.

In hydraulic engineering, for instance, the comprehension over water has traditionally been restricted to the convey of water through a technical or semi-natural system in a desired way (minimize energy loss, seepage, erosion, etc.). This is no longer enough. A view on environmental issues, water quality, resource management, project evaluation (financial, technical, economical, environmental, social, informational, institutional, cf. Munasinghe 1993) is necessary. Not at the level of knowing all details, but to understand the issue (project, plan, policy, program) as an entity. At the contingency planning level, such as city development, this is still more crucial. The world has evidenced too many cases that have been fully successful at detailed levels, but disasters as a whole. One could continue to other disciplines, and the same outline would apply to them as well.

IV AN AGENDA FOR FURTHER RESEARCH

4.1 New paradigms and approaches are needed for global assessments

Recent years have seen a spectrum of global summits and comprehensive assessments targeted to set light to possible development pathways on many key issues constraining or facilitating the development of nations and the mankind. These issues include water, food, population, urbanization, various environmental and social aspects, and many more. The tendency of growing concern of our future, with wide-ranging international contributions to put together and expand the knowledge of these issues is a highly welcomed one. The water sector has recently seen a number of highly qualified assessments (e.g., Kulshreshtha 1993, Shiklomanov 1993, SEI 1997). They have set a new standard and basis on discussions of global water-related issues.

However, there is still plenty of room for development of these assessments. We argue that they generally suffer from far higher inaccuracies and uncertainties than the reports themselves reveal. This can simply be seen when comparing assessments with one another. Moreover, there is still a plenty of room for increasing their interdisciplinarity, and integration with one another, as has been demonstrated earlier in this report. Such features are mandatory in order to increase their applicability in policy advice and analysis. The importance of global studies is unarguable, but there are still major challenges, which partly are related to approaches and methodologies used.

This section presents an agenda for the analysis of the water and food situation as a global phenomenon, in light of the urbanization process. 45 variables—including development theories (11), driving forces (5), impacts on water and land (5) and on socioeconomy (5), and policy tools (18)—were selected to allow an itemized analysis of interdisciplinary connections. 5 key regions are in a closer scrutiny: (1) China, (2) S Asia, (3) SE Asia, (4) the Nile Basin countries, and (5) the Sahel West Africa. These account for 85% and 68% of the populations of Asia and Africa, and 60% of that of the globe, but a much higher proportion of humans that will face water scarcity, poverty, hunger, and uncontrolled urbanization in the coming few decades. The time horizon to be used is from 1970 to the present, and from the present to 2025. This horizon gives a framework for the analysis of sustainable development and its policy implications, one generation in retrospect and another one to the future.

The present state of the assessment, and the approach which is based on a Bayesian expert judgement elicitation scheme (Kuikka and Varis 1997, Varis and Kuikka 1997) are documented. First, a narrative description of the philosophy of the approach is presented. Then the different phases are summarized (see also Varis 1997a, 1998, and Vakkilainen and Varis 1998a, b).

4.2 On uncertainties and certainties

To know something is a positive thing. The more one knows, the better, given that the knowledge is not overly one-sided. The associative ability to connect issues with one another, detecting analogies and controversies is the more important the more complex issues one is dealing with.

Let us play with the idea that we stated to construct a model of global water, given the myriad interconnections of water to poverty, urbanization, food production, and others that we only can put on paper. We had heard the term sustainability, and understood, that it means we should leave this planet to our kids in a shape that they have no reason to blame us in this respect. Then, after one generation they would do the same to their kids, we hope. From this standpoint, it would be highly interesting to look, how this planet was one generation ago, and what it could be after one generation from now.

We would select a few dozen most significant things that cause changes here—such as population growth, urbanization, climatic change, economy, and industry—and then tried to define the ones impacted by these changes: from ecology, social issues, economy, and so on. This passivity would start to bother us soon; we would brainstorm how things could be driven to the direction we want, to make the world as good as possible after a few decades. We could also recall how politicians, and in fact many other people are enthusiastic in some ideologies in some times and on other ones in some other times. Therefore, we should consider some policy tools and theoretical frames that would make our exercise a more active and attractive one. Then, we would organize the issues under a few titles so, that issues of similar character fall under one single title.

Now, it would be most interesting to brainstorm all the various interconnections of these issues. Naturally, they all can be—and to a certain level are—interconnected. To make this without loosing the track in processing so many connections at the same time, we need a systematic way to do it. We could, e.g., make a table, in which one axis includes all the items, and so does the other axis. In that table, we would fill in—for each interconnection—be it negative or positive, whether it can be ignored, is small, or big.

After this, we would start to think whether there were some more critical regions than all others, regarding water, poverty, hunger, and urbanization. Evidently yes, yet we need some clear criteria for the selection. Given such criteria, we would be able to identify certain regions that deserve a closer look. For that look, we can now use the issues we identified earlier, plus all the knowledge we have on their interconnections.

What we need now is knowledge on the state of the issues in each of the region selected. How should such diverse and uncertain things be presented in a way which could be used to each issue in the same way? Perhaps a good idea would be to set absolute numbers partly aside, and emphasize things as relative to one another, and relative as well as to the state of any of the issues in some specific time slot, as we consider the time to go on in our exercise, years ahead from now. Yes, the present situation could be a good comparison: whether the issue will grow, decrease, stay unchanged. Very few of us could, though, say anything with certainty, but prefer to say on a certain item that it is likely to grow, but there are reasonable chances that it does not change at all, or even goes down. We could take probability distributions to describe all this.

Now that we have wrote down all we know about the issues and their interconnections, it would be most rewarding to see how consistent we are, what are the most critical issues vis-à-vis some other issues, what if we changed something, how the other issues would react, or even what we should say to our politicians and ministries to do to make the world better for the next generation. For that, we would need some sort of apparatus that would help us with all the knowledge we have on desk. Ordinary computer simulation models would not help much: they have only some of the interconnections, and they assume they are known precisely, which would make us very suspicious. They also would appear very restricted, because they look the problem from only one direction—from water, from agriculture, from poverty, from population growth, or from somewhere else—disregarding most of the others, that we considered of being important as well. Ordinary models appear so overly deterministic, yet missing the most interesting things; the associations between issues that do not belong to any single discipline.

We did the job so far mostly by brainstorming, using our own brains. Of course, we were forced to feed the brains with huge piles of books and reports and newspapers and whatever. Now, we would need something—perhaps some artificial intelligence—to help us make the dull work of processing the brainstorming results.

4.3 What would be the key issues

That is tough: they are so many! Having been thinking about them for quite a while, having been sitting and participating in workshops, meetings, conferences, and other types of discussions, having made attempts to get ideas from literature, some of them seem to be the crucial ones. Figure 29 shows those few dozen issues.

This mess still needs some organization to become more clear. There are certain types of issues in play now. First, some theoretical concepts. Then, there are policy-making instruments. Third, we can distinguish a set of positive and negative impacts of development, that influence water, land, and societies. Fourth, some issues that can be controlled only to a very limited extent. Let's call them driving forces. Figure 30 shows these categories, and the issues grouped under the titles, to make things better organized.

4.4 Everything is interconnected with everything

Yet, some interconnections are more important than others. Now, that the variables are there, the interconnection tables or matrices can be produced. The number of variables taken under analysis defines now how much work this stage requires. If there were 2 of them, we would need to define two links: from the first one to the second, and from the second to the first one. If we had 5, the number of links would be 20, if 10, then 90, if 20, then 380 (Figure 31). The formula that can be used in this context for the number of links is $n(n-1)$.

FIGURE 29
SOME IMPORTANT WATER ISSUES IN THE POOR, HUNGRY, AND URBANIZING WORLD

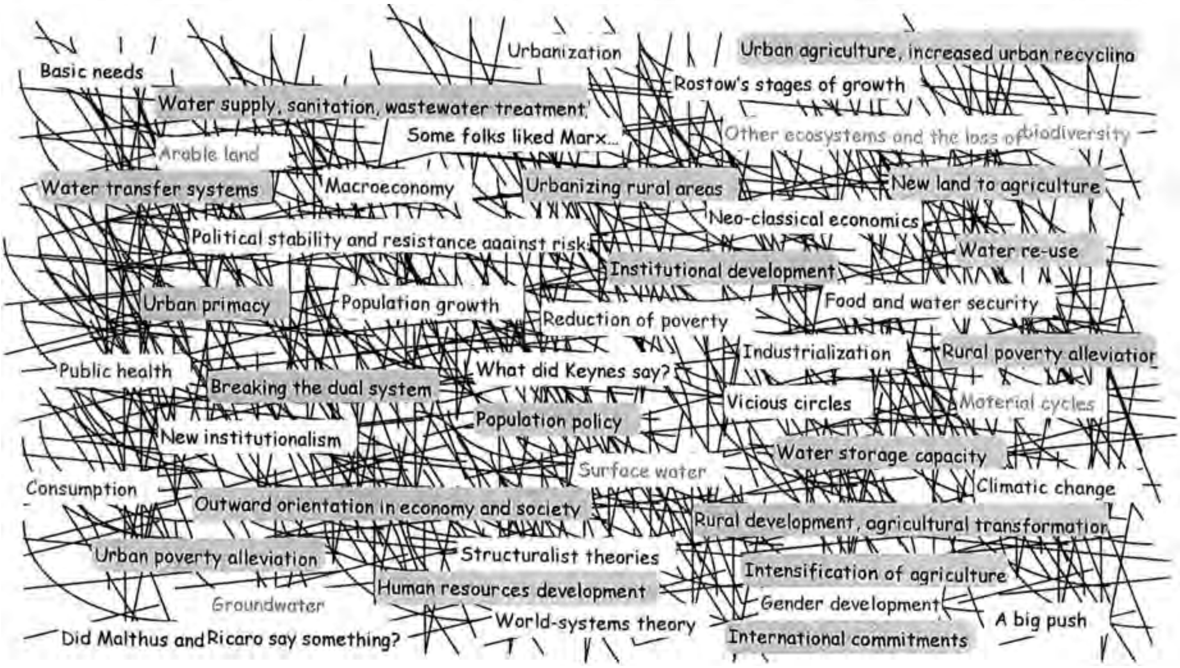


FIGURE 30
THE ISSUES ORGANIZED UNDER FOUR TITLES, AND A FEW SUBTITLES

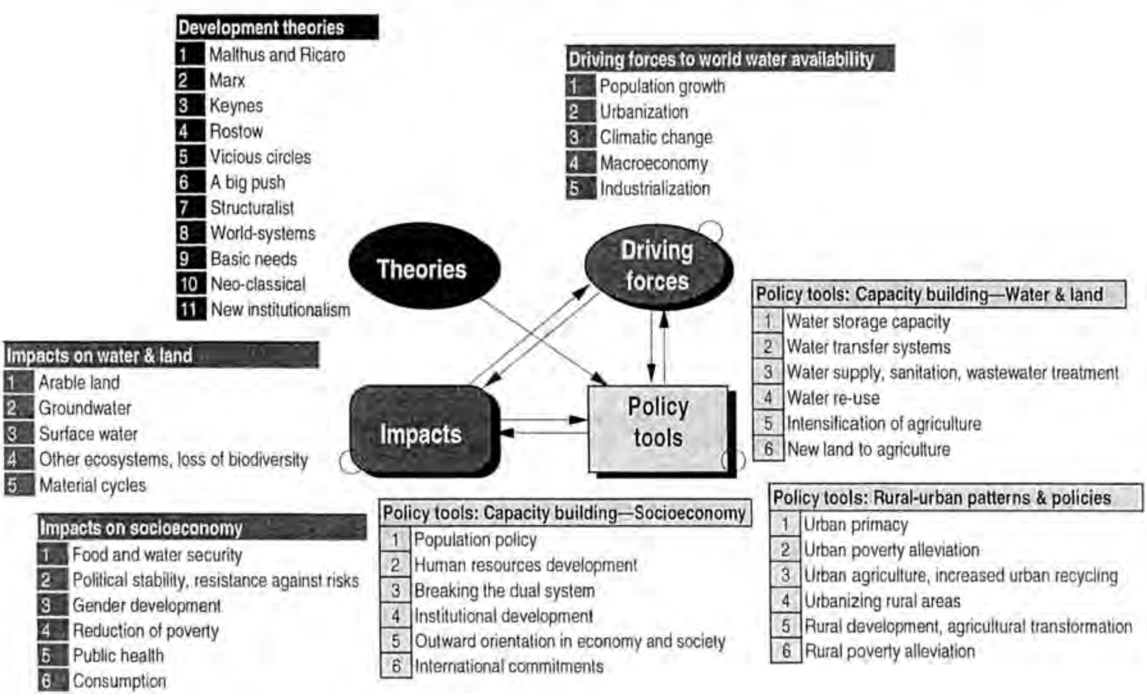
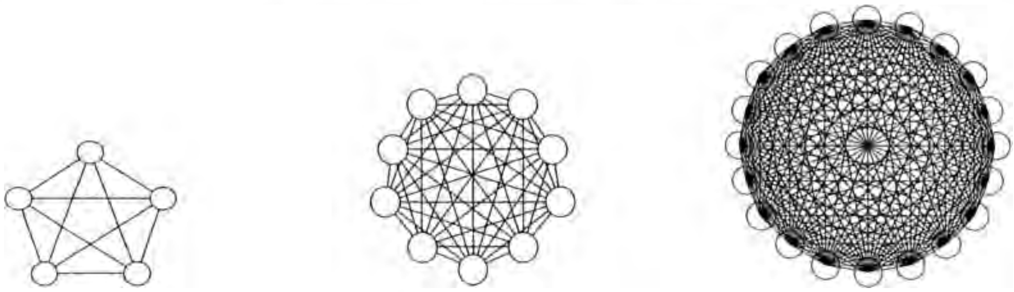


FIGURE 31

AN EXAMPLE OF COMPLEX INTERCONNECTIONS: THE INTERCONNECTIONS BLUR WITH THE GROWING PROBLEM DIMENSION



Now we have 45 variables, and the number of interconnections grows up to 1980. Table 3 shows some selected links, as presented by Varis (1997a). That study contains the link matrices to all possible interconnections, except those in which the development theories are included. Those seem to be so case and region specific, that they have to be considered in a later stage of this work.

TABLE 3

SAMPLE INTERCONNECTIONS: POLICY TOOLS

from v to >		p1	p2	p3	p4	p5	p6	w1	w2	w3	w4	w5	w6	s1	s2	s3	s4	s5	s6
Rural-urban patterns and policies																			
Urban primacy	p1	p1	+*		-	-	-	+	++	+	-*	-	-	+*	+*		+*	+*	
Urb poverty all	p2	+	p2	+	*	*	*		+*	+				++	++	+	+	+*	
Urb agriculture	p3	+*	+	p3	+			++	++	+	++	++	++		+*	+*	+*		
Urb rural areas	p4	-*	+	+*	p4	++	+			+*	-*	+	-*	+*	+	+	+	+*	+*
Rural develop	p5	-*	+*		++	p5	++	+	+	+	+*	++		+	++	+	++	+	+*
Rur poverty all	p6	*	++		+*	++	p6	+*	+*	+		+*	+*	++	++	+	+	+*	
Capacity building: Water and land																			
Water storage	w1	*	*	+*	+*	+*	+*	w1	+	+*	*	++	++	*	*	+*	+	+*	*
Water transfers	w2	*	*	+*	+*	+*	+*	+	w2	+*	-*	++	++	*	*	+*	+	+*	*
Water supply	w3	+*	+*		+*	+*	+*	+*	+	w3	*			+*	*	+*	+	*	+*
Water re-use	w4			+*		+*		-*	-*		w4	+*				+*	+		
Intensific of agr	w5	-*	*	+	+*	++	+*	++	++	-*	*	w5	*	*	*	+*	+	*	*
New land to agr	w6	-	*	+	-*	+*	*	++	++	-*	*	*	w6	*	*	+*	+	*	*
Capacity building: Socioeconomy																			
Population pol	s1	*	+		+	+	+	*	*	*	*	*	*	s1	++	+*	++		+*
Human resourc	s2	*	+	*	+*	+	+	*	*	+	+	+	+*	++	s2	+*	++	+	+*
Breaking dual s	s3	*	++		+*	+	++	+*	+*	++	+*	+	*	+	++	s3	++	*	++
Institutional dev	s4	+*	+	+*	+	+	+	+*	+*	+	+*	+	+*	+*	+	++	s4	+*	+
Outward orient	s5	+*	*	-*	*	*	*	+*	+*	+*	+*	+*	*		+*	+*	+*	s5	+*
Int'l commitm	s6	*	+*				+*	*	*	*	*	*	*	+*	+*	+	+	+	s6
from ^ to >		p1	p2	p3	p4	p5	p6	w1	w2	w3	w4	w5	w6	s1	s2	s3	s4	s5	s6

Legends: + = *positive*, - = *negative*, ** indeterminate, two marks: strong interconnection or combination.*

No [ ] [+] [+*] [++] [-] [-*] [--] [*]

Source: For these and other interconnections, see Varis (1997b)

4.5 Some regions are more critical than others

Due to the above, it is evident that some regions of the globe are more vulnerable than the others and are impacted to a more profound manner of global water, food, poverty, and urbanization development. The following 6 criteria were used to detect the regions, that should be taken under closer scrutiny:

i) Water resources vulnerability and scarcity;

ii) populated in global scale;

iii) population growth is rapid;

iv) urbanization and megacity growth is extensive;

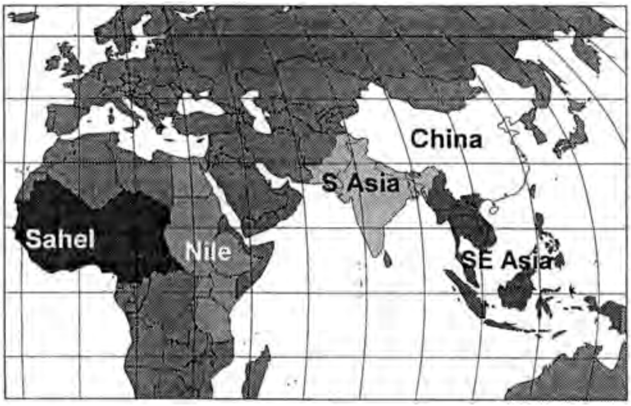
v) low/middle income dominance; and

vi) widely distributed undernourishment or notable grain net importers.

There are 5 regions that completely or nearly fulfil these criteria (Figure 32). Of the world total, they account for 59% of the total population, 80% of urban population, 60% of urbanization, 7% of GNO, 34% of arable land, 48% of cereal production, 57% of irrigated land, and 45% of fertilizer use.

FIGURE 32
THE WORLD'S MACROREGIONS WITH RESPECT TO THE 6 CRITICAL FACTORS. = DOES NOT FULFILL, NO MARK = SOME RISK, + = FULFILLS THE CRITERION

Region	*1*	*2*	*3*	*4*	*5*	*6*
N Europe	—	—	—	—	—	
L and W Europe	+	+	—	—	—	
E Europe			—	—		
Ex-USSR/European	—		—	—		+
N America		+			—	—
C America	+		+	+		
S America	—	+	+			
N Africa, Egypt excl.	+	—	+			+
Nile Basin	+	+	+	+	+	+
Sahel/W Africa	+	+	+	+	+	+
C Africa	—		+	+	+	+
S Africa	+		+	+		
N Asia	—	—				
C Asia, Kazakhstan	+	—	+			+
China	+	+	+	+	+	+
Middle East	+	+	+			+
S Asia	+	+	+	+	+	+
SE Asia	+	+	+	+		+
Japan	+		—	—	—	
Australia and NZ		—		—	—	—
Oceania	—	—		—	—	



Somewhat surprisingly, the following regions were dropped off, including N Africa, C Asia, C America, and Middle East. We do not want to say, that these regions would be well off with water, quite in contrary, but rather we want to draw some of the attention to the following regions, which appear to us crucial to the world-scale water, food, poverty, and urbanization development: China, S Asia, SE Asia, the Nile basin, and the Sahel/W Africa.

The states of the variables listed in Figure 2, as they are assessed to evolve till 2025, are under work still. The probability distributions are defined on the basis of thorough literature survey, data analysis, plus a plenty of expert judgment with interviews is used. The literature survey and the data analysis will produce a monograph, with a chapter of a fact-sheet character on each of the variables. Some databases such as World Bank (1997), and corresponding products by FAO, World Resources Institute (Anon. 1996), UNDP, UNICEF, and some other organizations are systematically used.

4.6 The approach and the analysis

The approach used is based on a probabilistic, Bayesian elicitation scheme:

i) *Fact sheets* for each variable are produced. They will constitute a monograph.

ii) *Cross-impact matrices* (Bayesian likelihood) contain the information on interconnections.

iii) *Assessment of change probabilities* (Bayesian priors) will be assessed for each variable and each region.

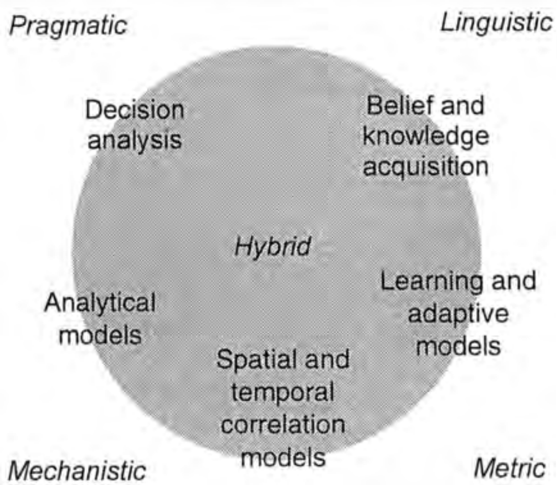
iv) *A Bayesian network* is used to combine and analyse the consistency of the assessment, the unknowns, the knowns, the risks, the threats, and opportunities.

The prior probability distributions and link strengths are connected to a Bayesian belief network, which updates the distribution for each variable using the information from other parts of the net; i.e. in all other priors, and in each interconnection. The updated probability distribution, the posterior, should not diverge too greatly from the prior. If it does, it indicates the presence of inconsistency in the assessment. The inconsistencies may be due to unclear terminology, problems in model structure, and the expert's inconsistency. The last one implies that the expert(s) cannot be consistent in assessing all the attributes and their interactions.

Belief networks belong to the Bayesian family of techniques emerged from artificial intelligence research. Characteristic to them—belief networks, causal networks, Bayesian networks, qualitative Markov networks, influence diagrams, and constraint networks—is the principle of networking nodes (here *variables*) representing conditional, locally updated probabilities (Horwitz et al. 1988, Pearl 1988, Shafer 1990, Szolovits and Pauker 1993). The local updating principle allows construction of large, densely coupled networks without excessive growth in computation. The networks can be constructed to operate interactively and on line. Recently, they have spread to many application areas, including resource and environmental management.

The mathematics of the generalized belief network methodology by Varis (1998) applied in this study are extended from that by Pearl (1988), and allows varied ways to perform integrated analyses (Figure 33). More details of the methodology and its applicability are given by Varis (1995, 1998).

FIGURE 33
BAYESIAN BELIEF NETWORKS ALLOW HYBRID MODELING. THE GENERALIZED BELIEF NETWORK APPROACH (VARIS 1998) FACILITATES THE COMBINED USE OF SEVERAL FACETS OFTEN SEEN AS BEING FAR FROM ONE ANOTHER



The analysis has a diagnostic character. It attempts to detect and examine the following issues in particular:

i) The *most important* variables and variable clusters.

ii) The *relative importances* of different variables.

iii) The key *knowns*, *unknowns*, *threats*, *risks*, and *opportunities*.

iv) *Inconsistencies* in present comprehension of the issues, and in policy recommendations.

v) The *differences* in the roles of those variables *among macroregions*.

vi) Possible, interdisciplinary *cycles and feedback* that are difficult to find without an integrated analysis.

vii) Further *development of the methodology*.

V CONCLUSIONS

The fundamental resources enabling the human life – water and land – are getting increasingly scarce and stressed. Time, money, and political willingness to solve the expanding old and emerging new problems are all very short in comparison to the character and seriousness of the issue. As the world is experiencing tendencies such as trade liberalization, belief on market mechanisms, privatization, decreasing public sectors, and growth of informal sectors, there is a danger that water and land will be considered as economic externalities of infinite availability and/or of marginal weight. This should not happen. Their sustainable management should be taken under most careful concern.

The social function of safe drinking water and secure food supply should not be fully faded away. More attention should be paid to adverse effects of improper resource use, such as damage of overexploitation of water and land, social problems due to pollution and waste accumulation, and costs due to remedy of damaged environment. Institutions such as weak governments, the informal sector, and too far localized or too unregulated markets cannot handle these issues properly. The "full price" for water – a concept that is used increasingly to mean a market price without subsidies – should include also these costs. Otherwise, it is a fake concept: not indeed the full price in long term.

The water consists not only of water supply and sanitation, nor does it consist only on irrigation, hydropower, flood control, waterways, or any single stakeholder use alone. Instead, it must be seen as a part of a continuum of management of natural resources and human societies. Growing cities need more and more food and water, together with other resources. This development increasingly cuts and violates the basic material cycles of the global ecosystem by leaving them open. Huge pollution problems on one end, and massive loss of productive land on the other end, is an alarming symptom of this development.

Holistic views and integrated approaches and comprehension are needed. In the long run, they can possibly most successfully be achieved by providing holistic views in education, at university level in particular. Fragmented, strictly sectorial approach to development of human habitats may create more problems than it can solve, as has been witnessed many times. The importance of improving education – at all levels from primary education to universities – and boosting public awareness on water and environment should be high in any development agenda. All in all, we should try to find solutions that in essence solve more problems than they create.

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