Water for Agriculture vis-à-vis Environment*

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Water is an integral part of man's environment and the extent to which it is abundant or scarce, clean or polluted, beneficial or destructive determines to a very large degree, the extent and quality of life. Although man has been able to modify, to a certain extent, the pattern of availability of fresh water supplies with respect to space and time, the total supply of water neither grows nor diminishes and is believed to be the same now as it was three billion years ago. Thus unlike other natural resources, water is not depleted through consumption, but the per capita availability reduces due to population growth, utilization for various purposes and water pollution. Between 1960 and 1997, per capita availability of freshwater worldwide declined by about 60% and another 50% decrease in per capita availability is projected by the year 2025 (Hinrichsen, 1998). Almost 85 per cent of all the water taken from rivers, lakes, streams and aquifers in India and most of the developing world is used for agriculture (Mohile and Goel, 1996). Water for agriculture (mainly irrigation) extended the agricultural frontier into arid regions, intensified production in low rainfall areas and increased dry season cropping in countries with monsoonal climate. Irrigated land, about 20 per cent of the crop land worldwide, provides 45 per cent of the world's food. Average yield per irrigated hectare is 2.2 times the yield of rain fed agriculture. In the next 25 years, the world will be challenged to produce sufficient food to feed an additional 90 million people each year, as well as to meet increasing and changing food needs resulting from rising incomes (Roelof, 1998). In the past the global irrigated area and annual water use have kept pace. However, the relentless increase in the demand of water for various purposes brought about the population growth, while economic development combined with increasing pollution of water supplies have raised serious problems for the environment.

Because of the uneven distribution of population densities worldwide, water demands already exceed supplies in nearly 80 countries with more than 40% of the world's population (Bennett, 2000). IWMI water scarcity studies (Seckler et. al, 1998) reveal that, by 2025:

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- Nearly one-third of the world's population, some 2.7 billion people will live in regions that will experience severe water scarcity. One third of the population of India (464 million people) will live in regions that will face absolute water scarcity.

- The world's primary water supply will need to increase by 22 per cent to meet the needs of all sectors.

- Seventeen per cent more irrigation water will be needed for the world to feed itself in 2025.

- Groundwater reserves will be increasingly depleted in large areas of the world, more severely in India and China.

- Salinisation of soils, compounded in many cases by increasingly saline or polluted groundwater, will continue to seriously affect land that has been highly productive in recent decades.

- The people most affected by growing water scarcity will continue to be the poor, especially rural poor, and among poor people, women and children will suffer most.

Reliable irrigation is the prominent input essential for green revolution technologies to realize high productivity and serves as the synergy for high yielding varieties, fertilizers, other production inputs and mechanization. Earlier analysis has indicated that water control alone can bridge the gap between potential and actual yields by about 20%. A remarkable achievement of humankind has been the ability to expand food production fast enough to keep pace with population growth. But the cost of this achievement has been a water crisis - a situation marked by water scarcity and competition, pollution and loss of species. Each person is responsible for converting between 2000 to 500 liters of liquid of water to vapour each day just because we have to eat (Molden, 2002). This is because of the biophysical process of evapo-transpiration necessary for the growth of food and feed-producing plants on rain fed and irrigated lands (Rao and Sinha, 1991). The Global Water Partnership concluded: "on the one hand, the fundamental fear of food shortages encourages ever-greater use of water resources for agriculture; on the other hand there is a need to divert water from irrigated food production to other users and to protect the resource and the ecosystem. Many believe this conflict is one of the most critical problems to be tackled in the early 21st century" (Global Water Partnership, Framework for Action, 2000). The challenge, then, is to grow more food with less water and other agro-inputs. This means reducing water use in agriculture to meet other needs and environmental goals, yet growing enough food, and improving livelihoods of the poor. This challenge requires substantial increase in productivity of water in agriculture. Mr. Kofi Annan, UN Secretary General concluded in the Millennium Conference (2000), "We need a Blue Revolution in agriculture that focuses on increasing productivity per unit of water – more crop per drop". How much more water is necessary for agriculture will depend on, amongst other factors, the productivity of water.

There are three basic approaches for improving water productivity in which water can be used to produce more food (Jinendradasa, 2002; Sharma, 2003).

1. **Supply Side**: Develop more infrastructure and more irrigated and rainfed land to supply more water for agriculture.

2. **Conservation:** Reduce wastage and loss of water by agriculture and other sectors.

3. **Unit Productivity of Water**: Increase the productivity of water for each drop consumed by agriculture.

The <u>supply side approach</u> is aimed at improving overall food production by supplying more water for more land. This can be done by large projects such as dams, diversions, and canals, but also by small-scale works like pumps and water harvesting structures. India has already completed more than 200 major irrigation projects and another 150 projects are under different stages of construction. More than 800 medium projects have also been completed. Groundwater now constitutes 54 per cent of the total irrigated area in the country. India has also embarked upon the "National River-Linking Project" – which will be the largest irrigation infrastructure project ever undertaken in the world. It will build 30 links and some 3000 storages to connect 37 Himalayan and Peninsular rivers to form a gigantic South Asian water grid. Initial estimates suggest a staggering cost of US$ 120 billion in order to handle 178 km^3 of inter-basin transfer/ year, build 12,500 km of canals, create 35 Giga watts of hydro-power capacity, add 35 m ha of additional irrigated area and generate substantial navigation and fishery benefits. Even before the Task Force has put its act together, doubts and apprehension, especially on the environmental impacts, are being raised from several quarters. When benefits outweigh costs (which generally may not be true in several of the mega projects), this represents a supply side approach to increase food production using water resources.

<u>The conservation approach</u> focuses on eliminating water losses. Every effort should be placed on conserving the available water resources and eliminating waste and pollution of water supplies by agriculture and other users. Converting wastewater or poor quality waters to productive uses is a means of creating additional water resources and improving the productivity of water supplies to agriculture. In partially-closed and closed basins like Indus, Nile, Amu Darya, Yellow River and Northeast Colorado farmers within the area are responsible for converting more than 80 per cent of supplies to productive evapo-transpiration – a practice that could be considered highly "efficient". The real problem in these areas are threats to agricultural sustainability and ecosystem degradation caused by burning too much water for crop production driven purely by economic necessity (e.g. rice in Punjab and Haryana). Table 1 shows that Punjab, with canals irrigating 14% of the area and tube wells 86%, has 71% of the irrigated area under rice during *kharif*. The area critical water table depth greater than 10m has increased from 3 to 56% of the central zone of the state during two decades of cropping (1973-1994) and the trend continues unabated (Hira, 1996).

Table1. Fall in water table in central zone of Punjab due to groundwater based rice cultivation.

Water table depth	Per cent area during		
	1973	1990	1994
Less than 5 m	37	10	5
5 – 10 m	60	61	39
Greater than 10 m	3	29	56

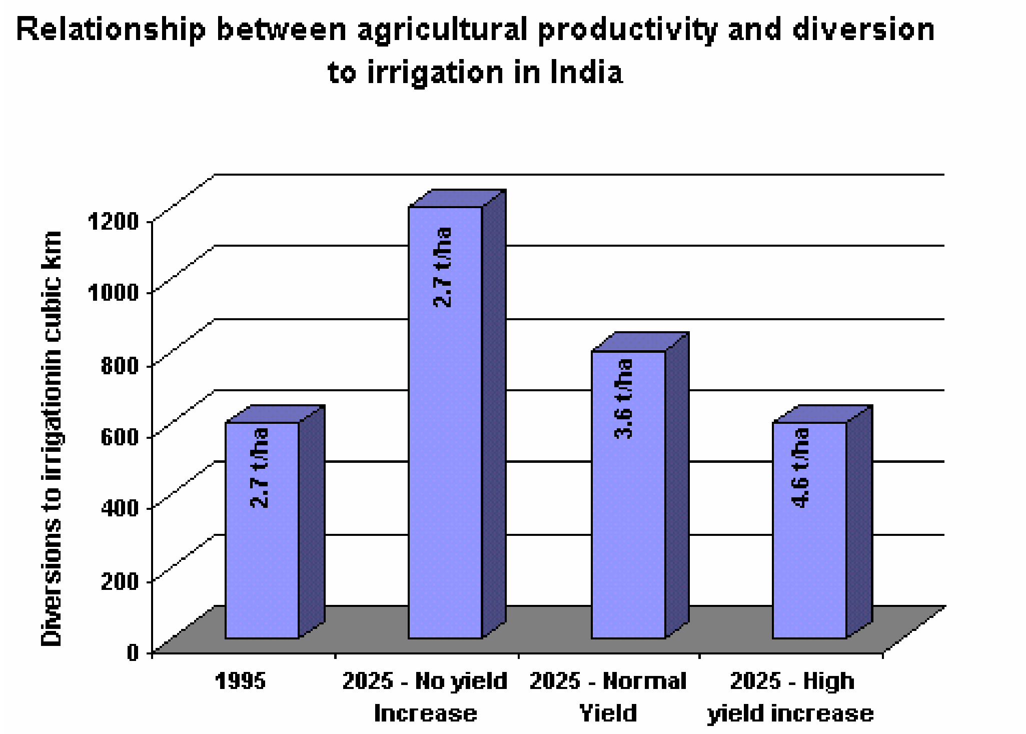
When ill managed, this situation leads to exploitation of non-renewable groundwater resources, mining from important ecosystems, contamination or pollution of the resources and salinity build up. It is alarming how many overstressed agricultural systems are being observed (Molden, 2002).

Under such a scenario of supply side augmentation and resource conservation, the following water management issues become highly relevant for consideration.

I. Improving the Water Productivity:

Producing more food with the same amount of water (more crop per drop) is an alternative to the supply side approach. In highly stressed areas, producing more food with less water may be the only option to ensure food security, and to restore systems so that they can sustain long-term agricultural practices. For farmers with a limited supply of water, improving water productivity is a chance to improve incomes and livelihoods. Considering the productivity of water in more than 40 irrigation systems worldwide, a 10-fold difference in the gross value of output per unit of water consumed by evapo-transpiration was demonstrated. Even under relatively similar environments, the level of management can cause significant changes in water productivity. India's Bhakra irrigation system constitutes a major part of India's breadbasket, and is situated across the border form the Pakistan Punjab. The Imperial Valley, USA is also situated in a desert environment. The wheat yields in these areas vary from 2 to 6 tons per hectare, with a corresponding spread in water productivity form 0.5 to 1.3 kg/m^3 ET. In spite of the variation in environmental, market, soil and other conditions, there appears to be a scope to manage resources to achieve greater productivity.

To illustrate the food, water and productivity links, consider water needs for India in 2025. In 1995, average irrigated grain yields were 2.7 t/ha and about 600 cubic kilometers of water were diverted for irrigation. Considering the growth in population and environment in diet, the diversion requirement in 2025 was calculated for different settings (Fig. 1). If there is no increase in grain yield, India will have to double diversions to irrigation with the risk of environmental damage, on the other hand, if grain yields increased by 70 per cent, no more increases in water diverted to irrigation will be required (Anonymous, 2000). We have to strike a balance between the two approaches. There are a variety of inter-connected paths that can improve the productivity of water including: i) Crop breeding for improved water productivity and abiotic stress tolerance, ii) Improved agronomic and field practices including resource conservation technologies, iii) Low cost supplemental irrigation technologies for rainfed water scarce areas, iv) Improved irrigation management practices and precision/micro irrigation, v) Integrating recycling and reuse into basin and irrigation management, and, vi) Integrated natural resource management within basins.



Increases in water productivity are necessary to solve many of the problems of water crises and environmental requirements but they are not sufficient. It is imperative that these be accompanied with a poverty focus to help the poor reap the grains of increases in water productivity and help in ecosystem restoration.

II. Groundwater Management

Groundwater is accessible to a large number of users. It can provide cheap, convenient, individual supplies, it is generally less capital intensive to develop, and does not depend upon mega water projects. Between 1970 and 1995, the rapid growth of groundwater irrigation in South Asia (India, Pakistan, and Bangladesh, Fig.3) and North

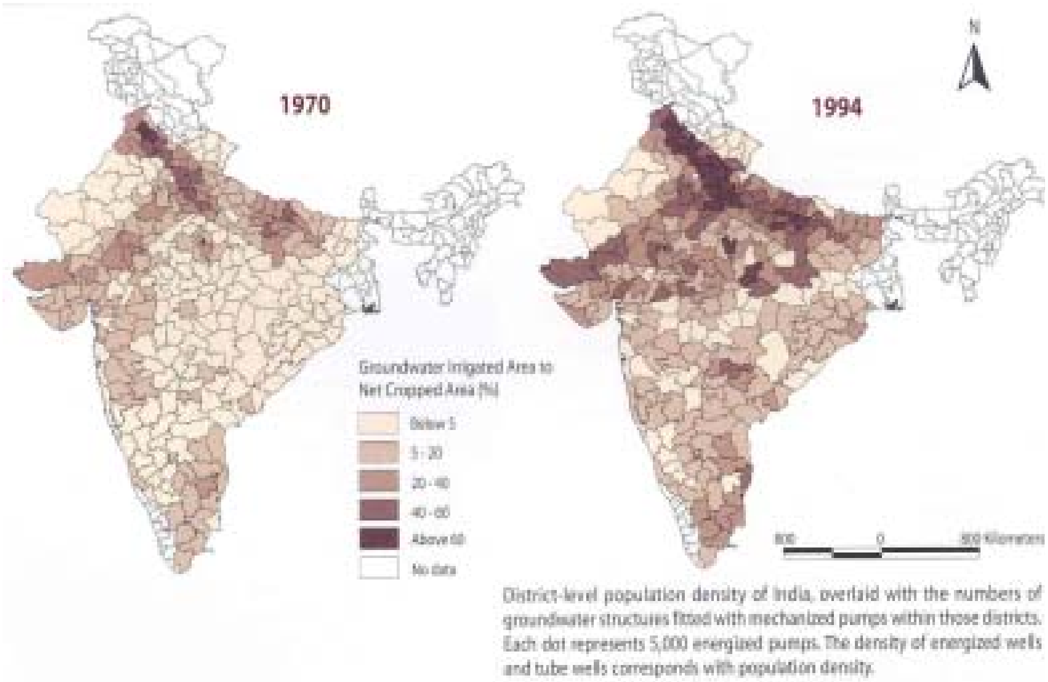


Fig.2.District-wise groundwater development in India during 1970-1994

China plains were at the heart of an agrarian boom. This placed Asia's groundwater socio-ecology under siege (Debroy and Shah, 2002). Groundwater depletion, pollution and water quality deterioration now cause concerns that are fueled by worries about their environmental consequences; the most common symptom is a secular decline in water tables. In western, north-western and peninsular India, over a million wells are added every year and groundwater withdrawal exceeds annual recharge in vast areas that are growing every year. In Punjab, Haryana and Rajasthan, the main consequence was salinity; in hard-rock southern India, it is declining well yields and increasing pumping costs arising from competitive deepening of wells. In West Bengal and Bangladesh, the consequence is arsenic contamination. In coastal areas, the most serious consequence of intensified pumping of groundwater for irrigation is saline ingress into coastal aquifers. All these problems will impair the region's capacity to feed its growing population. Concerns were raised to a level that a quarter of India's harvest may well be at risk from groundwater depletion (Sharma, 2002). It is also true that crop yield/m^3 on groundwater-irrigated farms tends to be 1.2 – 3 times higher than on surface irrigated farms. By far the most serious groundwater challenge facing the world, then, is not in developing the resource but in its sustainable management. Several innovative measures have been suggested for enhancing groundwater recharge in critical areas; these include, i) check dams on natural streams, ii) percolation tanks in hard rock plateau regions, iii) recharge tube wells/shafts, iv) rainwater conservation in paddy fields, v) integrated watershed development, vi) rainwater harvesting from urban areas and, vii) efficient and sustainable use of poor quality groundwater resources.

Lessons learned from a 10-year pilot project in Uttar Pardesh (Upper Ganga Canal System – Lakhoati Branch Canal) indicate a practical and low-cost way to conserve and rejuvenate falling groundwater reserves (IWMI, 2002). Here, monsoon river flows are being channeled through earthen canals to irrigate wet-season crops. Seepage water from canals and fields simultaneously recharges the underlying aquifers. Sakthivadivel (2002) has estimated the following benefits through this innovative groundwater recharge system:

i. 26% increase in average net income per hectare for farmers.
ii. Average depth to groundwater decreased from an average of 12 m below ground level (1988) to an average of 6.5 m (1996).
iii. Annual pumping cost saving of Rs. 180 million (900,000,000 m^3 of water pumped each year).
iv. Annual energy savings of 75.6 million Kwh.
v. Canal irrigated area increased from 1,251 ha (1988) to 37, 108 ha (1996).
vi. Increase in cropped area for rice – 83 ha (1988) to 14, 419 ha (1999) with potential for further 30,000 ha.

Similarly, studies have shown that unused drainage canals can be very conveniently used to help maximize the recharge benefits (Khepar et al., 2000). Excess water not needed for irrigation can be diverted into these unused channels, where check structures slow it for recharge
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Gearing up for groundwater resource management entails at least four important steps: i) information systems and resource planning, ii) demand side management, iii) supply side management, and iv) groundwater management in the river basin context.

Groundwater offers us several precious opportunities for alleviating the misery of the poor, but is poses many daunting challenges of preserving the resource itself. A big part of the answer is massive initiatives to augment groundwater recharge in regions suffering depletion, but, in the ultimate analysis, these cannot work without demand side management and appropriate policy decisions.

III. Rainwater Management

Presently, only about 20% of the world's arable land (260 m ha) is covered under irrigation and the rest 80% depend only on rainfall and are thus prone to seasonal or prolonged water deficits and droughts. The endemic poverty in these regions is probably caused by inadequate availability of water for crop, livestock and other enterprises. However, the shortage of water is not caused by low rainfall as normally perceived but rather by a lack of capacity for sustainable management and use of available rainwater (Sharma, 2001). The most critical challenge is how to deal with the poor distribution of rainwater leading to short periods of too much water and flooding, and long periods of too little water. It is estimated that in much of the semi-arid tropics, the time when it is actually raining is in total about 100 hours per year, out of the 8,760 hours of the year. And even in the "dry" regions, rainwater is often available in abundance during the raining season. The main reason is the practical difficulty posed by the nature of rainfall.

Climate change phenomenon is further accentuating the climate variability. Under climate change scenario, the onset of summer monsoon over India is projected to be delayed and often uncertain. This will have a direct effect on rain fed crops (Watson et al., 1998). The *rabi* rainfall will, however, have larger uncertainty (Table 2).

Table 2.The expected magnitude of change in climatic factors in South Asia by 2010 and 2070 AD due to global warming

Climatic factors	**Rabi**		**Kharif**	
	2010	**2070**	**2010**	**2070**
Temperature increase, C	0.3 to 0.7	1.1 to 4.5	0.1 to 0.3	0.4 to 2.0
Rainfall change in southwest monsoon region, %	0	-10 to + 10	0	0 to +10

The current approach to food security focuses on self-sufficiency at the household level due to dependence of a large population on agriculture. This is a strategic survival mechanism but prevents the people in the rain fed areas from investing in capital resources for rainwater management. As a consequence, there is critically low access to water for agriculture and even lower for drinking and sanitation, and the environment. Poor access to water is therefore among the leading factors hindering sustainable development and accentuating environmental degradation in semi-arid and other rain fed regions.

Approaches to overcome this problem include technologies for enhancing the productivity of water in rain fed production, rainwater harvesting and precision irrigation. Adoption of such practices at the community and watershed levels has produced more significant results than efforts at the individual level.

IV. Water Resources and Environmental Security

While the relationship between agriculture and environment is longstanding, concern continues to heighten over the pressure on the environment exerted by agricultural growth. Water mediated degradation may be manifested through soil erosion and nutrient depletion, water pollution and sedimentation, salt water intrusion, salinization and water logging, river desiccation and affected coastal areas and wetlands.

Development of large water resources and the use of water raise the important issues connected with ecological security. The ecosystems are affected in three ways: the adverse environmental implications of water resource development projects, the drying up of rivers, and the adverse effects of water pollution.

i. Water Resources Development

Several water resources development projects have been stalled by concern over adverse effects on environment and issues such as human rights. In India, Narmada (Sardar Sarovar Project) and Tehri dams and more recently the National River Linking Project have been heading the list. Fierce propaganda has been getting the attention of the media and the intellectuals alike. However, an analysis of 54 projects in India indicates that whereas only 0.217 million hectares of forestland was submerged by the Narmada project, 13.3 m ha of cultivated area was provided with irrigation that provided more bio-mass than that lost through forest submergence. Still, adequate and effective legal and administrative provisions need to be provided in India and other countries to minimize or prevent adverse impacts of development of water resources.

One serious environmental problem caused by irrigation projects is water logging and salinity. Estimates show that 15-25% of the command areas have been affected by these twin problems and considerable areas produce less than potential yields. Necessary steps need to be provided for adequate artificial drainage, restore natural drainage and ensure efficient use of the irrigation water.

ii. Minimum Flows in Rivers

Dams create reservoirs to store monsoon flows to be used during the lean season. Uncontrolled extraction of groundwater and direct pumping from the watercourses have reduced non-monsoon flows in rivers, and dried them up, thereby adversely affecting the river eco-system. Sabarmati in Gujarat, Cauvery in Tamilnadu (India), Amu Darya in Central Asia (Aral Sea Basin), Yellow river in China and scores of other rivers present scenarios when practically no water reaches the sea. Paradoxically, large reservoirs are needed to ensure minimum flows in rivers during the lean season. Integrated river basin management concepts need to be put in place for ensuring efficient use of the river systems in a sustainable and eco-friendly manner.

iii. Water Pollution

Water pollution is a major environmental concern in India and several of other developing countries. The main sources of water pollution are discharge of domestic sewage and industrial effluents, which contain organic pollutants, chemicals and heavy metals and run-off from land-based activities such as agriculture and mining. Intensive use of fertilizers and pesticides in certain crops and regions and run-off form other cultivated areas has been adding to the water bodies a variety of organic and inorganic pollutants causing pollution of rivers, lakes and coastal areas and thus affected the ecosystems.

The data on water quality generated by the Central Pollution Control Board (CPCB) indicated that the mean BO D values have gone up marginally in the 28 major river in India between 1979 and 1997. The quality of water in rivers is generally poor and critical in several cases. The most important source of water pollution is the wastewater generated in the cities and towns. A recent survey revealed that 212 Class I towns generated 12.1 billion liters of waste water per day, which was nearly 10 times the wastewater generated in all the Class II cities put together. In both class I and class II cities, wastewater was mostly disposed of in rivers and agricultural lands.

It may be mentioned that several developing countries including India have enacted strict environmental laws, which prohibit the discharge of pollutants beyond specified standards in the water bodies and lay down penalties for non- compliance. But for various reasons, it has not been possible to enforce these laws on the industries and municipalities with the consequence that these effluents have become a prime source of water pollution.

On the flip side these effluents act as a reliable source of irrigation water for millions of farmers practicing peri-urban agriculture in the vicinity of towns and cities. They are major producers of vegetables, forage crops and other value added agricultural produces. There is an urgent need to devise technologies and practices for the safe use of these poor quality waters, reduce the pollution of river bodies and ensure livelihoods of a large number of peri-urban farmers.

V. Potential Use of Virtual Water

Each person is responsible for converting between 2,000 to 5,000 litres of liquid water to vapor each day just because we have to eat. This is because of the bio-physical process of evapo-transpiration, necessary for the growth of food and feed producing plants on rain-fed and irrigated lands. Each tonne of wheat has about 1000 m^3 of virtual water embedded in it. So with the import and export of 1 tonne of wheat about 1000 tonnes of water is also exchanged from one region to another. Similar, is the case with other food items (Table 3). The concept of virtual water compares the amount of water embodied in a crop that can be purchased from another region/ international market with the amount of water which would be required to produce domestically. It is, therefore, easier and less ecologically destructive to import grain rather than to divert or pipe 1000 times' greater amount of water to produce the same commodity. The states, regions and nations with scarce water resources gain by importing water –intensive commodities, while exporting goods that require less water in production and also save precious water for the preservation of the environment.

Table 3. Estimates of water needed to produce different food items in water scarce regions

Food item	Amount of water needed (m^3 $tonne^{-1}$)
Pulses	1,000
Cereals	1,500
Rice	7,000
Citrus fruit	1,000
Palm oil	2,000
Meat poultry fresh	6,000
Meat sheep fresh	10,000
Meat bovine fresh	20,000

The role of virtual water to save the environment is important in certain regions such as the Middle East and parts of North Africa. The Middle East is the first region in the world that ran out of water. Israel and Palestine also ran out of water by the same time, Jordan in the 1960s, and Egypt in 1970s. In the past some of these countries have attempted to become self-sufficient in food while using their own water resources. Saudi Arabia began to produce sufficient wheat for most of its needs in the mid 1980's and even exported a large amount of water by utilizing its extremely pure but non-renewable fossil water resources. It had very serious repercussions for the hydrological environment and long-term water balances. However, the country had to reduce crop production because it was an un-economic way to use its fossil water. There are certain instances where water starved countries extracted their limited water resources to take a pride of self-sufficiency, which was not hydrologically sustainable and environmentally dangerous.

The hydrological system of water-starved countries/ regions is definitely less and less able to meet the rising demands being placed on it. Do the water starved countries and regions want large scale extraction of groundwater resources for maximum benefit of the present generation, to take a short- term pride of self-sufficiency and a surplus, or a restricted extraction that ensures sustainable development and conservation of the resource base and ensure a healthy environment? Allan (1999) states that since the end of the 1980s, the Middle East and North Africa region has been importing $40x10^6$ tonnes of cereal and flour annually. He reveals that more virtual water flows into the region each year than flows down the Nile into Egypt for agriculture. Paradoxically, in India food surpluses are being produced by utilizing the ever-diminishing groundwater in Punjab, Haryana and western Uttar Pradesh to meet the food requirements of some of the water abundant states. Efforts should be made in water-stressed states/regions /countries that they use good quality water on good soils to produce high-value crops that have low water requirements.

The economics of virtual water involve the opportunity cost of water, which is its value in other uses that may include production of alternative crops or use in municipal, industrial, or recreation activities and preservation of the environment. In particular, the opportunity cost of water use must be considered when seeking an efficient allocation of scarce water resources. Israel- a severely water deficient country that ran out of water nearly half a century ago- has been able to implement a more sustainable water policy. Despite needing up to four times more water than is available, Israel has been able to adopt the virtual water development strategy to balance its water budget through easy access to water that is embedded in cereals imported from water-rich countries. Moreover, trading of virtual water embedded in food and other commodities seems to be a very good political step to achieve peaceful solutions to water conflicts within water deficient countries, and between water-deficient and water-sufficient regions and countries.

Under such a scenario of the water-food-environment nexus, the following pathways to food and environmental security have been suggested by the International Water Management Institute (IWMI, 2003):

- Apply lessons from places where people have halted or reversed environmental degradation.
- Set well-informed priorities through an integrated analysis of problems and solutions.
- Produce a comprehensive assessment of the costs and benefits of irrigation in order to clarify future directions for irrigated agriculture.
- Target appropriate technology development for the food-insecure.
- Develop a policy and institutional environment that enables appropriate use of land and water.
- Encourage more holistic approaches.

Water-food-environment nexus is being increasingly recognized as inseparable from key development targets in the areas of poverty eradication, food security and human health. IWMI is actively contributing to this agenda through its research programs and leadership in the partnership-based CGIAR Challenge Program on Water and Food, the Comprehensive Assessment of Water Management in Agriculture, and the Dialogue on Water, Food and Environment. To follow the progress of these initiatives and track the publications and recommendations as they emerge, point your browsers to: www.waterfoodenvironment.org

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