Water Productivity: Challenges Facing Agricultural development

Changing Paradigm of water use

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Executive Summary:

In the early 1960s, Food security was an over-riding concern in many developing countries. Two main interventions have helped reduce uncertainties and stabilize agricultural production on millions of small farms in developing countries. The first was increased investment in irrigation and to lesser extent drainage, and the second was increased investment in research and development of agricultural production technology.

As irrigation systems were built and short maturing and high yielding varieties became available, farmers were able to cultivate two or three crops a year and increased the production of cereals, oil seeds, and industrial crops. Global Grain production increased from less than 900 million tons in 1965 to more than 2200 million tons in 2000. More than 40% of world grain production comes from irrigated areas which amount to less than 20% of total cultivated areas in the world.

The contribution of the water sector to sustainable agricultural growth is being challenged by increasing scarcity and competition from other sectors. This paper reviews issues related the productivity of the water sector in terms of its contribution to economic growth and national food security which are separate from measuring water productivity at the field level. We may increase crop productivity at the field level through improvement of on-farm water management, better crop husbandry, and advances in irrigation technology. But several water projects have adversely affected the quality of water and contributed to the degradation of aquatic ecosystems. In part, this damage has resulted because piecemeal evaluations of water resource projects have often overlooked the cumulative environmental degradation caused by several projects, and the interactions within the ecosystem have not been adequately considered. Growth of irrigated area is slowing as new systems are costly to develop, existing systems are poorly managed, and there is increasing competition for water use and the escalating demand for water by other sectors.

The review expands the discussion about the contribution of the water sector to include the systemic response to declining water quantity and quality at the macro level and the impact of this trend on national accounting for water and its allocation among competing sectors. The declining water quality and quantity requires that new paradigm of irrigation technology be developed. The new approach should be based on assessing the efficient utilization of low water quality including treated waste water, saline water, and polluted water for environmental protection, agriculture, forests, and landscape.

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Introduction:

Development and expansion of irrigation in the last 30 years has been concentrated in areas of high population density and high population growth in most developing countries. Where population density was low but population growth was high, agriculture expanded mainly by bringing new lands into cultivation. Yet this horizontal expansion was minor compared to the vertical expansion brought about by improvement in agricultural technology and irrigation. The vertical intensification, mainly in wheat and rice production, that began in the late 1960s has been called the "Green Revolution". Expansion of irrigation was instrumental in setting the green revolution in motion. Thanks to building dams and developing irrigation, the devastating impact of repeated droughts and failure of the seasonal rains have been brought under reasonable management systems. Some countries have been successful participants in this remarkable process of change and have thus achieved stable food production and remarkable growth in the agricultural sector (Table 1).

Table 1. Food Produced from Irrigated land

Region	% Food produced from irrigated land
Asia	60
China	65
India	70
Pakistan	80
Indonesia	50
Central Asia	45
Malaysia	60
Bangladesh	40
Middle East &North Africa	33
Egypt	98
Iran	50
Sub-Saharan Africa	9

Source: Wallingford 1997.

Water can produce more food:

Irrigation infrastructure provides a means to better manage water—the critical natural resource for agriculture. For millennia communities have harvested water using community-based irrigation systems dependent on simple but efficient technologies. Irrigation is an insurance against drought or failure of the monsoon and allows countries to sustain food production, achieve food self-sufficiency, and diversify cropping systems to respond to new market opportunities. Michael Lipton (Lipton 2004) summarized the benefit of irrigation because it increases agricultural production by: a) expanding cultivated areas, b) allowing for more intensive cropping, c) permitting adoption of modern varieties, and d) reducing risk of drought and crop failure thus allowing increased investment in other inputs. More than 40 percent of world grain is produced on irrigated areas, which account for less than 20 percent of total cultivated area

The Technical Advisory Committee of the Consultative Group on International Agricultural research (CGIAR 1998) estimated that the average annual value of all crop production in developing countries for the years 1987-1989 was $364 billion. Of this, $104 billion worth of crops or 28.5% was produced on irrigated land A simple cost benefit analysis of investment in irrigation would confirm that such option has its rewards. A study conducted to evaluate the performance of 192 World Bank (Carruthers 1996)–funded irrigated projects implemented between 1950 and 1993, concluded that 67% received an overall satisfactory rating with an average internal rate of return (IRR) of 15% at evaluation This average is quit high given the large initial investment required in irrigation. When irrigation projects were weighted by area served, the average evaluation IRR increased to 25%.

Irrigation may take many different forms from large dams and canals to small systems of shallow tube well, to pressurized small sprinkler and drip irrigation systems. There are different management systems in irrigation: large-scale farming which is usually developed along the major river basins downstream from dams. Most large schemes have an ancient history of development. Many schemes have combination of public and private land ownership. Several large-scale, fully irrigated schemes have emerged in recent years that are privately financed, owned and operated. There are millions of small scale-irrigation, found scattered in small areas throughout developing countries.

Areas under irrigation have increased by 4.5 million hectares annually through out the 1970s. The rate of growth declined to less than 2 million hectares since the mid 1980s. More recent data indicate that annual global expansion of irrigation is less than 1.5 million hectares in the 1990sIrrigation investment over the past 30 years has had major impact, increasing global irrigated area to 271 million hectares by 2000, more than double the area irrigated in 1961 (IWMI 2008)[2]. Horizontal expansion of irrigated area accounted for about eight percent of the increase in world cereal production and facilitated much of the additional increase from intensification of production systems (Barghouti 1999). However, growth of irrigated area is slowing as new systems are costly to develop, existing systems are poorly managed, and there is increasing competition for water use, and the escalating demand for water by other sectors

[2] IWMI 2008 web site states that 271.6 million hectares of agricultural land was equipped with irrigation infrastructure . About 68% of the area equipped for irrigation is located in Asia, 17% in America, 9% in Europe, 5% in Africa and 1% in Oceania. The largest contiguous areas of high irrigation density are found in North India and Pakistan along the rivers Ganges and Indus, in the Hai He, Huang He and Yangtze basins in China, along the Nile river in Egypt and Sudan, in the Mississippi-Missouri river basin and in parts of California. Smaller irrigation areas are spread across almost all populated parts of the world.

World food production has grown rapidly since the 1950s, and famines, though unfortunately still occurring, are localized. Total world cereal production, representing a major share of the world's staple food supplies, increased from 0.92 billion tons per year (1961-63) to 2.07 billion tons (1998-2000) and per capita cereal production in developing countries increased from 176-.7 kg (1961-63) to 259.8 kg (1998-2000) (FAOSTAT, 2001). However, global data mask significant regional differences, in part because of the dominance of Asia with 54 percent of the world population.

Annual per capita cereal production growth rates have been positive for most regions and time periods over the past 35 years, but are now declining (See Table 2). Per capita production growth was most rapid for the period 1967-82 in most regions, despite the higher population growth rates prevalent of that time. The drop in growth rates of per capita production in the 1990s is likely due in part to the fact that there is little new land to bring into cereal production or under irrigation.

Table 2: Annual per capita cereal production growth rates (percent)

	1967-1982	1982-1990	1990-1997
Latin America	1.0	-2.0	1.9
Sub-Saharan Africa	-1.0	1.2	0.3
West Asia/North Africa	-0.7	0.7	0.0
South Asia	1.1	0.8	0.0
Southeast Asia	1.6	0.7	1.1
East Asia	1.9	1.3	1.0
All Asia	1.6	1.0	0.7
Developed	1.2	0.2	-0.4
Developing	1.1	0.5	0.6

Source: Rosegrant and others 2001.

Cereal food consumption in developing countries grew from 282 million tons per year in 1961-63 to 751 million tons in 1996-98, but the rate of growth of cereal demand in developing countries has declined from 3.8 percent (1967-82) to 3.2 percent (1982-90) to 2.8 percent (1990-97) (FAOSTAT). Decline in population growth rates have helped bring down growth in demand for cereals, but still world cereal trade more than doubled from 1967 to 1997 reaching 256.9 million mt. Increasing incomes have spurred meat consumption and demand for grain for livestock feed.

Production increases derive from expanding area under cereal production, expansion of irrigation, and introduction of green-revolution technologies (improved germplasm, chemical fertilizer, and pesticides). However, with limited opportunity for further area expansion, yield increases become the major contributor to the production increases needed to feed the world. Area of cereals harvested per capita actually declined from 0.19 ha. in 1967 to 0.12 ha in 1997, but yield increases have contributed to the decrease in food prices over the last several decades and have been a major benefit to the poor (Rosegrant and others 2001). IFPRI annual reports indicate that the rate of growth of crop yields has declined over the past three decades, though there has been much variability between countries and regions. For developing countries the relatively good performance in Asia was balanced by poor performance in Africa.

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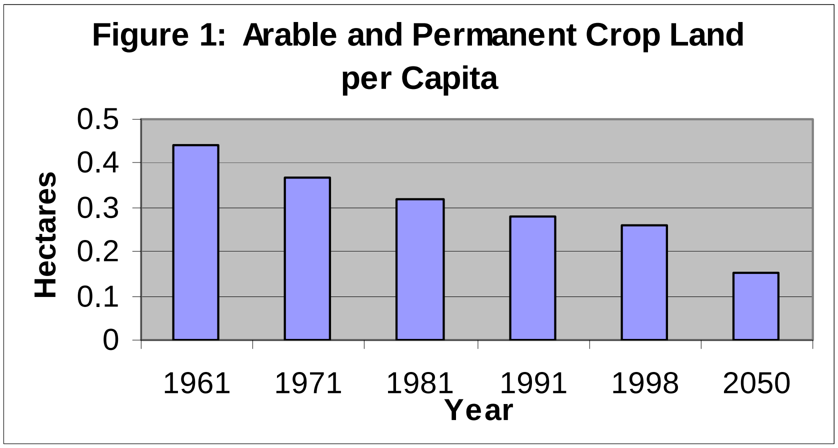


Past yield increases have been due principally to irrigation investments, germplasm improvement, and use of additional production inputs. Slowing rates of yield growth are due in part to the fact that most irrigable land is already irrigated and input use is already high. Improving the management of production inputs, mainly fertilizers and pesticides —especially with pressures from world cereal prices which are rising and may bring relatively poor lands in marginal production regions for cultivation and production—might result in higher profits but may lower yields. Germplasm improvements might also be reaching their limit with traditional breeding approaches.

Table 3: Growth Rate of Crop Yields (percent/year)

	1967-82	1982-90	1990-97
Developing Countries	2.9	2.0	1.9
Developed Countries	1.7	2.2	1.9

Source: Rosegrant and others 2001

In Asia, slowing of yield growth is due to a reduction in level of investment in infrastructure and research, shift to more profitable crops, achievement of high levels of use of modern inputs, resource and environmental constraints, and poor policy environments. In addition, more open trade regimes and declining water resources in several regions could make grain imports more attractive than increasing local production. Recent upward trends in grain prices may affect public investment in agriculture as pressure is mounting to provide affordable rice and wheat to millions of poor households in South and East Asia.

Latin America has seen rapid growth in cereal yields in the 1990s after a period of stagnation in the 1980s because of unsustainable macro-economic policies. Adoption of new technologies has been rapid, especially in the 1990s, but declines in investment in public research and extension, bode ill for the future, especially since the large farm sector in Argentina and Brazil was the major source of past yield increases. Recent changes in world process and the increasing support to use crops for bio fuel has attracted investment in both research and irrigation and may shift the balance toward increasing commercialization of crop production with strong subsidies to divert more crops to fuel production than food.

Table 4: Cereal yield growth rates by region (percent/year)

	1967-1982	1982-1990	1990-1997
South Asia	2.7	3.1	2.1
Southeast Asia	3.0	1.9	1.8
East Asia	3.9	2.7	2.2
Latin America	2.5	0.8	3.4
Sub-Saharan Africa	1.5	-0.2	0.3
West Asia/North Africa	1.7	2.3	2.4

Source: Rosegrant and others 2001.

<u>But not at the expense of the environment</u>:

No where has the impact of irrigation been greater than in South and East Asia where most of the countries of the region have managed to feed their people despite increasing population and the frequent recurrence of the familiar cycles of dry and wet monsoon. The impact of the green revolution is at risk and the contribution of the water sector to sustainable agricultural growth is being challenged by increasing scarcity and declining water quality.

More recently food situation has changed. The New York Times (March 28, 2008) and several papers highlighted the news about food shortages in different parts of the world. "Rising prices and a growing fear of scarcity have prompted some of the world's largest rice producers to announce drastic limits on the amount of rice they export. The price of rice, a staple in the diets of nearly half the world's population, has almost doubled on international markets in the last three months. That has pinched the budgets of millions of poor Asians and raised fears of civil unrest Shortages and high prices for all kinds of food have caused tensions and even violence around the world in recent months. Since January, thousands of troops have been deployed in Pakistan to guard trucks carrying wheat and flour.

Protests have erupted in Indonesia over soybean shortages, and China has put price controls on cooking oil, grain, meat, milk and eggs" The paper continues to state that "several factors are contributing to the steep rice in prices. Rising affluence in India and China has increased demand. At the same time, drought and other bad weather have reduced output in Australia and elsewhere. Many rice farmers are turning to more lucrative cash crops, reducing the amount of land devoted to the grain. And urbanization and industrialization have cut into the land and water devoted to rice cultivation.

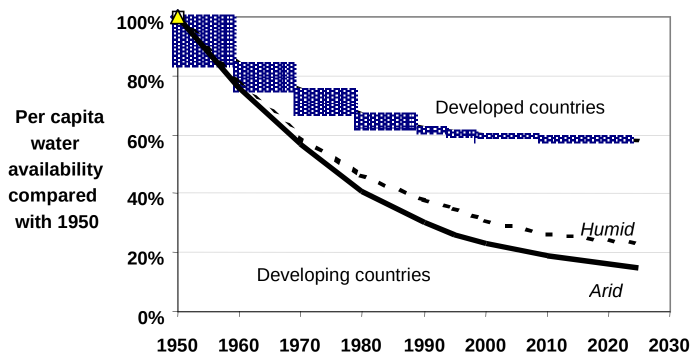
Global population growth has put the global environment under stress with agriculture the greatest user and abuser of the natural resource base. Globally, approximately 16 percent of agricultural soils are degraded with significant negative impacts on food consumption, rural incomes, and national economies (Scherr 1999). The potential to expand cultivated land is nearly exhausted; growing shortages of water require that available water resources be used more efficiently; and forest resources and fish stocks are declining. Agriculture is reaching the limits of available natural resources, as illustrated by the declining per capita water availability (Figure 1).

The deteriorating natural resource base is a concern to producers because of declining productivity, but wider public awareness of environmental issues brings urgency to broader conservation issues—many global in nature, such as global warming, deforestation, loss of biodiversity. Rural environmental issues include: conservation of natural resources—land, water, and forests; conservation of biodiversity and improved protected area management;

pesticide safety and residue minimization; livestock waste management; water quality preservation, and watershed protection. Protecting natural resources and the environment will require sustainable intensification of agriculture and new management strategies for natural resources (Barghouti& Hazel 2000)

In response to these changes, this paper attempts to review growing challenges facing the water sector and its potential contribution to sustainable growth.

Figure 1: Water Availability Continues to Decline in Developing Countries



Source: IEG 1995

Water Accounting: Productivity at the farm level or at the national level:

This paper advances the notion that measuring the productivity of the water sector in terms of its contribution to economic growth and national food security is different from measuring water productivity at field level. We may increase crop productivity at the field level through improvement of on-farm water management, better crop husbandry, and advances in irrigation technology. But many water projects have adversely affected the quality of water and contributed to the degradation of aquatic ecosystems. In part, this damage has resulted because piecemeal evaluations of water resource projects have often overlooked the cumulative environmental degradation caused by several projects, and the interactions within the ecosystem have not been adequately considered. Water pollution could be caused by various contaminants including fertilizers, farm chemicals, urban toxic chemicals, salt, bacteria, and nutrients from livestock, and faulty septic systems as well as natural depositions. The misuse of land, particularly in agriculture, forestry, and mining, has resulted not only the sedimentation of waterways and water pollution but also in poverty, as lands fail and families are forced to relocate, often to overcrowded cities.

Achieving high productivity for the water sector remains a challenge. The poverty of measurements used to assess productivity in terms of efficient management of national water resources beyond agricultural growth (or the delivery of clean drinking water to the households- a different subject not addressed in this paper), should be addressed to include long term impact on the resources. This paper presents several issues that support the need to revisit the relationship between water and agriculture by reviewing the impact of the two pillars: increased irrigation and improved agricultural technology, which triggered the green revolution on the water sector and the risk and challenges facing these two factors. These challenges require that we revisit the interaction between productivity of irrigation in terms of crop production and the contribution of the water sector to sustainable economic development. The review expands the discussion about water contribution from the micro level where crop water use efficiency is measured at the farm level to include the systemic response to declining water quantity and quality at the macro level and the impact of increasing demand for water for non agricultural activities on national accounting for water. There is strong evidence that there is decline in yield improvement of major agricultural commodities. There is also ample evidence that both water quality and quantity are declining which requires that new paradigm of irrigation technology be developed. The new approach should be based on assessing the efficient utilization of low water quality including treated waste water, saline water, and polluted water for environmental protection, agriculture and landscape.

Declining rates of yield improvement requires a new research strategy to complement and sustain the achievements of the green revolution which have been made through advances in breeding and management of main food crops including small grains and legumes and root crops. As we increase the use of non conventional water resources, we need to learn more about non traditional crops and about new ways of measuring productivity. In addition, these factors are being challenged by the increasing concern for climate changes which are likely to affect both water supplies and the performance of major food crops in several regions of the world.

Challenges Ahead:

Productivity of water and irrigation is likely to be affected by several factors. Some of these factors are universal in their influence on the water sector and others are regionally related. The paper will review some of the regional factors and will briefly describe the universal factors affecting water productivity.

I-The Regional Factors that affect water productivity:

a- ***Declining productivity of irrigation systems in the Dry Areas of the Middle East and North Africa (MENA):*** The return on water in many irrigation schemes in several countries in the Middle East and North Africa is low by international standards. Cropping intensities (which are the ratio between irrigated crops areas where double or triple cropping areas are counted twice or three times respectively, and the physical areas equipped for irrigation) in these countries vary from less than 0.8 to 2.2. . Figures available for some countries show a cropping intensity of 1.66 for Egypt, 1.19 for Syria, 1.15 for Oman, and 1.07 for Jordan. In Saudi Arabia, Bahrain and Kuwait the cropping intensity is reported to be less than 1:00, probably because no cropping is possible in the hot season and in Qatar only 0.66 in 1993 because of water shortages. Analysis of many farm budget data for irrigated projects shows that cropping intensity less that 1:00 is not always economically viable. Low cropping intensity is hardly profitable for small farmers.[3]

Areas with low cropping intensity usually suffer from low water availability, sustain only low productive agriculture, and produce low economic rate of return on irrigated farming. Policy guidelines and appropriate incentives would be needed to encourage farmers in these areas to invest in water saving technology for irrigation, or compensate them as an incentive to exiting irrigated farming altogether. This change may cause more efficient use of water in other sectors. In most countries, the issue of rehabilitation and modernization is becoming increasingly important because of shortage of suitable arable land and water scarcity. Also, increasing competition among sectors using water is urging water users to adopt new water and crop technology to suit changes in the quality and quantity of water being allocated to agriculture.

Several countries, especially Tunisia, Morocco, Algeria, Jordan, Israel and Yemen, and to some extent Egypt, Saudi Arabia and Syria, have been encouraging farmers to adopt modern irrigation technology systems (World Bank 2007). Such systems have expanded opportunities to enhance agricultural production, and at the same time increase water use efficiency, and reduce field level water losses. Traditional irrigation technologies (furrow, border, and flood irrigation) which involve water delivery to plants through gravitation have usually resulted in substantial water losses and limited uniformity in water distribution, have been replaced, only in some areas, by modern irrigation technologies particularly sprinkler and drip irrigation to increase water use efficiency.

Egypt has demonstrated successful use of modern irrigation system on newly developed lands in the Western Delta and other areas which cover more than 13 percent of the irrigated land in the country. Improved production and irrigation technology, including the latest in crop breeding, plastic culture and protected greenhouses, fertigation and pressurized irrigation delivery systems of low volume but high frequency, have permitted rapid change in the newly developed lands. But these technologies are being adopted only slowly in the old lands which constitute more than 87% of country's total irrigated areas. The success of modern technology in Egypt may pave the way for wider adoption throughout the country, thus converting Egypt irrigated lands to become among the most modern and productive in the world. This possibility could also allow for substantial conservation in water resources. The challenge is likely to be in mobilizing large financial resources needed for this desirable development prospect, and would require significant changes in water pricing regimes and the construction of modern water delivery and metering systems.

These new systems have opened greater opportunities to cultivate soils with low water-holding capacity (sandy and rock soils) and to farm low quality lands and steep slopes. This technology has also enabled farmers in regions facing limited water supplies to diversify their production systems, and shift from low-value crops with high water requirements such as grain crops, to high-value crops with lower water requirements such as fruits, vegetables and oil seeds. It has also allowed the use of low-quality (e.g. high saline and treated wastewater) water in regions with high temperatures and high evaporation rates.

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[3] Data on cropping intensity are available in FAO statistics data base, (**www.fao.org/ag/aquastat**). Unfortunately the data are not updated regularly. Cropping intensity in many countries has declined because of water shortages in many irrigation schemes.

The challenge facing these countries is to address the need for better management of the water resources within a comprehensive national development strategy. Investment in modern delivery and services in the water sector should also be enforced by investment in infrastructure (roads), diversification and commercialization of agriculture. Such effort requires strong partnership with the private sector, with financing institutions to provide rural credit, and with the farming communities to implement the fundamental changes needed to improve the performance of water and the dependent irrigated agricultural sub-sector.

Even with measures to contain and better manage demand, and to improve the efficiency of existing systems, new water supplies will be needed for agriculture and urban areas. As mentioned earlier, the lowest cost and most reliable sources of water have already been developed in many countries. The new sources of supply currently being considered have higher financial and environmental costs than those developed earlier. The costs of municipal water supply and irrigation will increase even further when adequate drainage and sanitation facilities are included as essential parts of these investments. For most cities in MENA region the cost of a cubic meter of water provided by "the next project" can be two to three times the cost of current supplies, even before environmental costs are factored in. In this context of intensifying competition for finite or dwindling resources, the principal challenge for policy makers is to determine the optimal allocation of water resources to irrigation, while minimizing the negative environment impact of water use.

In a review of water in the Arabian Peninsula (Al Alawi and Abdulrazzak 1994) the authors argue that, the countries of the Peninsula, especially Saudi Arabia, motivated by achieving the goal of food self sufficiency, have encouraged investment in irrigated agriculture. Successful subsidies and incentive programs have resulted in large scale expansion of farming activities with substantial water requirements. The current water demand for agriculture is more than 22 billion cubic meters, provided mainly from deep aquifers. The authors present data to indicate that deep water aquifer levels are declining, pumping cost are increasing, saltwater intrusion is contaminating the aquifers and causing disturbance of the dynamic equilibrium among aquifers. These factors have led to the abandonment of farm land, decline in agricultural productivity, and increase rural migration.

As water scarcity intensifies, irrigated agriculture and associated reliable food production systems are at risk, unless serious effort and investment is made to modernize irrigation and diversify agriculture. Prevailing irrigated production system in several countries in the Middle East and North Africa would have to undergo serious adjustment process. Because most of these countries would be forced to make adjustment in the agricultural sector to cope with increasing globalization and associated liberalization of trade in agricultural commodities.

The pressure on the irrigated sector is likely to intensify to meet challenges created by water scarcity (World Bank 2004), and the declining role and contribution of the agricultural sector to the national economy. The role of agriculture in the national economy varies from less than 3 percent in the GCC countries to 29 percent in Yemen, but employs a relatively large segment of the labor forces. This adjustment process needs to be carefully planned and implemented within a comprehensive water policy, which also recognizes the importance of incentives in guiding smooth transition in agriculture, and related adjustment in traditional water rights and allocation.

***b- Stagnation of Productivity of irrigation systems in South, Central, and East Asia*:**Substantial irrigated areas are still served by the traditional system especially in Pakistan, Malaysia, Bangladesh, Central Asia, and Indonesia and consume more than 80% of the renewable water resources. Central Asian countries and Pakistan have some of the largest irrigation schemes in the world. In Pakistan, the Indus Basin irrigation system is the largest contiguous irrigation system in the World. Irrigation in these countries expanded at a rate of 1.5-2 percent a year in the period from 1950s to the 1980s. Area expansion has slowed down in the last decade because the development of water resources is reaching its limits. But the irrigation systems suffer from poor maintenance. Water supply has become unreliable in many areas, and tail end farmers suffer from repeated water shortages caused by decaying water infrastructure. As a result yields per hectare have dropped, and the benefits of the green revolution are diminishing. Lack of investment in drainage has caused increased water logging and salinity which in turn, cause further decline in yields, and render large tracts of land barren.[4]

Management of irrigation system is undergoing substantial changes in these countries. Water users associations are being established to better manage community level irrigation systems, and are encouraged to collect fees to recover the cost of operations and maintenance. Decentralized management structure is being introduced and water policies are receiving attention at the highest level of policy makers in the countries. Investment in irrigation has made significant contribution to poverty reduction in the regions. Irrigation increased yields of staple and commercial crops, expanded cropping areas, increased cropping intensity (average number of crops grown per year on the same plot of land), and increased the production of high value crops, which also increased employment. Irrigation also increased the stability of farming systems through the construction of better water storage facilities which helped reduce adverse consequences of repeated droughts. However, expansion of irrigation came at some costs; the most visible and politically sensitive are environmental damage, depletion of water resources, changes in the water table, increase salinity, water logging, and destruction of natural habitats (Rosegrant, 2001).

Several studies conducted on the contribution of irrigation in South and East Asia confirmed the substantial benefits of this investment, and quantified the impact on poverty reduction. Some studies cautioned that irrigation may gave adverse effects on some groups, especially in the possible marginalization of the landless and the poor farmers in rainfed areas. The studies also warned that the benefits from irrigation may accrue more to large landlords, and that small farmers may be deprived from equitable market share of commodities produced under irrigation. Studies on irrigation in Malaysia and Indonesia reported significant improvement in water management which allowed for increased diversification of production systems beyond staple food to high value crops (Barghouti, 2004).

Irrigation is still essential for growth, poverty reduction and increased productivity in most countries in East and South Asia. A recent study by IFPRI to examine water allocation of

[4] For detailed analysis of the irrigation sector in Pakistan see Rashid Faruqee, 1999, “Strategic Reforms for Agricultural Growth in Pakistan”. Faruqee argues that the sector suffers from rigid system design, inadequate drainage, low delivery efficiency, inequitable distribution, increased water logging and salinity, and over exploitation of groundwater in Pakistan. For detailed analysis of irrigation in Central Asia see Bucknall and others, 2003, “Irrigation in Central Asia”. The analysis concluded that the impact of irrigation on poverty reduction is significant. This contribution is at risk because of the serious decay in the system. The cost of rehabilitation is beyond d the resources available to the countries. Foreign assistance is urgently needed.

the Brantas River in Indonesia, analyzed a wide variety of economic, institutional, and hydrologic factors, farmers production decisions, food production, urban and industrial water demand, and resource degradation. The study also examined the potential benefits and impacts of different national-level macroeconomic policies, and the implications of alternative water management regimes. The study found out that national level crop input and output price policies have major effects on water allocation at the basin level. Public investment in irrigation accounted for 23 percent of the increase in agricultural output between 1985 and 2000, making it the single most important source of output growth. Private irrigation pumps accounted for 6 percent more growth. The study concluded that a good case exists for resuming investment in irrigation in Indonesia where public financing for irrigation has declined in recent years. Such investment should be balanced between physical infrastructure and irrigation management reform, with increasing emphasis on the latter. (IFPRI, 2004).

Several studies conducted in the South and East Asia Regions agree that the impact of irrigation on poverty reduction has been significant, especially where investment in irrigation was also complemented by supportive research on modern crop varieties, adequate farm input such as improved seeds and fertilizers, and supportive local research. These benefits were quantified in the following areas: i) increase productivity. All irrigated crops produce higher yields, and irrigation allows for multiple cropping, thus increase land and labor productivity. ii) The second impact is on employment. Construction of irrigation infrastructure usually provides work opportunities to landless and rural poor households. Also improved productivity as a result of irrigation stimulates demand for additional farm labor and allows for longer seasonal employment because of increased cropping seasons. iii) The third is increase food supplies which may result in lower food prices. The experiences from Pakistan, Bangladesh, Malaysia, and Indonesia confirm that the poor befitted directly from increased the production of staples, especially rice. The share of expenditure tends to fall among rural and poor households as a result of increased food supply at lower process. iv) Another important benefit is that irrigation increases the security of farming. While rainfed crops may fail, irrigation acts as a buffer against drought years and poor seasonal variation in rainfall.[5]

Currently most of the traditional gravity irrigation systems which provide water to more than 94% of all irrigated lands in these countries are based on conveyance of water in unlined canals and on running water freely over the land surface. The farm level water efficiency of these systems is less than 50 percent. Most of the irrigation systems in Pakistan, Bangladesh, and Indonesia suffer from low efficiency on the field level. New irrigation techniques, by which water is delivered in closed conduits and applied in small quantities at high frequency directly to the plant at a controlled rate, can improve water use efficiency. These new systems offer greatest opportunities for conservation of water. For example, the total water requirement for one hectare of cotton would be reduced by one half and the yields would be much higher. They also increase flexibility in agricultural

[5] For detailed analysis of the impact of irrigation on poverty see the analysis provided by Rosegrant and others (2002) in World Water and Food to 2025. Also see Lipton and others, draft 2004 “The Impact of Irrigation on Poverty”. Also see Faruqee (1999) on the impact of irrigated agriculture on food production and poverty reduction in Pakistan

diversification into high value crops, and for reducing run off, water logging, and land degradation.

Warning signs, however, suggest that growth in food production has begun to lag. According to IFPRI, rises in food production did not keep pace with population growth in more than 50 developing countries, in the 1980s and early 1990s. The rate of growth of global grain production dropped from three percent in the 1970s to 1.3 percent in the 1990s, and the amount of grain produced per person has fallen in the past decade. Growth rates in yields of rice and wheat have begun to stagnate in Asia (including Indonesia, Malaysia, Pakistan, and Bangladesh, as major producers). A long-term decline in rice yields can be attributed to the combined effects of increased pest pressure, the rapid depletion of soil micronutrients, changes in soil chemistry induced by intensive cropping, and increase reliance on low quality irrigation water.

***c- Slow expansion of irrigation in Sub Saharan Africa*:** Agricultural yields have also been level or falling for many crops in many countries of Africa. Significantly, yields of most important food grains, tubers and legumes (maize, millet, sorghum, yams, cassava, groundnuts) in most African countries are no higher today than in 1980. Cereal yields average 1,120 kilograms per hectare, compared with 2300 kilograms per hectare for the world as a whole. Low productivity has seriously eroded the competitiveness of African agricultural products on world markets. Low productivity is the result of low investment in all the factors that contribute to agricultural productivity and effective use of available resources. To correct the problem will require Africa to significantly increase investment in agriculture. This in turn requires that the profitability of agricultural investments be increased and so made more attractive.

The majority of food production systems across Africa are largely based on small farms with low input low output systems except in few cases where maize and wheat are grown under irrigation. Almost all sorghum, millet, all root, tuber, and plantain crops and the majority of food legumes are produced on farms with limited resources (limited water, poor soil fertility, and inadequate mechanization, with little or no fertilizers.). Millions of small farmers in Africa cultivate low yielding food crops in addition to a great number of secondary crops such as coffee, cocoa, cotton, rubber, and fruits and vegetables. A sizable portion of export crops, perhaps even the majority, are produced by small farmers who are also producing food crops under low input crop management systems. For example in Kenya, 65 percent of coffee exports, 40 percent tea exports, and nearly 100 percent of cotton exports are produced by smallholders. Even in Malawi. With its large tea, sugar, and tobacco estates, small holders account for an estimated 65 percent of the value of agricultural exports in the 1990s.

***Options could improve agriculture in Sub Saharan Africa*:** In addition to the above mention food crops, Africa has diversified crop choices including industrial crops such as cotton and rubber, beverage crops such as coffee, tea, cocoa, sugar, and coconut, and high value cropping options including tropical fruits and vegetables, cut flowers, and seed production for vegetable gardens. Improving the performance of the sector would require increasing investment in selected options. Would investment in infrastructure such as irrigation and marketing network for advancing production of grain crops be cost effective? Or should the investment be targeting industrial and high value crops?

African countries have financed little investment to better utilize available water resources for agriculture or water supply. Recent reports by the United Nations Food and Agriculture Organization (FAO200 and (IFPRI 2002) indicate that there are about 15-25 million hectares of land suitable for year around irrigation, but many African countries need assistance and substantial investment to develop these attractive resources over the next decades. But to make investment in irrigation attractive, productivity and yield increases must be achieved and sustained through continued research and successful adoption for diversification of agricultural crops and technology for both food and high value crops.

The case for increasing investment in irrigation in Africa could not follow the Asia experience of the green revolution for several reasons. The scope for large irrigation schemes in Africa is limited. The large schemes such as the Gizera and Managel in Sudan (about 1.3 million hectare of contiguous irrigation), and the Office de Niger in Mali were built in the early 1920s were among the early innovations in irrigation in developing countries. For several decades, they efficiently produced cotton, oil seeds, and food crops. They made substantial contribution to agricultural growth and development in both countries. But these schemes were allowed to deteriorate due to increasing emphasis on food crops, poor operations and maintenance, and because ad hoc management, and intervention by the government failed to modernize the water system and to motivate the farmers to take increasing responsibilities for sustainable operations of the water services. The green revolution in Africa may be enhanced through investment in small scale irrigation accompanied by special focus on the improvement of non food crops especially tropical commodities where Africa can enhance its comparative advantage. African farmers can compete in world markets producing commodities that can not be produced by other regions such beverages (tea, coffee, coco), and industrial crops (rubber and cotton) and other commercial crop commodities suitable for the tropics and semi arid tropics

Priority attention should be given to sustaining the current capacity to improve productivity of agriculture in an environmentally sustainable manner, as well as to increase the capacity to improve the performance of the irrigated agriculture in the region. Better utilization of water for food and increasing productivity of other agricultural commodities is essential for reducing poverty in this region. Can Africa advance its own green revolution by focusing on improving the production of high value crops. Africa needs to focus on these crops to justify the costly investment in both science and technology and irrigation infrastructure? The technology for improving the industrial crops is largely in the domain of the private sector.This trend requires strong partnership with private sector which is different from the experience in other regions. To make investment in irrigation attractive, productivity and yield increases must be achieved and sustained through continued research and successful adoption and dissemination of new agricultural technology.

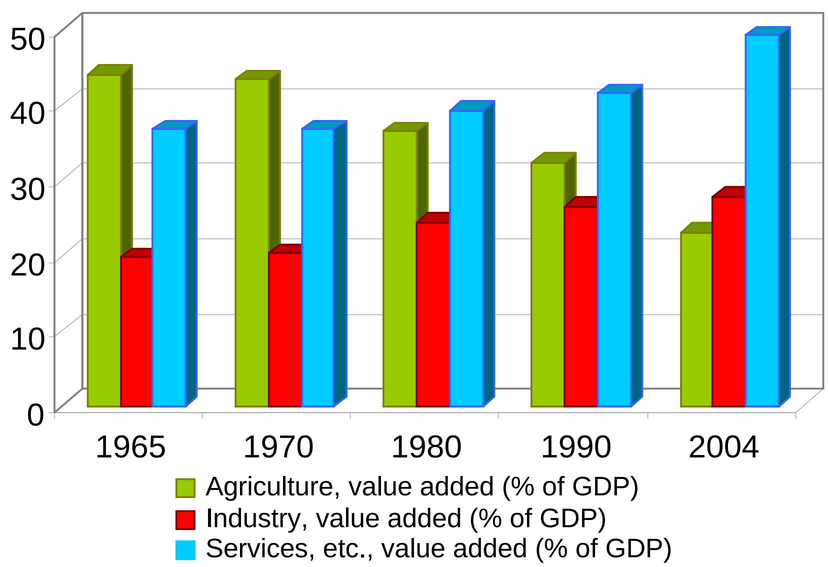
.Better utilization of water for increasing productivity of other agricultural commodities is essential for reducing poverty in this region. Progress in alleviating poverty in Sub Saharan Africa has been relatively slow for many reasons. But a glaring factor is the poor performance of the irrigated agricultural which could accelerate growth and income generation for poor million rural families in SSA. The experience in South and East Asia, where rural poverty has continued to decline in the last two decades, points to the important role agricultural growth played in achieving this progress. South and East Asia allocated significant financial resources for investment in irrigation and were supported by several donors in building dams, irrigation schemes, and strengthen institutions which deal with the water sector. Similar investments are needed in SSA to improve the performance of the water sector with careful selection of suitable cropping systems, for trade and commercialization not necessarily for achieving food self sufficiency.

<u>II- The Universal Factors that affect water productivity:</u>

***a New water resources: scarce, expensive, and unconventional*:**

Some policy makers in several countries are challenging the high water allocation to agriculture because the declining contribution of this sector to the national GDP of many countries. (Chart 2).

GDP Shares: Low-Income Countries



There are several reasons for the decline in the rate of growth of irrigation in developing countries. The most sited factors are diminishing new water resources suitable for irrigation and that most water resources have been developed and the cost of developing new sources for irrigation are beyond the reach of many poor communities.

Many countries are exploring non conventional sources of water including deep water aquifers, at high pumping and transport cost, and others are expanding investment in desalination of seawater. The pressure to reallocate water among different users is likely to intensify in the next decade. Since irrigated agriculture is the main user of these scarce resources, pressure is mounting in several countries in the United States, the Middle East, North Africa, and South Asia, to adjust water allocation to agriculture. The justification is to meet the growing demands of the increasing population, satisfy the expanding urban centers, and supply new industries with water. In addition, more water would have to be allocated to address serious impact on the environment and ecology which have been caused by investments in previous years which ignored allocation of water for environmental protection.

Some countries are searching for a reasonable solution to reducing the allocation of fresh water to agriculture. They are faced with urgent demands from the growing population in both urban and rural communities. Serious political, economic, and social dimensions are shaping the debate on water allocation. The pressure to satisfy the immediate demands may result in hurried reallocation decisions with little attention to the long term implications on the society in both social and economic terms. The debate is intensifying about the efficient use of water and its productivity as determined by the evolution of concept of water use efficiency over the last four decades. This debate has evolved from designing water allocation according to crop water requirements to allocating water "according to crop per drop: and later according to "cash per drop". This debate ignores the pressure to divert water away from agriculture is caused by the increasing demands for expanding sanitation and additional treatments of wastewater.

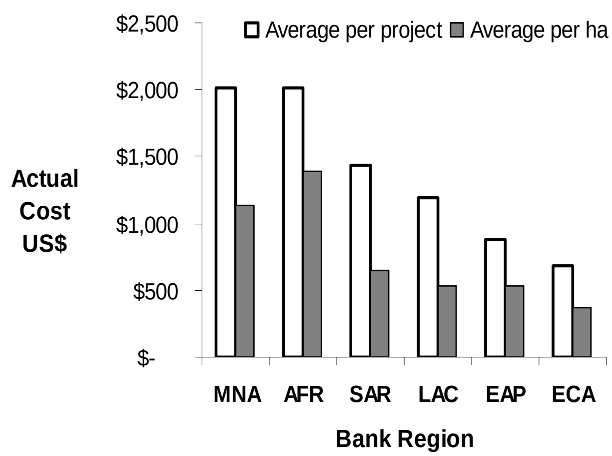
Urbanization and industrialization will also increase the demand for energy and hydropower. These developments pose a great challenge for governments in their effort to better manage water resources to increase food production and to also meet the goals of providing fresh and clean drinking water to millions of poor households in the next decade. The challenges for water supply and sanitation will be to respond to the backlog of demands while meeting the needs of growing population with rising incomes. To adequately address these challenges, these countries need to articulate new water policies, invest more in the water sector and develop new approaches for better water management and allocation.

Public agencies are being pressured to improve the delivery of safe and clean water to the burgeoning rural and urban population. The growth in population in the coming two decades, some 90 percent of which will occur in urban areas, will increase the political pressure to meet these demands especially for domestic and industrial use.

Most suitable and accessible fresh water sources have already been developed. The cost of building new dams and storage reservoirs continues to increase rapidly. The mounting opposition from environmentalists and non government organizations has virtually prevented many governments and international development agencies from financing new dams or reservoirs. The rising cost of new dams combined with increased deteriorations and sedimentation of existing reservoirs, net water storage is stagnant or declining in many countries. Governments do not have the resources to invest in building new water storage facilities. Instead, governments have allowed for expanded exploitation of ground water resources to meet the growing demands for water, especially in the burgeoning urban centers and crowded cities in developing countries. Overdrafting of groundwater resources has intensified in several river basins in many countries. The declining water tables make extraction cost too high.

A recent study by the Asian Development Bank estimated the average tariff charged by water utilities in 38 large Asia cities rose 88 percent between 1993 and 1997. In Amman, Jordan, the average incremental cost from groundwater sources was about $0.41 per cubic meter during the 1980s, but with shortages of groundwater in the 1990s the city began to rely on surface water pumped from a site 40 kilometers away at an average incremental cost of $1.33 per cubic meter (Rosegrant 2002). Several studies in Sub Saharan Africa also confirm this trend. An analysis of incremental cost based on a sample of previous and new water supply projects by the World Bank in SSA indicates that the unit cost of water supply would almost double and some cases increase by three times under new water development projects. In this study, the average incremental cost of new water project in Senegal increased from 0.60 to about $1.80 per cubic meter. The study listed the reasons for the cost increases as more distant sources have been developed, more complex source work and treatment plans were constructed, and lack of flexibility in allocation of lower cost water from other users. (The World Bank, 1995).

In recent studies by the World Bank Independent Evaluation Group (IEG 2006) :" A review of investment in irrigation between 1994-2004" and other studies by IFPRI (2002) and FAO indicate that the average cost of developing one hectare of irrigated land in the period 1967-2003 was about $5,021, ranging from $6,590 for new construction to $2,882 for rehabilitation. There are significant diseconomies of scale as project areas get smaller and thus small scale irrigation may be proportionately more expensive per hectare. An earlier study by the International Food Policy Research Institute (IFPRI) put the cost range between $ 6500-8500 per hectare in Sub Saharan Africa



As the figure from the recent IEG study shows, there is a high regional variation in unit area costs, average project costs per hectare in Middle East and Africa are being about three times more expensive than those in Europe and Central Asia. When average project costs are weighted by area, Africa becomes the most expensive region for irrigation investment followed by Middle East. Irrigation investment in both Africa and the Middle East are two to three times more expensive than the other three regions. The dramatic gains in agricultural output in Asia and Latin America during the last three decades occurred largely in areas with relatively fertile soils, a geology which permitted the wide spread development of irrigation. Based on current cost of developing irrigation in Africa, the cost benefit of irrigated food crops, especially the low value course grains such as sorghum and millet and maize would not justify the costly investment in irrigation in today real price. Modern breeding through genetic improvement and expansion of irrigation were the main pillars of the green revolution in Asia.

Despite the rising cost of developing new water resources, many governments still prefer expanding water supply and investing in infrastructure rather in enhancing demand management and efficient application of water resources. Water users in both industrial and developing countries often pay little for their publicly supplied irrigation water. They have few incentives to refrain from growing water-intensive crops or to conserve water. In some arid areas, water prices are so low that it is attractive to grow low value crops. Similarly, many towns and cities charge fees that provide no incentive to conserve water. A recent review by the World Bank of municipal water supply projects found that the price charged for water cover only about 35 percent of the average cost of supply, and charges in many irrigation systems are much less. The benefits of this cheap water go largely to the middle class and the rich. The poor usually depend on water vendors, and may pay many times more for water than the well off who usually enjoy piped water. It is therefore believed that cross-subsidies whereby the richer customers cover part of the cost of serving the poor can be achieved by incorporating a ‘progressive tariff schedule’, but in practice subsidies are often poorly targeted. (IFPRI 2002).

b- Increase Productivity achieved at high cost to the Environment:

Damage to the eco systems: Irrigation increased sharply as a result of the Green Revolution. But IWMI estimated that yet another 29% increase in irrigated area is needed by 2025 to meet the Millennium Goals for hunger reduction (Rijsberman 2006). Meanwhile the environmental community would like to see irrigation decrease by 8% in order to reduce damage to natural ecosystems, as also committed in global environmental conventions. In addition, more water would have to be allocated to address the serious impact on the environment which has been caused by investments in previous years which ignored allocation of water for environmental protection. Development and increased utilization of water resources have caused severe damage to the environment around the Aral Sea Basin in Central Asia, and the Dead Sea in Jordan. The consequences of the over-extraction of water for irrigation are now becoming clear in both basins. In the Aral Sea Basin, free-for-all diversion and use of the the Amu Darya and Syr Darya rivers, which are shared by five riparian countries, has caused enormous environmental damage. Before the 1960s, the level of the Aral Sea was relatively stable. When the Soviet Union compelled Central Asia to intensify to become a cotton-producing center, irrigation became necessary in the lower reaches of these rivers.

Extensive water diversions have caused the traditional ecosystems of the two deltas to perish. The marshes and wetlands and their rich biodiversity which once covered more than half a million hectares are giving way to sand deserts. More than 50 small lakes across the delta zone have dried up. The Aral Sea itself is drying up; its level has dropped by 17 meters, its water surface by half, and its volume by three-quarters. The adverse impacts include complete loss of the fisheries industry, unemployment for the population living around the Sea, and dust storms and severe respiratory illness emanating from windborne salts from the exposed dry parts of the former sea bed.

The Jordan River is another example of the consequences of over-exploitation of a water resource. After years of diverting water to irrigate thousand of hectares in the neighboring states, the flow of the Jordan River into the Dead Sea is now almost insignificant. The surface area of the Dead Sea was about 1,000 square kilometers before the development of irrigation. Since the diversion of the northern streams that had fed it over millennia, the Sea has fallen over the last three decades by some 20 meters (from 390 to 410 meters below sea level), and its surface area has shrunk to just over 700 square kilometers. The hydrological balance in the valley has been altered. Deep saline groundwater is contaminating water wells, and farmers are facing difficulties in using brackish water for high value, but mostly saline-sensitive crops.

Groundwater pollution: The over-extraction of groundwater beyond safe yield levels has resulted in the pollution of existing groundwater aquifers, due to intrusion of saline seawater and brackish and saline water from lower aquifers. This is particularly serious in Oman, Bahrain and Qatar where major deterioration of shallow groundwater quality has been observed and measured over the last few years. Recovery of the aquifers, even with the introduction of appropriate measures may take generations. The responsibility of the public water agencies is to ensure that these resources are better protected and sustained for future generations. But available scientific knowledge and associated technical skills are limited, and the enabling policy environment is largely restricted.

Salinity*:* Saline waters are often used unintentionally for agriculture because the incoming water has accumulated salts from upstream users. Improved irrigation management requires realistic planning for the capture, reuse and disposal of brine when salt concentrations are too high to be environmentally benign. Unlike organic wastes, of course salts cannot be removed from the soil through microbial action. This makes salts a special class of pollutant that must be considered separately from organic wastes. Salts can be leached down through the soil if the soils can be drained and would require scientifically designed water delivery and drainage systems**.** The large network of irrigation system in Iraq, have caused substantial damage to marshes in the lower reaches of the Euphrates and Tigris. Water logging and salinity have affected about 60 percent of the irrigated areas in Iraq. According to some reports, the total area under irrigation shrank from about 7.5 million hectares in the early 1970s, to about 6 million in the 1980s. Despite its great agricultural potential, Iraq has in the last decade become a net importer of grains to feed its population. Therefore an imperative need has risen to replace the old piecemeal salinity-prone irrigation system. In the early 1990s, Iraq completed the construction of a regional canal (about 565 kilometers long from Mohmudiya, just south of Baghdad, to the Basra “river”. The regional drainage canal is draining the reedy swamps. This large drainage system threatens to destroy an entire ecosystem as well as the way of life of the Marsh Arabs. The impacts pf drainage on the recipient water body (rivers, lakes, groundwater reserves) needs to be considered. Thus, great care and expertise must be applied to implement biosaline agriculture in a sustainable, environmentally safe manner.

Desalination technology has been a boon to water-short countries, enabling the growth of municipal areas. But the desalination process also creates environmental impacts that require proper mitigation. These impacts include the discharge of hot brine into the near-shore marine environment containing residual chlorine, trace metals, volatile liquid hydrocarbons, and anti-foaming and anti-scaling agents. The costs of waste treatment, environmental remediation and environmental impacts should also be factored into economic cost/benefit analyses.

c- Water Productivity and Agricultural Trade: **Will the increasing globalization in agricultural trade associated with the removal of trade barriers and improve wide**

access to competitive markets for importing grains add pressure on policy makers to re allocate water from agriculture to other sectors?

Most countries find that they have insufficient water to grow enough food to feed all their people. By importing food, they are in a sense also importing the water that it took to grow that food. Table 5 shows that this '**virtual water**' is a major water source. The table illustrates the significant volume of virtual water imported as cereals selected regions. West Asia and North Africa imported in 2000/2001 about 118 million tons of food grains (Khan 2003) that are equivalent of the annual flow of the Nile and double of the annual flow of the Euphrates. As the food gap is likely to increase because of population growth and increased income (which would allow for increased and diversified agricultural products including high quality small grains and livestock products. This debate should assess the benefits of various policy options regarding the advantageous aspects of imported food grains. This debate would also require that countries develop long term food security based on proper management of grain stocks and storage facilities, rather than in investing in developing expensive and scarce water resources to increase food.

Table 5: **Imported cereals by regions in year 2000/2001 in virtual water**

Region	Cereal Imported * 000 tons	Equivalent in virtual water** Million cubic meters
West Asia	32, 368	64,736***
North Africa	26, 687	53, 374****
East and Southern Africa	1,645	3,290
West Africa	5,382	10,764
Central Asia	794	1,588
South Asia	2,625	5,250
South East Asia	9,795	19590

Assume that one ton of cereal requires 2000 cubic meters of water. * Equivalent to double the

It may come as a surprise to learn that people consume 70 times more water to grow the food that we eat, than the water we use in our domestic lives (Rijsberman 2006). It takes one cubic meter of water (1,000-2000 liters) to produce a kilogram of cereal grain, and 13 times as much to produce a kilogram of beef under Californian conditions (Rijsberman 2006). A typical Californian consumes more than 5 virtual cubic meters of water daily in the form of water evapotranspired to produce the food eaten.

A recent report by the International Food Policy Research Institute (IFPRI) links global food security to efficient management of water and natural resources. IFPRI forecasts that demand for food grains and livestock products will grow fast in developing countries because of more rapid population and income growth. In the next 30 years, developing countries, according to IFPRI, will increase their total demand for food grains by 75 percent and for livestock products by 155 percent. This appears to be a substantial increase, but because of population growth, demand for food grains per persons is expected to increase by only 11 percent to 266 kilograms in 2020 and for meat by 56 percent to 26 kilograms..

As the world enters the year 2010, food needs are large and expanding and an estimated one billion men, women, and children go hungry. By 2020, food needs in developing countries could increase by 586 million tones—equal to one-third of current world food production (IFPRI 2007). Meanwhile, economic growth, rising incomes, and urbanization are shifting demand from much of the world population to higher-value, higher-quality foodstuffs. The challenge to agricultural productivity is no more starkly evident than in the fact that per capita area for food production will decline from 0.44 ha in 1961 to 0.15 in 2050. Increasing productivity of food systems is essential to avoiding mass famine in the growing population of the developing world

annual flow of the Euphrates, **** Equivalent to the annual flow of the Nile into Egypt.

d- New-Paradigm for increasing water productivity: Increase the utilization of marginal quality water:

As an important commodity water should not be wasted, and should be protected and where possible reused. Substantial volumes of wastewater are generated by both agriculture and municipalities. These marginal-quality waters carry both potential value, and risks to humans and the environment. But our knowledge is limited about effective utilization o f marginal water. We need to invest in applied research to better manage poor water quality. Almost all studies concur in identifying technological innovation as the key element in increasing agricultural productivity. Investment in agricultural research made possible to increase the performance of the agricultural sector through crop improvement and development. Successes of the green revolution and the agricultural productivity increases in developed countries were results of research investments. Much new technology is embedded in production inputs. Crop breeding was the foundation for increased production with use of modern varieties increasing rapidly, especially in irrigated areas with high production potential.

***Future Challenges require expanded water research agenda*:**

Similar effort is needed to enhance research in water issues. Technological innovation flows from agricultural research, which generates new knowledge and which demonstrates consistently high economic rates of return on investment.

The private sector is playing an increasing role in investment in developing , building and operating irrigated schemes on commercial basis. Public investments in developing groundwater resources received some attention, but much groundwater is privately owned. The role of the private sector in developing and managing water resources is taking a new role because of increasing water scarcity in several regions. The private sector is investing in water desalination and in waste water treatment and more recently in the delivery of water services for both drinking and irrigation purposes is several countries. The private sector is also investing in research in water technology and on the efficient delivery of water services. Recent data (OOSKAnews 2008) confirm that the several large international firms are increasing their investment in the water sector in areas related to water pumps, filter treatments, desalination, and production of modern irrigation technologies. This trend requires a new approach toward water management beyond the concern with irrigation technology and crop water use efficiency. Unlike agricultural technology which is ultimately adopted by individual farmers, water technology is usually adopted by public agencies such water agencies, municipalities, and town councils. While extensive research has been carried out on the adoption process by farmers and their communities, little research has been conducted on the adoption process of water technologies. Joint research efforts between the private and public sectors are needed in the following areas:

a-Municipal waters: In most countries drinking water supplies in cities and towns account for 10-15 percent of all water consumed.. In contrast to agriculture, where consumptive losses (evapotranspiration and losses to non-recoverable sinks) average around 50% at the field level, municipalities generally consume only around 10-20% of their water (Rijsberman 2006). This means that a large proportion (80-90%) of municipal wastewater either becomes a disposal problem, or is available for re-use, e.g. in agriculture.

Combining these figures leads to the inference that about 8-9% of fresh water used ends up as municipal wastewater. Much of the wastewater remains untreated; even in the Gulf States, which invest the most in municipal wastewater treatment, approximately 50% of municipal water is discharged untreated. Other countries discharge significantly higher untreated proportions.

On average, only about two percent of current water use comes from treated wastewater (Barghouti et al. 2006). Since most un-treated municipal wastewater is not re-used due to health concerns, it appears that 6-7% of all fresh water used in the region ends up as un-utilized, often un-treated municipal wastewater. It creates a pollution hazard whether it is disposed of in rivers, lakes, or the ocean coastline.

Since populations are growing much more rapidly in urban than in rural areas, municipal users will claim precedence for scarce fresh water supplies in the future. Consequently, these municipal wastewater volumes are expected to grow strongly in the future. Research to enhance its treatment and re-use could make a significant contribution to the region.

For the water-scarce countries, especially those who are meeting their needs by over-exploiting their non-renewable groundwater resources, municipal wastewater could become an important water resource if economically-efficient and environmentally-safe ways are found to re-use it.

Not all pollutants are removed in conventional water treatment processes, and different wastewater sources can carry different pollutants. Insufficiently-understood hazards such as pharmaceuticals, endocrine disrupters, pesticides, pathogens, heavy metals, plant-toxic elements such as boron, high pH, and others need to be studied. ICBA can help acquire, develop and share this knowledge across the region.

Policy and institutional issues are also important for optimizing the re-use of waste water. Standards, guidelines and infrastructure investments will need to be incorporated into government policies for wastewater re-use.

b-Treated wastewater: Secondary sewage treatment has as its objective removal of pathogens from the water, primarily parasitic and bacterial diseases, and the removal of dissolved organic carbon (BOD and COD). However viruses, bacteria, hormones, pharmaceuticals and other insufficiently-understood hazards may still be present after treatment, and occasional operational breakdowns may result in release of pathogenic bacteria. There is extensive research on bacteria but limited information on virus survival and transport and its potential risk to food crops. Monitoring protocols and safety guidelines can be developed once information is obtained on the nature and distribution of these hazards.

Disposal of home-care products and pharmaceuticals by households into the sewage system is a problem with emerging visibility and concern throughout the world. As with other contaminants, detection has occurred due to advances in analytical methods. These chemicals are mostly resistant to existing secondary treatment processes and with new analytical methods are now detected in secondary treated waste water.

Subsurface transport, possible plant uptake and contamination of receiving waters must also be considered. Research in this area should be mostly coordinated with other institutions that have relevant expertise. The proper treatment and monitoring of discharge water quality is essential. The management of treatment facilities must be overseen so that decisions are based on meeting safety standards rather than financial targets.

c-Re-use of municipal wastewater for agriculture: A prime option for the re-use of municipal wastewater is in agriculture. While degraded in some senses, most municipal wastewaters also carry agriculturally-valuable nutrients such as nitrogen and potassium. They are generally of better quality for agricultural use than are saline waters. Wastewater treatment also produces sludge as a byproduct, which contains agriculturally-valuable nutrients and organic matter. Another important benefit of the agricultural use of municipal wastewater is that soil microbes metabolize and thereby detoxify most organic pollutants, greatly reducing damage to the environment compared to the unmanaged disposal of untreated wastewater. Different crops have different susceptibilities to different water contaminants. Low levels of salts actually improve the quality of some fruits. Some crops are tolerant of boron while others are highly susceptible. Crop selection and breeding can play an important role optimizing the agricultural utility of municipal wastewater. Municipal wastewater tends to be of relatively low salinity so it may be utilized on high-value but salt-sensitive fruit, vegetable and tree crops if hazards are fully assessed and mitigated. Irrigation management practices such as buried drip lines, for example can prevent wastewater from contacting the marketable parts of the plant. The possible transport of undesirable compounds from roots into the marketable products needs to be tested and safety confirmed. Secondary treated municipal wastewaters are typically degraded relative to the fresh water supply by increased salinity and especially alkalinity, and thus elevated pH. The increase in salinity is primarily due to increased sodium and chloride concentrations, and the increased alkalinity through the decomposition of organic matter.

These additions all have a potentially adverse impact on water suitability for agriculture. Increased sodium and alkalinity may cause long term deterioration of soil structure and reduced infiltration. Downstream and groundwater impacts of wastewater re-use also need to be carefully assessed. Global knowledge on these topics needs to be validated and tailored to the conditions of the region.

Wastewater may contain elements such as boron in amounts that are harmful to many plant species, or metals that are environmentally hazardous. Part of the solution may lie in appropriate treatment processes, but policies and regulations may also be needed to control the sources of these dangerous pollutants.

A major limitation to the increased use of treated wastewater is that the treatment plants have often been sited adjacent to the sea for ocean disposal. This renders it too costly to transport this water to inland agricultural regions.

e- Salinity from an agricultural wastewater perspective: most arid and semi-arid regions have plenty of brackish and saline water (Suarez, 2003), i.e. water with electrical conductivity (EC) above 2 and 10 deciSiemens/meter (dS/m) respectively. This water is often found close to the soil surface, so pumping it to the surface is not costly. Some cropping systems can tolerate these levels of salinity. Water of up to 11 dS/m is used to grow cotton in Arizona without significant yield loss (Rhodes et al. 1992), and similar reports are described in Tunisia and India (Suarez 2003). Sensitive leguminous crops do experience 20-30% yield losses at these salinity levels, though. Much of the saline water resource in agricultural regions originates from agriculture itself — repeated cycles of irrigation followed by evapotranspiration, leaving salts behind in steadily-increasing concentrations over time. Seawater intrusion also traces its origin partially to agriculture, due to over-pumping of fresh groundwater in coastal areas. Alas, unlike organic wastes, salts tend to significantly reduce crop yields and therefore farm profits, while at the same time requiring more costly, expert management. Greater costs combined with lower returns reduces the profitability and of crop production using saline water. Biosaline agriculture though can contribute importantly to high-value, salt-tolerant crop production; or for species for which productivity is not a high priority, e.g. landscaping plants and plants grown in ecological reserve areas. To make such a contribution, ICBA will continue to strengthen its capacity in genetic resources acquisition and characterization.

Suarez (2003) considers plant breeding for salinity tolerance to hold good potential, even though progress to date has been modest. The new tools of biotechnology might be able to move some halophytic traits into cultivated crops, such as the ability to tolerate ion imbalances, and to sequester salt in the leaves where it does not interfere with root osmoses-regulation.

Careful management helps reduce crop losses to salt. Where fresh water is also available, either as irrigation or as seasonal rainfall, it can be utilized in the sensitive beginning stages to establish the crop, after which the crop becomes much hardier against salinity.

In a recent paper Chris Perry reviewed several studies which indicate that measuring water use efficiency (WUE) requires a new approach and that the old definition of water productivity at the field level is no longer a reliable indicator that could provide guidance for water allocation for crop efficient crop production. WUE is generally defined as the crop yield per unit of water. Since these units vary by water quality, the measurements are no longer reliable nor valid. {Perry concludes his paper that the concept of water use efficiency is outdated. Based on the above, a new way of measuring water productivity is required in order to guide policy decisions regarding investment in the water sector and in allocating water to competing economic activities, guided by strong concern for social and environmental impact of managing the water sector.

e- Research in partnership with users: Several countries have over the last few years, prepared water action plans which also highlight the importance of water in equitable economic growth and in sustained environmental management. Donors have reported that water resources assessment and the reform of water policies and institutions have been carried out or under way in several countries in the last decade. The main features endorsed by this framework are to manage national water resources as integrated system of hydrology and development, introduce decentralization as the basis of management services, and articulate rules and regulations and incentives to increase the participation of stakeholders, the private sector, and local communities in water management. Some countries have encouraged local communities to assume more responsibility, authority and control over improvements and operations of water services and to develop local water resources to meet local needs. Rural communities have also been empowered to address evolving community demands. This partnership would ensure equitable management of water for irrigation and water supply through community action in cooperation with water users and public service institutions. Further work is needed to assess the policy and cultural factors that affect the suitability of expanding the use of marginal quality water for agriculture.

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