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**Keynote Address
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USE OF WATER AND LAND FOR FOOD SECURITY ANDENVIRONMENTAL SUSTAINABILITY

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SYNOPSIS

According to the annual hunger report of the Food and Agriculture Organisation (FAO 2004) hunger and malnutrition cause tremendous human suffering, kill more than five million children every year, and cost developing countries billions of dollars in lost productivity and national income. Whilst steady progress has been made towards food production and achieving improved food security, the stark reality is that 1 in 6 people, or some 850 million people, many of whom are children, are suffering from chronic malnutrition. With only a decade left, the world is falling short of meeting the target of halving this number by 2015 in line with the World Food Summit and MDG goals.

One of the primary causes of the deterioration in the global food security situation is the continuing population growth. With population growth projected to increase by 2 billion in the next 30 years, there will be a need to double global food production by the year 2025. In many countries, the demand and competition for food, water, land and other resources will increase and difficult choices will have to be made about where, how and to whom the limited resources should be allocated. All this will have to be done against a backdrop of decreasing

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available arable land, increasing competition for water, and a growing concern for environmental protection and conservation.

The main thrust to increase food production in the future will have to come from irrigated agriculture, since with irrigation the land can be twice as productive. Hence, by 2030 almost half of the world's food production will have to come from irrigated lands. It is estimated that 17 percent more water will be needed for this purpose. At the same time demand for water from the other sectors will increase and the competition for water will intensify.

This paper will look at the challenges facing irrigated agriculture. As per capita water availability decreases, irrigated agriculture will have to be more efficient in water use as well as more environment friendly in operation and management. There will be pressure on the irrigation community to maximize productivity gains by increasing crop and water productivity. The way forward will be through more efficient and effective water use, and this can be achieved by moving from "more crop per drop" to "more crop less drop". Finally, to minimize the impact of externalities, future efforts will have to be carried out within the context of a holistic and integrated approach.

1. INTRODUCTION

A decade ago, there was an estimated 840 million people including 200 million children suffering from under-nourishment, the majority of which were from the developing world where the per capita food supply was inadequate to meet the threshold average dietary energy supply (DES) of 2,700 calories. As a result, some 25,000 people were dying daily of the consequences of chronic malnutrition. In response to this, the Food and Agriculture Organization (FAO) of the United Nations organized in 1996, a World Food Summit with the objective of renewing global commitment at the highest political level to eliminating hunger and malnutrition and to the achievement of sustainable food security for all people (FAO 1996).

The conference produced two key documents, the Rome Declaration on World Food Security and the World Food Summit Plan of Action. The Rome Declaration called upon the world community to reduce by half the number of chronically under-nourished people by the year 2015 while the Plan of Action spelled out the objectives and actions needed for achieving food security. The issue of hunger was considered so important that in 2000, eradication of extreme poverty and hunger was made the first of eight United Nations Millennium Development Goals (MDG).

How far have we gone towards meeting the target of the World Food Summit? Available statistics do not show a favourable report. In the decade following the Summit, the number of undernourished people in developing countries decreased by only 9 million with population growth wiping out most of the gains achieved in the early part of the decade. Figure 1 shows the trend and Figure 2 gives a breakdown by region.

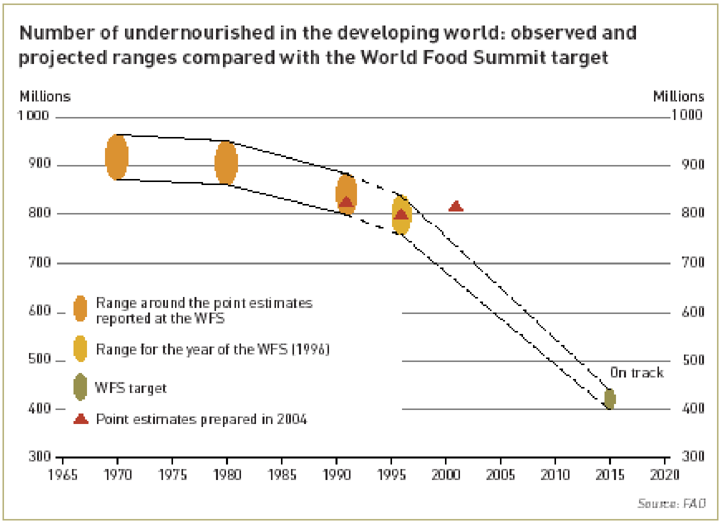

Figure 1. Meeting the World Food Summit Target (FAO 2005)

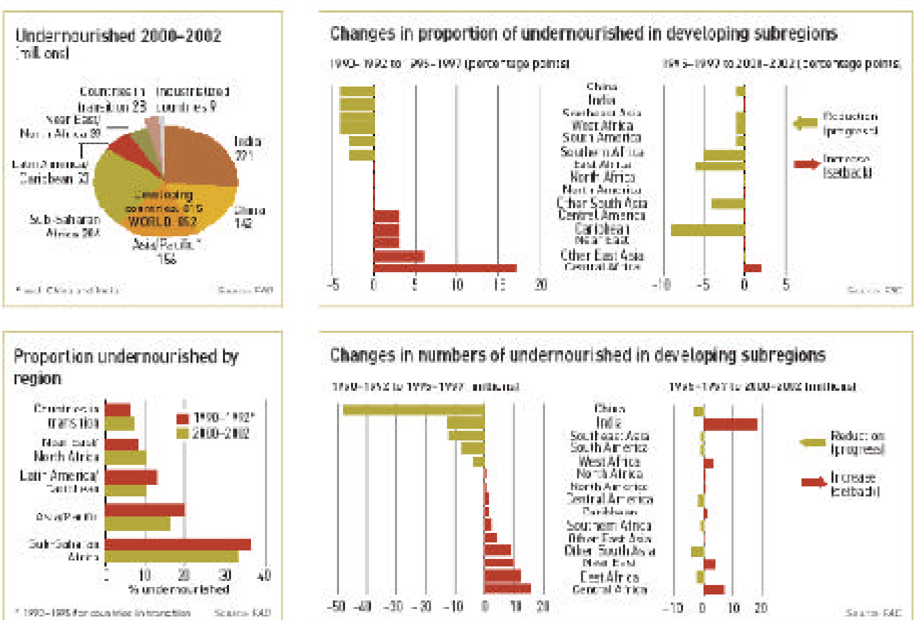

Figure 2. Breakdown by Region (FAO 2005)

One of the primary causes of the deterioration in the global food security situation is the continuing population growth. The population of the world is projected to increase from the present day 6.45 billion to an estimated 7.85 billion by 2025 and 8.92 billion by 2050. At present, 1.2 billion people live below the poverty line and 70 percent of them live in rural areas. At the present rate of population growth, there will be a need to double global food production by the year 2025.

The problem is further exacerbated by losses during and post harvest. A five year survey of grain losses in China's leading cereal-producing provinces found that about 15 percent of the grain crops are lost annually during harvesting, threshing, drying, storage, transport and processing. For rice, this survey found losses of 7 percent in harvesting, 2.5 percent in threshing and drying, 2 percent in transport and 5-11 percent in storage.

Irrigation offers the quickest way of increasing food production, enabling productivity gains through increased yields and increased cropping intensities. Irrigated agriculture occupies less than 20 percent of cultivated land, but produces 40 percent of world food supplies and almost 60 percent of cereal production in the developing world. An adequate water supply is thus a pre-requisite to achieving increases in agricultural yields. However, irrigated agriculture is already the largest user of water, taking 70 percent of total water use. To increase food production, agricultural water withdrawals is anticipated to increase by some 14 percent from 2000 to 2030. This will increase further the competition for water from the other sectors such as domestic and industry water use, leaving even less for nature and the eco-system.

In addition, improper operation and management of irrigation systems can lead to environmental problems while inadequate drainage has led to soil salinization in arid and semi-arid zones. In the humid tropics, recurrent flooding can destroy productive farmlands. Time and again over the past few decades, water related hazards have increased the vulnerability of a country to food shortages.

2. FOOD SECURITY

FAO defines food security as physical, social and economic access for all people to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. The problem of food security can be looked at from various perspectives and levels. On a global basis, sufficient food is being grown to meet the needs of all, though this ability to produce food is not matched by the ability to deliver the food to those in need, or in some cases, the ability to pay for the food. This problem exist to some extent at the local level, even in countries which are largely self sufficient in food production.

At the national level, a country has two broad options for achieving food security, viz. through food self-sufficiency or food self-reliance. Food self-sufficiency is the growing of food needs within the country with minimal or no dependence on food imports, while food self-reliance takes into account the possibilities of importing food to meet any shortfall in production. Under a food self-reliance situation, a country will maintain an acceptable level of domestic food production while building up a capacity to import the balance of food needs by generating wealth through other mechanisms or through exporting other products. However, such a policy is subjected to the supply-demand situation of food trade, and carries with it an element of risk, given that the surplus in global food grain stock is only about 15 percent and therefore there will not be very much reserves available in the event of shortfalls in production due to disasters, natural or otherwise.

At the individual level, food security can be defined as having access to an adequate level of energy intake to meet the body's daily requirements. For an adult, this is in the range of 2,800-3,100 kcal/day. A threshold value of 2,200 kcal/day is generally taken as indicative of a very poor level of food security. In some developed countries, daily intake can be as high as 3,400-3,800 kcal/day, while in many developing countries (excluding Brazil and China where the food supply is relatively good) the average per capita availability is less than 2,500 kcal/day. Again, there can be very wide variations within a country and a good example is China where nearly 200 million people have daily intake in excess of 3,000 kcal/day while some 130 million are struggling to reach 2,500 kcal/day. Thus there is obesity amongst the undernourished.

Notwithstanding this, the costs of not taking immediate and strenuous action to reduce hunger can be staggering. Annually more than 5 million children die from hunger and a child whose physical and mental development is stunted by hunger and malnutrition is likely to earn 5 to 10 percent less over his lifetime than one who is well fed. In economic terms, developing countries lose billions of dollars in lost productivity and earnings. It has been estimated that deaths and disability from hunger will cost developing countries a loss in future productivity with a present discounted value of US$500 billion or more (FAO 2004).

Overall though, most countries have managed to achieve reasonably high levels of food security, sometimes against great odds. Bangladesh in the 1970s could not produce sufficient food for a population of 70 million. However, by 2000, the country was nearly self-sufficient even though its population had since then risen to 130 million. Much of this increase was through productivity gains from irrigated agriculture.

3. THE CHALLENGES AHEAD

As a result of the Green Revolution, irrigated agriculture was able to make significant contributions to reducing poverty and increasing food production especially in the developing countries. The provision of infrastructure (irrigation and drainage facilities, improved transportation systems, etc.) in the agricultural areas have resulted in higher productivity, surplus production and thus increase the nutritional and economic well being of the rural population.

However, there are many challenges ahead which will make meeting the World Food Summit and the MDG targets that much more difficult. Unit costs for new projects continue to spiral, making the returns low. Inadequate operation and maintenance of existing infrastructures has contributed to breakdown in services in some cases failure of the system. There are problems with low efficiency of water use, poor costs recovery, and adverse environmental impacts coming from large scale irrigation projects.

3.1 Population Growth

Population growth is the single most critical obstacle against our efforts to feed the world. In the last thirty years, the world population increased by 3 billion. Over the next thirty years, it will increase by another 2 billion and the following thirty years by another 1 billion. At this rate of population growth, there will be a need to double global food production by the year 2025. By then, the world's urban population would have double from the current 2.5 billion to 5 billion. With urbanization, the demand and competition for food, water, land and other resources will increase and countries will have to make difficult choices about where, how and to whom the limited resources should be allocated.

Meanwhile, with population growth and urbanization of rural areas, the availability of uncultivated fertile land will become a limiting factor, and increasingly farmers will have to move into the marginal lands where the productivity is much lower. The figures for Asia are even more critical. Although Asia has only 24 percent of the land area in the world, it supports 60 percent of the world's population. For the humid zones of Asia, the population density is even higher, with 54 percent of the population living on 14 percent of the land area, thereby making the issue of producing sufficient food for this part of the world even more demanding.

With urbanization and industrialization, the role of agriculture to the national economy will lessen and agriculture's share of GDP and labor force will decline. Invariably agriculture will become less attractive to the labour force and to investors, more so with commodity prices approaching historical lows. Taking the case of a typical developing country like Malaysia, the role of agriculture in the national economy has dropped four fold, from 40 percent of GDP at the time of independence in 1957, to less than 10 percent today. For mature economies like Taiwan, the drop is even more significant, from 35 percent to 1.9 percent though agriculture especially rice cultivation still utilizes 65 percent of the water resources and 30 percent of the land area.

3.2 Water

Water is essential for the survival of all species on earth but it is agriculture that claims the domination share of water abstraction. For humans and animals the basic water needs are relatively small, with the average basic need for man being only 50 litres per person per day, inclusive of 5 litres for drinking. However, the water needed to produce our food is considerably higher, with basic crop water demand of 1000 litres rising to between 2000 to 5000 litres depending on the type of crop. On the other hand, water required for some fibre crops can be much higher (see Table 1).

Table 1. Crop Water Requirement (FAO)

Crop	Typical water requirement (litres/ kilogram of crop)
Cotton	7,000 – 29,000
Rice	3,000 – 5,000
Sugar cane	1,500 – 3,000
Soya	2,000
Wheat	900
Potatoes	500

World-wide, 70 percent of total water use goes towards irrigated agriculture and in many developing countries the portion of agriculture water use is between 85 to 95 percent (see Figure 1). FAO estimates that by 2030 (FAO 2000) irrigated land would have increased by about 45 million ha in developing countries and the resulting water withdrawals for irrigation would have increased by about 14 percent. This will create more competition for water in many countries.

Currently, some 30 countries are considered to be water stressed (where average water availability falls below 1,700 m^3 per capita), 20 of which are deemed to be water scarce (where it falls below 1,000 m^3 per capita) and by the year 2025 the number of water scarce countries will increase to 35 with a combined population of nearly one billion people (see Figure 4).

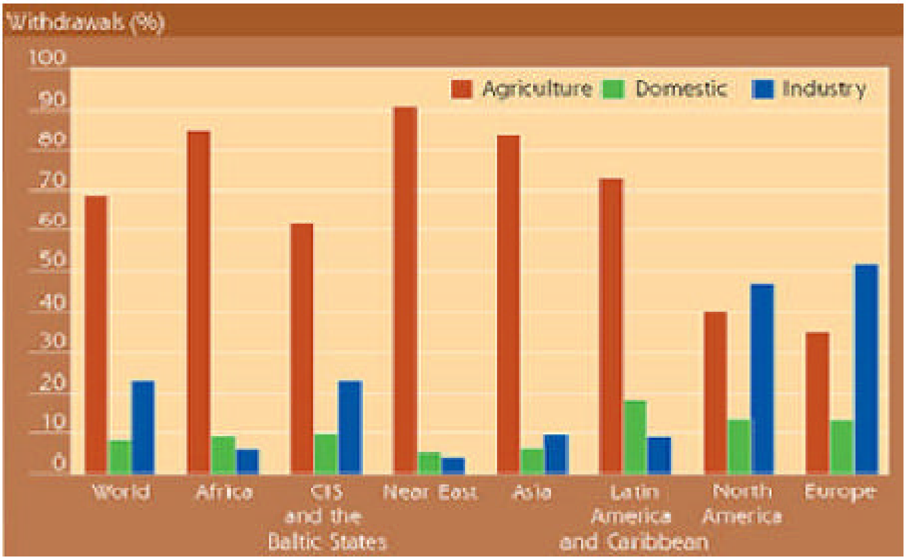

Figure 3. Water Use Distribution (World Bank)

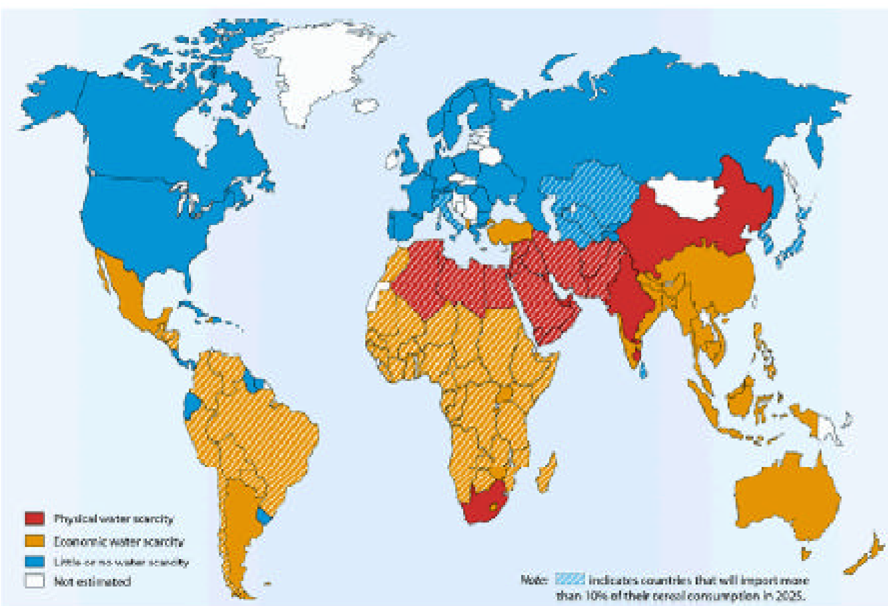

Figure 4. Water Scarce Countries (IWMI)

Equally worrisome is that virtually all developing countries, including even those with adequate water supply, suffer from seasonal and regional shortages. The freely available fresh water supply is getting less, and even this amount is being affected due to pollution. In addition, impending climate change will worsen the situation.

Unfortunately, many countries do not treat water as the scare resource that it is. Adding to the problem is the prevalence of massive subsidies on water use for both urban and rural water users. Irrigation water is almost free in a number of developing countries while in urban areas the price of water often does not even cover the cost of delivery. Many countries subsidise the operation and maintenance of the irrigation water delivery system and this subsidy encourages wasteful use of irrigation water.

Nevertheless, as allocation of water for food production and human use are non-negotiable issues, and water is a finite element, the biggest challenge will be to provide enough water to produce food, especially in regions where water is scarce. Here, the primary opportunity for improving overall water supply will depend to a very large extent on achieving improved water productivity. As irrigated agriculture is the biggest water user, it offers the best opportunity for water savings as even a small incremental increase in water efficiency use will free a comparatively large amount of water for all sectors.

3.3 Land

Next to water, land is one of the two fundamental natural resources required for food production as only some 2 percent of the global food energy and no more than 7 percent of all dietary proteins are sourced from seas, rivers and lakes. About 1.5 billion hectares or 11 percent of the world's total land surface is currently being utilized for agriculture of which some 1.5 million hectares are used for food production. Driven by increasing population and the need to house and feed them, the hunger for land and water has intensified to such an extent that one-third of temperate and tropical forests and one-quarter of natural grasslands have been developed for agriculture. At the same time agriculture land is being converted for urban and industrial use and this process will accelerate over the next two generations of population growth.

To meet the World Food Summit targets, continued expansion of agriculture land will be necessary. For example, there is a need to increase rice production by 40 percent and to achieve this, an additional 9.8 million hectares of land will have to be brought into production. In addition, irrigated agriculture itself is also a significant consumer of arable land as the irrigation systems and infrastructure themselves take up between 5 to 10 percent of the available land.

Since the 1960s, world population has doubled but land for agriculture use has increased by only 12 percent and thus arable land per person has declined from 0.43 hectares in 1962 to 0.26 hectares in 1998 and 0.2 hectares in 2002. There are however, regional differences and while per capita land availability remains high in Latin America and more than adequate in sub-Saharan Africa; the Middle East and South and East Asia are fast approaching the practical limits with little potential arable land left.

Future development of agricultural land will, more and more, be on marginal lands as most of the good lands have already been used up. This will create serious impacts and consequences on the biodiversity, soil quality, quantity and quality of water supply. The encroachment of agriculture into wetlands, catchment areas and hillsides in the past has caused environmental pollution and unprecedented damage to the environment. Effluents from pesticides and fertilizers have caused environmental degradation and contamination to the surface and groundwater supplies. There is hence a need to ensure that our land resources are used wisely for food production without adverse impact to the environment.

3.4 Changes in Diet

Whilst food demand will increase due to population growth, another critical factor will be the changes in dietary habits of people as they earn more and are able to budget more for food purchases and to include more meat into their diets. Also, with education and better employment opportunities, a higher proportion of the female population will become gainfully employed away from the traditional agriculture sector. Households will have higher combined incomes and will not only able to purchase food, but invariably the food is processed and include more meat.

In developed countries where disposable incomes are higher, the annual meat consumption often exceeds a person's body weight (70 to 100 kg/capita), while in most developing countries it is less than 20 kg/capita. However, the developing countries are fast catching up. Armed with greater prosperity, consumption of meat in developing countries has been growing at a rate of about 5 to 6 percent per year and that of milk and dairy products at 3 to 4 percent per year. Statistics on food consumption patterns in China show that annual meat consumption has risen from about 11 kg/capita in 1975 to nearly 50 kg by the end of the 1990s.

A meat-rich diet impacts on both water and land use. In terms of water requirements, a largely vegetarian diet can be produced with as little as 900-1,200 m^3 of water per person per year, while a meat based diet will require well over 2,000 m^3 of water annually. For land, the requirements will depend heavily on the type of diet of the populace and on the intensity of cultivation.

A diet that is overwhelmingly vegetarian based will require no more than 700-800 m^2 of land per capita, while a diet which includes about 15 percent animal foodstuff requires an average of 1,100 m^2 /capita. A western-type diet with its high proportion of meat consumption and dairy products requires up to 4,000 m^2 /capita.

Meanwhile, livestock have to be fed and watered. It is estimated that cereal production will have to be increased by about 1.84 billion tons by the year 2030, but only half of this increase will be for direct food consumption while the balance will go to feed livestock which are then consumed. Water-wise, the production of meat requires between 6 and 20 times more water than for cereals, depending on the feed/meat conversion factor. Table 1 gives the water requirement equivalent of some food products.

Table 2. Water Equivalent (FAO 1997)

Food Product	Unit	Equivalent water, m^3
Cattle	head	4,000
Sheep and goats	head	500
Fresh beef	kg	15
Fresh lamb	kg	10
Fresh poultry	kg	6
Wheat	kg	1
Paddy	kg	5
Rice	kg	2
Citrus fruits	kg	1
Palm oil	kg	2
Pulses, roots, tubers	kg	1

3.5 Investments in Irrigation and Drainage

The Green Revolution of the 1960s introduced high yielding varieties of food crops such as paddy which were capable of increasing productivity gains by 2 to 3 fold. As irrigation provided the enabling water management environment for optimum crop growth for these varieties, many countries in Asia made significant investment in irrigation and drainage infrastructure and the ensuring food production enabled them to reach self-sufficiency or near self-sufficiency in food particularly in rice.

Africa on the other hand was not able to harness the benefits of the Green Revolution as only 6.2 percent of the 12.7 million hectares of arable land in

Africa is irrigated. In addition, this irrigation coverage is highly skewed, being as low as 0.1 to 0.2 percent in countries like Ghana and Uganda to almost 100 percent in Egypt. As a result, Africa has not been able to realize her potential to achieve food security and is still importing some $19 billion of food per year. About 25 countries of Africa are at present food insecure, while the large potential of water resources development remains untapped, especially in the Central African countries.

The investments in irrigation and drainage in Asia were mainly public sector funded, and for developing countries, mainly through loans from the International Lending Banks. By the 1990s, with the advent of globalization and market economies, and changes in Bank lending policies, such loans were greatly reduced and the rate of irrigation expansion slowed down. From an increase of about 2.3 percent in the 1970's, it declined to 1.3 percent in the next decade and declined again to 1 percent in the 1990's. It is anticipated that over the next 20 years the rate of expansion will drop further to about 0.6 percent.

As an example, World Bank funding for the irrigation sector some 10 to 15 years back was about US$ 1.5 billion a year. It has since dropped to US$ 300 to 400 million a year. At its peak, there used to be 20 to 25 irrigation projects funded by the Bank, but this has now dropped to 5 or 6. In addition, the World Bank gradually shifted its funding focus away from new projects into rehabilitation projects, and for software rather than hardware, covering governance and institutional reforms, including greater participation by farmers, and greater accountability from irrigation departments as against investment in infrastructure. Under its Water Resources Strategy, the Bank aims to provide more effective assistance to countries, using water as a vehicle for increasing growth and reducing poverty in a socially and environmentally responsible manner. An important element of this strategy is aimed at transforming water from a potential source of conflict, into a major catalyst for economic integration and cooperation at all levels, from villages to international river basins.

At the same time, lending agencies are avoiding irrigation projects as they find that these are controversial and attract unwanted attention especially from the NGOs. Being the biggest user of water, irrigation and drainage projects are often seen as depriving the other sectors, and in particular the eco-system, from a fair share of the water resources. People also see the excessive use of chemicals, fertilizers and pesticides in the fields and the polluted effluents returning back to the river system as signs that irrigation schemes are not friendly to the eco-system. Further, many irrigation systems are suffering from salinization as a result of over-irrigation and there is a need to provide for drainage facilities. It is estimated that without drainage, 1 to 1.5 million hectares of land a year will be lost to salinization. Another area of concern is in some parts of the South Asia region, where ground water is being extracted for irrigation at a rate faster than it is being replenished.

Meanwhile, the cost of irrigation investment has increased, with typical costs increasing from US$ 8,000 per hectare in the 1980s to US$ 15,000 in the 1990s. This has placed financial pressures on public funding and more and more, there is now a need to consider a role for private investment. Currently it is estimated that about 20 percent of investment comes from the private sector, and this proportion is expected to increase in the future. Investments are needed not only for new projects, but also for renewal and rehabilitation of existing irrigation schemes, and for operation and maintenance.

4. FEEDING THE WORLD

Irrigation and drainage can make significant contributions to increasing food production to meet the nutritional needs of the world. Whilst only about 17 percent of all cultivated land is irrigated, they produce roughly 40 percent of the global food output. Thus irrigated lands are producing twice as much food per unit area compared to the non-irrigated lands. Hence over the past half century, the world's total irrigated area has increased from 90 million ha in 1950 to about 250 million ha by the year 2000. Even in the humid regions with high annual rainfall, irrigation systems are needed to allow the cultivation of more than one crop in a year, especially where rainfall is so variable or where there is a pronounced dry season. With irrigation systems in place, better water management is possible, and this will result in higher productivity.

Although the world population almost doubled from 3.1 to 5.9 billion between 1960 and 1990, global agriculture was able to meet the food demand of this growth, thanks mainly to the productivity gains from irrigation and the Green Revolution. Over the same period, the world average grain yields doubled from 1.4 ton/ha/crop in 1962 to 2.8 ton/ha/crop in 1996 (FAO 2000). To satisfy the cereal demand for this growth in population, annual world production of cereals grew by almost a billion tons from 0.94 billion in the mid-1960s to 1.89 billion in 1998.

By increasing food production through productivity gains, we will contribute to hunger eradication, poverty alleviation, national food security and economic development. However, food production is now facing serious constraints, including declining yield growth rates, natural resource depletion, labour shortages, gender issues, institutional limitations and environmental pollution. Globally, food prices are low and this has made agriculture less attractive to new investments. The migration of youths to the urban areas and lack of interest of the younger generation to be involved in farming has resulted in abandonment of farmlands. Enhancing the sustainability and productivity of food production systems, while protecting and conserving the environment, will require a more diverse approach for development that includes participation from the local to the international level and the commitment of government and inter-governmental bodies. Overall, efforts have to be mobilized towards a multi-prong approach, covering many different areas.

4.1 Increasing Water Productivity

Irrigation and drainage can significantly increase production output and reduce the risk posed by water-related hazards. The downside is that large quantities of water are needed and present water use efficiencies are low. To meet food demand by the year 2025 an additional 2,000 cubic kilometers of water will be needed for irrigation. This amount is 24 times the annual flow of the Nile River. Over the same period, one third of the world's population will be living in countries facing severe water shortage, and competition for water is expected to further intensify. Along with efforts for improvement in how water is used, the immediate challenge will be to strive for higher efficiency, both in the irrigation systems as well as in the field.

A portion of the water is lost in the irrigation system due to seepage losses and breakages in the canal system. Seepage losses can be reduced by lining of canals while operational losses can be better managed by having more control and measuring structures. Irrigation return flow can be re-tapped and returned to the system. In the field, farming practices will have to be improved to secure higher field application rates. For rice, the traditional practice of transplanting is giving way to direct seeding where the ground is made just moist enough to meet the agronomic needs, thus greatly reducing the amount of water used.

In the late 1980s, the International Water Management Institute (IWMI) coined the term, "more crop per drop", to highlight the need for the agriculture sector to be more efficient in water use. The aim then was to increase production and obtain higher yields for a fixed quantity of water. However, given that overall water demand will continue to increase, and the irrigation sector cannot remain as a waster and inefficient user of water, there will be more pressure on the sector to increase water productivity by moving from "more crop per drop" and to "more crop less drop" ie. producing more output from a lesser amount of water.

Improvements to irrigation water use efficiency will depend largely on the willingness of governments and irrigation services to make the required investment and management decisions to improve the systems; while at the same time, providing sufficient incentives and enforcing penalties to make it worthwhile for farmers to comply with best practices. While the challenge looks daunting, it is achievable. As an example, farmers in China have improved the productivity of rice from half a kilogram that is normally produced from 1,000 litres of water to more than 2 kilograms, using a number of agronomic options such as no-till techniques, alternate wetting and drying, better soil fertility, and better management by farmer associations.

Overall, being the biggest water user, the irrigation and drainage sector provides the biggest opportunity for water savings as even a modest 10 percent savings in irrigation water use will free significant amounts of water for other uses, including meeting the needs of the eco-systems. The challenge here is to increase substantially the level of investment for rehabilitation and modernization of irrigation and drainage schemes so as to achieve higher efficiency of water use. For much too long, donors and lending banks have neglected this very important sector and it is hoped that more attention and funding will be directed here to realize this potential savings.

4.2 Increasing Crop Productivity

Productivity gains can be achieved by increasing the cropping intensity or improving plant yields. Cropping intensity is the frequency at which a crop can be grown in a year. The intensity can be increased multi-fold by the introduction of multiple cropping ie. growing two or more crops per year. Many developing countries are not constrained by climatic seasons and the main limitations to multiple cropping are lack of water or a long growing period of the particular food crop. The provision of irrigation and drainage works will facilitate the growing of a crop during the drier season, which would otherwise be subjected to the vagaries of weather. For the other limitation, agriculture research has produced varieties with shorter maturation periods. For paddy, maturation periods have been shortened to less than four months, allowing a potential cropping intensity of 300 percent, and thus a potential 3-fold increase in output.

Another area offering better prospects of increasing crop productivity is through yield improvements. Presently there is a wide gap in productivity between developing and developed countries. As an example, farmers in the Netherlands can harvest 658 tonnes of cucumber and 452 tonnes of tomato per hectare for each crop, compared to only 16.6 tonnes of cucumber and 28.4 tonnes of tomato by Malaysian farmers. Most of the gains in productivity is a result of better technology. For rice, yields in South Asia is barely a third of those in East Asia. Many of these varieties used in East Asia though, are sensitive to water stress and will need good irrigation and drainage infrastructure to ensure a reliable yield.

Yield increases can be achieved through four areas, viz. better inputs for the plant, use of technology, building capacity for farmers and through good water management (usually through well designed and managed irrigation and drainage infrastructure) to realize the full yield potential (see Figure 5).

Timely application of fertilizers will lead to higher yields while judicial use of pesticides can reduce the damage from pest attacks. Scientists are working on better hybrids of the high yielding varieties obtaining a doubling of yields has become fairly common. However, convincing traditional farmers to adopt new

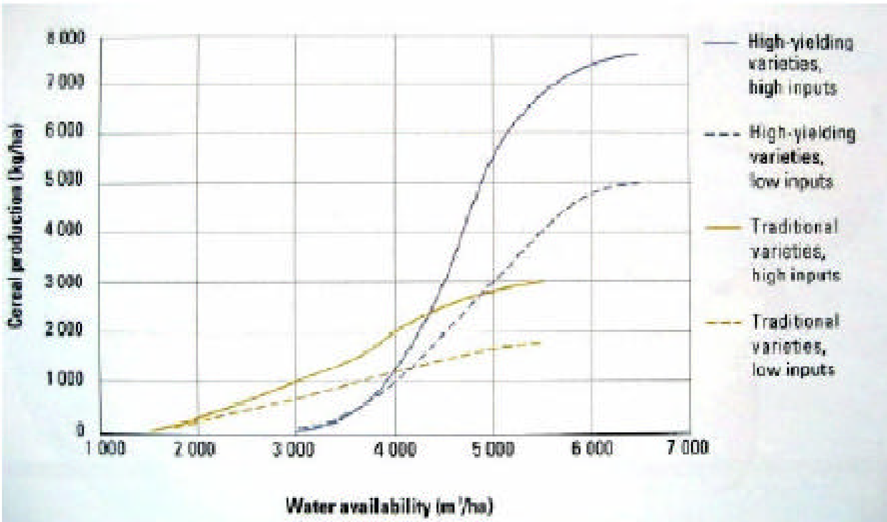

Figure 5. Typical Response to Water for Cereal Crops (Smith 2001)

cropping practices and technology will not be easy and a more comprehensive approach in capacity building and extension services will be required. As an example, in the Muda Irrigation Scheme in Malaysia, farmers were initially skeptical about the possibility of growing two crops of rice in a year. Later, when double cropping became a common phenomena, farmers were then skeptical that paddy yields could break the 10 tonnes per hectare level.

4.3 Irrigation Modernization

Traditionally, the irrigation engineer has depended sorely on engineering measures to meet water savings targets. However, the future will require modernization of irrigation and drainage, which is not only modernizing the infrastructure but includes improving the management of the scheme as well as bringing in institutional reforms. Irrigation Modernization can be defined as :

> *"a process of technical and managerial upgrading of an irrigation scheme combined with institutional reforms with the objective to improve resource utilization (labour, water, economic, environmental) and water productivity".*

In terms of infrastructure and technical aspects, modernization is relatively straight forward. The bigger challenge will be in the 'software' and 'humanware' components. Modernization requires an upgrading of the management of irrigation systems to achieve better operation and maintenance. Irrigation service providers will have to be more client-focused and customer oriented, and include wider stakeholders' participation with the empowerment of water user organizations such as Farmers' Associations and their involvement through Participatory Irrigation Management (PIM) ie. in the planning, management and operational aspects of water and land resource development. Ultimately, the aim will be to move into precision farming using technology at its best.

Here, research and development, knowledge mining and knowledge acquisition will be critical. Comprehensive research programs need to be carried out in areas such as making systems more efficient; improving irrigation and drainage processes; and introduction of environmental friendly measures. Continuing research and development of irrigation and drainage technologies including ICT are needed to sustain development on existing and new agricultural areas.

An area actively being promoted by ICID is benchmarking, which is a process of comparing a scheme's performance with that of the leaders in the industry. It is not a competition but rather, a process to help improve whatever weaknesses or fallbacks that occurred and to find improvements for good performance and best practices. Through this process, benchmark reports are prepared, based upon the criteria most relevant or common among the irrigated areas in a region or among countries. In developing such a report, one is able to learn, borrow and adapt the best practices from the leaders. Benchmarking can therefore be a stimulant for improved irrigation management techniques and water savings measures

For irrigated agriculture to be sustainable, there must be adequate cost recovery, at the very least for operation and maintenance costs. In many developing countries, there is a reluctance to recover costs from the farmers, and even where this is being done, the quantum is often too low and inadequate. The agriculture sector is often made up of the poorer segment of the population and inputs and subsidies are seen as financial instruments to redress imbalances in society. In addition, the political structure and electoral boundaries, usually favour the rural areas and farming or rural constituencies can hold the balance of power.

Since water is priced so low, if at all, and water rates are often based on the area irrigated rather than amount of water delivered, there is little or no incentive for farmers to practise water conservation. Frequently, water is left to flow continuously into the fields and runs to waste. Adequate and appropriate charges, coupled with metering, can be very effective in raising the level of water conservation and thus reducing the amount of water used.

4.4 Rain-fed Areas

As noted earlier, only about 17 percent of all cultivated land is irrigated and the rest is rain-fed, ie. dependant entirely on rainfall or on rainwater stored in the soil at root zone level. For rain-fed agriculture to be feasible, there must be sufficient rainfall for crop water requirement during the critical periods of crop growth. In developing countries where there is inadequate investment in irrigation and drainage infrastructure, rain-fed agriculture contributes some 60 percent of the food production.

In the absence of irrigation, crops are vulnerable to the vagaries of climate and this is reflected in the low yields achieved. Also, as the possibility of crop failure is high, farmers are then reluctant to invest their scarce resources in using fertilizers or other inputs needed by the high yielding varieties. The effects of unreliable rainfall can be minimized by having small-scale irrigation systems to tide over the sporadic dry periods that can result in desiccation of the crop.

Starting from such a low yield base, rain-fed agriculture offer the greatest prospect for increasing food production, particularly since yields could easily be doubled with proper land management and judicious application of water at critical stages of plant growth. Through proper land preparation it is possible to capture a larger portion of the surface runoff and lead it to infiltrate closer to the root zone. Conservation tilling and mulching can retain moisture levels for longer periods. With low-cost water-saving irrigation techniques and technologies, it is now possible to apply small quantities of water directly to the root zone of crops, thereby eliminating waste and avoiding soil degradation. One of the easiest ways to do this is by having rainwater collection from roofs and delivering the water collected to the farm through a trickle irrigation system. Other possibilities include the use of low-cost technologies such as treadle pumps, trickle and seep-hose systems.

Tests carried out by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have shown that farmer-affordable improved systems can increase the carrying capacity in traditional rain-fed systems from 4 to 18 people/ha/year. Such systems require changes to tillage techniques and judicious use of nitrogen, phosphorus and micro-nutrients such as boron, sulphur and zinc. In one 500-hectare community in India that has used this system, yields have doubled since 1998. A 200 square metres drip-irrigated plot which cost $8 can generate more than $50/year in net income from vegetables, fruits and other cash crops.

4.5 An Integrated Approach

In irrigated agriculture, water is diverted from rivers and reservoirs into an irrigation system and distributed to the fields. In the past, the amount of water diverted is normally within the carrying capacity of the river basin. However, as more and more areas are brought under irrigation, and with competition for water increasing, local water resources are no longer adequate to meet the demand and increasingly, water has to be sourced from outside the area or even from another catchment (watershed). At the same time, irrigation return flow can go to recharge groundwater or to replenish the rivers downstream. Thus, from a water resource point of view, the physical diversion of water for agriculture will modify the circulation of water in rivers, water courses and aquifers (hydrological cycle) in the river catchment; and this will have consequential effects on land and environment beyond the immediate vicinity of the irrigated area. Such impacts are known as the externalities to irrigated agriculture and can be positive or negative.

To manage water resources in a sustainable way, a more holistic approach is needed, blending the environmental integrity of the land and water systems and managing the water within the river basin in an integrated way rather than the narrow focused approaches of the past. Essentially this is a holistic approach to manage water on a river basin basis rather than a scheme or project basis; and seeks to balance the demand with the supply, the upstream with the downstream, and the hardware (infrastructure, technology) with the software (institutions, laws, governance). Thus, as water resources become more scarce, a holistic and integrated approach through IWRM (integrated water resources management) or IRBM (integrated river basin management) will allow for optimization of resources and a more rational balancing of benefits and costs.

4.6 ICID Strategy For Food Security

The ICID strategy for food security has been developed taking into consideration criteria such as food self-sufficiency, economic status of country, status of potential and actual water resources development, sustainable water and land productivity, equity, efficiency, economy in water use and governance. The strategy lays out different approaches depending on the stage of development of a country (see Table 3).

In the worst case scenario affecting the Least Developed countries (LDCs) like many Sub-Saharan countries which are food deficit, have low GNP, low water resources development and relatively inadequate governance mechanism, the strategy would be to have better population control policies, provide small scale water facilities for improving rain-fed agriculture, and increase investments for water resources development (irrigated agriculture) and transport infrastructure. Irrigation can make significant contributions to reducing poverty and increasing crop production. It is, and will remain, a vital activity in the livelihoods of many people. In the immediate future, such LDCs may still need to continue their dependency on food aid.

The emerging developing countries such as India and China, are better off and are more likely to be food self-sufficient though not necessarily food secure. Such countries have low to middle level GNP, medium level of water resources development and are still evolving governance structure and reforms. Here, the strategy is to improve water use efficiency and increase investments in infrastructure and water resources development. Strategies to control growth of population have also to be in place.

Table 3. ICID Strategies For Food Security

Category of Countries[1]	Food Self Sufficiency	Economic Status (GNP)	Population	Status of WRD	Governance	Strategies
Least Developed Countries	Deficient[2]	Low	High	Low	Deficient	Population control, Improvement to rain-fed agriculture, Water resources infra-structure, Improve efficiency, Food aid.
Emerging Developing Countries	Sufficient	Low and Upper Middle	High	Medium	Evolving	Investment, Develop water resources, Improve efficiency, Population control
Developed Countries	Surplus	High	Low	Adequate	Adequate	Trade Export

1 Categories of countries arranged from deficiency to surplus food self sufficiency.

2 Some countries, like oil exporting West Asian countries and Japan may not be food self sufficient but they can practice virtual water – food import, due to their high GNP and still be food secure.

For the developed countries like many American and European countries, the strategy is to produce surplus food for trade, since food security is not a problem due to high GNP, adequate WRD and governance and relatively low population.

7. CONCLUSION

Population growth will be the single most critical factor in our efforts to feed the world. At the present rate of population growth, there will be a need to double global food production by the year 2025. In many countries, the demand and competition for food, water, land and other resources will increase and difficult choices will have to be made about where, how and to whom the limited resources should be allocated. All this will have to be done against a backdrop of decreasing available arable land, increasing competition for water, and a growing concern for environmental protection and conservation.

The main thrust to increase food production in the future will have to come from irrigated agriculture, since with irrigation the land can be twice as productive. Hence, by 2030 almost half of the world's food production will have to come from irrigated lands. It is estimated that 17 percent more water will be needed for this purpose. At the same time demand for water from the other sectors will increase and the competition for water will intensify. Hence irrigated agriculture will have to be more efficient in water use as well as more environment friendly in operation and management. As per capita water availability decreases, the pressure will be on the irrigation community to use water more efficiently by moving from “more crop per drop” to “more crop less drop”. Finally, to minimize the impact of externalities, future efforts will have to be carried out within the context of a holistic and integrated approach.

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