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Rice Production and Paddy Irrigation in the Asian Monsoon Region

Datuk Ir. Hj. Keizrul bin Abdullah
President, International Commission on Irrigation and Drainage

Synopsis

Rice is the staple food for more than half of the human population, and in Asia alone, more than 2 billion people depend on rice and its products for their food intake. Grown in Asia for at least 10,000 years, rice (the main product of the paddy plant) has become deeply embedded in the cultural heritage of Asian societies and is the life, heart and soul of the people throughout Asia.

Paddy is grown in fields with small boundary earth bunds to maintain a shallow water depth as most rice varieties maintain better growth and produce higher yields when grown in flooded soils than when grown in dry soils. The standing water layer helps to provide for water storage to tide over the vagaries of weather, is a mechanism for weed control and also allow for rice-fish-duck farming. However, paddy fields give far more benefits than merely that of rice cultivation and some of these multi-functional roles are described in this paper.

By the year 2020, as a result of population growth, another 1.2 billion new rice consumers will be added to the population of Asia, and to feed these extra mouths, rice production must be increased by one third of the present production of 320 million tons. This effort must be carried out against a backdrop of decreasing available arable land, increasing competition for water, and a growing concern for environmental protection and conservation.

One of the key enabler for paddy growing is water, and for many countries in Asia, the water needed for paddy irrigation constitutes between 70 to 90 percent of total water diversion. Increasingly however, as these countries develop, more water resources will be needed for household and industries and the resulting competition for water is expected to further reduce the proportion allocated for irrigation. Achieving the rice production targets will therefore require an optimum mixture of horizontal and vertical development. The paddy irrigation sector will have to be more efficient in water use as well as more environment friendly in operation and management, and will have to move from "more crop per drop" to "more crop less drop".

1.0 INTRODUCTION

In 1996 the Food and Agriculture Organization (FAO) of the United Nations organized a World Food Summit in response to widespread under-nutrition and growing concern about the capacity of many countries to meet the food needs of their population. At that time, the per caput food supply in many developing countries were inadequate to meet the threshold average dietary energy supply (DES) of 2,700 calories. As a result, there was an estimated 840 million people including 200 million children suffering from under-nourishment, mostly from the developing world. In addition, every day, some 25,000 people die of the consequences of chronic malnutrition.

The objective of the Summit (FAO 1996) was to renew global commitment at the highest political level to eliminating hunger and malnutrition and to the achievement of sustainable food security for all people. 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).

Seven years on, the FAO's latest estimates (FAO 2003) show that a number of countries have reduced hunger steadily since the Summit baseline period of 1990–1992, and in 19 countries (including five in Asia and the Pacific), the number of chronically hungry people had declined by over 80 million between 1990–1992 and 1999–2001.

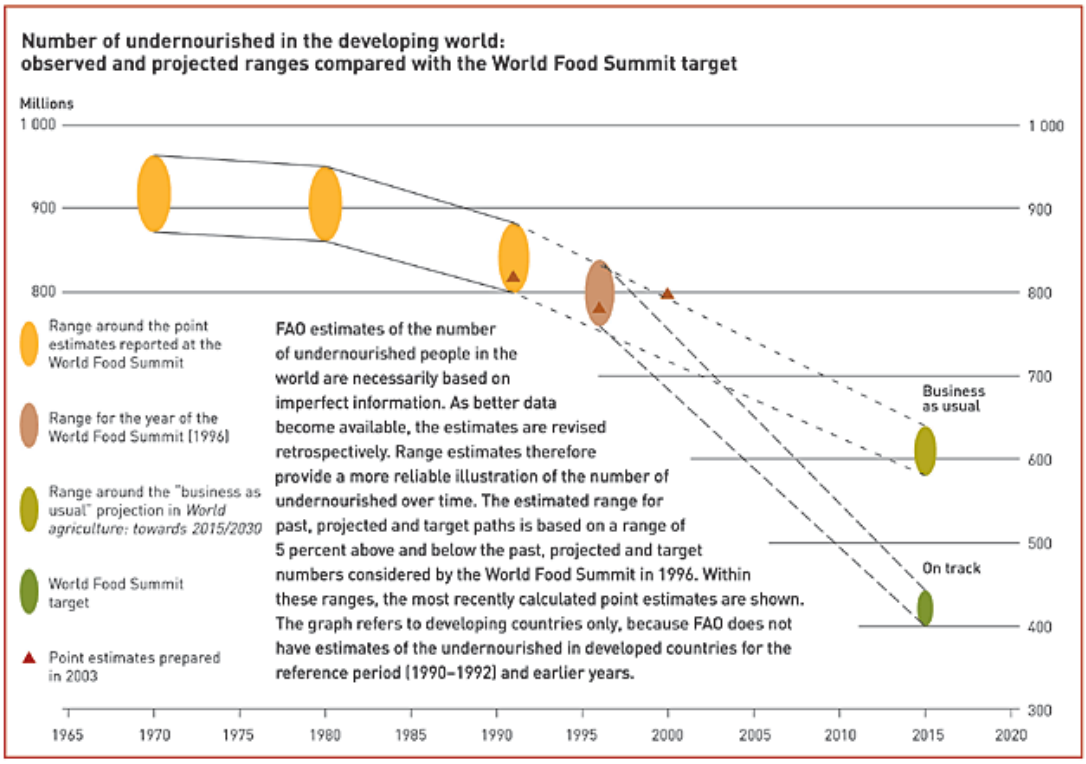

Figure 1 - Meeting The WFS & MDG Target (FAO 2003)

Unfortunately, this is not the situation in most other countries. Across the developing world as a whole, an estimated 798 million people were undernourished in 1999-2001, only 19 million fewer than during the World Summit's baseline period. Of this, around 60 percent were from Asia (East Asia 145, South Asia 293, South-east Asia 66 million). Worse yet, the number of undernourished people in the developing world is no longer falling but climbing. Whilst in the first half of the 1990s, the number of chronically hungry people decreased by 37 million, by 1997, however, the number has increased by over 18 million, with the vast majority comprising people who live in rural areas of the developing world. Figure 1 shows the situation if we carry on "business as usual".

Today the global food security situation is further compounded by the continuing population growth. The population of the world is projected to increase from the present day 6 billion to an estimated 8.1 billion by 2025 and 9.3 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 is a need to double global food production by the year 2025.

2.0 RICE FARMING

Rice (genus *Oryza*) is the staple food for more than half of the human population ie. three billion people. In Asia alone, more than two billion people obtain 60 to 70 percent of their calories from rice and its products. With the average person in much of Asia eating rice 2 to 3 times a day, the per capita annual consumption in Asia is many times that of Europe or America. For example, the per capita annual consumption is 195 kg in Myanmar and 160 kg in Cambodia, in contrast with 3 kg in Europe and 7 kg in America (ARF 2004).

A plant of the grass (*Poaceae*) family, rice is tolerant to desert, hot, humid, flooded, dry and cool conditions and can survive in saline, alkaline and acidic soils. As such it is the world's third largest crop, behind maize and wheat. Of the 23 *Oryza* species, only two are cultivated: *Oryza sativa* which originated in the humid tropics of Asia, and *Oryza glaberrima*, from West Africa. There are more than 140,000 varieties of cultivated rice and so far more than 90,000 samples of cultivated rice and wild species are stored in the International Rice Genebank. The three commonest rice cultivars are *indica, japonica and javanica* and they are often classified by their grain shapes, with the long-grain variety generally containing less starch than the short-gain variety. After harvesting, the seeds of the rice plant are milled to remove the outer husks of the grain and the processed seeds are usually boiled or steamed to make them edible.

However, rice is more than just a food for the almost 3 billion people whose main staple is rice. Grown in Asia for at least 10,000 years, rice has become deeply embedded in the cultural heritage of Asian societies and it has entered into their lives in many other aspects, namely, in religion and beliefs, culture and tradition, politics and business, at religious festivals and wedding parties, in paintings, poems and in songs. Many religious rituals are tied to the rice cycle, and social and cultural behaviour tied to rice production. In remote villages of South-east Asia, farmers still compare a grain of rice to a "grain of gold". In modern Japan, people see rice as the very heart of their culture. Rice cultivation has changed landscapes and cuisine, and provided farmers with new sources of income. It has become the most rapidly growing source of food in Africa, and is of significant importance to food security in an increasing number of low-income food-deficit countries.

It is for all these reasons that in 2002, the United Nations General Assembly took the unprecedented step of declaring 2004 as the International Year of Rice with "*Rice is Life*" as the theme, reflecting the importance of rice as a primary food source.

Rice was first cultivated in ancient China and India. From China rice growing was brought to neighbouring countries in East and South-east Asia, while from India it spread to southern Europe and Africa. From its Asian homeland, rice is now cultivated in 113 countries and on all continents except Antarctica. It is often grown in paddy fields ie. fields with small boundary earth bunds to maintain a shallow water depth (typically from 100 to 200 mm depth) as the plant itself is an aquatic plant capable of "breathing" through its hollow stem. The main reason for flooding the rice fields is that most rice varieties maintain better growth and produce higher yields when grown in flooded soils than when grown in dry soils. The standing water layer provides for water storage to tide over the vagaries of weather, helps to suppress weeds and allows for breeding of fish and ducks. Such a paddy system facilities increased productivity, although rice can also be grown on dry land (including on terraced hillsides).

Rice cultivation is well suited to poor countries as it can grow fairly well even with rudimentary or no water infrastructure. About 80 percent of the world's rice is grown by small-scale farmers in low-income and developing countries where rice-based production systems and their associated post-harvest operations employ nearly 1,000 million people in the rural areas. Only about 5 percent of the world's production is exported with Thailand exporting 5.3 million tones a year, Vietnam 3.3 million and the United States 2.3 million tones. Efficient and productive rice-based systems can lead to economic development and improved quality of life, particularly in rural areas, as well as help in the efforts to eradicate hunger and malnutrition.

3.0 MULTI-FUNCTIONAL ROLES OF PADDY FIELDS

Paddy fields give far more benefits than merely that of rice cultivation. Some of these multi-functional roles are described below.

3.1 Source of Protein

In many rural communities, inland fish production contributes greatly to putting protein on the table. In paddy irrigation, a standing water layer is established in the fields and become ideal locations for breeding of fish with very little extra cost or effort. Traditional rice paddies may require some modification for the concurrent culture of fish, such as the deepening of part of the paddy field to serve as a fish shelter and harvest area. The fish eat algae, rice pollen, weeds and insects while also fertilizing the soil more effectively than the commercial products. Fish also reduce pests by eating leafhoppers, stem borers and aphids and lower the incidence of several rice diseases.

In its most simple form, fish stocks are not managed. Wild fish enter the paddy during flooding and are captured at the end of the rice growing season. This method of raising fish together or concurrently with rice is as old as rice culture itself. Other techniques are based on either managed concurrent culture of fish with rice, on rotational production of fish and rice crops; or utilizing caged culture in reservoirs and in some of the larger irrigation canals.

Ducks have a similar function and produce enough meat to compensate for any fish that they might eat. Rice-fish production of 125 to 240 kg/ha/year have been reported in various parts of Asia. Ducks eat crabs and insects and their droppings act as a nutritive addition. Thus, rice-fish-duck cultivation creates a reliable source of protein (or cash) for the farm family and at the same time can increase rice production (up to 30 to 35 percent) while requiring reduced application of fertilizers and pesticides.

3.2 Navigation

In many parts of rural Asia, few roads have been constructed, and water transport, utilizing rivers, canals and drains remains the most important means of travel at the local level. In large scale paddy irrigation schemes, the main and secondary canals frequently perform the functions of serving as arterial transportation networks.

3.3 Groundwater Recharge

In many parts of Aisa, flood irrigation is practised for paddy fields, providing some level of insurance in terms of water supply as well as for weed control purposes. Under this system, paddy field are usually filled with a water depth of 100 to 150 mm and this standing water is maintained until prior to harvesting. Some water percolates through the heavy soils and moves into the ground as ground water recharge. Most of the percolated water flows back into the rivers and drains and are an important source of water for irrigation reuse or recycling. An estimated 7 percent goes towards recharging the underground aquifers and this will be an important source of groundwater recharge in the future, when dependence on groundwater supply is expected to increase as competition for surface water increases.

3.4 Water Purification

Apart from solar energy, paddy fields can also help as a purification zone for nitrogen discharged from other sources. Observations have shown that 80-90 percent of NO_3-N in irrigation was removed when contaminated water passed through the paddy field over a rice cultivation period. Nitrogen is the most important nutrient for rice, and its deficiency is common unless nitrogen is available from sources other than the soil organic matter. In lowland rice, 50 to 80% of nitrogen absorbed by the crops is from the native soil nitrogen pool.

3.5 Flood Control

The field bunds (*batas*) of paddy fields function like the dikes of flood dams and paddy fields surrounded by *batas* can store and regulate the discharge of heavy rainfall. As an example, taking the average height of *batas* as 30 cm, the water depth for growing rice as 4.5 cm, the coefficient of water permeability of paddy field as 1.5 mm/day and average duration of flood as 3 days; then the amount of water reservoir capacity calculated would be 300 mm, or 3,000 cubic meters per hectare. Potentially this storage will have an appreciable effect on flooding.

3.6 Soil Erosion Control

Soil erosion leads to not only to loss of soil fertility and agricultural production, but also bring sediments into the river system and causing flooding downstream. Paddy fields with its level surface and *batas* can reduce the impact of rainfall on the soil surface and control erosion and in fact help to retain soil eroded from the upland. This suggests that the rice field has a capacity to protect against soil erosion by at least the amount of soil loss from the upland.

3.7 Air Cooling Effect

The standing water layer in paddy fields is important not only for the production of rice and recharging groundwater but also on the redistribution of solar energy at the surface of the earth through evapotranspiration. When water evaporates from the surfaces of rice fields and plants into the atmosphere, it takes up heat from the air, lowering the atmospheric temperature. The differences in energy balance and surface temperature among various types of land use influences the air temperature environment. Air temperature above the paddy fields are thus lower than that of the surrounding area as the fields absorbed some energy of air, thus contributing to the moderation of air temperature.

3.8 Aesthetics of Landscape and Green Lung

Paddy fields contribute to the rural landscape in many ways. During the early part of the irrigation season, the fields are little ponds of water, creating reflections which are very aesthetic and soothing to the eyes. At the middle part of the season, the fields become green verdant landscape, serving as green lungs to the nearby urban areas. When the paddy plant is in full bloom and ripening, then the green landscape gives way to one of rich golden hues. Many people, both urban and rural, enjoy these changing scenery and landscapes of paddy fields. There is now a growing market for agro-tourism which includes special trekking tours in paddy fields, introduction to paddy farming activities, and homestays with paddy farmers. These are designed to be both educational as well as holiday experiences especially for the urban population and school children. At the same time, they help to increase the incomes of the rural farmers.

3.9 Environmental Role

Paddy fields become part of a new environment with ecological processes that reflect the influences of both man and nature. The paddy fields act as artificial wetlands, where certain type of aquatic ecosystem suitable for plant and animal forms, such as aquatic birds, insects and animals, including fish is maintained.

The value and landscape or bio-diversity depends on personal preference and culture, and is called *non-use value*. The non-use value of paddy fields would become more precious if the bio-diversity of paddy (wetland) ecology is developed and encouraged. They can be further developed under the concepts of agro or eco-tourism.

4.0 THE CHALLENGES AHEAD

During the years of the Green Revolution, irrigated agriculture has made significant

contribution to reducing poverty and increasing crop production especially in the developing countries. Virtually without exception, infrastructure development (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, the prospects for new irrigated projects do not look promising. 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.

There are many challenges ahead which will make meeting the World Food Summit and the MDG targets that much more difficult.

4.1 Population Growth

The future outlook for the world is clouded by the spectre of uncontrolled population growth. 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.

By the year 2025, the world's urban population will double from the current 2.5 billion to 5 billion. With urbanization, the demand and competition for water and other resources will increase and countries will have to make difficult decisions about where, how and to whom the limited water 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 more and more people will have to move into the marginal lands where the productivity is relatively low. The figures for Asia are even more critical. Although Asia has only 24 percent of the land area in the world, it supports some 60 percent of the world population. For humid Asia, the respective figures are 14 percent and 54 percent. These make the issue of producing sufficient food for this part of the world even more crucial.

At the same time urbanization and industrialization impacts on the contribution of agriculture to the national economy resulting in a decrease with respect to GDP and labor force. Globally, commodity prices are approaching historical lows and this has made agriculture less attractive to investments. 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.

4.2 Land Utilization

Since the 1960s, land for agriculture use has increased by 12 percent to about 1.5 billion ha or 11 percent of the world's total land surface. Since world population has doubled over the same period, arable land per person declined by about 40 percent from 0.43 ha in

1962 to 0.26 ha in 1998. At the moment, some 1.5 million hectares of land are used for food production, but there has been a gradual decline in expansion of land put under cultivation. To meet the World Food Summit target, there is a need to increase rice production by 40 percent and to do this, an additional 9.8 million hectares of land will have to come under production. However, the increase in production areas has been slowing down to a rate of 1.3 percent compared to the 2.2 percent over the past 30 years. Taking into consideration population growth, the harvested area per capita will reduce from 0.1 hectare per capita today to 0.08 percent hectare per person by the year 2030.

Thus, there is a gradual decline in bringing additional land under cultivation. In addition, this additional expansion will, more and more, be on marginal lands because the good lands have already been used up. This hunger for land and water, driven by increasing population and its demand for food, 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, with 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 without proper planning 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 ground-water supplies.

4.3 Water

Water is one of the most critical resources for agriculture and food production. Without water (either through irrigation or rain-fed) no crops can be grown. In terms of global water use, the irrigation sector presently uses 70 percent of all the water which is diverted, though in some developing countries, this amount may be as high as 90 percent. By 2030, it is estimated (FAO 2000) that irrigated land will increase by about 45 million ha in developing countries (for a total of 242 million ha) and the resulting water withdrawals for irrigation will increase by about 14 percent while irrigation water use efficiency will improve by only 4 percent thus requiring a net increase in volume.

It is fortunate that humid Asia is fairly water-rich, with rainfall averaging more than 1,500 millimeters per year. With such abundant rainfall, it has been possible to grow rice without the need to invest heavily in irrigation and drainage facilities. In fact, in 2000, of the total world rice production of about 600 million tons, 91 percent was grown in Asia. However, as Asian economies continue to expand, there is now greater competition for water. Water is needed for domestic use, for industries, for agriculture, and increasingly, for nature or the eco-system. Unfortunately, many countries still do not treat water as the scare resource that it is. Both urban and rural water users receive massive subsidies on water use - irrigation water is essentially free in some countries while in urban areas the price of water often does not even cover the cost of delivery. Many countries subsidy the operation and maintenance of the irrigation water delivery system and this subsidy encourage overuse of irrigation water.

Currently, some 30 countries are considered water stressed, of which 20 are absolutely water scarce. By the year 2020, the number of water scarce countries will likely approach 35. Equally worrisome, virtually all developing countries, even those with adequate water supply, suffer from seasonal and regional shortages. The fresh water supply is getting less, and even the amount available is sometimes unusable due to pollution. In addition, as a

result of climate change, there will likely be more evapo-transpiration requirements and there may be less rainfall or more variable rainfall in certain regions of the world.

4.4 Changes in Lifestyle

Generally, when a country becomes more developed and its citizens more affluent, the demand for food changes. Whilst food demand will increase due to population growth, a more critical factor will be the change in dietary habits as people earn more and are able to budget more for food purchases. With education and better employment opportunities, a higher proportion of the female population becomes gainfully employed away from the traditional agriculture sector. Households have higher disposable incomes and are not only able to purchase food, but invariably the food is processed or include more meat.

In developed countries the annual meat consumption often exceeds one's body weight (70 to 100 kg/capita), while in most developing countries it is less than 20 kg/capita but catching up. In the past few decades, 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. Chinese statistics are showing annual meat consumption rising from about 11 kg/capita in 1975 to nearly 50 kg by the end of the 1990s.

A meat-rich diet impacts on total water use as processing of food requires more water while livestock have to be fed. 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 would be for direct food consumption while the balance would be to feed animals that is then consumed. Further, 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.

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

Table 1 - Water Equivalent (FAO 1997)

4.5 Investments in Irrigation and Drainage

In the 1960s, many developing countries made significant investments in irrigation and drainage infrastructures to take advantage of the Green Revolution. However, with globalization and market economies, the rate of irrigation expansion has been reducing

over the past decades. From 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 be in the order of only 0.6 percent.

Even in humid Asia, 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. As a result of the green revolution, the productivity of irrigation water has increased by 3.3 times. Also, 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.

Irrigation expansion requires that adequate investment is made available. In terms of investment, there has been a reduction in investment for irrigation. The present situation is that banking and financial support for agricultural development is lacking. Banks are often reluctant to grant loans to small entrepreneurs and innovative farmers as they are considered high risk due to the vagaries of climate and natural disasters such as floods or droughts. In addition, irrigation facilities in most developing countries are public funded, often with loans from the World Bank or the Asian Development Bank.

World Bank funding for irrigation projects 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 World Bank, but this has now dropped to 5 or 6. In addition, the World Bank has shifted its funding policy away from new projects, and it now mainly goes to rehabilitation projects, and for software rather than hardware. Another reason that major lending agencies are avoiding irrigation projects is because they feel that it is controversial and that it attracts unwanted attention especially from the NGOs.

As the biggest user of water, irrigation and drainage projects are often perceived to be the major culprits in adversely impacting the environment. People see the excessive use of chemicals, fertilizers and pesticides in the fields and the polluted effluent returning back to the river system as a sign that irrigation schemes are not friendly to the eco-system. In some parts of the South Asia region, ground water is being extracted for irrigation at a rate faster than it can be replenished.

In February 2003, the World Bank endorsed a new Water Resources Strategy aimed at providing more effective assistance to countries, using water as a vehicle for increasing growth and reducing poverty in a socially and environmentally responsible manner. A central water management challenge will be in agriculture, which accounts for over 70 percent of water use. Irrigation has played a major role in food security and poverty reduction in many developing countries but the Bank believes that there is an urgent need to reform irrigation institutions to improve accountability and to maximize returns per unit of water used. This will require institutional reforms, including greater participation by farmers, greater accountability in irrigation departments and investment in modern infrastructure. An important element of the new World Bank strategy aims at transforming water from a potential source of conflict, to a major catalyst for economic integration and cooperation at all levels, from villages to international river basins.

Meanwhile, the cost of investment has increased, with typical costs having almost doubled 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 shift from public to 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.

In addition to investments for new projects, funding is also required for renewal and rehabilitation of existing irrigation schemes. Considering that the average irrigation infrastructure has a useful 40 year life span, there is a need to rehabilitate 2.5 percent of such infrastructure each year. These will be critical for providing facilities for more than 200 million hectares of land. However, environment and social issues are making it more and more difficult for investments in irrigation and drainage.

5.0 INCREASING RICE PRODUCTION

Of the total world rice production of about 600 million tons, 91 percent is grown in Asia, and most of this production is consumed locally. Meanwhile, the population of Asia is increasing by 1.7 percent annually and by 2020, 1.2 billion additional rice eaters will be added to the population. To feed these additional numbers, rice production must be increased by almost 100 million tons, or a third of the present 320 million tons. This means that the production must be increased by an extra 3.7 million tons each year, notwithstanding the problems and challenges described in the previous section.

Paddy Production in metric tons	
1. China	166,000,000
2. India	133,513,000
3. Indonesia	51,849,200
4. Bangladesh	38,060,000
5. Viet Nam	34,605,400
6. Thailand	27,000,000
7. Myanmar	21,900,000
8. Philippines	13,171,087
9. Brazil	10,219,300
10. Japan	9,863,000

Table 2 - Top 10 Rice Producers, 2003 (FAO 2004)

Between 1960 and 1990, when the world population almost doubled from 3.1 to 5.9 billion, the productive potential of global agriculture was able to meet the food demand of this growth, thanks mainly to the yield increases from 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, and by 2003, nine of the top ten rice producers in the world were from Asia (Table 2).

Improving the productivity of rice systems would contribute to hunger eradication, poverty alleviation, national food security and economic development. However, rice production is facing serious constraints, including declining yield growth rates, natural resource depletion, labour shortages, gender issues, institutional limitations and environmental pollution. Globally, commodity prices are very depressed 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 rice-based production systems, while protecting and conserving the environment, will require a more diverse approach for global rice-based 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 moblilised towards a two-prong approach, ie. through both horizontal and vertical development.

5.1 Horizontal Development

Horizontal development is by expanding the area to be brought under cultivation. To meet the World Food Summit and MDG target, there is a need to increase rice production by a third of the present output and to achieve this, an additional 9.8 million hectares of land will have to come under production. Unfortunately, there is not much additional suitable arable land available for new development in Asia and much of this required production increase will have to come through vertical development.

5.2 Vertical Development

Vertical development is achieved by increasing the cropping intensity or improving yields. Cropping intensity can be doubled by the introduction of multiple cropping ie. growing two or more crops of paddy per year. Many parts of Asia are not constrained by climatic seasons and can take advantage by growing the many short term paddy varieties that are now available. Many of these varieties though, are sensitive to water stress and will need irrigation and drainage infrastructure to ensure a reliable water supply.

Yield improvement will offer the best opportunity to achieve the desired future increase in rice production, and already 70 percent of the rice production increases in developing countries are a result of improving yields. Given that rice yields in South Asia is barely a third of those in East Asia, this area represents one of the most promising potential. 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 2).

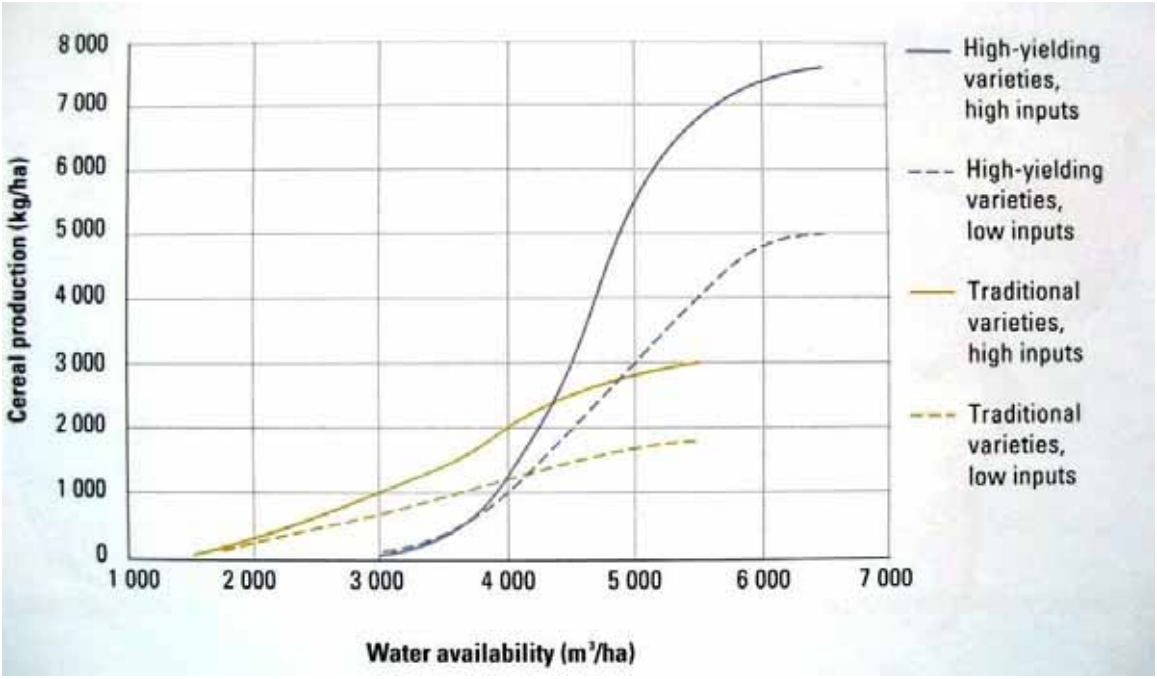

Figure 2 – Typical Response to Water for Cereal Crops (Smith 2001)

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 paddy hybrids of the high yielding varieties so as to push the yield curve even higher and with the right input, paddy yields of 10 tons per hectare or higher has become fairly common. However, converting traditional farmers to new cropping practices and technology has never been easy and a more comprehensive approach in capacity building and extension services is 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.

6.0 PADDY IRRIGATION

World-wide, the areas which are irrigated comprise only 17 percent of the world's cropland, yet from this small percentage it contributes 40 percent of the total food production. Thus per unit area, irrigated lands are producing twice as much food as the non-irrigated lands. However, in the process, water is a crucial component, and irrigated agriculture has become the biggest user of water, responsible for using approximately 70 percent of all the fresh water withdrawn for use in the world.

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. Water still remains as the most critical resource for irrigation, and will increasingly become the limiting resource in future economic development.

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 grow more production and obtain more yields for a fixed quantity of water. However, given that overall water demand will continue to increase, and the present unfavourable perception of the irrigation sector as a waster of

water, there will be more pressure on the sector to move from “more crop per drop” and to “more crop less drop” as future allocations of water to agriculture will likely be reduced from the present 70 percent.

6.1 Irrigation Water Use Efficiency

Presently, irrigation water efficiency is generally low. Efficiencies for the flood irrigation practiced in paddy fields can be as low as 20 percent while on the other end of the scale, efficiencies can be as high as 90 percent for drip irrigation systems. For most developing countries, the average efficiency of irrigation water use is less than half. 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. To improve irrigation efficiency and to meet the requirements of “more crop less drop”, a number of issues would have to be resolved and new strategies evolved.

6.1.1 Delivery Systems

A portion of the losses in the irrigation delivery system is due to seepage losses and breakages in the system. Seepage losses in the irrigation systems can be reduced by lining of canals while operational losses can be better controlled 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.

6.1.2 Improving Operation and Management

Operation and management (O&M) of paddy irrigation systems is one of the most neglected areas faced by developing countries in Asia. Governments struggling to balance budgets invariably end up with cost trimmings in the area of O&M. In an era of market liberalization, issues of privatization, turnover programmes and cost recovery dominate discussions on financial allocations for the various sectors.

Advances in technology provide some opportunities for achieving water savings. In the area of Information and Communication Technology (ICT), recent advances has made electronic devices more reliable and affordable and it is now possible to control the operation of an irrigation system remotely from the office. This can be coupled with Decision Support Systems which will help the operator in minimizing water use, e.g. by maximizing the use of effective rainfall.

One other area actively being pushed by the International Commission on Irrigation and Drainage (ICID) is benchmarking. Benchmarking 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

6.1.3 Cost Recovery

In many Asian countries, there is no policy of cost recovery from the farmers, and even where there is cost recovery, 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 rural constituencies can hold the balance of power.

Given that water is priced so low, if at all, and that water rates are often based on area irrigated rather than amount delivered, there is little or no incentive for farmers to practise water conservation. As a result, 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.

6.1.4 Irrigation Modernization

The traditional reliance on engineering measures to meet water savings targets will no longer be sufficient. The future will require modernization of irrigation and drainage. Irrigation modernization is not just modernizing the infrastructure but it is also a process to improve the management of the scheme as well as bring 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*".

Modernization in terms of technical aspects is relatively straight forward. The bigger challenge is in the software and humanware components. Modernization requires an upgrading of the managing of irrigation systems to achieve a better and more effective operation and management. Irrigation service providers (whether public or private) will have to be more client-focused and customer oriented. There will be a need to work towards transferring irrigation management to water user groups and to water user associations.

Likewise, getting greater farmers' participation in Farmers' Associations or in turnover programs such as Participatory Irrigation Management (PIM), can assist in effective and integrated land and water resources management and should be encouraged. Good governance includes wider stakeholders' participation. The empowerment of water user organizations and their participation in the planning, management and operational aspects of water and land resource development is essential for putting in place an effective management system that will ensure better performance and higher water use efficiencies.

6.2 Research and Development

Research and development is critical for pushing back the frontiers of knowledge. Comprehensive research programs should be carried out in areas such as making system more efficient; developing crops that use less water, or lower quality of water, or that are more salt tolerant; 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.

7.0 CONCLUSION

Rice is the staple food for more than 2 billion people in Asia. Due to population growth, 1.2 billion new rice consumers will be added in Asia by the year 2020, and to feed these extra mouths, rice production must be increased by 3.7 million tons a year. Furthermore, this effort must be carried out against a backdrop of decreasing available arable land, increasing competition for water, and a growing concern for environmental protection and conservation.

Achieving rice production targets will require an optimum mixture of horizontal and vertical development. One of the key enabler will be the provision of adequate water for the paddy fields. It is estimated that rice production will need 14 percent more water to meet the food demand of future population increase. The main thrust to produce this food will have to come from lands which are irrigated, since irrigated agriculture has long been synonymous with higher productivity as the 17 percent of farmland that is irrigated produces 40 percent of the food supply. Hence, by 2030 almost half of the world's food production will have to come from irrigated lands. At the same time the paddy irrigation sector 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 to increase water use efficiency and to move from "more crop per drop" to "more crop less drop".

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