Irrigation (Group Nile)

Water, Irrigation and Food Supply - a Keynote Address

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The challenge

The present 6 billion world population is projected to increase to 9 billion over the next 50 years with an estimated 95% of the growth taking place in developing countries. The associated increase in food requirements coupled with increasing constraints on available water and land resources presents a tremendous challenge for present generations working to overcome poverty in less-developed countries without compromising living conditions for future generations. The increasing demand for food will occur at the same time as a large part of the world population suffers from food shortages and heavy malnutrition. Much of the required increase in food production over the next 30 years will be in developing countries.

Land and water resources play a major role in increasing food production. But land and water resources are limited. Land degradation in the developing countries is increasing rapidly. A large part of rainfed agriculture is already extremely vulnerable to drought, soil loss, declining soil fertility, and disruption of water resources. Many of the agrosystems are ecologically fragile and require soil and water conservation measures and techniques to prevent degradation and maintain yield potentials. Land resources in irrigated and potentially irrigated areas also suffer from mismanagement, flood hazards and salinization.

Water is abundant globally but scare locally. Of the earth's 1,360 million cubic kilometres of water, 97 percent is in the oceans. Three quarters of the freshwater is in glaciers and icebergs, another fifth is groundwater, and less than 1 percent is in lakes and rivers. Almost two-thirds of the renewable freshwater provided by annual rainfall over land evaporates. Much of the rainfall transformed into runoff is lost to floods. Given current global water use of 4,000 cubic kilometres, the remaining 14,000 cubic kilometres of effective runoff would be adequate to meet demand for the foreseeable future if supplies were distributed equally across the world's population. But freshwater is distributed extremely unevenly across countries, across regions within countries, and across seasons.

Fortunately, there is a potential for expanding food production. Actual cereal yields in the developed countries is now over 4 t/ha, while in developing countries it is only 2.3 t/ha. Irrigated land accounts for 18% of the cultivated land, but produces 33% of the world's food supplies. It is expected by Pereira et al. (1996) that appropriate intensification and expansion of irrigated areas may account for more than 50% of food requirements by the year 2025. Thus, to meet the expanding food demand there is a need for increasing the average yields and a need for irrigated agriculture.

Water resources play a major role in expanding irrigated agriculture and associated food production. Existing technologies and management techniques for improved water utilisation in agriculture will play an important role in meeting the enormous challenge of population growth and increased food demand. Because of this challenge research efforts have to be increased. There is especially a need to redirect research to fully meet the requirements of sustainable land and water resources utilisation in agriculture. This research and associated information transfer should lead to technologies that would conserve the natural resources, land, and water in particular, and be environmentally nondegrading, technically appropriate, economically viable, and socially acceptable.

Water

The water crisis, which some arid and semi-arid countries are facing already for some time and which more and more other countries will start to face as we enter the 21st century, can be according to Biwas (1991) considered to be the direct result of four important but interrelated phenomena.

First, the amount of fresh water available to any country on a long-term basis is limited. Since nearly all the easily available sources of water have more or less been developed or are in the process of development, the unit costs of future projects can only be higher.

Second, world population is increasing steadily, in some parts of the world even dramatically. Consequently, water requirements for domestic, agricultural and industrial purposes and hydroelectric generation will increase as well. There is of course no one-to-one relationship between population and water requirements, but that the water requirements will increase that is for sure. In this connection we have to consider that past experiences indicate that as the standard of living increases, so do per capita water requirements. Hence, if the present poverty alleviation programmes succeed, both water requirements will increase further and the water management process must become significantly more sophisticated. These two facts have often not been considered by policy makers and planners, both nationally and internationally.

Third, as human activities increase, more and more waste products are contaminating available sources of water. These contaminants are seriously affecting the quality of water, especially for domestic use. They also restrict the amount of fresh water available.

The fourth major factor is the increasing delays that are likely to be witnessed in the coming decades to implement new water projects. Higher project costs and lack of investment funds will be two major reasons for this delay. Equally, social and environmental reasons will significantly delay project initiation time, certainly much more than what have been witnessed in the earlier decades.

There is no doubt according to Biwas (1991) that water requirements of developing countries will continue to increase significantly during the next several decades. However, the traditional response of increasing water availability to meet higher and higher water demands will no longer be adequate in the future for two important reasons:

- Many countries simply do not have any major additional sources of water to develop economically.
- Even those countries that may have additional sources of water, time periods required to implement those projects are likely to be much longer than expected at present.

Seckler et al. (1999) pointed out in a more recent publication that after thousands of years of human development in which water has been a plentiful resource in most areas, amounting virtually to a free good, the situation is at the beginning of the twenty-first century changing abruptly to the point where, particularly in the more arid regions of the world, water scarcity has become the single greatest threat to food security, human health and natural ecosystems.

Talking about water scarcity raises the question: When does water scarcity becomes a problem? Water analysts use the following rule of the thumb: countries with freshwater resources of 1,000 to 1,600 cubic meters per capita per year face water stress, with major problems occurring in drought years. Countries are considered water scarce when annual internal renewable water resources are less than 1,000 cubic meters per capita per year. Below this threshold, water availability is considered a severe constraint on socio-economic development and environmental quality. Currently, some 30 countries are considered water stressed, of which 20 are absolutely water scarce. By 2020, the number of water scarce countries will likely approach 35. Equally worrisome, virtually all developing countries, even those with adequate water in the aggregate, suffer from debilitating seasonal and regional shortages that urgently need to be addressed.

Analysing water scarcity in the next century Rosegrant (1995) identified the following challenges for the future:

Low water use efficiency. The foremost challenge related to water scarcity in developing countries is the need to increase generally inefficient water use in agriculture, urban areas, and industry. Irrigated area accounts for over two-thirds of world rice and wheat production, so growth in irrigated output per unit of land and water is essential. Improved efficiency in agricultural water use is required both to maintain productivity growth and to allow reallocation of water from agriculture to urban and industrial uses.

Expensive new water. New sources of water are increasingly expensive to exploit. Water to meet growing household and industrial demand may thus need to come increasingly from water savings from irrigated agriculture, which generally accounts for 80 percent of water diverted for use in developing countries. To truly contribute to reducing water scarcity, improved efficiency in urban and industrial use.

Resource degradation. The quality of land and water must be sustained in the face of mounting pressure to degrade these resources through waterlogging, salinization, groundwater mining, and water pollution.

Water and health. Pollution of water from industrial effluents, poorly treated sewage, and runoff of agricultural chemicals is a growing problem. Unsafe water, combined with poor household and community sanitary conditions, is a major contributor to disease and malnutrition, particularly among children. One billion people are without clean drinking water, and 1.7 billion have inadequate sanitation facilities. As many as

1 billion episodes of diarrhoea occur annually in developing countries. The World Bank has estimated that access to safe water and adequate sanitation could result in 2 million fewer deaths from diarrhoea among young children.

Massive subsidies and distorted incentives. Most of the world does not treat water as a scarce resource that it is. Both urban and rural water users receive massive subsidies on water use; irrigation water is essentially unpriced; in urban areas the price of water does not cover the cost of delivery; capital investment decisions in all sectors are divorced from management of the resource. In most countries, water subsidies go disproportionately to the better-off: irrigated farmers and urban water users connected to the public system. The inequity is exacerbated because subsidies are often financed from regressive taxes.

Irrigation and food supply

One measure of the importance of irrigation as a factor in agricultural development is the share of food and agricultural output that is produced off irrigated Land (Yudelman, 1994). The Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) has estimated that between 1987 and 1989, the annual value of all crop production in the developing countries was around US$364 billion. US$104 billion worth of crops, that are 28.5% of the value of all production, was produced on irrigated land. More than 30% of all food production was grown under irrigation. Perhaps, irrigation's largest contribution to both consumers and producers is that an estimated 46.5% of all grain and 57% of the total value of the most widely grown basic staples (rice and wheat) were produced under irrigation.

On a regional basis, it is estimated according to Yudelman (1994) that around 60% of the value of crop production in Asia is grown on irrigated land. This includes about 80% of Pakistan's food, 70% of China's food and over 50% of the food of India and Indonesia. In the Middle East and North Africa, more than one third of the region's crop production by value is irrigated, including all food grown in Egypt and more than half of that grown in Iraq and Iran. A relatively small proportion of agricultural production in Latin America, around 10%, is grown under irrigation, but half of the crops grown for export in Chile and Peru are irrigated. Madagascar produces more than 20% of it's agricultural output and food on irrigated land. Sub-Saharan Africa has the smallest regional area under irrigation, and produces an estimated 9% of it's total food production of irrigated land (Yudelman, 1994).

The irrigated sector performs an essential task in meeting the basic food needs of billions of people in the world, especially in Asia. It has provided according to Yudelman (1994) more than half of the two most important basic staples and close to a third of all food crops. In the future, the irrigated sector will have to provide an even larger proportion of the total food output.

For most of modern history the world's irrigated area grew faster than the population. Since 1980 the irrigated area per person has declined and since the mid-1980s cereal grain production per capita has also declined.

The debate regarding the world's capacity to feed a growing population, brought to the fore in the writings of Malthus two centuries ago, continues unabated. But the growing scarcity and competition for water adds an important element to this debate over food security. The eighteen percent of the world's cropland that is irrigated accounts for over a third of the food production. Fifty percent of the increase in food production over the past three decades has come from higher yields on an expanding irrigated land area.

Table 1. Estimates of values of food and agricultural crop production and percentages grown on irrigated land in developing countries 1988 - 89.

Crops	Value (US$ billion)		Percentage grown on irrigated land
	Total	Irrigated	
All crops	364.2	104.1	28.5
Food crops	310.8	96.1	30.9
All grains	148.3	69.1	46.5
Rice and wheat	117.1	67.1	57.1
Wheat	31.1	15.5	50.0
Rice	85.9	51.6	60.0

Source: Yudelman, 1994

Between the 1960s and the 1990s real food grain prices fell by approximately 50 percent. This decline was, according to Barker and v. Koppen (1999) due principally but not entirely to the impact of the so-called green revolution in the developing countries. The subsidisation of food grain production by the developed economies also contributed to the decline. Determining the precise share of the gains in cereal grain production attributable to new varieties, fertilisers, and irrigation is an almost impossible task. However, there is little doubt, according to Barker and v. Koppen (1999), that without the advances in irrigation technologies and extraordinary investments in irrigation expansion by both the public and private sectors, the impact of the green revolution would have been greatly reduced. The benefits of lower food grain prices to the people in third world countries, especially to the poor are obvious. Sixty percent of the money spent on food by the people below the poverty line in Asia is apportioned for cereals, which provide as much as 70 percent of their total nutrients.

While irrigated area grew at 2 percent per annum during most of the past three decades, the period of major construction of new irrigation systems has come to an end. Future growth in new cropland irrigated is projected at less than 1 percent per annum. In fact, with the losses in irrigated land due to salinity, urbanisation, and other factors, the net irrigated area in the world may already be declining. With potential crop yields still well above those now being obtained by farmers, water is now more binding than the agronomic constraint to increased crop production.

The development and expansion of tube well irrigation contributed significantly to the increase in food production during the last decades. However, in the arid and semiarid regions, the point has now been reached where overexploitation of groundwater poses a major threat to the environment, health and food security. Barker and v. Koppen (1999) consider this a threat to the welfare of the poor far more serious than that posed by the widely criticised construction of large dams.

Prerequisites for sustainable solutions

A large share of water to meet new demands must come by saving water from existing uses through comprehensive reform of water policy. Such reform will not be easy, because both long-standing practice and cultural and religious beliefs have treated water as a free good, and because entrenched interests benefit from existing arrangements.

The precise nature of water policy reform will vary from country to country, depending on underlying conditions such as level of economic development and institutional capability, relative water scarcity, and level of agricultural intensification. Additional research is required to design specific policies within any given country. According to Rosegrant (1995) key elements of comprehensive reform should include the following:

Secure water rights. Reform must provide secure water rights vested in individual water users or groups of water users. In some countries and regions, these rights should be tradable, which further increase the incentives for efficient water use. Such a reform can empower water users, provide investment incentives, improve water use efficiency, reduce incentives to degrade the environment, and increase flexibility in resource allocation.

User management of irrigation systems. In many developing countries, devolving irrigation infrastructure and management to water user associations will be beneficial. In the past, such steps often failed because they were not accompanied by secure access to water. Well-defined water rights provide the incentive for user groups to economise on water use, to bargain effectively with the water conveyance bureaucracy for timely and efficient service, and to undertake operations and management.

Reformed price incentives. Privatisation and deregulation of urban water services, together with reduced subsidies for urban water consumption, can also improve efficiency. When incremental water can be obtained at low cost owing to subsidies there is little incentive to improve either physical efficiency (such as through investment in pipes or metering) or economic efficiency. Secure water rights held by the urban companies and an active market have encouraged the construction and operation of improved treatment plants that sell water for agricultural or urban use. Removing subsidies on urban water use can have dramatic effects. Rosegrant (1995) assumes that the reforms described would free up substantial resources for both productive investment and targeted subsidies to the poor and groups who might be left out of the reform process.

Appropriate technology. Availability of appropriate technology will be essential as incentives are introduced for water conservation. Small-scale water harvesting techniques can have high payoffs in certain agro-climatic environments. As the value of water increases, sprinkler, computerised control systems, and drip irrigation using low-cost plastic pipes, all of which are common in developed countries, could have promising results for developing countries.

Environmental protection. Greater protection must be afforded to water and soil quality. The appropriate approach to environmental protection is likely to include both regulatory and market elements. Increased water prices or establishment of tradable water rights can cause farmers to take account of the costs their water use imposes on other farmers, reducing the pressure to degrade resources. Rosegrant (1995) illustrates this in a simple example. A farmer at the head of a canal who overuses water, thereby waterlogging other farmers' land through excess return flows, seepage, and percolation. If he could trade the excess water instead, he would conserve resources. Although any society can design effective environmental protection policies, how much environmental protection will be provided will be a matter of political choice and commitment.

International co-operation. Water policy reform must transcend national boundaries. In many regions, long-term solutions will require international co-operation between countries sharing scarce water resources. Intergovernmental activities to settle conflicts over shared water bodies of water have had mixed success. Co-operation between countries sharing the same water basin will become increasingly important as water becomes scarcer. Reconciliation is cheaper than armed conflict. Rosegrant (1995) sees a key to defusing potential international conflicts over water in a national water policy reform to ensure the most efficient use of available water supplies. Countries must therefore begin the painful process of reforming national water policies and treating water as a scarce resource.

A Vision of the Future

Through it's own research coupled with that of the International Food Policy Research Institute (IFPRI) has allowed the International Water Management Institute (IWMI) to arrive at a vision of the world water situation over the next 25 years. This is best characterised by summarising some of the major findings of this research:

IFPRI projects that demand for cereals will increase by 48% by 2025. Virtually all of this increase will be in developing countries, and most of it will be for feed grains to produce animal products - meat, milk, eggs, etc. The demand for vegetables and fruit, nearly all of which must be irrigated, will increase even more rapidly.

Population will grow about 38%, from the present level of 6.0 billion to 7.8 billion people in 2025. Again nearly all of the increase will be in developing countries. Per capita food supplies are expected to increase in most developing countries enough to satisfy reasonable nutritional requirements - with the major exceptions being in sub-Saharan Africa.

In order to achieve these food production levels, the irrigated area of the world will have to increase by about 34%, from about 250 million hectares in 1995 to 350 million hectares in 2025. This is true even with the most efficient and productive use of existing irrigation water that can be reasonably expected.

IWMI projects that better utilisation of existing water resources in irrigated agriculture could generate additional water supplies to irrigation, increasing by 17% over present levels. The only alternative to increasing productivity per unit of land and water would be massive and environmentally destructive conversion of forests and grasslands in agroclimatically favourable areas of Latin America and sub-Saharan Africa to rain fed agriculture.

Even so, nearly one-third of the population of developing countries in 2025, some 2.7 billion people, will live in regions of severe or ‘absolute’ water scarcity. They will have to reduce the amount of water used in irrigation and transfer it to the domestic, industrial and environmental sectors. Many countries in the arid regions of the world will depend on increased imports to meet the food needs of their people. While there is sufficient production potential in exporting countries to provide this food, it is not at all clear how the importing countries - especially those in sub-Saharan Africa - will find the funds to pay for these food imports.

Groundwater reserves will be increasingly depleted in large areas of the world. In some instances this will threaten the food security of entire nations dependent on highly productive agriculture irrigated with pumps, such as India; it will certainly lead to major problems for food security and access to safe water for poor households in the affected regions.

The people most affected by growing water scarcity will continue to be the poor, especially rural poor, but also the urban poor; and among poor people, women and children will suffer most. If the world fails to invest in the research and development needed to find solutions, and in the application of these solutions, the health, livelihoods and incomes of millions of poor people will deteriorate.

Last, if irrigation and water resources generally are not managed much more effectively and efficiently, the additional water required by irrigation will double. It is now generally recognised that water is the major constraint on food production and one of the major constraints on health and environmental quality in a large number of developing countries. It is water, not land, that could provide the foundations of a Malthusian crises in these countries.

A vision of Egypt's water future ?

Egypt has only one main source of water, the Nile River. The availability of the reliable water supply from the Aswan High Dam is governed by the existing water-sharing agreement, under which 55.5 billion cubic meters are allocated to Egypt. Most of Egypt's water uses are within the agricultural sector, with 84% for agriculture, 8% for industry, 5% for municipalities, and 3% for navigation (Abu Zeid, 1994). Meanwhile, yearly about 4 billion cubic meters of agricultural drainage water is officially reused for irrigation. The groundwater aquifer underlying the Nile Valley and the Delta is entirely recharged from deep percolation from the Nile. The per capita share of fresh water resources is now 950 cubic meters per person per year; it is expected to drop to 350 cubic meters per person by the year 2025. With other words the distribution of Egypt 's share of the Nile's water to its population barely reaches the water poverty threshold and will fall well below this threshold in the years to come.

In a study to project the water supply and demand for 118 countries over the 1990 - 2025 period Seckler et al. (1999) came to the conclusion that Egypt is projected to be in a state of absolute water scarcity by 2025. Egypt belongs to the group of countries, within the 118, which do not have sufficient annual water resources to meet reasonable per capita water needs for their rapidly expanding populations. These countries will almost certainly have to reduce, according to Seckler et al. (1999) the amount of water used in irrigated agriculture and transfer it to the other sectors, importing more food instead. By importing food Egypt is virtually importing water in huge amounts. If one considers that the amount of 1,000 tons of water is needed for evapotranspiration to produce 1 ton of grain Egypt is already importing virtually up to 10 billion cubic meters of water annually. This amount will increase as Egypt's population increases and more food is needed in the years to come. This is because there is no extra water to increase food production within Egypt in quantities necessary to meet the growing demand by the population increase.

Looking at the water balance of Egypt it becomes clear that it is an illusion to believe that the Egyptian agricultural area can be expanded to the planed extent. Because of the scarcity of water there are also limitations in increasing agricultural production, as the increase in plant production is correlated with the plants consumptive use of water. Because of these limitations will have to open-up and develop alternative branches of the economy, instead of investing in the reclamation of marginal lands.

Of course Egypt still can hope, that rapid advances in technology, governance and the economy will help to solve the existing and upcoming problems of water scarcity and degradation. But they will not allow Egypt to assume that the water problems of the country will go away. The eminent historian Charles van Doran (1991) has said,, according to Serageldin (1999), that forecasting the future of knowledge is not just difficult, it is 'impossibly squared'.

But while we cannot see far into the future, on the water front we can see some distance ahead, and what we see gives more reasons for alarm the comfort. The challenges are daunting. We must think boldly, and act now (Serageldin, 1999).

Egypt has to act now. The necessary action will involve not only water sector and environmental professions, but also policy and decision makers, all the Egyptian people, that is the whole of the Egyptian society.

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Irrigated Agriculture in Egypt - notes of an external observer

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Introduction

Agriculture is still an important economic activity of Egypt, and the sustainability of this sector is vital for the overall development of the country. Agriculture employs over 40% of the labour force and provides a noticeable source of the GDP with a share of 16%. Consequently, how to sustain the development of agriculture and thus the national economy is an important issue in Egypt. This issue is becoming ever more acute as the pressure on water, land and other natural resources increases. This papers intends to highlight some of the most important constraints irrigated agriculture is facing in Egypt.

Resource base and frame conditions

Soil resources

Egypt occupies a total area of about one million square kilometres, or 238 million feddans (99.17 million hectares), of which only a small portion (about 3.5%) is agriculturally productive. The agricultural land base of Egypt totals about 7.8 million feddans (3.25 million hectares) covering three different production zones. The first is the old irrigated land with an area of 5.4 million feddans (2.25 million hectares) lying within the Nile Valley and Delta. It represents the most fertile soils in Egypt, which is alluvial, level, deep, dark brown and heavy to medium in texture. Its organic matter content ranges from 1.1 to 2.3 % with pH values between 7.3 and 8.3. According to USDA soil taxonomy, the order Vertisols dominates the major part with the existence of the orders Entisols and Aridosols.

The second production zone is the "newly" reclaimed land, which is viewed as an opportunity for increasing the cultivated area by about 1.9 million feddans. This includes the newly reclaimed land of sandy, calcareous, and saline origin. Soils are poor in organic matter and in macro and micro nutrients.

The third zone is the rainfed area (about half a million feddans) located along the Northwest Coast and in North Sinai. On a per capita basis, Egypt's area of cultivated land, at 0.13 feddan per person, is among the lowest in the world. Despite the ever increasing cultivated area through the governments abuios land reclamation programs, land per capita has steadily declined over the years (Abdel Monem et al., 1998).

Water resources

Agriculture in Egypt is almost entirely dependent on irrigation; the country has no effective rain except in a narrow band along the northern coastal areas. Egypt has only one main source of water, the Nile River. The availability of the reliable water supply from Aswan High Dam is governed by the existing water-sharing agreement, under which 55.5 billion cubic meters are allocated to Egypt. Most of Egypt's water uses are within the agricultural sector, with 84% for agriculture, 8% for industry, 5% for municipalities, and 3% for navigation (Abu Zeid, 1994). Meanwhile, yearly about 4 billion cubic metres of agricultural drainage water is officially reused for irrigation. The groundwater aquifer underlying the Nile Valley and the Delta is entirely recharged from deep percolation from the Nile. The per capita share of fresh water resources is now below 900 cubic meters per person; it is expected to drop to 350 cubic metres per person by the year 2025. With the expected increase in population, not only demand for irrigation water will continue to increase in the next decade and beyond. This implies that the agricultural sector will have to adjust to a smaller amount of available water than previously.

Cropping system

Egypt's agricultural land is, on the average, highly productive and ideally suited to intensive agriculture. With good climatic conditions and a perennial source of irrigation water, agriculture is provided with excellent growing conditions, resulting in high crop yields. Crop productivity levels in Egypt are relatively high when compared to world standards. Productivity of wheat, corn and rice are 5.92, 6.21 and 8.26 tons per hectare (Gomaa, 1996). Due to intensive cropping, the total cropped area was estimated at about 12.1 million feddans, giving a cropping intensity of around 180% for the country as a whole. At present, it is estimated that cotton, wheat, rice, maize and clover (berseem) account for 80% of the cropped area. Wheat and berseem are the principal winter crops. In summer, cotton and rice are important cash crops while maize and sorghum are major subsistence crops. Livestock is an important and integrated part of the agricultural system, as 85% of all livestock is found on small farms.

Economic Policies

Egyptian agriculture is currently in a transitional period. The two decades of the 1960s and 1970s were characterised by heavy government intervention in agriculture. Output prices were controlled, inputs were subsidised, quota deliveries at fixed prices of the major food commodities, like wheat, maize, and beans, were compulsory, and land rent was controlled. Cropping pattern was influenced by area allotments required for the major crops like cotton, sugar cane, rice and wheat. Farmers decisions during that period were heavily influenced by those policies. In the late 1980s, as part of an economic reform program, agricultural market liberalisation policies were initiated. Output markets were liberalised and quota deliveries were eliminated. In addition, subsidies on inputs were reduced and crop area allotments were eliminated for most crops. The new policies have provided farmers with new flexibility in the cropping patterns and resource allocation that will affect the agricultural sector. Increasing wheat production in recent years following a dramatic rise in prices and improved technology gives an example of the impact of new policies.

The period of rapid adjustment, during which government revenues from the agricultural sector fell sharply, also provided an opportunity to adjust other prices to more appropriate levels. To some extent this was done - subsidies for farm inputs were as mentioned above reduced. But charges for water services to agriculture and to other users were not introduced. Water still is provided free in bulk to all users by the Ministry of Public Works and Water Resources. Intermediate services of treating water for domestic consumption are charged for by the agencies concerned (Perry, 1996).

Threats to sustainability

Despite the fact that the use of high levels of inputs, developing improved varieties, using the agricultural land to its potential, and implementation of other cultural controls has resulted in historic increases in crop productivity, the sustainability of Egypt's agricultural system is endangered by a number of constraints. These constraints have been identified in part during inventory studies carried out by the Agricultural Research Centre of Egypt (ARC), the International Centre for Agricultural Research in the Dry Areas (ICARDA) within the EU financed Nile Valley and Red Sea Regional Program (Hamissa, M.R. et al., 1998).These constraints can be grouped into water management, agronomic, extension and institutional and policy constraints.

Water management constraints
Water management in Egypt faces the following constraints:

- Inequity of water distribution between the heads and tail ends of distributary canals and *mesqas*.
- Irrigation farmers are increasingly apathetic towards the operation of the irrigation system and seek to exploit localised solutions to obtain more reliable water supplies.
- The major problems in unlined canals are generally seen in weeds, seepage, and unstable cross-sections. But if one analyses the maintenance problems of the public irrigation and drainage infrastructure in Egypt it becomes obvious that this is a very complex issue. Under 4. the results of such an analysis are summarised.
- Removal of weeds and general maintenance of private *mesqas* is traditionally the responsibility of the farmers. However, in view of the excessive weed growth in some cases and the blocking of canal cross-sections caused by sediment, garbage materials, and debris in others, especially those running through or besides villages, farmers in many cases are unable to cope with this situation.

Agronomic constraints
Poor soil fertility, associated with salinity and alkalinity problems, represents a major limiting factor for the productivity of most field crops. About 500,000 feddans (210,084 hectares) of heavy soils, located in the northern part of the country, are highly saline, partly with poor internal drainage properties. The sodicity hazard of some of these soils is high and their permeability is low. Reclamation requires improvement of their physical and chemical properties through leaching, amendments, subsoiling, and deep plowing with good, appropriate drainage.

Other constraints are:

- Excessive freshwater loss to drains due to over-irrigation, poor land levelling etc.
- Poor plant stands, associated with hand seeding. The resulting low and uneven plant density cannot make efficient use of fertilisers.

- Poor management practices such as:
    - Poor seedbed preparation at planting.
    - Uneven seed depth and cover.
    - Late planting in some locations.
    - Fertiliser abuse, as a result of high application rates and low percentages of nutrient (nitrogen) utilisation.
    - Poor weed control in the field.
    - Disease damage in some field crops.
    - Insect damage, especially aphid, to food legumes, wheat, and barley.
    - Primitive methods of harvesting, threshing, transportation which might cause heavy yield losses.
    - Storage insects lead to grain loss and bad seed quality.

Extension constraints

Although there are constraints in any research program, the main problem in Egypt is how to transfer the already available research results to the farmers. Extension programs in Egypt face a variety of constraints.

These constraints are mainly:

- Lack of communication between research and extension.
- Inadequacy in delivering research results quickly and effectively to extension specialists and dissemination to farmers.
- Isolation of extension agents from each other.
- Farmer suspicion towards government personal.
- Shortage of well-trained extension workers.
- Engagement of extension personnel in many other governmental activities.

Institutional and policy constraints

The failure to deal effectively with the problems of farmers and their relationship to environmental degradation, to sustainability issues arises from numerous complex and interacting factors. Here institutional and policy constraints play an important role.

In Egypt such constraints to irrigated agriculture are:

- Top-down centralised state-controlled institutions and minor official role of traditional local institutions in areas such as conflict resolution and the regulation and maintenance of the irrigation system.
- Inflexibility of state-controlled irrigation systems management.
- Inability of national institutions to exercise authority effectively at the local level and the lack of empowerment of local institutions to co-ordinate activities at their level.
- Land losses and low land/population ratio: Due to urbanisation expansion, it is estimated that about 30,000 feddans are lost annually (El Belassy, 1992). The per capita share of land declined from 0.5 feddan in 1897 to 0.1 feddan in 1992 (Abu Zeid, 1994).
- Division of various research and production efforts on the same crop between various institutes and sections.
- Gap between research and extension.
- Nonavailability of inputs in quantity, quality and in time.
- Lack of dynamic administrative and management systems.

Maintenance - the bottleneck of Egypt's irrigation and drainage system

General remarks

Maintenance is defined simply by Ostrum (1993) as "any activity that slows the deterioration of a facility, whether caused by use or ageing." Carruthers and Morrison (1994) provide according to Svendsen (1994) a somewhat more operational specification of maintenance as

> *.... a management response to the deterioration of the physical condition of irrigation and drainage systems that threatens to make it impossible to achieve operational targets.*

The above definition contains several notable features. The most important being that maintenance is described as a management response. This suggests that, for effective maintenance at least, the responsible institution must have objectives related to maintenance and make real-time decisions regarding maintenance in response to changing conditions. In short, it must be a managing agency and not an administrative one.

Four basic categories of maintenance can be identified in the O&M of irrigation and drainage systems:
(1) desilting, (2) weed control, (3) maintenance of structures, (4) maintenance of mechanical equipment such as pumps and engines. To this list can be added, according to Svendsen (1994), (5) maintenance of decision support facilities. The category comprises the measurement, communication, and decision support systems which allow the intelligent and responsive control of water in the irrigation and drainage system. Together the condition of these system facilities constrains or enables the ability of the system to deliver or drain water by affecting canal carrying capacity, water storage capacity, and regulatory capacity. A sixth category of maintenance usually carried out by irrigation and drainage agencies comprises of maintenance of appurtenant structures and facilities such as project buildings and access roads.

Maintenance of open canals and drains is not just the physical part of deweeding and desilting operations. It is a management undertaking requiring a high degree of flexibility in decision making on the spot, at the local level.

Maintenance problems observed in Egypt

Weed problems are generally severe on the Egyptian canals and have been attributed to the closure of the High Aswan Dam which reduced the annual silt load of the Nile enhancing the penetration of light through the water and increasing the growth of submerged species like *Potamogeton pectinatus* and *Potamogeton nodosus*. It is according to Barbben and Bolton (1988) reported by maintenance engineers that weed growth was not a problem in the period before regulation of the Nile. Whether this also applies to the then relatively sparse open drainage system is not known.

The irrigation and open drainage system in Egypt consists mainly of unlined earth canals to distribute or collect water. Canal velocities are low. Drains often contain stagnant or very slow moving water. Together, with favourable climatic conditions, make ideal habitats for aquatic plants. The increase in fertiliser application most probably increased the nutrient content of the drainage water and encouraged even more the growth of weeds. All types of aquatic weeds are common in the open drains that is submerged, ditch bank, emergent and floating weeds. It seems to depend on the site conditions whether one or the other type is dominant. Because of the weed infestation the roughness is sufficiently high to decrease the flow of the irrigation canals and open drain system.

The maintenance of the irrigation and drainage infrastructure in Egypt is, as in other countries, a very complex issue. Therefore no simple solutions can be found. The following reasons for poor maintenance are most commonly found in Egypt:

(1) technical problems

- inadequate physical operation of maintenance works
- oversized canal sections through over excavation
- missing service road network
- bridges and pipelines as obstacles
- difficult mechanical removal of biomass (especially submersed weeds)
- mechanical maintenance makes large amount of specialised equipment necessary

(2) management problems

- lack of strategic vision in relation to maintenance
- inadequate long range conceptual planning capability
- staff availability unsatisfactory
- training of staff insufficient
- contracts for annual instead for several years maintenance
- no preventive maintenance
- lack of comprehensive operational plans
- lack of accountability and incentives
- lack of liaison between irrigation or drainage authority and water users

(3) financial problems

- dependency attitude of farmers upon free services from the state
- no well developed direct cost recovery system
- system for assessment and collection of O+M costs missing
- inadequate budget
- underpayment of contractors
- bureaucratic financial procedures

(4) legal problems

- use of chemicals banned since Dec. 1991
- legal framework for drainage associations and engagement in maintenance is non-existent or not in operation

(5) sociocultural problems

- attitude of society in respect to preventive maintenance is underdeveloped
- lack of interest of farmers in participating or collaborating in maintenance work
- poverty and maintenance
- over fishing of grass carp
- maintenance lacks the prestige of construction among professional staff
- low social status of maintenance work

(6) ecological problems
- maintenance interferes with ecosystems of canals
- solid waste disposal at canal banks
- disposal of sewage into irrigation and drainage canals

(7) health problems
- increase of vector borne diseases through poor maintenance (Schistosomiasis)

The Fayoum Water Management Project (1996) in studying different weed control methods came to the conclusion that:
- mechanical weed control, using the mowing buckets is an efficient method, as it prevents any further expansion and deepening of the water channels resulting from the use of the traditional excavation buckets;
- mowing buckets can be installed on various equipment available in Egypt;
- mowing buckets are cost efficient and can operate with high performance, if carefully used by the operators and if the labourers carry out the necessary maintenance works systematically with the required efficiency.

Despite these facts deweeding of irrigation and drainage channels in Egypt is still done in most cases by using the traditional excavation buckets. The single most important issue constraining a shift from this traditional method of channel excavation to weed mowing are the contracts for annual maintenance. The problem concerns the design of contracts, the duration of contracts, the tendency to follow an established maintenance system, the imprecise specifications for contracted work items and the structure of the unit rates.

A new strategic thinking is required

There is a broad consensus among irrigation and drainage professionals that present maintenance standards are a crucial impediment to the efficiency and sustainability of irrigation and drainage systems. In many ways the irrigation and drainage maintenance problem is not unique. It is perhaps but a visible example of a general infrastructure maintenance problem provading education, health, transport and other elements of the public sector in the developing world (Carruthers and Morrison, 1994).

The recurrent cost problem has been identified by Carruthers and Morrison et al. (1994) as a major constraint on even the best designed maintenance organisations. However, throwing more money at the maintenance problem is very unlikely to resolve it. It is much more than likely that without other changes any additional resources will be wasted. More precision in diagnosis and clear criteria by which improvements can be judged will be required. The norms for rehabilitation and maintenance of drainage systems being developed by the M&E Project of the Egyptian Public Authority for Drainage Projects (EPADP) leads in the right direction and should be consequently implemented.

One has to be aware that in the maintenance of irrigation canals and open drains no general solution exists. This is because site conditions, especially weed growth conditions differ across Egypt, requiring different maintenance measures. This is why site specific maintenance strategies have to be developed and a high flexibility of the organisation responsible for maintenance and in management of the irrigation and drainage system is required.

Much maintenance presents arduous tasks and the potential returns are often not perceived by those involved especially in irrigation and drainage system management. This failure to recognise the value of maintenance is true for governments, for irrigation and drainage agencies and farmers. All these groups must be encouraged to participate in all aspects of planning, construction and implementation. Participation, especially of farmers, seems to be missing in Egypt. Especially drainage is seen by the beneficiaries in Egypt to be solely a government undertaking. In order to reach a high degree of sustainability of the irrigation and drainage system practical maintenance issues have to be high on the agenda at each stage in development. Beneficiaries have to become aware of the value of well functioning drainage systems.

The increased effective participation of farmers in maintenance is seen as one solution to its neglect. There is a general understanding that beneficiaries of the drainage systems installed by EPADP have to finance and execute its upkeep in the future, most likely through ”drainage associations”. It is not clear whether this general call for greater participation of beneficiaries in all aspects of drainage management can be applied in Egypt at present or in the near future, especially since drainage does not seem at present to be very high on the agenda of the farmers all over Egypt. This is particularly valid for the sugarcane farmers in the Nile Valley. To encourage optimal participation, the valid incentives must be clearly evident to all the players. But what are the incentives for the farmers for example? What can EPADP do to deliver these incentives? What organisational structure is appropriate to deliver these incentives? Under which conditions is it beneficial for farmers to participate?

One has to be aware that there might also be another side of the picture. The expectation that the farmers in Egypt are to execute and to finance the work that needs to be done on the drainage and partly on the irrigation systems could turn out to be wishful thinking of those remote from the field level problems, a reaction to shortages of government revenue, or simply a switch of tactics from centralised planning approaches to devolved participative mechanisms in line with a widespread current political fashion. If this is the case a different strategy has to be developed to improve the maintenance situation of the irrigation and drainage systems in Egypt on a sustainable basis. At least it is necessary to change from the present more or less schematic maintenance operations to more situation-conforming management of the maintenance works. It seems to be necessary to develop a respective strategy or concept which increasingly involves the beneficiaries in operation and maintenance of the irrigation and drainage system.

The maintenance of watercourses and especially open drains is in Egypt as in other countries increasingly discussed from an ecological point of view. The Research Institute of Weed Control and Channel Maintenance of Egypt's Water Research Centre besides others are considering weed growth in channels to some degree desirable for ecological reasons. It was found also to be of some advantage for water quality improvement. Such changing attitudes have to be considered when developing a maintenance strategy.

Conclusions

Egypt's highly productive irrigated agriculture is subject to unprecedented expansion in area and intensification, while competition with industrial and domestic sectors for fixed supply of Nile water continues to increase. Salinization, heavy use of inputs, and pollution all threaten the health of the soils. At the same time, developing newly reclaimed desert soils and rainfed areas to possess economically sustainable productive capacities is seen as a major challenge. To achieve a sustainable development of Egypt's irrigated agriculture it takes more than just solving the technical and agronomic problems. Among others the the sustainable solution of legal, sociocultural, ecological, health and financial problems have to be considered. Furthermore, limited resources and threatened production sustainability call for an efficient resource-management strategy and farming-system approach for agricultural development and research in Egypt. Such an research approach is followed within the EU financed Nile Valley and Red Sea Regional Program by the Agricultural Research Centre of Egypt and the International Centre for Agricultural Research in the Dry Areas (ICARDA). The approach should by extended to all agricultural research in Egypt. Such approaches have to be holistic, taking into account the socio-economic requirements of all sectors of the economy, of Egypt's society.

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Surge flow irrigation for corn in clay soils

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Abstract

Field experiments were carried out during 1996 and 1997 summer seasons at Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt. These experiments aim to evaluate the furrow surge irrigation system for corn under different land levelling practices as a method to improve the efficiency of surface irrigation and water saving. The experiment was arranged in split plot design with three replicates. The main plots are assigned to land levelling practices (dead and traditional levelling), while the subplot treatments were the continuous flow irrigation and four cycle ratios of surge flow irrigation.
Obtained data showed that all tested cycle ratios of surge flow irrigation gave lower water advance times, lower amounts of applied water, higher water application efficiency and higher water distribution efficiency than that continuous flow irrigation. Advance inflow times were reduced in the case of surge flow to 21% and 20% of the time required for continuous flow under dead and traditional levelling, respectively. Amounts of applied water were reduced using surge flow irrigation by 19.1% and 16.5% of continuous flow irrigation under dead and traditional land levelling respectively. The average values of water application efficiency (WAE) varied from 68.6 to 84.2% and from 53.8 to 73.4% for surge flow irrigation under dead and traditional land levelling respectively. The corresponding values for continuous flow irrigation were 63.1% and 51.4%. Water distribution efficiency (WDE) increased using surge flow irrigation. The average WDE values under continuous flow irrigation were 85.4% and 77.1% for dead and traditional land levelling respectively. Corresponding values for surge flow irrigation varied from 88.0 to 94.7% and from 79.6 to 90.2%.

The results revealed also that the values of water consumptive use of corn were higher for continuous flow irrigation than that for surge flow one. The water consumptive use reduced with increasing the off-time in surge flow irrigation. The average of grain yield of corn under surge flow irrigation varied from 3.09 to 3.48 ton/fed. The corresponding value under continuous flow irrigation was 3.0 ton/fed. The dead levelling achieved higher grain yield than that traditional levelling. The average values of water utilization efficiency for continuous flow irrigation were 0.90 and 0.78 Kg/m^3 under dead and traditional land levelling, respectively. The corresponding values for surge flow treatments varied from 1.04 to 1.46 and from 0.86 to 1.14 Kg/m^3. For all the studied parameters the surge flow irrigation with cycle ratio of 0.5 (20 min. on and 20 min. off) gave the best results.

Introduction

Irrigation was initially introduced in Egypt as surface irrigation, about more than 3000 B-C. Surface irrigation is practiced as flooding the soil surface by basin or border irrigation, or running the water in small ditches of furrows. Despite the fact that, sprinkler and trickle irrigation are used to maximize the crop yield for unit water, the surface flooding irrigation is still the most widely used. This is because of the high cost of trained labor and energy required to conduct the alternative systems.

Generally, surface irrigation efficiency is around 50%. Over years, minor changes have been made to increase the efficiency of surface irrigation. Land smoothing, cutback technology and tail water reuse along with proper scheduling are used to reduce water losses and improve irrigation efficiency. The latest improved surface irrigation method is through surge flow irrigation (James, 1988). Many researches have been carried out either theoretically and/or experimentally, to study the several aspects of surge irrigation and to determine the involved mechanisms. However, in Egypt little work has been done on the field of water management and yield of field crops under surge irrigation, e.g. Ghalleb (1987), Zaghloul (1988) and Osman (1991).

The main objectives of the present study are:

1. To evaluate the furrow surge irrigation system of corn under different land levelling practices in heavy clay soils of Kafr El-Sheikh Governorate. 2. To improve efficiency of the surface irrigation and water saving. 3. To define the best surge flow furrow irrigation practices for corn crop owing to optimize the water utilization efficiency.

Material and Methods

Field experiments were carried out at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, during the two successive summer seasons of 1996 and 1997. The station is situated at 31^{o}C-07 N latitude, 30^{o}C-75 E longitude. It has elevation of about 6 meters above sea level. It represents conditions and circumstances of middle northern part of the Nile Delta. The experimental site located near to the main open drain and was served by tile drainage established since 1989. The tile drainage system consists of subsurface, 10 cm inner diameter, PVC pipes spaced 20 m apart and buried at 1.65 m depth.

Soil samples from the experimental field were collected for different soil depths, 15 cm each down to 60 cm, and analyzed for both some chemical properties and soil texture. The soil saturation extract was obtained. Total soluble salts (EC), acidity number (pH) and soluble cations and anions were determined by the methods described by Jakson (1962). The mean values are given in Table (1). In general the soil is non saline.

Table 1: Some chemical and physical analysis of experimental site.

Soil Depth	Particle size distribution			Text-Ure	Bulk density	FC w%	PWP w%	Avail-Able Water	EC	Cation c mole/kg soil				Anion c mole/kg soil			pH
	Sand	Silt	Clay		Mg/m^3			W%	dS/m	Na^+	K^+	Ca^{++}	Mg^{++}	$HCO_3^=$	Cl^-	$SO_4^=$	
0-15	15.18	18.85	65.97	Clay	1.09	47.2	25.38	21.82	1.50	0.76	0.02	0.30	0.10	0.55	0.21	0.46	8.15
15-30	19.90	13.80	66.30	Clay	1.15	40.5	21.85	18.85	1.57	0.79	0.02	0.31	0.10	0.57	0.22	0.48	8.00
30-45	16.59	16.97	66.94	Clay	1.24	39.0	21.19	17.81	1.65	0.89	0.02	0.34	0.10	0.65	0.23	0.50	8.00
45-60	12.65	15.24	67.12	Clay	1.26	38.5	20.81	17.69	2.78	1.25	0.03	0.84	0.27	0.45	0.23	1.71	7.90

The particle size distribution was determined according to the international pipette method, Black (1965). The obtained results (Table, 1) indicate that the soil is clayey in texture and the soil profile is uniform without distinct change in texture. Corn (*Zea mays* L.) as summer crop was sown in an agricultural rotation after wheat as winter crop. This rotation was repeated for two years. Sowing dates for corn were June 29, 1996 and June 30, 1997 for the first and second year, respectively. All cultural practices were the same as recommended for the area except the levelling and the irrigation treatments under study. The experiment was arranged in split plot design with three replicates. Each plot was 3.5 x 80 m= 280 m^2 = 1/15 feddan). Eight stations (S_1 to S_8) were arranged every 10 m along the furrow to measure the flow advance pattern. The treatments were as follows:

Main treatment (land levelling):
A. Dead levelling (0.0%) B.Traditional method of land levelling.
Sub treatments: five irrigation treatments were applied after sowing:
1: Represent a continuous flow irrigation (control),
2: Surge irrigation with cycle ratio of 0.8 (20 min on and 5 min off),
3: Surge irrigation with cycle ratio of 0.67 (20 min on and 10 min off),
4: Surge irrigation with cycle ratio of 0.57 (20 min on and 15 min off), and
5: Surge irrigation with cycle ratio of 0.5 (20 min on and 20 min off).
The cycle ratios were chosen according to the possible applicability. The irrigation intervals were 15 days. The amount of water in each application was added whatever number of surges needed until reaching 95% of the run length (75 m). The irrigation water was conveyed to the experimental plots through an open channel using a centrifugal pump with a water meter to measure the total volume of applied water. The inflow rate was about 5.4 L/sec.

Soil samples were taken from three selected stations along the furrow of two replicates, before and 2 days after each irrigation and immediately before harvesting from the successive soil layers 0-15, 15-30, 30-45, 45-60 cm depth. Their moisture content on the dry weight basis were determined. The advance time of the water flowing in furrow of each treatment was recorded when the water front was reached each station along the furrow. The on-off cycle time was controlled by means of stop watch. The number of surges needed until the water reached 95% of the furrow length were recorded and the irrigation time was determined.

The applied irrigation water to each experimental plot was measured using spile tubes. The effective head of water above the cross section center of irrigation spile was measured several times during irrigation and the averaged value was 6 cm. The water in the canal was controlled to maintain a constant head by means of fixed sliding type gates.

The amount of water delivered through a spile of 10 cm inner diameter was calculated by the equation:

$$q = CA\sqrt{2gh}. \quad \text{or } q = 0.0226\, D^2 h^{1/2}$$

Israelson and Hansen (1962)

Where: q = Discharge of irrigation water (L/sec),
C = Coefficient of discharge = 0.64 according to Osman 1991,
g = Gravity acceleration, 980 cm/S^2, A = Inner cross section area of irrigation spile,
h = Average effective head, cm, and D = Inside diameter of the spile tube, cm.

The volume of water for each strip (3.5 x 80 = 280 m^2) delivered to five furrows of 80 m length and 0.7 m apart was calculated by substituting Q in the following equation:

$$\mathbf{Q = q \times T \times n}$$

Where: Q = Water volume m^3/strip, q = Discharge m^3/min,
T = Total time of irrigation (min) and n = Number of spile tube per each strip.
The total on-time under continuos and surge flow irrigation was calculated using a stop watch. To evaluate the flow advance rate for different treatments the approach of Christiansen *et al.,* 1966 was used as: $L = a\ t^b$
In which: L = Length of advance, t = Time of advance and a, b = Empirical constants.
Crop water consumptive use (cm) was determined as follows:

$$\mathbf{Cu} = \sum_{i=1}^{i=4} \frac{Pw_2 - Pw_1}{100} \times D_{bi} \times D_i$$

Where: Cu = Consumptive use, cm. i = Number of soil layers,
Pw_2 and Pw_1 = Percentage of soil moisture content 48 hours after irrigation and before irrigation for the specified layer, D_i = Depth of soil layer = 15 cm, and
D_{bi} = Bulk density of the specified soil layer gm/cm^3.

Dates of harvesting of corn were Oct. 20, 1996 and Oct. 25, 1997 for the first and second season, respectively. Five plants from the central ridges at each station, were randomly chosen to determine the grain yield (ton/fed.). The water utilization efficiency as a measure to clarify variations in yield due to irrigation water was calculated according to Michael (1978) as follows:

$$\mathbf{WU_tE = Y/Wa}$$

In which: WU_tE = Water utilization efficiency (kg/m^3),
Y = Total yield produced kg/fed., and Wa = Total applied water m^3/fed.
The collected data for grain yield were subjected to the statistical analysis according to Snedecor and Cochran (1967) and the mean values were compared by L.S.D. test and Duncan multiple range test (DMRT) according to Duncan, 1955.

Results and Discussion

1. Advance rate:

The data listed in Tables (2 and 3) revealed that the surge flow treatments had higher water advance rates, either under dead or traditional levelling, compared with the continuous flow irrigation treatments. The equations relating L and T, mean values, were: $L = 0.79\ T^{1.004}$, $L = 0.741T^{1.039}$, $L = 0.680\ T^{1.082}$, $L = 0.635\ T^{1.136}$ and $L = 0.619\ T^{1.176}$ under dead levelling, respectively for treatments A_1, A_2, A_3, A_4 and A_5. The corresponding equations for the traditional levelling were $L = 0.729T^{0.975}$, $L = 0.654T^{1.027}$, $L = 0.583T^{1.069}$, $L = 0.503T^{1.116}$ and $L = 0.527T^{1.121}$, respectively for the treatments B_1, B_2, B_3, B_4 and B_5. Also the constant (b) of the equation increased with decreasing of the cycle ratio and had relatively higher values under dead levelling than under the traditional one. This indicates that water advance rate is faster with decreasing the cycle ratio (or with increasing off-time) and under dead levelling than under the traditional levelling treatments.

The overall mean of time required for water advance to reach the end of the furrow varied from 86.3 to 66.7, with an average of 76.3 min and from 106 to 85.7, with an average of 95.2 min for surge flow treatments, under dead and traditional levelling respectively. The corresponding values for the continuous flow varied from 97.3 to 115.5 min under dead and traditional levelling, respectively. This means that the irrigation is completed faster when surge flow irrigation technique is used. Surge flow saved 21% of the time required for continuous flow to complete the irrigation, under dead levelling. The corresponding value under traditional levelling was 20%. This saving of irrigation time under surge flow was mainly because of the faster water advance rate under surge flow than under the continuous flow. The best treatment was that of 0.5 cycle ratio (20 min on and 20 min off). These results indicated that surge flow had faster advance rate with the longer off-time due to the effect of wetting and drying cycles on soil infiltration characteristics, Goldhamer *et al.* (1987). Increasing the off-time in surge flow reduces infiltration rate and results in greater advance on wetted area, Guirguis (1988). The trend of these results is in accordance with those obtained by Moustafa (1992) and Osman *et al.* (1996).

2. Applied irrigation water:

The number of irrigations during the whole season was seven irrigations including the sowing irrigation. The amount of the applied water to each treatments are given in Tables (4 and 5). The total amount of applied water varied according to the differences in irrigation treatments. All tested cycle ratios of surge treatments used less amount of water than that continuous one. Average volumes of applied water for continuous flow treatment (A_1) were 3402 and 3813 m^3/fed for dead and traditional levelling, respectively. The average amounts of added water by surge flow treatments A_2, A_3, A_4 and A_5 were, 3074, 2832, 2665 and 2447 m^3/fed, under dead levelling, respectively. The corresponding values under the traditional levelling were 3516, 3261, 3053 and 2883 m^3/fed for treatments B_2, B_3, B_4 and B_5, respectively. The surge flow irrigation reduced the applied water by 9.7, 16.8, 21.8 and 28.2% for the treatments A_2, A_3, A_4 and A_5, respectively under dead levelling. The corresponding reductions of the added water by surge flow under the traditional levelling were 7.8, 14.3, 20.2 and 23.9% for treatments B_2, B_3, B_4 and B_5, respectively. In other words, surge flow irrigation saves water, on average for all treatments, by about 19.1% and 16.5% of the continuous flow irrigation, under dead and traditional levelling, respectively.This means that dead levelling emphasized the saving of the applied irrigation water to corn crop. Increasing the off-time in surge flow results in greater water saving. The best treatment in saving water was that of 20 min on and 20 min off (0.5 cycle ratio). It saved water of 28.2% (959.4 m^3/fed) and 23.9% (911.4 m^3/fed) of the applied water using continuous flow irrigation under dead and traditional levelling, respectively. The trend of these results is in accordance with those obtained by Ghalleb (1987) and Osman (1991). On the other hand, data revealed that the soil under traditional method of land levelling received higher amount of irrigation water than that under dead levelling. These results are in a harmony with those obtained by El-Mowelhi *et al.* (1995).

3. Water application efficiency (WAE)

The calculated WAE values for the different irrigation treatments are illustrated in Figure (1). The surge flow had higher values of WAE compared with the continuos flow irrigation. The overall average WAE values for continuous irrigation were 63.1% and 51.4%, under dead and traditional levelling, respectively. The corresponding values for surge flow irrigation treatments varied from 68.6% to 84.2% with an average of 74.5%, and from 53.8% to 73.4%, with an average of 63.9% under dead and traditional levelling, respectively. These results indicate that WAE under surge flow irrigation exceed the continuous flow irrigation with about 11.4% and 12.5% under dead and traditional levelling, respectively.

The high efficiency of surge flow can be attributed to the surface seal that causing by the intermitted wetting and the surface hydraulic roughness of the wet advance, Guirguis (1988). It was found that WAE increase with the decrease of the cycle ratio or the increase of off-time. The best treatment was that of 0.5 cycle ratio (20 min on and 20 min off). It had the highest value of 84% and 73% as average of the two seasons, under dead and traditional levelling, respectively. These results are in close agreement with those of Osman (1991) who found that the WAE values were 60.9, 73.7, 74.4 and 77.7% for continuos flow and for surge flow of 5/5, 5/10 and 5/15 on/off min, respectively at Sakha (Kafr El-Sheikh).

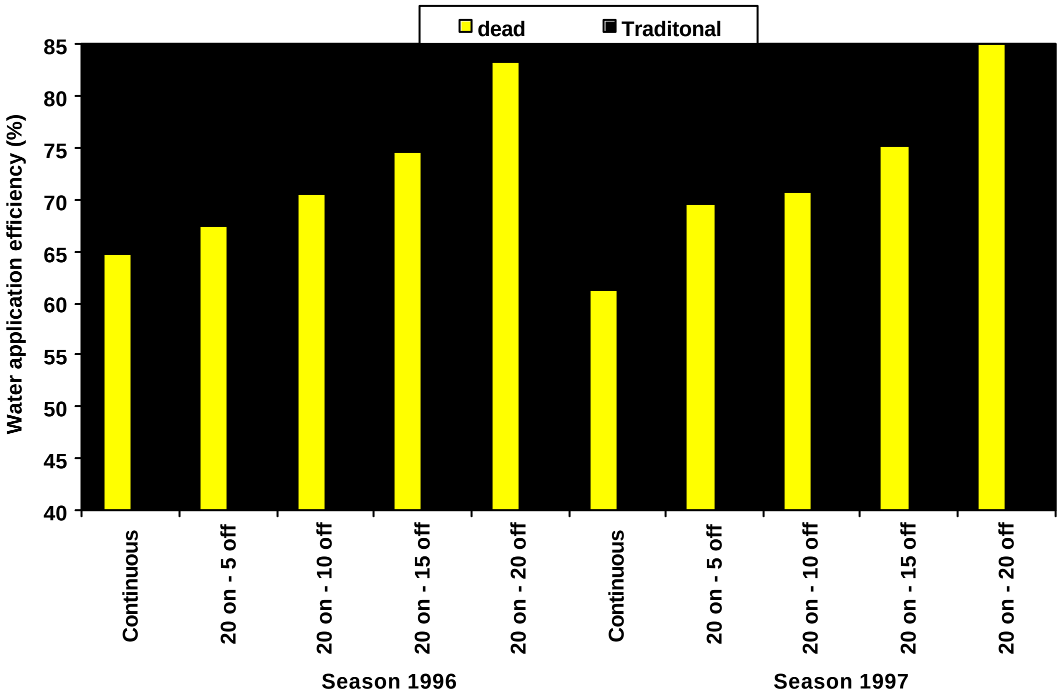

Figure 1: Values of water application efficiency (WAE) under dead and traditional levelling for furrow irrigation of corn during 1st and 2nd seasons.

4. Water distribution efficiency (WDE):

As shown in Table (6) surge flow technique recorded higher values of WDE compared with continuous flow irrigation either under dead or traditional levelling. The overall average of WDE values, for the two growing seasons, under the continuous irrigation were 85.4% and 77.1% for dead and traditional levelling, respectively. The corresponding values for the surge flow irrigation treatments varied from 88.0 to 94.7% with an average of 91.4% , and from 79.6 to 90.2% with an average of 84.9% for dead and traditional levelling, respectively. It was found that WDE values increased whenever the cycle ratio decreased or the off-time increase. The best treatment was that of 0.5 cycle ratio (20 min on and 20 min off). It had the highest values of 94.7% and 90.2% for dead and traditional levelling, respectively. The trend of these data is in agreement with those obtained by Moustafa (1992) and Evans *et al.* (1995) who mentioned that the use of surge flow was superior to continuous flow furrow irrigation for maintaining acceptable application uniformities. On the other hand, the difference between WDE values of surge flow and these of continuous flow irrigation was relatively low. It varied between 6 and 7.7%. This may be due to the nature of the clayey soils that crack severely, Pitts and Ferguson (1985).

Table (6): Values of water distribution efficiency (WDE) under different irrigation treatments for the furrow irrigation of corn.

Land Levelling	Treat.	Cycle ratio		Season 1996 Date of determination				Season 1997 Date of determination				Average of two seasons	
		On	Off	19/8	15/9	10/10	Average	13/8	7/9	28/9	Average		
Dead	A_1	Cont.	0	80.1	85.7	87.4	84.4	83.3	87.2	88.4	86.3	85.4	85.4
Levelling	A_2	20	5	83.4	86.5	92.6	87.5	85.5	89.3	91.7	88.5	88.0	
	A_3	20	10	90.0	89.2	93.8	91.0	90.6	94.0	95.0	93.2	92.1	91.4
	A_4	20	15	91.3	91.5	95.0	92.6	93.3	95.2	95.3	94.6	93.6	
	A_5	20	20	93.0	94.5	96.3	94.6	94.4	95.3	96.2	95.3	94.7	
Traditional	B_1	Cont.	0	73.5	76.0	77.0	75.5	75.3	80.2	80.3	78.6	77.1	77.1
levelling	B_2	20	5	78.4	79.3	80.5	79.4	78.6	79.8	81.0	79.8	79.6	
	B_3	20	10	80.0	83.2	87.0	83.4	83.3	84.3	86.2	84.6	84.0	85
	B_4	20	15	83.4	87.2	88.3	86.3	85.6	86.0	87.0	86.2	86.3	
	B_5	20	20	89.7	90.3	90.4	89.9	89.0	90.4	91.0	90.4	90.2	

5. Water consumptive use (WCU):

As shown in Table (7) the values of WCU, average of the two seasons, varied from 41.6 to 47.9 cm and from 45.4 to 51.5 cm under the surge flow irrigation treatments for dead and traditional levelling, respectively. The corresponding values for the continuous irrigation treatment were 50.1 and 53.5 cm for dead and traditional levelling, respectively. The tendence of these results are in agreement with those obtained by Musick *et al.* (1987) who showed that surge flow irrigation reduced seasonal water use during 7 irrigations by 6%. Ghalleb (1987) found that the consumptive use for the continuous flow irrigation was higher (3.36 mm/day) than those for the surge flow irrigation, 3.18 and 3.0 mm/day respectively with cycle ratios of 1/2 and 1/4. Also, the surge flow treatments A_5 and B_5 recorded the lowest values of WCU (41.6 and 45.6 cm) under the dead and traditional levelling, respectively. The continuous irrigation treatments A_1 and B_1 had the highest values of 50.1 and 53.5 cm, respectively.

6. Grain yield:

Data tabulated in Table (8) showed that the highest grain yield was obtained under the surge flow treatment of 0.5 cycle ratio (20 min and 20 min off). It had an overall average of 3.48 and 3.40 ton/fed for the first and second seasons, respectively. On the other side, the lowest grain yields of 3.05 and 2.98 ton/fed were obtained under the continuous irrigation, for 1st and 2nd seasons, respectively. This means that the increase in corn grain yield under the best treatment (0.5 cycle ratio) was 14.1% above the yield of the continuous irrigation.

Table (7): Water consumptive use (cm) of corn (season 1996 and 1997) for different treatments.

Land levelling	Treat.	Cycle		Season 1996		Season 1997		Average of two seasons	
		On	Off	Cm	m^3/fed	cm	m^3/fed	cm	m^3/fed
Dead levelling	A_1	Cont.	0	51.80	2175.6	49.3	2070.6	50.1	2104.2
	A_2	20	5	48.30	2028.6	47.6	1999.2	47.9	2011.8
	A_3	20	10	46.56	1955.5	45.3	1902.6	45.9	1927.8
	A_4	20	15	44.47	1867.7	43.2	1814.4	43.8	1839.6
	A_5	20	20	42.62	1790.0	40.6	1705.2	41.6	1747.2
Traditional levelling	B_1	Cont.	0	54.60	2293.2	52.4	2200.8	53.5	2251.2
	B_2	20	5	52.60	2209.2	50.4	2116.8	51.5	2163.0
	B_3	20	10	48.20	2024.4	47.3	1986.6	47.8	2007.6
	B_4	20	15	46.40	1948.8	45.4	1906.8	45.9	1927.8
	B_5	20	20	45.60	1915.2	45.2	1898.4	45.4	1906.8

Table (8): Grain yield (ton/fed) of corn in the two growing seasons 1996 and 1997 as affected by irrigation treatments and land levelling practices.

Cycle ratio		Season 1996			Season 1997		
On	Off	Dead Levelling	Traditional levelling	Mean	Dead Levelling	Traditional levelling	Mean
Cont.	0	3.110 CD	3.00 D	3.055 D	3.000 EF	2.960 F	2.980 D
20	5	3.260 BCD	3.040 CD	3.150 CD	3.150 CD	3.030 DEF	3.090 C
20	10	3.340 ABC	3.170 CD	3.25 BC	3.220 BC	3.110 CDE	3.165 C
20	15	3.480 AB	3.270 BCD	3.375 B	3.430 A	3.150 CD	3.290 B
20	20	3.600 A	3.360 ABC	3.480 A	3.530 A	3.270 B	3.400 A
Mean		3.358	3.218		3.266	3.104	
L.S.D. at 5% = 0.323					L.S.D. at 5% = 0.1136		

Generally, surge flow irrigation had higher grain yield values than that the continuous one, either under dead or traditional levelling. The overall average of grain yield under surge flow treatments varied from 3.15 to 3.48 ton/fed and from 3.09 to 3.4 ton/fed for 1st and 2nd seasons, respectively. The corresponding values under the continuous treatment varied between 3.05 and 2.98 ton/fed for 1st and 2nd season, respectively. The dead levelling treatment achieved higher grain yield values than that the traditional levelling treatment. It had an overall average values of 3.35 and 3.26

ton/fed compared with 3.2 and 3.1 ton/fed for 1st and 2nd season, respectively. The statistical analysis showed significant differences between treatment of 20 min on/20 min off and the other treatments. While there were no significant differences between the treatments 20 on/5 off, and 20 on/10 off for the two growing seasons. The high production of corn under surge irrigation compared with continuous one may be attributed to the improvement of soil areation conditions, more uniformity water distribution along the furrow and maintenance of nutrients. These results are in agreement with Ghalleb (1987) and Osman (1991) who found that the grain yields of corn under surge irrigation were higher than under the continuous one.

7. Water utilization efficiency (WU_tE):

Values of WU_tE for the different irrigation treatments under dead and traditional levelling are presented in Table (9). The surge flow treatments had higher values of WU_tE than those of continuos flow ones. Also, WU_tE values were higher under dead levelling than that under the traditional levelling. The overall average of WU_tE values (average of two seasons) for continuous flow irrigation were 0.9 and 0.78 kg/m^3 under dead and traditional levelling, respectively. The corresponding values for surge flow treatments varied from 1.04 to 1.46, with an average of 1.25 kg/m^3 and from 0.86 to 1.14, with an average of 1.00 kg/m^3 under dead and traditional levelling, respectively. The best treatment was that of 0.5 cycle ratio, it had the highest WU_tE value of 1.46 and 1.14 kg/m^3, respectively for dead and traditional levelling. The explanation of these results, as mentioned before is that surge flow irrigation especially with dead levelling leads to higher water distribution uniformity, less water losses by deep percolation and less amount of applied water during the irrigation.

Table (9): Water utilization efficiency of corn (in kg/m^3) under different irrigation treatments.

Treatment				Season 1996			Season 1997			Average
Land levelling		Cycle ratio On	Cycle ratio Off	Yield kg/fed	Wa m^3/fed	WU_tE Kg/m^3	Yield kg/fed	Wa m^3/fed	WU_tE kg/m^3	of two Seasons
Dead levelling	A_1	Cont.	0	3110.0	3435	0.91	3000.0	3368	0.89	0.90
	A_2	20	5	3260.0	3137	1.03	3150.0	3011	1.04	1.04
	A_3	20	10	3340.0	2952	1.13	3220.0	2713	1.18	1.15
	A_4	20	15	3480.0	2780	1.25	3430.0	2423	1.41	1.33
	A_5	20	20	3600.0	2583	1.39	3530.0	2310	1.52	1.46
Traditional levelling	B_1	Cont.	0	3000.0	4082	0.73	2960.0	3544	0.83	0.78
	B_2	20	5	3040.0	3780	0.80	3030.0	3259	0.92	0.86
	B_3	20	10	3170.0	3465	0.91	3110.0	3057	1.01	0.96
	B_4	20	15	3270.0	3288	0.99	3150.0	2818	1.11	1.05
	B_5	20	20	3360.0	3133	1..07	3270.0	2675	1.22	1.14

Wa = total amount of the applied water during the season.

The above mentioned results are similar to those obtained by Osman (1991) who found that surge irrigation leads to increase water use efficiency by 0.69 kg/m^3 at Sakha farm and by 0.9 kg/m^3 at Abis farm than that water use efficiency for continuous irrigation. Ghalleb (1987) compared continuous flow irrigation with three different surge irrigation treatments of cycle ratio of 1/2, 1/3 and 1/4. He showed that WU_tE was 0.58 kg/m^3 for continuous flow and varied between 0.79 to 1.0 kg/m^3 for surge flow irrigation.

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Irrigation information in the Internet

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Introduction

In less than a decade the Internet has become a real alternative to the well established means of information exchange. Electronic means of accessing information are rapidly gaining importance, thus increasing the speed of international and intercontinental information exchange. The use of the Internet has many advantages, since it grants online access from the own desktop to information distributed from anywhere else, without the hassle of visiting libraries, ordering and waiting for the ordered information or other restrictions.

The enormous advantages are clearly shown by the fact that the Internet is growing exponentially, both in the size of web sites, web pages and in the number of users. As shown in a study recently performed in the U.S. [17], in mid-1999 more than 100 million adult Americans used the Internet, which represents more than one-half of U.S. adults. Moreover, the Internet has become an important factor in their daily lives, which is clearly evidenced by the following statistics about their online-habits: daily use of the Internet has risen to 60 percent for home users and 69 percent for work users, clearly indicating the advantages linked with this medium. The average user sends 6.4 emails per day, and 77 percent of all users send emails with files or attachments weekly - an example of the even more sophisticated use of this tool. Also, more and more users are actively taking part in the process of information dissemination, with 22 percent of all users having created or updated a web page within the last three months.

An analogous development can be found in the amount of information offered in the Internet. The so-called network of the networks is growing exponentially, enclosing already more than 10 million web sites (Figure 1) with the publicly indexable web containing an estimated 800 million pages as of February 1999 (1997: 320 million pages), encompassing about 15 terabytes of information or about 6 terabytes of text after removing structural elements, comments, and extra whitespace [7]. This growth is even expected to continue in the future, with an estimated number of 8 billion web sites in 2002.

The immense growth of both the number of Internet users and web sites indicates clearly the advantages of this medium, which almost each new user or web site indicating the expectation of potential benefit for the individual or the company they are working for. Each new user and each new web site can therefore also be considered as a vote for these possibilities and the further use of this new medium.

The Internet - a short definition

According to a definition [4] unanimously agreed by the US Federal Networking Council, the term "Internet" refers to the global information system that

- is logically linked together by a globally unique address space, based on the Internet Protocol (IP),

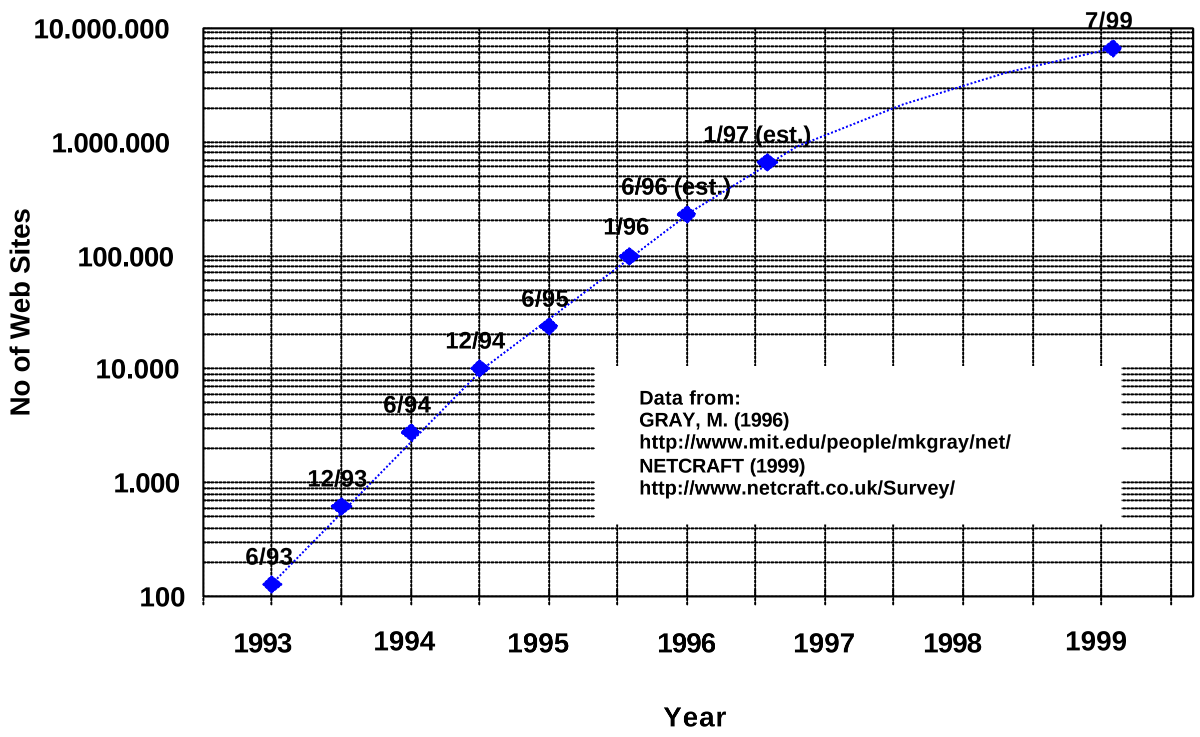

Figure 1: The world wide growth of web sites form June 1993 till August 1999. Graph derived form data published by GRAY (1996) and NETCRAFT (1999).

- is able to support communications using a specific transmission protocol (TCP/IP) and
- provides, uses or makes accessible, (...) high level services layered on the communications and related infrastructure described herein.

It is important to notice that each computer that is part of the Internet has an unique IP-address, which is an indispensable condition for utilising these services or serving requests from other machines. Furthermore information transmission is standardised by the TCP/IP protocol in a platform-independent manner, so that different computers with differing operating systems all can share the resources of the Internet.

Internet resources - Where to find information about irrigation?

World Wide Web (WWW)

Originally initiated by Tim Berners-Lee while working on a networked information project at CERN, the World Wide Web is nowadays surely one of the most important, if not the single most important high level service of the Internet. The WWW is specifically designed for the exchange of documents available to the Internet community. These documents are formatted in a language called HTML (HyperText Markup Language) that supports links to other documents, as well as graphics, audio, and video files. This means one can jump from one document to another simply by clicking on hot spots, also called *links*. There are several applications called web browsers that make it easy to access the World Wide Web; two of the most popular being Netscape Navigator and Microsoft's Internet Explorer.

Search engines and their deficiencies

With an estimated size of 800 million web pages, information retrieval can sometimes be quite difficult. Therefore, the proper use of search engines, which enable users to search for documents on the World Wide Web, plays a pivotal role. The database for the search engine can be either created by humans or by automated software tools, called spiders. An example of the human approach is Yahoo!, while Altavista or WebCrawler rely on an automatically created database. Beside these search engines, which were the very first at the time of their launch, numerous other engines have been installed since. A comprehensive list of search engines can be found at http://www.amdahl. com/internet/meta-index.html.

Unfortunately, the use of search engines can be quite tricky since finding the right information is not always easy. It can even be a very tough task - especially finding the engine that produces the output needed. Allegedly, the engines Google, DirectHit, and Northern Light are making use of some of the more innovative and best techniques used by search engines today, but even this does not guarantee good results. Furthermore, the use of search engines is generally subjected to some major restrictions:

A recent study about accessibility and distribution of information on the WWW indicated clearly that search engine coverage relative to the estimated size of the publicly indexable web has decreased substantially in the last two years, with no single engine indexing more than about 16 % of the estimated size of the publicly indexable and accessible web. To overcome this problem, the use of meta search engines, which submit a single inquiry to several different engines at the same time and then list the results grouped together, is encouraged. Table 1 lists some of these meta engines.

It should be remembered when using search engines that their databases might be out of date resulting in outdated search results. As showed in [7], indexing of new or modified WWW pages by just one of the major search engines can take months.

Despite being indispensable tools, search engines still remain tools with adherent deficiencies. A search for the mere expression "irrigation" produces more than 310.000 matches using "NorthernLight" and almost 11.000 matches using "Google". In order to prevent one from becoming entangled and frustrated due to this flood of information, the next chapter will give some hints on finding the most valuable sites within the area of irrigation.

World Wide Web Pages related to irrigation issues

A list of valuable WWW pages in the field of irrigation is shown in Table 2. Far from being complete, this list can serve as a starting point for retrieving professional and scientific information about irrigation on the Internet. Some of these sites are described in more detail in [8] and [11] (both sources can be accessed online). Especially valuable are search engines within a site, since the contents of their database are restricted to the visited web site. These tools can enormously facilitate the search for specific information since unlike the general search engines described above, they will narrow the search to irrigation specific contents.

Table 1: Meta-search engines for searching the WWW

Name	URL	Name (cont.)	URL
All4One	http://www.all4one.com/	Highway 61	http://www.highway61.com/
Ask Jeeves	http://www.askjeeves.com/	Metafetcher	http://www.metafetcher.com/
Copernic	http://www.copernic.com/	Metacrawler	http://www.metacrawler.com/
Cyber 411	http://www.cyber411.com/	Savy Search	http://www.savvysearch.com/

Table 2: Selected web sites dedicated to irrigation

Name/Category	URL	Maintained by	search engine
General overview, "portal sites"			
Virtual Library Irrigation	http://www.wiz.uni-kassel.de/ kww/irrig_i.html	Thomas-M. Stein	yes
Microirrigation Forum	http://www.microirrigation forum.com	Richard Mead	yes
Soil water content sen-sors&measurement	http://www.sowacs.com	Bruce Metelerkamp	no
Research institutes / Other organisations			
Water Management Research Unit	http://www.cprl.ars.usda.gov/ wmru.htm	Conservation & Production Research Laboratory Bushland, Texas USA	no
Water Management Research Laboratory	http://pwa.ars.usda.gov/fno/ wmrl/	USDA-ARS-WRML, Fresno, California, USA	no
FAO, Land and water development division	http://www.fao.org/ag/agl/aglw/ aglw.html	Water resources, develop-ment and management service (AGLW), FAO	yes
Online Articles / Bibliographies			
Drip bibliography	http://asset.arsusda.gov/ WMRL/dripbib.html	Richard Soppe, USDA, WMRL, Fresno, California	no
Journal of Applied Irri-gation Science	http://www.wiz.uni-kassel.de/ kww/zfb/	Thomas-M. Stein, Peter Wolff	yes
Software resources and other tools			
Irrigation Engineering Software	http://www.engineering.usu.edu/ Departments/bie/software.html	Utah State University, Department of Biological and Irrigation Engineering	no
IRRISOFT - Database on Irrigation and Hydrology Software	http://www.wiz.uni-kassel.de/ kww/irrisoft/	Thomas-M. Stein	yes
Professional / Industrial sector			
Irrigation Association	http://www.irrigation.org/	Irrigation Association, Fairfax, Virginia, USA	yes
Irrigation and Green Industry Network	http://www.igin.com/	IGIN: The Irrigation & Green Industry Network	no

Discussion lists dedicated to irrigation matters

The World Wide Web enables users to obtain information about many different subjects related to irrigation matters. However the situation may arise where, despite all efforts, the needed information cannot be found on the net. Or questions may arise, perhaps arising from the results of actual research work, or from reading an article. In such cases, the WWW will not help very much. An expert forum, where questions may be submitted in the hope that someone can answer these queries, may be the best approach in such a situation.

Email based Discussion lists are an ideal forum for discussions on a certain topic. Anyone with email access can participate in these discussions. The principle of such lists is as shown in Figure 2. Anyone who has subscribed to the list can contribute to the discussion, either in form of a new question or an answer, by sending an email message to the list-address (e.g. "irrigation-l") at the listserver (e.g. listserv@gmd.de") that hosts the discussion list. The listserver acts as a mere message duplicator and sends a copy of each incoming mail to each person who has subscribed to the list. With a few hundred experts in the field of irrigation as addressees, there is a high chance of getting an appropriate answer to one's request.
As listed in [8], there exist four discussion lists for irrigation that might be of interest.

The most general list is **irrigation-l** (http://www.wiz.uni-kassel.de/kww/ irrigation-_i. html), others are **trickle-l** [9], **salinity-l** [12] or **sowacs-l**. A comprehensive listing of discussion lists primarily concerned with topics related to water resources, comprising of 46 entries can be found at http://www.nal.usda.gov/wqic/lists.html. Subscribing to a list is fairly easy, and is achieved by sending an email message to the administrative address of the listserver that hosts the list, which can be found in Table 3. The subject must be left blank, the body of the email should only contain the command *subscribe* (or: *sign off* or *unsubscribe*). A confirmation of the subscription should be promptly received.

A slightly different version of an email based information service is the land-and-water-l newsletter published by the Land and Water Development Division of the F.A.O. This newsletter is a passive means for publishing information from that division rather than a discussion list, meaning that subscribers cannot send messages directly to the service.

From each contribution to the discussion list, a copy is stored in the archives of these lists. Since these discussion lists have existed for several years, these archives are a huge information pool and a major source of irrigation information, and they have the potential to be an invaluable help in many cases. Fortunately, for most of them a full-text search-engine has been implemented. The use of these engines is highly encouraged, both before placing a question to make sure it has not recently been subject of a discussion and as a general information source.

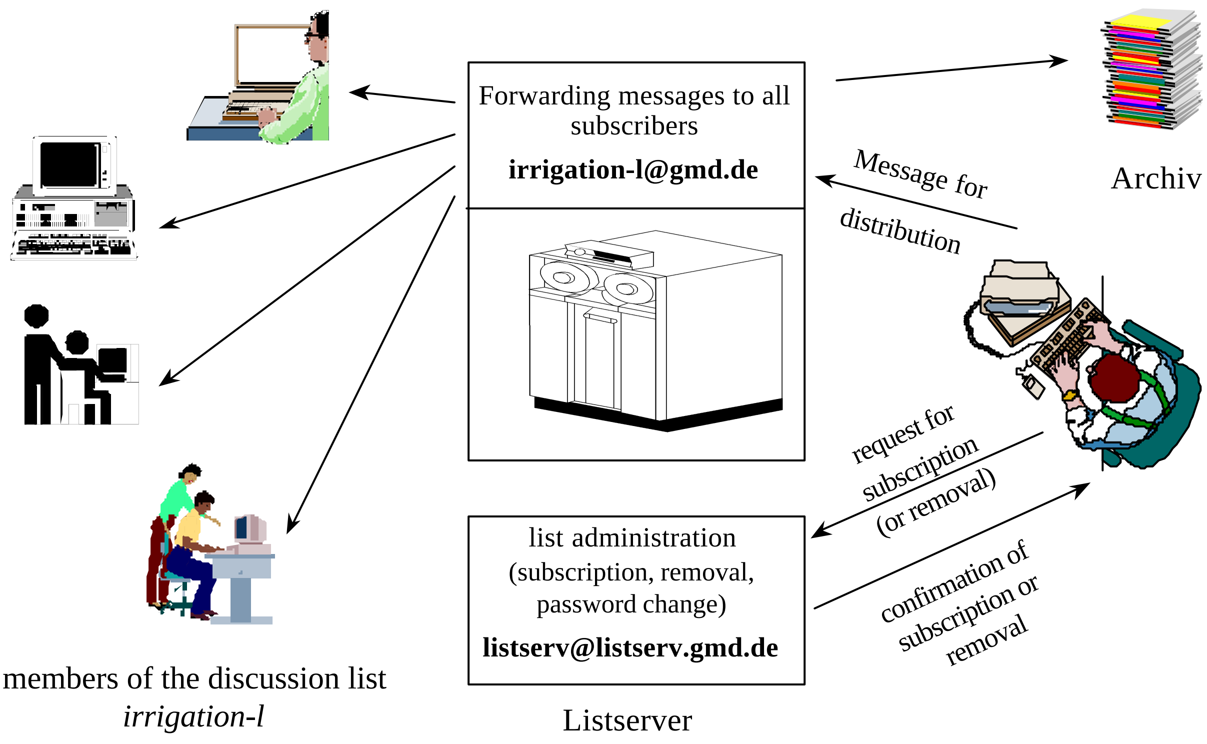

Figure 2: Schematic diagram of the functionality of Internet discussion lists (example for: irrigation-l)

Table 3: Email-based internet discussion lists and newsletters in the field of irrigation

List name	**per-sons**	**list-owner**	**host**	**foun-ded in**	**Online-Archives** URL	search-able
			Discussion lists			
irrigation-l	598	Stein, T.	listserv@listserv.gmd.de	Dec. 1994	http://www.wiz.uni-kassel.de/kww/sakia/sakia_i.html	yes
trickle-l	656	Mead, R.	listserv@crcvms.unl.edu	mid 1994	http://www.microirrigationforum.com/new/archives/	yes
salinity-l	251	Soppe, R.	listserv@crcvms.unl.edu	late 1995	http://crcvms.unl.edu/archives/salinity-l.html	yes
sowacs[1]	n. a.	Meteler-kamp, B.	majordomo@aqua.ccwr.ac.za	late 1995	http://www.sowacs.com/archives/index.html	no
			Newsletter			
land-and-water-l	n.a.	AGLW, FAO, Hooge-veen, J	mailserv@mailserv.fao.org	June 1996	www.fao.org/ag/agl/lwissues.htm	no

[1] soil water content sensors

Newsgroups holding irrigation related information

Newsgroups are also an email based Internet service for online-discussions. Contrary to a discussion list, the messages sent to the newsgroups are distributed to other news servers rather than to the participants of the discussion itself. Each user can retrieve a list of the header lines from the emails sent to the newsgroup, and if he or she is interested, can request the whole document.
While newsgroups can be an extremely useful tool for solving computer hard and software problems, the chance of initiating a discussion about irrigation on a high level are pretty low. Some potentially suitable newsgroups are sci.agriculture, gov.us.topic.environment.water, sci.environment or alt.agriculture.

Irrigation Software on the Internet

Beside information about irrigation in written form, numerous software programs of different kinds have been written which can be valuable tools both in the research and the professional area.

Software Catalogues

As described in [6] and [16], various approaches have been undertaken to index and summarise the various known software programs in the field of irrigation, resulting in three major inventories:

- an inventory, published in form of a book (ILRI special report, [3]);
- LOGID, an inventory in form of a database which can be accessed via a software program for microcomputers. The software including the database is distributed at no cost and can be downloaded via ftp (file transfer protocol) from the anonymous ftp-server of the university of Kassel (ftp site: ftp://ftp.hrz.uni-kassel.de/pub/irrisoft/logid). Downloading instructions can be found at http://www.wiz.uni-kassel.de/kww/irrisoft/download.html.
- IRRISOFT [15] - a World Wide Web database on irrigation and hydrology software that has been established and is maintained at the University of Kassel, Germany. This database lists 105 programs which are described in detail in "software description pages". The database is fully text-searchable. A few freely available programs can be downloaded from the ftp-site set up together with the IRRISOFT catalogue (ftp site: ftp://ftp.hrz.uni-kassel.de/pub/irrisoft/).

From these three approaches, IRRISOFT [14] is certainly the most promising since it relies on the internet as medium of information interchange, thereby allowing the addition of programs and modify existing entries at any time. Even an user-interface to prepare entries for submission has been created, exonerating the maintainer from translating the contents into a format usable on the WWW. With the rapid development of software and hardware technologies in mind, one can imagine that static media like that of the ILRI report or the LOGID inventory, which have not changed their contents for years neither do depict the actual state of the software market for irrigation software, nor they do represent the state of the art for the dissemination of information in such a dynamic sector like software development.
In the long term, one should expect that software is partly made executable on the WWW using the platform independent language Java. Such Java programs can be executed directly inside a web browser on any platform, thus freeing one from creating software catalogues describing the programs and their hardware requirements.

Software programs
Not all software programs and tools are listed in the catalogues described above. A description of a choice of programs can be found at [10]. A variety of other web sites are also offering various software programs or tools or will present links to such applications. Surely one of the most comprehensive sites for software programs in the irrigation sector is maintained at the Department of Biological and Irrigation Engineering at the Utah State University, USA (http://www.engineering.usu.edu/Departments/bie/software.html). Altogether 24 programs are listed, 17 of them for DOS-platforms, the other seven are Windows programs. While five of the products are distributed at no cost, the prices for the other programs range between 15 and 3.500 US $.
The Water resources, development and management service of the Land and Water Development Division at the FAO offers various tools at their site http://www.fao.org/waicent/faoinfo/agricult/agl/AGLW/dss.htm, amongst them the software program CROPWAT (for DOS and Windows) and the climatic database CLIMWAT. The microirrigation research group at the New Mexico Climate Center offers links to various programs and Excel-Spreadsheets at the URL http://weather.nmsu.edu/w128/. The Water Management Research Lab inside the Agricultural Research Station of the USDA offers its products at http://pwa.ars.usda.gov/fno/wmrl/software/index.html.

How to offer irrigation related information at the Internet?

Having all the advantages of the new internet technologies in mind, one might think of getting actively involved in disseminating information on the web. All companies or organisations working in the field of irrigation which are already present on the Internet, are highly encouraged to register their institution to the Virtual Library of Irrigation. An online accessible form for the automated creation of an entry in the virtual library based on the user input is available at this site. It can be found at http://www.wiz.uni-kassel.de/kww/projekte/irrig/add/add_s.html. Applicants have to specify some data about the institution and what is offered on the web page and they can deliver a short abstract that describes their site and the information held there. After submission, applicants promptly will receive an email, indicating the temporarily URL of a created web page based on the contents that were submitted. If not content with the resulting page one can make proposals for corrections, otherwise the created page will be

added to the Virtual Library Irrigation after being approved by the maintainer of the site.
In order to publish own contents on the WWW, like findings of recently conducted research work, users should contact their system administrator. Designing own web pages and putting them on a server is not as complicated as it is thought to be. If there is no opportunity to publish on the servers of the institution one is working with, everyone has the opportunity to get free web space which is offered from several companies (have a look at http://freeweblist.freeservers.com/ for further information).

Global efforts to improve the access to the Internet

The "information world" is dramatically changing as electronic means become more and more widespread and it seems obvious that internet-based technologies will gain even more importance in the near future. This position is held by the Advisory Committee of the U.S. Federal Networking Council which firmly believes "that the Internet is a critical resource for the national research and education communities. This resource should be made available to the widest possible customer/user base with the highest possible level of service" [3].
As well as all the positive statements, some negative effects may also need to be considered like those stated by ARUNACHALAM (1998), i.e. that history has also shown that technology inevitably may enhance existing inequalities and thus widen the gap between industrialised and developing countries. Despite the enormous general growth of the Internet the availability of scientifically valid and approved information is disproportional low and far from being sufficient to meet the steadily increasing demand and growing expectations, especially concerning developing and less developed countries. Great efforts have been made over the last few years by international and national organisations, universities and individuals to improve the availability of information and access with several examples mentioned above. While there have been some impressive efforts, many users still have difficulty in accessing the full range of information on water conservation in agriculture.
As stated by SEIBEL et al. (1999), the private sector and international development agencies still appear to underinvest in information and communication technologies (ICT) in low income countries. For many developing countries the financial and technical constraints on accessing the Internet still form the major hindrances to accessing adequate and high quality information. To improve the communication and Internet facilities in developing countries, more than eight major programs funded by international organisations have been started. With regard to the African continent, for example, two major projects will establish a sound starting basis for an African wide connectivity which potentially covers the entire continent and should be established this year. The geo-stationary communication satellite above the area of Lake Victoria, which covers the entire African continent and the Indian subcontinent, and the laying of high speed and high capacity undersea fibre-glass cables surrounding the entire African continent allows 32 coastal countries to be linked up.
So we can expect that the situation in these countries will improve in the near future, giving them broader access to information that hopefully can be disseminated to allow the further development of their nations.

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Land Reclamation in Egypt - a critical external review

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Introduction

The area of the Egyptian state totals about 1 million km^2, 96% of which is desert and barely 4% is cultivated land. This means that c. 40,000 km^2 are available as effective Lebensraum for its approximately 63 million inhabitants. Restricted predominantly to the Nile Valley and the Nile Delta, this cultivated area is one of the most densely settled areas on earth, carrying more than 1,575 inhabitants per km^2. The scarcity of living space in this country is even more striking when seen in the context of the effectively managed area used for agriculture. With an agricultural utilised area of altogether 2,607 million hectares, at present about 0.048 hectares of agriculturally used area is available per inhabitant. For years Egypt has been presenting an almost explosive population growth, with a growth rate of around 2.8% p.a. Recently the growth started to decline. What is giving cause for concern is the fact that for years the growth rate of agricultural production, especially foodstuffs, has not kept pace with the population growth. Increased agricultural production has therefore represented the most important economic policy aim of all Egyptian governments since the 1952 revolution.

A rise in agricultural production in Egypt can be achieved by raising the cultivation intensity (by intensification of irrigation, fertilising, plant protection, drainage etc.) and by raising organisational intensity (like substituting tuber crops and vegetables for grain), as well as through extending the agricultural area by cultivating part of the huge desert area. Over past decades Egypt has sought to make use of all three of these options for raising agricultural production, with the government making particular efforts in the field of desert cultivation and opening up of new land. The latter tend to involve expansion of the agricultural area into desert areas, i.e. into a natural area which is difficult to manage. In what follows, the history and the development problems of the newly reclaimed areas will be presented and analysed - not only in order to explain the difficulties Egypt meets with in its endeavours to expand the scope for food growing, but above all in order to draw attention to the problems in general which occur today with the expansion of the agriculturally utilised areas, even in over-populated agricultural countries.

The history of desert cultivation and the reclamation of new land in Egypt

In Egypt efforts to open up new land have a history that reaches back into antiquity. These efforts tended to concentrate in the valley and delta of the Nile, or on directly adjacent areas. In the last two centuries in particular attempts were made to reclaim land for agricultural use through perennial irrigation and drainage measures.

Measures to reclaim new land up to 1952

In the early 19th century the agriculturally used area of Egypt included c. 2 million feddans (840,000 hectares), c. 250,000 feddans (c. 105,000 hectares) of which were restricted to summer use only. Under the regency of Mohammed Ali efforts to reclaim new land and to extend field use in summer were markedly intensified. Already in about 1830, c. 600,000 feddans (c. 250,000 hectares) were also available for summer use and in 1848, by the end of Mohammed Ali's regency, the agriculturally used area of Egypt had risen to c. 2.6 million feddans (1,092,000 hectares). During that time efforts to open up new land were concentrated above all on the amelioration of saline clay soils in the northern delta between the two arms of the Nile. With the help of more or less forced labour the government mainly constructed irrigation canals and main drainage channels, whereas the opening-up of the individual plots was left to private initiative. Attempts to cultivate the desert remained modest, and the results questionable, especially in the oases of the Western Desert (Busche, 1979: Meyer, 1978; Wolff, 1983).

In the third quarter of the 19th century, measures to reclaim land in the northern delta not only continued, but at the same time were extended to include central Egypt as well. In the year 1880 approximately, the agriculturally utilised area had increased to c. 4.7 million feddans (1,974,000 hectares). By the end of the 19th century, additional investments in the irrigation system, especially in the construction of delta barrages, had led to an increase in the agriculturally utilised area to c. 5.2 million feddans (2,184,000 hectares).

In the beginning of the 20th century the construction of a barrage, the building of various feeder canals in central Egypt, and the completion of the first Aswan dam, the level of which was raised twice - though only leading to a modest increase in the area under cultivation-, nonetheless had the effect of a marked intensification of the utilisation of the available area, chiefly by expanding the area under perennial irrigation. However, construction of a drainage system of appropriate dimensions, matching those of the measures described above, was omitted. This resulted in increased occurrences of fields becoming marshy and salty, and to a subsequent reduction in the productivity per feddan. From the turn of the century to the 1952 revolution measures to reclaim new land only succeeded in extending the agriculturally utilised area of Egypt by c. 125,000 feddans (c. 52,500 hectares). The major part of this area was opened up by private investors. The government mainly concentrated on the completion of the drainage network during the period (Hopkins et al., 1988; Wolff, 1980 and 1986).

Measures to reclaim land and cultivate desert areas since 1952

The revolution of the year 1952 presents a turning-point in the governments policy towards land reclamation and desert cultivation. In post-revolutionary Egypt the relatively small area available for agricultural utilisation and the rapid growth of the population resulted in according high priority to the opening-up of new land. In this, the corresponding government measures were often directed primarily towards the physical reclamation of new land for cultivation, whilst neglecting the necessary raising of productivity by of plot amelioration measures. The occurrence of a food deficit in the late-60s, which deepened steadily in the following decades, together with the negative agricultural trade balance as a consequence of this deficit, led to special attention always being paid to the opening-up of new land in the following years and up to the present.

In recent decades the definition of the term "reclamation" or "new land development" has undergone several changes. In its comprehensive form the term describes the development of the entire infrastructure affecting production, the development of village social and physical infrastructures, as well as the improvement of soil fertility to so-called positive marginal productivity. The comprehensive development package has been slimmed down several times in the course of recent decades. Even the concept and philosophy of the policy of new land reclamation has undergone several amendments, or even fundamental change. In the 1950s priority was given to the provision of land and the improvement of the living conditions of the growing proportion of landless people among the population. Raising agricultural production was seen as being of comparatively secondary importance. In the early days of the post-revolutionary new land reclamation, co-operative or mutually beneficial forms of land use were attempted in the new land areas. Entirely novel, "modern" forms of rural society were to be created. Expectations were very high: extremely ambitious, large-scale programmes for the opening-up of new land and extending over an area of c. 1 million feddans were decided upon and tackled. In reality, however, only 80,000 feddans were reclaimed in the period up to the late-fifties. Co-operatives, which took over the distribution of land and the means of production, as well as the buying of production means and the marketing of produce, were set up; However, co-operative or mutually beneficial farming was not introduced (Voll, 1980; Wolff, 1983; Hopkins et al., 1988).

In the sixties, until the war with Israel in 1967 to be precise, the new land reclamation made good progress. The construction of the Aswan High Dam in particular had a stimulating effect. Admittedly, the corresponding efforts were substantially directed towards the actual work of reclamation, whilst the transformation of the reclaimed areas to permanently productive cultivation areas was not undertaken with the requisite emphasis. A large part of the reclaimed area was run as state farms with an army of workers, or remained in the care of national development companies. During this phase, areas not exceeding 5 feddans were leased to peasants, but rarely turned over to them. In principle, however, it was assumed that large state farms were better suited to mechanised cultivation of the land and better placed to obtain foreign exchange by careful management of fruit and vegetable production for export. This change in policy of land reclamation influenced not only the new schemes, but also affected the areas which - though reclaimed - hat not yet been assigned to those peasants for whom they had been originally intended. Henceforth the aim of land reclamation was no longer to meet the wishes of landless people for a small plot of their own, but to expand agricultural production and grow marketable surpluses, thereby increasing state revenues and above all foreign currency earnings.

In the years up to 1966 a total of 307,000 hectares of new land was opened-up to cultivation in various parts of Egypt. Most of these areas - 122,500 hectares - were in the Nile areas, followed by Tahir Province with 62,500 hectares, and the desert areas with 59,900 hectares. Other major foci of new land reclamation during this period were in Upper Egypt, in the so-called Nubian Settlement Area (16,300 hectares) and in the districts of Kuta, Kom Ashim and Abis (15,200 hectares). Official statistics for the period up to 1966, moreover, include wasteland (30,900 hectares) in all parts of the country which had been brought back into cultivation by reclamation (Wolff, 1983).

After 1966 the area of newly reclaimed land in Egypt increased at first only slightly, and almost exclusively in the Nile area, where a further increase of around 70,000 hectares had been registered by 1974. The main reason for the slow-down, or even standstill, in the opening-up of new land are thought to be the military conflicts with Israel in the year 1967 and the subsequent years of economic recession (Meyer, 1978).

In 1975 the reclamation of new land reached its peak after the 1952 revolution, when a total of 411,000 hectares had been reclaimed; but it also reached its first critical phase, since only about 259,000 hectares , i.e. 63% of the reclaimed area was agriculturally used. Even the further development of the actually utilised areas proved to be quite problematic. In almost all the new land areas it took a disproportionately long time to reach even marginal productivity - that is, a production level at which the cost of production is covered by the resulting yields. Not inconsiderable parts of the new land areas have still not reached even marginal productivity.

In the seventies the reclamation of land was restricted to the completion of the on-going projects; next to no new projects were started. However, the policy of opening-up new land, i.e. the distribution and utilisation of areas already reclaimed, once again underwent change at this time. The low productivity of the state farms showed that under Egyptian conditions large state farms were evidently unsuited to the management of new land areas. The intensive cultivation of the new land areas by peasants, and the higher yields produced by them, led to a return to greater peasant-orientation in respect of opening-up and, above all, distributing already reclaimed areas. Attempts to retain state farms for the production of high quality fruit for market of fresh produce and industrial processing were confined to the western delta and the adjacent areas. At the same time a programme was set up in the mid-seventies, which made land for individual cultivation available to graduates.

In the Spring of 1978, the Egyptian government, notwithstanding these and other problems, announced the start of a "Green Revolution" for the country. Besides increased intensity of cultivation, this "green revolution" aimed at substantial expansion of the agricultural area. In a highly euphoric estimate of the production potential of Egyptian desert areas and the useable water resources, the "Egyptian Master Water Plan" provided for an expansion of the agricultural area by the year 2000 of about 1.24 million hectares, i.e. by about 44% of the area under cultivation in the early-eighties (Samaha, 1980). If this goal was to be reached c. 62,000 hectares of new land per year would have had to be opened up. Considering the fact that in the first phase of new land reclamation (1952 - 1966) an average 20,000 hectares were reclaimed per year, and that the areas available for reclamation in the late-seventies were much more difficult to open up, the Egyptian ideas as set out in this plan did not seem very realistic. Furthermore, the development problems of areas hitherto reclaimed could in no way be regarded as solved (Hopkins et al., 1988).

Thus, after a period of resignation in the seventies, new efforts were made to expand the Egyptian agricultural area. The announcement of the so called "Green Revolution" by the Egyptian Government is seen as a turning point in reclaiming new lands. That's why lands reclaimed before 1978 are termed "old new lands", while the post 1978 reclaimed lands are known as the "new new lands". From 1978 onwards the opening-up of new land formed an essential part of various five year plans, and almost 40% of the total investments of the agricultural budget were set aside for this field. However, due to financial bottlenecks in the country's budget, it became more and more difficult to fulfil the planing states from one year to the next. The actual expenditure in the period 1982/83 to 1986/87 turned out to be only 50% of that budgeted for new land reclamation. In the period 1978 - 1988 the area of newly reclaimed land increased by 242,634 hectares, i.e. by c. 24,000 hectares a year. The original goal of 62,000 hectares a year was not reached. The five year plan for 1987 - 1992 had envisaged the opening-up of a total of 315,000 hectares. 14.700 hectares of this were situated in the so-called "New Valley", and are to be irrigated with groundwater. 300,300 hectares were scheduled to be irrigated with Nile water. By the year 1997 1,092,000 hectares had been reclaimed since the beginning of the fifties, but still only 672,000 hectares were under agricultural production at that time.

In the context of the drawing-up of the so-called "Land Master Plan" in 1986, 2.6 million feddans (1.09 million hectares) were identified as suitable for reclamation under certain conditions. 997,000 hectares of these require water supplies from surface waters, i.e. the Nile, whilst 92,000 hectares are thought to be within reach of groundwater reserves. The Egyptian government aims at present to open up 1.43 million hectares up to the year 2017 and from thereon an other 2.18 million hectares; though the question of where the water for irrigation of these areas is to come from remains. The question will be addressed in greater detail below. For the present, the fact is to be noted that, in the face of the dramatic population growth in Egypt, the opening-up of the new land will for the foreseeable future continue to play an important role in the framework of Egyptian agricultural policy. This was among others stated in a more recent speech by President Hosni Mubarak on the launching of the Upper Egypt New Delta Project. In his speech President Muhammad Hosni Mubarak pointed out that "It is time for Egypt to be released from captivity within the narrow valley to stretch out into the vast expanse of its entire territory, in pursuit of a better tomorrow, gleaming with hope for all Egyptians." And in the Egypt State Information Service Web Site "Egypt in the 21st Century - Vision 2017" the following is stated under the heading "Development Strategy Outline" as the first development objective:

> *Extend the scope of development to the entire area of the country, explore its wealth and provide opportunities for settling millions of Egyptians outside the narrow valley, which accounts for maximum 5.5% of the total area of the country, thus raising the ratio of inhabited space to 25%. The next twenty years represent an important phase for such expansion. Areas rich in national resources are to be opened, and increasingly utilized, population is to be settled down at locations which will be integrated and interlinked in the long run.*

Making use of the fast desert areas will stay high on the agenda in Egypt for the years to come, despite the limitations of expanding agricultural activities into the desert.

Perspectives for the future

Considering the limitations of the world's agricultural area, Andreae (1977) in his *Agricultural Geography* notes that "with expectation of rising income and living standards, higher agricultural yields are necessary. And this is why in the course of development, land which has been regarded until now as fairly productive will become marginal land, and previously marginal land will go out of production". The application of this general statement to the Egyptian case confirms the fact that agriculture already displays a tendency to withdraw or to stay away from marginal locations. The abandoning of cultivated land in the Wadi El-Natrun (Wolff and Bliss, 1980) and the fact that some of reclaimed land does not reach marginal productivity is an unambiguous example of this.

The growth rate of private measures for land reclamation which, to name just a few examples, occurred along the Cairo - Alexandria desert road, in Nubaria, in the countryside around Cairo and elsewhere, does not contradict this development trend. Many of these private reclamation measures are the result of speculative considerations and the very high prices for agricultural property in Egypt, although numerous investors have been complaining in Egypt for some years about the inadequate profitability of the farming activities within the reclamation schemes. Even with crops of relatively high market value (fruit, vegetables), it is exceedingly difficult to achieve sufficient profitability in the predominantly marginal areas. In addition there is a relatively high capital requirement for water supplies and distribution at farm level as well as for the improvement of the fields. It is an open question whether the investors will keep interest in new land developments on a medium and long term basis. Because of the apparent success of some large scale and highly specialised farming operations in new land areas this farming systems are seen as the future for the development of Egypt's new lands.

Since the marginal locations of agricultural production in Egypt tend to be new land areas, the development outlined above runs counter to the government's policy of land reclamation and to the euphoria of private investors over recent years. By contrast with those in the old lands, unalterably low yield levels in most new land areas do not raise expectations that these areas will ever become, in the long term, fully adequate locations. They will in comparison to the Nile Valley and Nile Delta always remain marginal locations, and it is to be expected that they will cease to be competitive in the course of further economic development or be forced to rely on high state subsidies to survive. The latter already applies to the majority of the sub-projects of the New Valley as it does to many other new land areas. Every further new land reclamation in Egypt contains, at least potentially, the danger of a rise in state subsidy payments for the new land areas, and thus of the withdrawal of state investments in areas of the Egyptian economy which have development potential.

In Egypt agriculture may retreat to the most productive locations, which in accordance with Andreae's hypothesis is to be expected; in connection with the rise in the cultivation intensity it may also come up against a limiting factor in respect of the limited scope to expand food supply given the explosive growth of population.

Due to the surplus on the world's agricultural markets and the relatively low price levels, as well as high qualitative demands, it cannot be expected that Egypt will succeed in exporting agricultural products on a large scale, and thereby making land use in the new land areas more profitable. In view of this fact the author suggests the following three measures for raising the agricultural and the overall economic capacity as being of greater importance for Egypt than the reclamation of new land:

- improving and sustaining the production capacity of the old land areas through measures affecting cultivation techniques, the agrarian structure and the sustainability of the natural resource base;
- opening-up and developing alternative branches of the economy, i.e. especially in industry and services;
- increasing investments in human development as the Egyptian people are the most valuable resource of the country.

Limitations of new land reclamation in Egypt

Limiting factors

New land reclamation in Egypt has its limits, especially in regard to the availability of fertile soils and suitable water resources (Wolff, 1992). Although land seems to be abundant, properties and fertility of the newly reclaimed soils and of the ones left for reclamation are marginal. Most of the newly reclaimed soils are sandy and calcareous. Sandy soils are structureless. Field capacity and wilting point are low (8 - 9 and 2 - 3% of soil moisture content, respectively), and the soil is poor in organic matter, and the macro- and micronutrient content is low. The average pH value is 7.7, and EC values range between 0.2 and 0.5 dS/m. Calcareous soils have totally different chemical and physical properties. They are high in CaCO3 content (26 - 59%) while organic matter percentage ranges between 0.23 and 1.50. The cation exchange capacity is relatively higher than that of the sandy soils and pH values are between 7.8 and 9.6. The EC is less than 4 dS/m (Bedier et al., 1998).

Water resources to reclaim the vast desert lands of Egypt represent the most critical constraint. As mentioned above: Egyptian agriculture depends entirely on a fixed supply of water annually from the River Nile, while groundwater is limited in quantity and quality at certain locations. Egypt's expected water balance in the year 2000 has been calculated by Abu-Zaid (1989) on the basis of a continuation of the Water Master Plan (Table 1).

Egypt's water balance, as presented in Table 1, shows reserves of 1.7 billion m^3 in 1990/91. It is doubtful whether all of these reserves have actually existed, as not all of the new new land hitherto reclaimed had reached full productivity, and consequently it had not called upon the full amount of water which had been earmarked for them.

Table 1. Water balance for the Arab Republic of Egypt in the years 1990/91 (actual) and 2000 (expected)

	1990/91 (actual) billion m^3	2000 (expected) billion m^3
Available water supply	55.5	55.5
Release Aswan High Dam	53.8	
Contribution Upper Nile Projects		2.0
Evapotranspiration	36.6	38.9
Domestic use, industry[1]	1.5	4.8
Evaporation losses	2.0	2.7
Drainage to the Mediterranean	12.1	11.8
Shipping, water power	1.6	0.3
Surplus	1.7	-1.0

[1]non-recyclable water; actual requirements are much greater
Source: Abu-Zaid, 1989; v.d. Molen, 1997

In future, it might become increasingly difficult to satisfy the actual demand for water, especially if the ambitious policy of the Egyptian government to reclaim new land is carried out as planned, and hitherto reclaimed areas are fully utilised. As it cannot be assumed that the Jonglei Canal Scheme in the Southern Sudan will be operating by the year 2000, or that the so-called Winter Water Project will be effective, i.e. that the unexploded discharge of 2.8 billion m^3 can be calculated for the year 2000.

Some thoughts on agricultural water use in Egypt under special consideration of new land developments

To judge the availability of water for an encroachment of Egypt's irrigated agriculture into the unexploded desert areas of the country a calculation , based on a similar calculation of van Leeuwen (1997), was carried out with the following results.

Irrigation water requirements under special consideration of further new land developments - Irrigation requirements of new land developments

The net evapotranspiration of an average cropping pattern in the Nile Delta amounts to 1,200 mm/year. The cropping pattern in New Valley is supposed to be adapted to desert environment and will exclude crops with a very high consumptive use. However, this will still be offset by higher temperatures and advection (horizontal heat flux from desert to arable land) that will increase the evapotranspiration rate with about 10 to 20%

Assumption 1: Evapotranspiration in New Valley: 1,600 mm/year
Net water consumption of 1 feddan: 6,700 m^3 /feddan/year

Surface irrigation water from lake Nasser contains 250 mg/l total dissolved salts. The maximum permissible salt concentration in soil moisture is 2,500 mg/l (Ece = 4 dS/m). This requires a leaching ratio of 250/2,500 = 10%.

Assumption 2: An additional 700 m^3/feddan/year has to be supplied for leaching

Evaporation losses from open canals, field ditches and spill areas are estimated to amount to 5 % of the net irrigation application (evapotranspiration + leaching fraction).

Assumption 3: An additional 300 m^3/feddan/year has to be supplied to cover unavoidable evaporation losses.

It is assumed that only modern irrigation methods and distribution systems will be applied in the New Valley Project. This will include provisions to recirculate tail losses and other spills from the supply network.

Assumption 4: The gross irrigation supply for one feddan amounts to the sum of the three above mentioned requirements being a water duty of: 7,700 m^3/feddan/year.

During the first stage of the Project, some 500,000 feddans will be reclaimed for irrigated crop production.

Assumption 5: Annual water supply for 500,000 feddans amounts to 3.85 billion cubic metres.

Assumption 6: Irrigation of 500,000 feddans in New Valley will generate 350 million cubic metres drainage water, with a salinity that is too high for other uses. This drainage water will either percolate to the groundwater, or has to be disposed of in a drainage sump of the same size as the Wadi Rayan Lakes (120 – 150 km^2).

Proposed conjunctive use of groundwater

The present abstraction of groundwater from the Nubian aquifer in the New Valley is estimated at 1 billion cubic metres per year. According to studies of the Groundwater Research Institute of Egypt's Water Research Centre, the potential abstraction could be about 2 billion cubic metres per year. It is proposed to use the additional 1 billion cubic metres of groundwater in the presently reclaimed areas only during the peak periods in irrigation demand. This means that during the summer season conjunctive use of surface- and groundwater will be applied and that during the winter season only surface water will be applied.

The application of this option might result in the reduction of the canal capacity and thus saving considerable investments.

Effect on the water and salt balance of the Nile Valley and Delta

At present, the Aswan release is 55.5 billion cubic metres per year. This water carries a saltload of 14 million tons of dissolved salts. It is estimated that an additional 1 – 2 million tons of salt is added from agricultural chemicals, industrial waste and domestic effluents. In the northern fringe of the Delta an unknown quantity of salt enters the hydrological system through seawater intrusion.

The Drainage Research Institute Reuse Project estimated that a total saltload of 20 million tons has to be evacuated to the sea per year.

Assumption 7: When the salt concentration of percolation water (leachate) or other drainage effluent exceeds 2,500 mg/l, then it will not be recoverable for reuse and must be discharged to the sea, or other safe disposal sites.

Assumption 8: Disposal of 20 million tons saltload requires a minimum drainage flow to the sea of 8 billion cubic metres per year.

With the current 55.5 billion cubic metres the following water allocation can be realised:

Net domestic consumption	2.5	billion cubic metres
Net industrial consumption	2	billion cubic metres
Unavoidable evaporation losses	2	billion cubic metres
Saltload disposal to sea	8	billion cubic metres
Net evapotransporation of crops	41	billion cubic metres

Assumption 9: The potential area for crop production, based on the availability of 41 billion cubic metres and a net evapotranspiration of 5,100 cubic metres per feddan and year amounts to 8.0 million feddan.

The present net cropped area is estimated at 6.8 million feddan. It should be noted that many of the new reclamation areas did not yet realise their targets and have only between 50 and 70 percent of the designated area under crop production.

The planned expansion of reclamation areas in Sinai (240,000 feddans), West and East Delta (360,000 feddans) and completion of the areas in existing reclamation projects (200,000 feddans) will result in a total cropped area of 7.6 million feddans. This leaves only a potential of 400,000 feddans for future expansion.

Water savings, made through improvements in the irrigation system do not contribute to additional water resources. The only real saving that can be made is the reduction of non-productive losses from evaporation. Reduction of tail-end losses, percolation losses and surface run-off result in almost the same reduction of drainage water. On the other hand, the reduced dilution of drainage water with irrigation losses, will result in a higher salinity of the drainage water.

With respect to the proposed savings from rice and sugar cane, only the lower net evapotranspiration of the substitute crops should be accounted and not the difference in gross water duty. The evapotranspiration rate of rice and sugar cane is about 1.4 times more that that of alternative crops.

Assumption 10: The proposed conversion of 800,000 feddans rice and sugar cane to other, less demanding crops could result in a decrease of evapotranspiration of some 450 mm/year, corresponding to a total water saving of 1.5 billion cubic metres per year.

It remains doubtful, that farmers will accept the reduction of their rice area. The government has no capacity to inforce their decision on cropping patterns, like 10 years ago. The solution of this problem should be a rather radical one: Revoke the import ban on rice and sugar and import large quantities of cheap rice from S.E. Asia and sugar from America, in order to swing the market to an over-supply situation.

Future situation
Abstraction of 6 billion cubic metres for New Valley has the following impact on the water and salt balance of the Nile valley and delta.
Salt loads: Influx of salt at Aswan will be reduced with 1.5 million tons. Total salt load to be disposed of (including seawater intrusion): 18.5 million tons at a concentration of 2,500 mg/l, requires a drainage flow of 7.4 billion cubic metres.

Assuming that the net water saving from rice and sugar cane can be partially realised, some 1 billion cubic metres will be available. Without rice and sugar cane, the net evapotranspiration of the average cropping pattern will be about 5,000 cubic metres per feddans and year.

For the short-term it is assumed that domestic and industrial consumption remains the same amount.

Substituting these new figures in the water balance results in an availability of 36.6 billion cubic metres for net crop evapotranspiration.

Assumption 11: In the new situation some 36.6 billion cubic metres available for net evapotranspiration could sustain crop production in some 7.4 million feddans in the Nile Valley and Delta.

Assumption 12: The developments in Sinai and reclamation schemes in West and East Delta are jeopardised if the proposed abstraction of 6 billion cubic metres is released. The limit of abstraction for New Valley should not exceed 4.5 billion cubic metres.

Development of the additional groundwater potential will add 1 billion cubic metres per year. About 50% of this water could be used for domestic and industrial consumption, while the other 50% is for conjunctive use during the winter season.

Assumption 13: The total net available supply for crop production in the New Valley will not exceeded 5 billion cubic metres per year, including groundwater. This amount limits the irrigated arable land to 740,000 feddans.

Concluding remarks

All this implies that, according to the present state of knowledge, a marked water shortage is to be expected in Egypt in the years to come. Though the calculation of the water balance deficit above was based on the assumption that the discharge conditions of the Nile will not change in the foreseeable future, i.e. that the other countries bordering on the Nile will not draw larger quantities of water, in which case the water deficit in Egypt would be even more severe.

The water balance presented above and the calculation carried out show that it is an illusion to believe that the Egyptian agricultural area can be expanded to the planned extent, especially since it cannot be assumed that the other states sharing the Nil will agree to a substantial increase in the drainage of Nile waters through their canalisation and wetland drainage. Moreover, Egypt has no groundwater resources which could be renewed by natural precipitation.

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