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Water for Food Production in Sub-Saharan Africa

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ABSTRACT: Water control is an essential requirement if food and energy crises in Africa are to be resolved on a sustainable basis. The paper reviews the problems and prospects associated with the expansion of irrigation in Africa, where experiences with large and medium scale water management have been of comparatively recent origin. The present status of water development and management issues are approached carefully and cautiously, they can make an important and lasting contribution to the resolution of Africa's food crisis.

Introduction

Most sub-Saharan countries have faced a series of crises during the past 15 years, ranging from serious shortages of food and energy to falling commodity prices, which constitute their main exports, and heavy external debts. While some of these crises were undoubtedly precipitated and even accentuated by inappropriate policies and inadequate performances by the governments concerned, many other aspects were clearly beyond the control of the continent, which was thus forced to be basically dependent on external assistance to feed a signigicant portion of its population.

Among the litany of the serious problems faced by the sub-Saharan African countries are the following:

- Population growth in Africa is the highest in the world and is accelerating.

In nearly all African countries, 50-75% of the population subsist in absolute poverty.

- For sub-Saharan Africa as a whole, GNP per capita in 1984 was $420, and its annual growth rate during 1965-84 was 1.8%. There are 25 countries of low-income Africa that are poorer today than in 1960. According to the World Bank, 'for the first time since World War II, a whole region has suffered retrogression over a generation'. Per capita income in countries like Chad, Niger, Tanzania, and Togo has declined by approximately 30%, equivalent to the situation in the USA during the Great Depression.
- From 1970 to 1984, sub-Saharan external public and publicly guaranteed debt increased from $5.426 billion to $58.828 billion, and the combined external debts of Africa now exceed $125 billion. Per capita GNP for Mauritania for 1984 was $450 but the per capita long-term public debt was $703. Corresponding figures respectively are: Guinea-Bissau, $180 and $170; Male, $140 and $130; Sudan, $340 and $264; Togo, $250 and $225; Zaire,$140 and $134; and Zambia, $470 and $429.
- Annual per capita food production declined for the sub-Saharan Africa by 2.3% during 1965-73 and by 1.7% during 1973-84; corresponding figures for total agricultural production were declines of 0.7% and 1.9%, respectively.
- The number of severely hungry and malnourished people is estimated to have increased from close to 80 million in the early 1970s to over 100 million in 1984. By 1979-81, on a global basis, the percentage of undernourished population was highest in Africa; a decade earlier it was the highest in Asia.
- Life expectancy at birth in 1983 for sub-Saharan Africa was 49 years compared to 76 years for industrial market economies. Life expectancy at birth in 1983 for Gambia was 36 years, Guinea 37 years, and for Guinea-Bissau and Sierra Leone only 38 years. These statistics are half or less than half of the industrial market economies. Child mortality in Sub-Saharan Africa, which was 50% higher than the average of developing countries in 1950, is now almost double the average.
- For Africa, there is one doctor per 21 000 people and one nurse for every 3 000. For the USA, there is one doctor for every 520 persons and one nurse for every 140.
- Number of children enrolled in secondary

school in 1982 as a percentage of age group in Sub-Saharan Africa was 15 compared to 87 for industrial market economies.
- Commercial energy consumption per capita in sub-Saharan Africa in 1983 was 110 kg of oil equivalent; the corresponding figure in industrial market economies was 4730 kg.

Many other similar data can be produced to indicate the extent and magnitude of problems faced by Africa, but in this article the emphasis will be only on those issues that have direct implications in term of water use for food production.

Water for Food Production

For optimal, sustainable food production through rainfed or irrigated agriculture, an essential requirement is the reliable availability of water as and when required by crops. In Africa, for climatic, demographic, and a variety of other reasons, water resource development has thus far been primarily concentrated in the N and NE part of the continent, so much so that only six countries in this region account for 70% of all irrigated land in Africa. Irrigated agriculture has a minor place in the economies of the sub-Saharan countries with the exception of Sudan, Madagascar, and Nigeria. Of the 2.6 million ha of modern irrigation developed in sub-Saharan Africa, Sudan alone accounts for nearly two thirds of the total at 1.7 million ha. Similarly, out of 2.4 million ha of small-scale or traditional irrigation practised in the region, Madagscar and Nigeria (800 000 ha each) account for slightly over two thirds of the area.

Irrigated area as a percentage of a country's area under temporary and permanent crops varies tremendously from one African nation to another. For example, nearly all the cropped land in Egypt is irrigated, but in countries like Angola, Central African Republic, Gabon, Togo, and Zambia less than 0.3% of cropped land was under irrigation in 1982.

On the basis of climatic analyses, 29% of the land area of the continent is under desert-like conditions (annual rainfall less than 100 mm), 17% is arid (100-400 mm/year), 8% semi-arid (400-800 mm/year), 10% dry sub-humid (800-1200 mm/year), 20% moist sub-humid (1200-1500 mm/year), and the balance of 16% of land area is humid (annual rainfall over 1500 mm). Generally speaking, the dry sub-humid zone (growing period of 120-179 days) have adequate moisture availability for rainfed production of staple food crops like millet, sorghum, and maize. Overall, considering the total African land area, approximately 25% can be considered suitable for rainfed production and another 10% is marginally suitable. The remaining 65% of the land is unsuitable.

The availability of surface water varies tremendously in Africa. In the region of the Sahara and the Horn of Africa, there is no surface water since there is no runoff. In the Sudano-Sahelian region, extending from Senegal to Somalia, the average runoff is up to 10% of rainfall, and it increases to more than 20% in the wet tropical highlands of Ethiopia.

In terms of irrigation development and management in Africa, there are several facts worth noting:

1) Africa generally has less available surface water per unit area and higher evaporation than most other regions of the world. Consequently, it also has less runoff into the sea per unit area when compared to other parts of the world.

2) With the exception of the Saire River, most African rivers show considerable seasonal variations in flow. The variations are more pronounced if natural regulators - lakes or swamps - are absent or if rivers drain form savannah or semi-arid areas where intense short-term precipitation may occur.

3) Natural sediment loads in the African rivers are generally lower than in other parts of the world, except when flowing through younger geological formations. Accordingly, for a major reservoir like Lake Kariba which has more than 60% of the volume as dead storage, the originally-designed reservoir life of 1 000 years has recently been increased to 1 600 years. In parts of Africa, however, human activities like overgrazing and deforestation are increasing silt loads of the rivers. Thus, Ibohamane and Moulela reservoirs on the River Niger have lost nearly half of their storage capacities during the past 15 years.

4) The distribution of surface water resources in Africa is very skewed. For example, the Congo River Basin, which at 4 000 000 km^2 covers nearly 16% of the sub-Saharan Africa, has a mean annual discharge of 1325 km^3, which accounts for 55% of the mean annual discharge for that region. An additional seven rivers (Niger - mean annual discharge 179.8 km^3, Ogooue - 148.9 km^3, Zambezi - 103.4 km^3, Nile - 84 km^3, Chari-Lagone - 43.2 km^3 and Volta - 39.8 km^3) contribute a further 25%.

5) Flat terrains in the W part of the continent mean a limited availability of good dam sites. Many of the dams built in recent years have some of the highest ratios of area inundated to area irrigated in the world. Such topography also means long offtake canals may be necessary, unless pumping proves to be a more economic alternative to supply irrigation water.

6) With the exception of Sudan, irrigable soils are generally found in small areas dispersed over the entire region.

7) The occurrence of intense storms of short duration require high design capacities for not only spillways but also for surface drainage systems, thus increasing both costs and design and operating comlexities.

8) Ground water accounts for some 20% of the total water resources of Africa, but only about 10% of the land lies over high-yielding aquifers. The occurrence of ground water is localized because of climatic and geologic conditions. Unlike Asia, fewer areas have extensive, shallow ground water that is comparatively more economic as well as complex and quicker to develop.

9) The average annual water requirements of main food crops vary from 3000 m^3/ha for the countries of humid central Africa to 16 000 m^3/ha in North Africa.

On the basis of information available at present, some 9 million ha of land was being irrigated in Africa in 1982. This estimate includes all types of irrigation: large scale, small scale, and various traditional forms of irrigation practiced in different African countries. In contrast, total potential land that can be irrigated under the present social, economic, and institutional conditions is on the order of some 45 million hectares. Thus it can be inferred that approximately 20% of potentially irrigable area was irrigated in 1982.

The extent of irrigated area, as may be expected, varies significantly from one country to another. If the country with the maximum irrigation in Africa, Egypt, is considered, currently 2.5 million ha of land is under irrigation, and this constitutes nearly 28% of the total land under irrigation in Africa. At present, very limited potential exists in Egypt to expand irrigation into new areas economically. In contrast, the percentage of potentially irrigable lands that are under irrigation at present in many countries is quite low. The figures for a few select countries that have significant irrigation potential are as follows: Angola - 0.2%, Ethiopia - 6%, Mozambique - 2%, Nigeria - 23%, Tanzania - 5%, Zambia - 0.05%, and Zimbabwe - 37%

Even though the extent of irrigated area in Africa is limited at present (for example, a country like India, which has only about one tenth of the surface area of Africa, has nearly five times as much irrigated area), its overall contribution to agricultural production is quite significant. For 43 African countries, for which data are available for agricultural production for both rainfed and irrigated agriculture for 1979-80, 58% of the total rice production and 77% of total sugar-cane production come from the irrigated areas. Also, for these 43 countries, even though irrigated area accounted for only 6,5% of the total cultivated area, it provided for about 20% the total value of all agricultural produce. In other words, in terms of average production value per ha, irrigation generates approximately 3 times that from rainfed production.

Need for Water Development

If the concept of self-sufficiency in food production in individual African nations continues to be an important policy in the future, the total food production must inexorably continue to increase to feed increasing population and also to increase the present per capita food availability to improve the nutritional status of people.

According to the latest estimates, in 1982 the total population of Africa, excluding that of South Africa, was 470 million, out of which some 370 million were in sub-Saharan Africa. The projected population growth rates during 1980-2010 in 51 countries in Africa ranged from 4.1% in Kenya to 1.5% in Cape Verde, but the range is between 3.67 and 2.02% for all but 4 countries. In all but three countries, population will grow at a faster rate from 1980 to 2010 than it did from 1970 to 1980. If the hypothetical stationary population is considered, it is expected to be around 2200 million, which may be reached toward the end of the 21st century. The corresponding sub-Saharan population is expected to be around 1800 million, which is approximately 5 times the 1982 population.

The initial results of a study on population-supporting capacity indicate that the continent of Africa as a whole, as well as the sub-Saharan region, should be potentially able to grow adequate quantity of food to satisfy their own needs from rainfed production, but this will require intermediate to high levels of inputs. The low level of inputs corresponds broadly to customary practice; intermediate level of input includes modest advances like some improved genetic material, some fertilizer, some additional animal power and equipments, and some elementary conservation practices; and high level of inputs means modern mechanized farming systems and methods suitable for the environment. Expressed in terms of cereal production, for all classes of cultivable land, the three levels of inputs correspond to national averages as follows: low levels - 280 to 430 kg/ha, intermediate levels - 1200 to 1900 kg/ha and high levels at 4500 - 6000 kg/ha.

While the overall conclusion that the rainfed agriculture has the potential to support the future population of Africa appears to be most reassuring, it should be noted that it hides the wide disparity of the various individual nations to achieve food self-sufficiency. For example, if the 5 countries of the Mediterranean (North) Africa are considered, they appear to be unlikely to support their population from their own environmental resource base, even at the high level of inputs, after about 1990. The largest nation of this region, Egypt, already uses most of the water available from the River Nile for irrigation; and irrigation already makes an important contribution to agricultural production in the other 4 countries. In spite of such developments, however, the 5 nations had a combined net import in 1982 of about 15 million tons of cereals, 1.5 million tons of sugar, and 0.2 million tons of pulses. This total import was necessary to feed more than 50 million people, which is nearly half of their present population. While there is not much scope to expand irrigation in the region, there is no doubt that water and other resources available could be used more efficiently.

Overall, this preliminary analysis indicates that for about 25 African countries it may be desirable to concentrate limited resources available on improving rainfed agriculture, which at intermediate level of inputs can support the future population. Even then, where there is effective domestic or market demand for extra agricultural output, further irrigation development can be justified. In the long run, however, even in these countries their land and water resources have to be optimally developed to support their population base, and irrigation will be necessary if the adverse effects of the unreliability of rainfall is to be substantially reduced in order to stabilize agricultural production. For the countries where population tends to equal or exceed the productive capacity of rainfed land, irrigation development has to be an important policy alternative (Biswas 1986).

With the serious consequences of droughts in recent years, and the concept of food self-sufficiency being almost universal in Africa, water resources of all countries must be properly developed to ensure long-term sustainable production. Even in those countries, where irrigation requirements are likely to be needed only after 10 to 20 years, it is desirable to introduce irrigation programmes at present to assure that adequate expertise and institutional capability can be gradually built up to successfully plan, implement, and manage irrigation projects. In other words, even though the immediate importance and the urgency of irrigation development may vary from one country to another, in the final analysis long-term food self-sufficiency cannot be achieved without irrigation development.

Under these conditions and with the present food crisis in many African countries, there has been a natural tendency to look at both large- and small-scale irrigation as an important solution to increase the productivity of existing dry-land farming. It is not surprising to find that many countries, international institutions, and bilateral donors are looking at irrigation (especially large-scale irrigation) as an important means to increase agricultural production in Africa, when given the facts that: considerable potentail exists to increase irrigated agricultural land by both surface- and ground-water irrigation; irrigation has played a minor role thus far in national economies; neither soil nor water are limiting factors to expand agricultural production; and many Asian countries, especially India and China, have increased food production significantly through the introduction of large-scale irrigation. However, if irrigation development is to be expanded in Africa, cropping intensity must receive adequate attention. Cropping intensity at present is about 130% in N and NE Africa but is only about 110% in other areas. This means that the irrigation land-use systems have to be further intensified in order to make them more efficient than they are at the present.

Economics of Irrigation Development

For a variety of reasons, experience with the economics of irrigation development in Africa has generally not been positive. Costs of irrigation development have been higher than in most other regions of the world. As to be expected, irregation development costs vary tremendously from one part of Africa to another and are not readily comparable. One reason for the variation in costs is the extent of infrastructure development costs (transportation networks, bridges, power supply, settlements, agricultural machineries, etc.) incorporated within the project. Thus, if a region is relatively well developed, the total cost of developing rural and urban infrastructure may not be very high since many of the requirements may already exist. On the other hand, in an underdeveloped region, incorporation of massive infrastructural development costs within irrigation projects is likely to produce a high cost of irrigation development per unit area. The extent of social service that are provided to the irrigators and their families will also influence irrigation costs.

Other important factors that may influence irrigation development costs are degree of water control necessary, remoteness of the site, types of structures that need to be constructed, source and availability of materials including construction machineries, government policies (inflated exchange rates, import duties and fuel costs), and availability of skilled and unskilled labour and technical services.

An idea of the variations of investment costs for different types of irrigation development in various parts of Africa can be best obtained by reviewing some recently completed projects. Tab 1 shows such an intercomparison of irrigation development costs for 11 different projects from 8 African countries constructed since the early 1970s (FAO 1986). It should be noted that the total cost figures are based on actual expenditures incurred during the various years of con-

Country/Project	Project type	Construction period	Development cost ($) Per hectare	Per family
Cameroon				
SEMRY I	Full control and dykes	1972–75	2 277	3 234
SEMRY II	Full control and dam	1978–85	9 778	9 128
Egypt				
Drainage I	Drainage	1970–80	500	764
Madagascar				
Lake Alaotra	Full control	1970–75	894	3 193
Morondava	Full control and dam	1973–81	14 835	11 928
Mali				
Mopti Rice	Partial control	1972–75	503	1 682
Morocco				
Doukkala I	Sprinklers, buried pipes	1976–80	5 374	5 443
Senegal				
River Polders	Full control	1973–78	4 172	7 485
Sudan				
Rahad	Full control, no dam	1975–82	3 138	2 826
Tunisia				
Medjerda	Rehabilitation	1975–82	909	10 100
Nebhaha	Rehabilitation	1975–82	858	2 145

Tab 1
Costs of selected irrigation projects in Africa (from FAO 1986)

struction of the projects. In addition, inflation, rates during the mid- and late 1970s were very high, and accordingly costs of those projects completed in the mid-1970s are quite low compared to present-day development costs.

The range of irrigation projects listed in Tab 1 is quite broad. It ranges from low-cost rehabilitation schemes like the Drainage I scheme in Egypt where development costs were $500/ha and $364/family, to full water control at Morondava in Madagscar with costs of $14835/ha and $11928/-family. High though the figure of $14 835/ha may be, it is no longer uncommon to find irrigation development costs in Africa in the range of $15000-$20000/ha if all infrastructural development costs and technical and production support services costs are included. Thus, for the Bura Project in Kenya, the development cost has been around $20000/ha, 60% of which was non-productive infrastructure ($12000). Similarly for the Tshovane Project in Zimbabwe, the development cost was $10800/ha. However, when items like costs for settlement, agricultural buildings and machinery, and road networks are omitted, the cost of irrigation-development part only was $750/ha.

An important implication of the high costs of irrigation development is their overall economic justification. For staple food crops like maize and paddy, investment costs higher than $4500/ha generally mean that economic returns from agricultural production are not adequate to justify the costs incurred. If the investment costs are higher than $6000/ha, none of the cereal crops are likely to generate profit at the best levels of production efficiency found in Africa. High investment costs can only be economically justified with high value cropping patterns consistent with high levels of agricultural production. While in a few instances like the Mwea Scheme in Kenya (5692 ha of irrigated land that was developed in 1954 using Mau Mau detainee labour) the rice yields have been more than 5 tons/ha, the actual yields have not been as high as expected -- in fact in many cases they have stagnated or even fallen during the past decade.

For irrigation projects with high development costs, it is necessary to either obtain very high levels of efficiency that have not been achieved thus far, add to the cropping pattern higher-value crops, or to provide subsidies. Because of this situation, there is already some pressure to change the cropping pattern in many projects by replacing ordinary crops with cash crops. Low-cost recovery is a major problem in irrigation projects in Africa. Even for the relatively successful Mwea Scheme, the National Irrigation Board (NIB), which administers it, made a loss of K 262 391 in 1979-80 and K 429 063 in 1980-81. NIB's income from the water rates, cultivation charges, and other sources covered only about half of its expenditure for the scheme during those years.

Faced with this type of situation, the government responses have been to waive cost recovery, subsidize part of operating and maintenance expenses of irrigation systems, and/or subsidize producer inputs and services. Pressure to continue these policies are likely to increase in the future if the debts incurred for irrigation infrastructural developments are expected to be services from project incomes.

One noteworthy exception to the above state of affairs has been Zimbabwe. The Zimbabwean government has generally undertaken to build and operate the storage facilities and infrastructures necessary; downstream developments like construction of irrigation networks and land development works have been left to the private sector. This combined effort of irrigation development between public institutions and the private sector has worked quite well, certainly significantly better than in most African countries where the records of the government-sponsored authorities to develop and manage irrigation works generally have been disappointing.

For irrigation in commercial settler farms and commercial farm units in Zimbabwe (together they account for 90 500 ha of irrigated land or 69.6% of total irrigation in the country), beneficiaries have to reimburse the government all capital costs as well as operating and maintenance costs over a 40-year period, at a fixed interest rate that was prevalent when the project was completed. Accordingly, the country has a wide range of water charges that vary from Z\$2.5/1000 m^3 for old projects to over Z\$25/1000m^3 for new schemes because of inflation and higher interest rates, which have risen from 3.5% in 1947 to 9.5% in 1981.

Small-Scale Water Development

Much has been written recently on small-scale irrigation development in Africa. There is no doubt that considerable potential exists for small-scale development where easily obtainable water - rainfall, runoff, natural storage in dry season - can be used. Under appropriate site conditions, small-scale irrigation has some special attractions. It does not require major investments in physical infrastructures, and foreign exchange requirements, if any, are low. Such schemes can be developed at relatively low costs and thus can be cost-effective for a wide variety of crops including basic staples. Farm-level investments are also lower when compared to large-scale irrigation projects. Since small-scale projects are less complex and simpler to construct, less time is required for planning and construction, and hence they contribute to the national food production effort quite quickly.

For small-scale irrigation projects, the cost per hectare of development is likely to be less than similar costs for large-scale development. Rigorous cost analyses for small-scale irrigation projects in Africa are few and far between. Generally, the beneficiaries provide some labour and/or resources for the construction of the projects and they also play a more important role in their operation and maintenance. This means that the government costs are reduced, and the costs that are currently quoted are only the financial costs to the government; the contributions of beneficiaries are generally not accounted for.

Even when taking into account the above facts, government costs for small-scale irrigation projects are generally much less than for large-scale developments, although they naturally vary depending on the complexity of schemes, terrain conditions, etc. The use of runoff water, bottomland development, or lifting of water from shallow wells by hand or animal power for irrigation purposes cost under \$1250/ha. If it is necessary to construct river diversion structures with gravity flows, development costs range from \$2500 to \$3750/ha. Current estimates of irrigation cost in Francophone West Africa for low-pressure sprinkler systems suitable for small farmers is on the order of \$3200/ha, but high-pressure systems for large estates are likely to cost \$4400/ha or more.

Development costs of small-scale irrigation in Zimbabwe have not been cheap due to their remoteness, long haulage distances for construction networks, and the density of field networks. Recent costings by the Ministry of Agriculture for 80-ha schemes for the National Small-Scale Irrigation fund have ranged from Z\$3 000 to Z\$5 500 /ha. However, costs for some individual projects have been estimated at as much as Z\$12 000/ha. For ground-water irrigation with boreholes and pumping, costs of small-scale village schemes (tens of ha) in Francophone West Africa have been estimated at \$12 000-\$15 000/ha. When the additional high costs of pump operation and maintenance are added, unit costs of development of these types of schemes appear to be substantially higher than for most large-scale surface irrigation costs.

Although small-scale irrigation schemes have many advantages, they also tend to suffer from certain disadvantages like diseconomies of scale, poor efficiency and quality control and lack of appropriate governmental interest and supervision due to their decentralized nature and small size.

Integrated Approach to Water Development

In order to obtain optional returns from irrigation development projects, it is essential that an overall integrated approach should be used. The integration, however, has to be carried out at several levels.

First, for the current needs of most African countries to be met, it is necessary to have national policies that effectively integrate rainfed and irrigated agriculture. While the balance between these two types of agriculture is likely to vary from one country to another - depending on climatic and other physical conditions, relevant constraints, and prevailing socio-economic circumstances - most countries may find it desirable to extend rainfed agriculture to the extent it is possible and simultaneously establish a base on irrigated agriculture that could then be expanded as and when considered necessary in the future. Experiences with the recent droughts indicate that such an integrated approach is inevitable.

Second, for those countries that already have an appreciable irrigated area, irrigation should be considered a major component of agriculture, which in turn should be properly integrated within the framework of overall national development plans. It is thus necessary that water development plans in a project area be coordinated with other plans like population policies, health, education, and other aspects of rural development plans. Only when these plans of various sectors are coordinated and their implementation processes are integrated full benefits of development can accrue to the people.

Third, irrigation is a means to an end, albeit a very important means, but it is not an end by itself. The end is to increase agricultural production. Thus, the other associated activities like the selection of mix of crops, timely availability of inputs, machineries, transport, fuel and power supplies, and presence of workshops, markets, and agro-processing plants have to be coordinated. Only with such integration can individual and collective efforts to increase agricultural production be supported and sustained.

Constraints to Water Development

There are many constraints to appropriate water development in sub-Saharan Africa that generally are instrumental in seriously reducing the overall benefits and positive impacts of the projects. Among these constraints are technical complexities of projects, return to investments, poor planning and management, lack of financial resources, inadequate operation and maintenance, lack of trained manpower, inadequate research, poor understanding of health and environmental issues, lack of adequate data, inadequate monitoring and evaluation, and absence of beneficiary participation. Naturally, many of these constraints are interrelated. Because of lack of space, only three constraints will be discussed here: lack of adequate data for planning and management, lack of trained manpower, and inadequate research.

1) *Lack of adequate data for planning and management*. - For proper design and operation of irrigation systems, it is necessary to have reliable data on various hydrological factors (time-series data on precipitation, river flow, ground-water levels, etc.), soil types, agriculture, social and economic factors, and manpower availability. Reliable time-series hydrological data for any extended period of time are available only for certain scattered locations that have been the subject of detailed monitoring and study over a certain period. Accurate and nationwide inventories of land and water resources is mostly lacking in most countries, and even whatever data are available at present, lack proper storage and retrieval facilities. Intercomparison of data from different sources or agencies often show wide variations and discrepancies, which make planning and management of irrigation projects a most complex task under the best of circumstances.

Lack of hydrological and soil data in many areas has made irrigation development technically a more difficult process. A typical example is the Limpoo Project in Mozambique planned potential of which has never been reached due to poor soil conditions in part of the project area that were undetected in the planning stage. Under these circumstances, foreign consultants - who are generally not very familiar with the project areas and often concerned with their own reputation - have opted for a more conservative design than necessary, which has in turn increased project costs.

While the physical data base is often weak, information on social issues is even weaker. Identification and assessment of social values that determine community preferences and requirement for lifestyle, employment, and leisure, foods, and even food varieties are mostly lacking.

This overall lack of reliable data on physical and socio-economic issues in many African countries has made irrigation project planning a most difficult task. Not surprisingly, the overall performances of some of the projects that were designed on the basis of inadequate and unreliable data, are significantly below expectations.

2) *Lack of trained manpower*. - While traditional irrigation based on simple technology has long been practiced in suitable locations, introduction of large-scale formal irrigation for commercial crop production requiring extensive physical and social infrastructures, efficient management and marketing, and experienced farmers, and using modern technology and regular supplies or inputs, is of comparitively recent origin in most African countries. These two types of irrigation have relatively very few things in common.

The lack of adequately trained manpower at all levels forms one of the major constraints to irrigation development and management, including the subsequent use of water by farmers to optimize agricultural production. Thus, the absence of adequate number of properly trained and experienced irrigation engineers has tended to increase the cost of irrigation projects. Once irrigation is introduced, lack of trained water management personnel and the absence of farmers experienced in irrigated agriculture reduces the benefits expected from the schemes. In addition, lack of technicians and similar other personnel of lesser level of expertise, who are essential for irrigated agriculture, is creating another serious bottleneck.

In spite of this situation, however, there is little doubt that the present status of African irrigation could be made to perform much more efficiently if serious attempts are focussed on making better use of existing trained manpower that would improve their performance by removing many constraints that lie both within and outside the institutions wherein they are employed.

Expatriate staff have been a mixed blessing to African countries. On the positive side they have contributed considerably to the planning, construction, and operation of irrigated agriculture as in the SEMRY (Société pour le Développement des Plantations de Canne à Sucre, l'Industrialisation et la Commercialisation du Sucre) projects in Cameroon. Projects in the Gambia and the Burkina Faso, largely developed 10 tons of paddy per hectare per year. In most cases, however, training of African personnel, who were supposed to have taken over from their expatriate counterparts, has not been satisfactory. In many instances such training and manpower development has not taken place at all: in the 1250-hectare Kou Project in Burkina Faso, where there were 60 expatriates at one time, not even a single African staff received any training in 5 years. Consequently, when the expatriate staff leave, project performance starts to decline rapidly. Furthermore, the cost of expatriate staff is high; they accounted for 20% of the total costs of the SEMRY projects over the 5-year construction period.

Another problem is the lack of trained extension workers required to ensure that benefits from irrigation projects accrue. A recent review of extension workers used in the Sahelian irrigation concluded that 'their theoretical training is sometimes barely credible to the farmers whom they are supposed to guide' (Club du Sahel 1980). Manpower requirements and training needs for the staff of the irrigation institutions are likely to vary from one country to another, but there is a general need for providing more practical experience at all levels. In addition, irrigation professionals should have a multidisciplinary approach, which can successfully combine the various aspects of engineering, agronomy, and socio-economic studies.

Manpower planning has to play an important role for irrigation in Africa. Because of a severe lack of data on the present and future manpower availability and requirements, and training needs, manpower analysis is urgently needed in all African countries.

3) *Inadequate research.* - There have been substantial funds available for agricultural research in Africa during the past two decades. Expenditure on agricultural research as a percentage of agricultural GDP in Africa is now substantially higher than in Asia and most of Latin America as shown in Tab 2 (Evenson 1985). The number of agricultural research scientists more than doubled during the decade 1970-80.

In spite of this expenditure, 'agricultural research after political independence has been of limited scope, poorly organized, badly managed, and lowly funded' (FAO 1985) and 'most observers agree that the technology shelf (in agriculture) in sub-Saharan Africa is nearly bare' (World Bank 1986). Reasons for such a poor state of research are many. Among the problems are the following:

- donors who pay for most of the agricultural research generally shape research policies, priorities, and institutions with minimal national involvement;
- poor bilateral and multilateral donor coordination contributes to duplication of efforts, confusion due to conflicting advice, changing priorities, and differing requirements;
- high cost and underuse of researchers (average cost $ 50 000/scientist/year in sub-Saharan Africa compared to half this cost in Asia);
- isolation of researchers;
- lack of incentives, equipments, library and computing facilities, one-time fund availability, and supporting personnel to conduct research effectively; and
- weak institutional research bases that have

Tab 2
Comparison of agricultural research efforts, 1980 (from Evenson 1985)

Region	Expenditure on agricultural research: As % of agricultural GDP	Expenditure on agricultural research: Per scientist man-year ($$10^3$)	Agricultural scientist (man-year/$10 million agricultural GDP)
Africa			
West	1.19	83	1.42
East	0.81	46	1.76
Southern	1.23	50	2.47
Asia			
South	0.43	34	1.29
Southeast	0.52	25	2.07
Latin America			
Temperate South America	0.70	53	1.32
Tropical South America	0.78	56	1.77
Central America and Caribbean	0.63	62	1.20

very little high-level political or bureaucratic support.

Any attempt to make irrigated agriculture an overall success in Africa must include more effective research that considers the continent's tremendous heterogeneity in climate, soils, availability of other natural resources, levels of development, types of institutions, and social and cultural norms.

Concluding Remarks

While a first glance at irrigation development shows it to be a tempting alternative to resolve Africa's present food crisis by providing better water control, in reality the issues are not so simple. Undoubtedly irrigation can significantly increase agricultural production, but many other conditions need to be satisfied before this can happen at reasonable investment costs. It would require the simultaneous availability and support from smoothly-functioning infrastructure in the areas of: agriculture (research, training and extension), economics (ready availability of inputs, credit, agro-industry, and marketing and transportation network), and social services (education and health). If irrigation projects are properly managed and if the above conditions are satisfied, irrigation can live up to its promised potential. It should also be noted that it will not be an easy task to satisfy these conditions, especially in Africa where experiences with irrigation management have been of comparatively recent origin. Thus, irrigation is unlikely to prove to be a panacea for Africa, but if approached carefully and cautiously, it can undoubtedly make an important and lasting contribution to the resolution of Africa's food crisis.

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