# Irrigation in Africa south of the Sahara

FAO INVESTMENT CENTRE TECHNICAL PAPER

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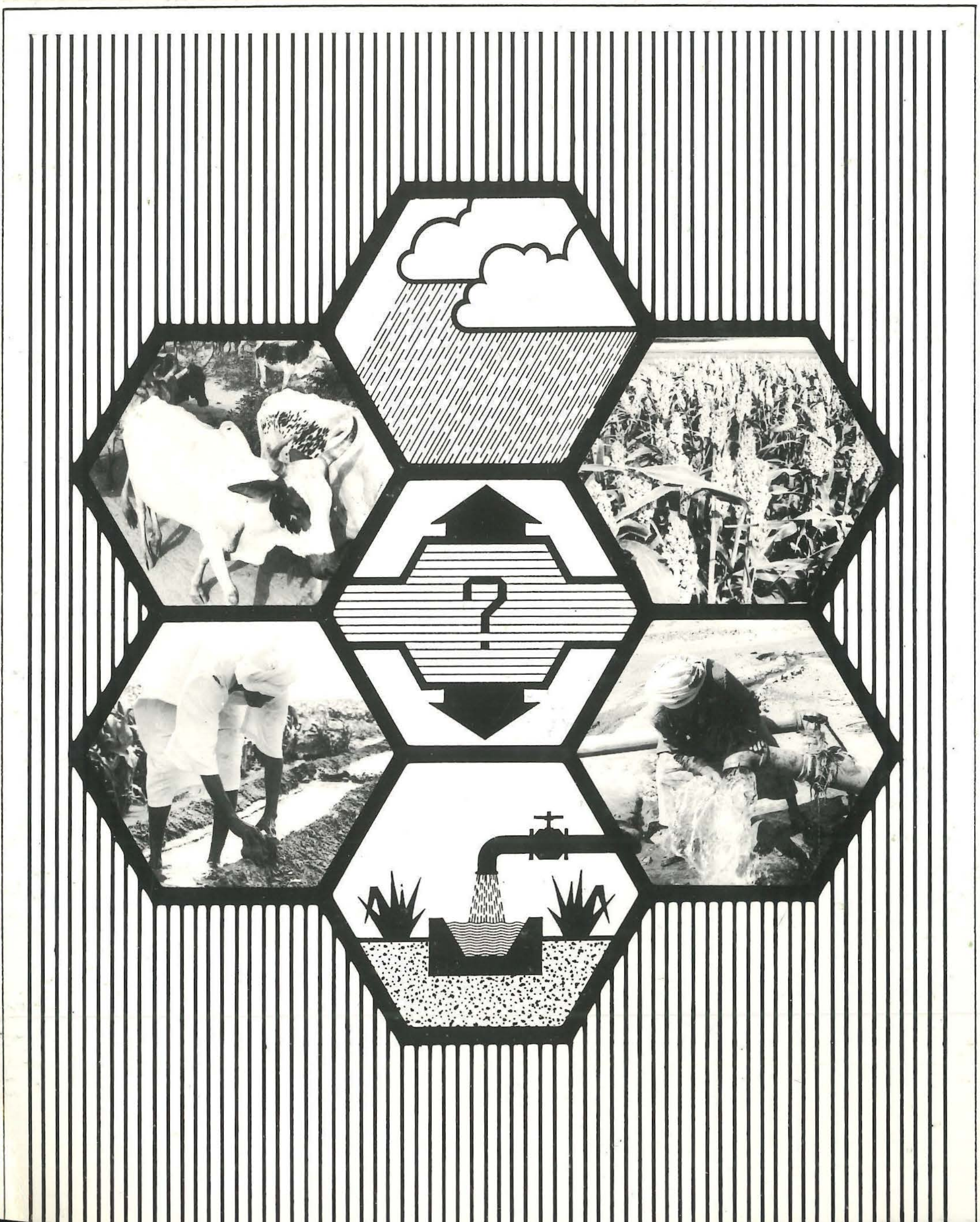

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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# IRRIGATION IN AFRICA SOUTH OF THE SAHARA

## A STUDY, WITH PARTICULAR REFERENCE TO INVESTMENT FOR FOOD PRODUCTION

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ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| BRGM | Bureau de Recherches Géologiques et Minières |
| CCCE | Caisse Centrale de Cooperation Economique |
| CDC | Commonwealth Development Corporation |
| CIRAD | Centre de Cooperation Internationale en Recherche Agronomique pour le Développement |
| cm | centimetre |
| EEC | European Economic Community |
| FAC | Fonds d'Aide et Cooperation |
| FAO | Food and Agriculture Organisation of the United Nations |
| FCFA | CFA Franc (50 CFAF = French Fr.1.00) |
| GERSAR | Groupement d'Etudes et de Réalisations des Sociétés d'Aménagement Régional |
| ha | hectare |
| hr | hour |
| IFAD | International Fund for Agricultural Development |
| kg | kilogramme |
| km | kilometre |
| l | litre |
| m | metre |
| mm | millimetre |
| O & M | Operation and Maintenance (of irrigation systems) |
| ONAHA | Office National des Aménagements Hydro-Agricole |
| ORSTOM | Office de Recherche Scientifique et Technique Outre-Mer |
| SAED | Société d'Aménagement et d'Exploitation des Terres du Delta |
| sec | second |
| SEMRY | Société d'Expansion et de Modernisation de la Riziculture de Yagoua |
| SODEMO | Société pour le Développement Economique de la Region de Morondava |
| SODESUCRE | Société d'Etat pour le Développement des Plantations de Canne à Sucre, l'Industrialisation et la Commercialisation du Sucre |
| SOMALAC | Société Malgache d'Aménagement du Lac Alaotra |
| SSA | Sub-Saharan Africa |
| t | metric ton |
| UNDP | United Nations Development Programme |
| US$ | US Dollar |
| WARDA | West African Rice Development Association |
| yr | year |

# IRRIGATION IN AFRICA SOUTH OF THE SAHARA

## A STUDY, WITH PARTICULAR REFERENCE TO INVESTMENT FOR FOOD PRODUCTION

### Summary


1. The 40 African countries covered by this study had an estimated population of about 380 million in 1982, increasing at 3.2% annually. Their food production is increasing at an estimated 2.3%/yr, and cereal output at only 1.8%/yr. As a result food imports are rising alarmingly. This trend has recently been accelerated by the effects of a series of droughts which may represent a permanent decline in rainfall.

2. The region has an estimated five million ha of irrigation. Of this, Governments have developed an area of 2.1 million ha, mostly under major modern schemes; three quarters of this land is leased to small-scale tenant farmers. Traditional flood, swamp, surface and low-lift irrigation, developed largely without government support, account for 2.4 million ha, and the balance consists of modern private-sector developments. Half the regional total is located in only two countries - Sudan and Madagascar. The total represents 15% of the technical irrigation potential of Sub-Saharan Africa and contributes an estimated 5.3 million tons (10%) to regional cereal demand plus 6 to 8% to demand for root crops and vegetables. Other main crops are sugarcane and cotton.

3. Most African governments have seen irrigation as a means towards food self-sufficiency, or as a source of foreign exchange earnings from export crops. Tenants on major schemes are therefore usually required to concentrate on commercial production of the crops given priority by the government and to sell them to the state. Due to the novelty of modern irrigation to most farmers and the remoteness of many sites, governments have often had to supplement already costly irrigation works with extensive production and social support services. High foodcrop yields are needed to pay for these investments. By contrast, traditional irrigation is more often used only to provide subsistence food. It is normally less costly, and often integrated with rainfed and livestock farming as a means of reducing climatic risks.

4. A review was made of about 50 irrigation projects, many executed with World Bank assistance. Results give two contrasting impressions. Although performance sometimes declined later, five out of six major Bank projects studied in detail had by the end of disbursement achieved or come close to many of their targets. Costs were not unduly high and economic returns, sometimes favoured by improved commodity prices, were acceptable. However on many other projects poor surveys, planning and administration have led to long construction delays and high cost overruns. Due to weak management and insufficient operating budgets, scheme operation and maintenance, as well as production support services, are frequently inadequate. In such cases, and in the face of unfavourable procurement policies, farmers have all too often lost confidence in projects and sought to retain their traditional diversity of activities. These problems have led

to neglect of irrigated areas, low production, and sometimes to the need for scheme rehabilitation. Even on the better major irrigation projects in the region foodcrop yields have seldom been sufficient to justify the costs of modern irrigation works, which for full water control now range from about US$4,000 to over US$8,000/ha, excluding roads and social infrastructure.

5. Government support for small-scale schemes has suffered many of the problems of large schemes, unless based on simpler technical approaches closer to those of the traditional irrigator, and with an obvious appeal to the beneficiaries.

6. Nevertheless, for eight countries (Senegal, Burkina Faso, Niger, Mauritania, Mali, Somalia, Botswana and Kenya), containing some 14% of regional population, lack of rainfed potential and/or rising demographic pressure on rainfed land are likely to make irrigation an essential element of future food strategies in the short and medium term. Entirely new, large-scale schemes may seldom be economically justified in these countries but there is scope for cheaper rehabilitation, and in some cases expansion, of existing perimeters. Simple improvements to traditional swamp and recession irrigation, although giving smaller yield gains, could in aggregate also make an appreciable contribution to national food supply.

7. For the remaining thirty-two countries first priority is more likely to be given to rainfed development, which is usually simpler to organise, cheaper, and can give quicker benefits. Nevertheless few of these countries can afford to discard any existing schemes where rehabilitation is feasible, and most also have some traditional irrigation which could be improved.

8. Regardless of these strategic considerations, over half the countries have some of their territory in drought-risk zones where small-scale irrigation based mainly on small dams and groundwater - and probably, of necessity, grant-funded - could do much to reduce rural hardship and the need for costly disaster relief.

9. There are at present many constraints to these developments. Social, institutional and economic factors appear more important than technical limitations. To improve the future performance of irrigation in the region governments would have to make difficult policy and institutional changes. Planners must recognise that, to become established, modern irrigation requires long periods of social change and adaptation, in a consistently favourable policy and budgetary environment. Financial returns from irrigation need to be raised to improve the commitment of irrigators, and to encourage the emergence of private sector agricultural services. Inefficient government irrigation agencies need to shed excess staff, and abandon unprofitable activities and wasteful methods. Manpower development is needed at all levels, especially for managers. This will only be possible with substantial international support to governments through policy dialogue, loans, grants, training and technical assistance programmes.

10. The study concludes that, even with reasonable success in making such changes and adequate external support, the pace of construction of new, modern schemes will decline. However the rehabilitation of existing schemes might reach 50,000 ha/yr and expansion of traditional and small-scale irrigation could accelerate somewhat, to 140,000 ha/yr. Combined with some yield increases, this would allow irrigated cereal production in the region in the year 2000 to reach 2.6 times the present figure. But due to population growth the contribution of irrigation to regional cereal demand would be raised from 10% to only 14%.

# IRRIGATION IN AFRICA SOUTH OF THE SAHARA

## A STUDY, WITH PARTICULAR REFERENCE TO INVESTMENT FOR FOOD PRODUCTION

## I. INTRODUCTION

1.1 The population of Sub-Saharan Africa (SSA) is rising at an estimated 3.2% per annum. Total food production is rising at only 2.3% and cereal production at no more than 1.8%. While the region produced an estimated 90% of its cereal needs in 1970 this had fallen to 76% in 1985 and is projected to decline to 57% by the end of the century. Furthermore, food production has recently been affected by the latest in a series of periodic droughts. Cereal imports, which totalled 3.4 million t in 1970/71, rose to an estimated 9.5 million t in 1982/83 and FAO estimates that on present trends the all-Africa net deficit of cereals will reach 40 million t by 2010.

1.2 Faced with these alarming trends, many African countries have turned to irrigation as a possible means of feeding their growing populations. An estimated 2.1 million hectares of modern irrigation have so far been constructed by governments in the region. Often the results of such government investments have been disappointing. The introduction of modern irrigation to traditional farmers has not been free of problems in most parts of the world; however the impressions received by the Investment Centre and Land and Water Divisions of FAO over recent years have suggested that in the case of Sub-Saharan Africa there may be especially severe obstacles.

1.3 This study reviews the present state of irrigated agriculture in SSA with special reference to its contribution to food production. It examines the results of some past investments in irrigation schemes and from the results it seeks to identify the various forms of irrigation development which are likely to be most appropriate to regional needs in the future. For this latter purpose irrigation is considered in the widest sense: not only as any human action which can influence the natural flow of water to or from the farmer's crop, but also as those forms of agriculture which take advantage of naturally rising or falling water levels for crop production.

1.4 The study considers the implications of past experience for African governments, financing and technical assistance agencies, and donors. It is intended particularly to assist those in FAO and in government agencies who are responsible for developing irrigation policy, and for the selection, design, execution and operation of irrigation projects. It is hoped that it may also be found illuminating by financing agencies and bi-lateral donors. The reader is warned, however, against springing too rapidly to general conclusions on the basis of the examples discussed, since each potential irrigation project site presents a unique mix of physical, economic and social circumstances. This study reviews the factors which are likely to be important in deciding whether, and in what form, irrigation development may be justified. But the decision itself must, at the end, still be made by those on the spot.

1.5 The authors <1> have drawn heavily on unpublished data and personal contacts with the national and international specialists who have been closely associated with many of the developments which are reviewed. We would like to express our gratitude to the institutions and to the many individuals who so generously contributed their experience and ideas, and to those who subsequently commented on this report in draft. It is their views which we have tried to synthesise; but if they are misquoted or misinterpreted, the fault remains ours.

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<1> The Study Team consisted of S.D. Hocombe (Team Leader), P. Kidane (Economist), and A. Jazayeri(Research Assistant). Mr. M.L. Gadelle (Consultant, Irrigation Engineer) drafted Annex 1.

# II. IRRIGATION POTENTIAL AND PRESENT STATUS OF DEVELOPMENT

## A. The Physical Setting

### Geography, Topography, Climate and Soils

2.1 Africa South of the Sahara is defined for the purposes of this study as the 40 countries listed below and shown in Map 1. Those without access to the sea are marked with an asterisk. Their population in 1982 totalled some 378 million. Individual country land areas and populations are given in Table 1.

| | | | |
|---|---|---|---|
| Angola | Ethiopia | Madagascar | Sierra Leone |
| Benin | Gabon | Malawi* | Somalia |
| Botswana* | Gambia | Mali* | Sudan |
| Burkina Faso* | Ghana | Mauritania | Swaziland* |
| Burundi* | Guinea | Mauritius | Tanzania |
| Cameroon | Guinea Bissau | Mozambique | Togo |
| Central African Republic* | Ivory Coast | Niger* | Uganda* |
| Chad* | Kenya | Nigeria | Zaire |
| Congo | Lesotho* | Rwanda* | Zambia* |
| Equatorial Guinea | Liberia | Senegal | Zimbabwe* |

The region extends from approximately $28^{o}$N to $31^{o}$S, and from $17^{o}$W of Greenwich to $51^{o}$East. It contains a huge diversity of climate, soils and topography which can only be very briefly summarised here.

2.2 The topography of much of SSA consists of undulating or gently sloping plains, at a variety of altitudes. Typically these relatively flat areas are bordered by sharply rising or falling land representing the eroded edges of ancient geological features, volcanoes or, in the case of the rift valley system of East Africa, the results of continental drift. Most of the coastline is without indentations or a broad coastal plain; there are no major coastal deltas to compare with those of the Ganges or the Mekong.

2.3 Most of Africa is geologically ancient and highly weathered, and is often based on crystalline rocks. Soils tend to be leached and deficient in major mineral nutrients, as well as lacking organic matter due to high temperatures. Often they have only limited potential for arable agriculture. There are, however, patches of more fertile alluvium along the present and past courses of major rivers, as well as inherently fertile vertisols deposited in old lake beds - the black cracking soils of the Sudan Gezira are the most extensive example of the latter. Both riverine alluvium and vertisols have attracted irrigated agriculture. Irrigators have also been drawn to peaty soils formed under swampy conditions, for instance in Madagascar. In most cases, however, potentially irrigable soils are in scattered patches rather than large blocks, and often at some distance from a potential water source.

2.4 There are huge variations in climate. Mean annual rainfall ranges from a few millimetres in the central Sahara to several metres in parts of the humid tropical zone of West Africa. Isohyets as well as annual rainfall distribution for some representative locations are shown in Map 2. Potential evapotranspiration ranges from under 1,500 mm/yr in more humid areas to 2,000 to 2,500 mm/yr in semi-arid and arid zones. Cloud cover is relatively low in much of SSA for much of the year. Most of the region has temperatures which permit year-round crop growth but at higher altitudes and in the southernmost countries there may be temperature limitations, and sometimes a frost risk. In semi-arid and arid areas high temperatures may be a limiting factor; but even in the Sahelian belt of West Africa there are seasonally lower temperatures and cloud cover which are sufficient to limit yields of rice, the most common irrigated crop.

2.5 The climate of SSA can be very broadly divided into three major zones.

i) The humid tropical zone. Mean annual rainfall exceeds 1,200 mm and is usually over 1,500 mm. Rain is fairly well distributed, seldom with more than four dry months. The growing period for annual crops usually exceeds 280 days/yr. Irrigation is seldom economically justified except for dry-season supplementation of some perennial crops.

ii) The savannah zone. Mean annual rainfall is between about 800 and 1,200 mm, distributed unimodally or bi-modally. Within-season rainfall patterns as well as seasonal totals may be erratic, with as much as a tenth of the seasonal total falling in one day; the growing period for annual crops ranges from 240 down to 120 days. Below about 200 days there are likely to be increasing risks of crop failure due to drought. Supplementary irrigation may give worthwhile benefits even in average rainy seasons, by compensating for within-season dry spells. Irrigation is essential for dry-season annual cropping and for many perennial crops.

iii) The semi-arid/Sahelian zone. Mean annual rainfall is below 800 mm and may be less than 100 mm, and is usually very erratically distributed within the rainy season. Up to 20% of annual rainfall may occur within a single day, giving very heavy runoff and a high potential for erosion. The growing season for annual crops is below 100 days in much of the zone. Irrigation is essential for arable agriculture. Low-intensity grazing is the traditionally preferred land use.

2.6 Many countries span two or all three of these climatic zones. Table 1 shows the range in length of growing period to be found within each country of the region, as defined in the FAO study of population carrying capacity for Africa. Map 3 gives a thematic presentation of estimated growing periods. It also indicates the parts of SSA in which existing population is estimated to have already exceeded the rainfed carrying capacity of the land, assuming only traditional farming systems at low input levels.

2.7 The above study shows that there are eight countries, listed below, which have little or no land with a rainfed growing period above 200 days, and which have also exceeded their population carrying capacity for low-input rainfed farming. Together they contain almost 14% of the population of SSA. For these countries irrigation is likely, for climatic and demographic reasons, to be an essential part of any overall national strategy for increased agricultural production.

| Country | Range of Growing Period (days) |
|---|---|
| Senegal | 70-180 |
| Burkina Faso | 75-230 |
| Niger | 0-120 |
| Mauritania | 0-120 |
| Somalia | 0- 65 |
| Kenya | 75-270 (a) |
| Botswana | 0-120 |
| Mali | 0-210 |

Source: FAO
(a) More than 85% of area below 200 day growing period.

2.8 Twelve countries (Mauritania, Niger, Burkina Faso, Mali, Chad, Sudan, Ethiopia, Somalia, Kenya, Tanzania, Zimbabwe and Botswana) have a rainfed growing period of less than 120 days on over a quarter of their territory. A further ten (see Map 3) have up to a quarter of their area in the same semi-arid zone. In the high-risk tracts of these countries irrigation is usually necessary for reliable arable agriculture, regardless of any justification based on national agricultural strategy.

2.9 Annual rainfall in the central semi-arid belt of Africa has gradually declined over the last twenty-five years from the averages for 1930 to 1960. It is not clear whether the change is permanent or temporary. Within the last 20,000 years, for instance, it appears that parts of the Sahel have been both much wetter and drier than they are now. However it seems prudent to assume for planning purposes that the current drying of the Sahel will not suddenly be reversed. For this reason the growing periods quoted, which are based mainly on rainfall data for 1930 to 1960, may now be shorter and needs for irrigation correspondingly greater.

## Rivers and Surface Water

2.10 In general Sub-Saharan Africa has less available surface water per unit area, higher evaporation, and (a consequence of the first two factors) less runoff into the sea per unit area than most other regions of the world. The principal river basins of SSA are shown in Map 1. One, the Nile, discharges into the Mediterranean, ten into the Indian Ocean, three into the South Atlantic and four into the North Atlantic. Two major rivers, the Niger and the Nile, pass through major inland swamps (the Niger Inland Delta, the Sudan Sudd), where they lose a considerable amount of water through evaporation. Several other basins - most notably the Lake Chad system - are fully landlocked and eventually lose all their water by evaporation or infiltration. Some details of the main river basins of SSA are shown in Table 2.

2.11 With the exception of the Congo, all the major rivers of SSA show considerable seasonal variation in flow. This is most marked where there are no natural regulators such as lakes or swamps, or in rivers draining savannah or semi-arid areas, with their possibilities of intense short-term rainfall.

2.12 Natural sediment loads in African rivers are lower than in other regions. However despite this general picture they can be locally high in the rapidly increasing areas which have lost their vegetation cover due to human activity, either from overgrazing or deforestation. Mainly for this reason many of the smaller reservoirs constructed in the region are silting up faster than expected. The Ibohamane and Moulela reservoirs on the Niger, for instance, are said to have lost half their storage capacity over the last 15 years. For Lake Kariba, however, which has over 60% dead storage, the original estimated reservoir life of 1,000 years has recently been re-estimated as 1,600 years.

2.13 It can be seen from Table 2 that surface water is very unevenly distributed. The Congo basin, which occupies some 16% of the surface of Sub-Saharan Africa has 55% of the mean annual water discharge. A further seven rivers (the Niger, Ogooué, Zambezi, Nile, Sanga, Chari-Lagone and Volta) contribute a further 25%. Only a few major rivers - most notably the Senegal, Niger and Nile - flow through the substantial drought-prone areas mentioned earlier, where there are severe climatic restrictions on rainfed agriculture.

## Groundwater

2.14 Until very recently most of the studies of groundwater potential in the region have been rather generalised or, if detailed, have covered only limited areas. They have suggested that:

- The rocks of the basement complex which underlie over a half of SSA contain only small, discontinuous aquifers. Recharge rates are usually too slow and the water is often also too deep for irrigation to be viable except perhaps for vegetables and similar high-value crops. Such sources are widely exploited, however, for livestock watering and domestic use.

- Groundwater yields in some sedimentary basins (e.g. the Chad and Senegal) are generally intermediate, although in some cases (e.g. Somalia and Sudan) the water may be over 100 m deep and hence very costly to extract for irrigation.

- Shallow reserves of groundwater are most likely to be found in quantities suitable for dry-season irrigation along the alluvial beds of some of the major rivers - for instance in Northern Nigeria and in coastal deltas and plains. It is not always clear how much exploitation these aquifers can stand. In a few places - e.g. parts of Mali - artesian groundwater is known to exist.

2.15 More intensive recent work by BRGM in association with CIRAD and GERSAR has identified zones in the Sahelian countries, comprising between 10% and 30% of their areas, which can yield shallow groundwater in volumes adequate for localised small-scale irrigation. Situated between the 200 mm and 1,000 mm isohyets, exploitation of these resources appears to be economically viable if based on dry season vegetables, supplementary watering of wet season foodgrains, and fodders. Similar conditions appear to exist in southern Sudan and in the drier parts of East Africa.

## Water Quality

2.16 Water quality is seldom a limiting factor for irrigation. Such problems as exist are localised - for instance due to salt intrusion in the tidal sections of the Senegal, Gambia and Casamance rivers and in mangrove swamps; in the drainage water from areas of high evaporation such as parts of the Chad basin and in Botswana; and in countries such as Mauritania where brackish groundwater is used for irrigation.

## Technical Potential for Irrigation

2.17 Provisional data, derived from ongoing FAO studies, suggest that about 34 million ha of SSA have soils suitable for irrigation, located in reasonable proximity to adequate surface runoff from hills and mountains or in alluvial areas with substantial groundwater recharge. Individual country figures are given in Table 3. Only six countries have 3% or more of their territory rated as potentially irrigable and 15 - over a third of the countries in the region - have less than 1%.

2.18 However, many of the high potential countries fall mainly within zones with a long growing period for rainfed crops. Future revisions of the FAO estimates are likely to eliminate such areas where, despite the existence of a technical potential, irrigation is unnecessary for climatic reasons. In contrast, the eight countries with high overall irrigation needs listed in para 2.7 have a total potential of only 1.55 million ha on the FAO definitions. The twelve countries with over a quarter of their area in zones with a rainfed growing period of less than 120 days (para 2.8) have a combined potential of about 9.1 million ha. But nearly a half of this is concentrated in only two countries - Sudan and Chad.

2.19 Comparing Sub-Saharan Africa to other regions with major irrigation developments, it can be concluded that:

- the generally flat topography of much of the west of the region offers few good dam sites, and those that do exist are often far from land suited for irrigation;

- for the same topographic reason long offtake canals may be necessary, unless pumping provides a less expensive means to supply water to irrigable land;

- soils do not often have the same irrigation potential as, for instance, in Asia;

- furthermore irrigable soils tend to occur in small, scattered patches in much of the region (the Sudan being a notable exception);

- the intense short-term rainfall which can occur in Africa means that surface drains on irrigation schemes and the spillways of dams must have large designed capacities;

- surface water resources are often mis-matched to the areas where irrigation could be of advantage;

- groundwater is probably more localised and there are fewer areas of widespread, very shallow groundwater like those which are exploited for conjunctive use in Asia.

## B. Existing Irrigation and Remaining Potential

### Irrigation Types

2.20 Very many types of irrigation are practiced in Sub-Saharan Africa and they can be classified in several different ways - for instance by size, degree of water control, level of technical sophistication, type of operator or the extent to which they involve changes from traditional forms of land occupation and use. Often one method of classification conflicts with another. For example both modern fully-controlled irrigation and traditional flood-recession irrigation can be found in very large as well as in very small blocks. For the purposes of this study, however, the size of irrigated development is taken as the main basis for classification. Three broad categories are considered.

i) Large schemes with an irrigated area of at least 500 ha and sometimes 10,000 ha or more.

ii) Medium schemes, roughly in the range 50 to 500 ha.

iii) Small-scale developments, comprising:

- village-level schemes, usually of 10 to 50 ha although sometimes a little larger;
- individual or family-operated developments of less than 10 ha, and usually in the range 0.5 to 5 ha.

### Large Schemes (over 500 ha)

2.21 The most important large and very large schemes are listed for eleven of the main irrigating countries (Burkina Faso, Ethiopia, Ghana, Kenya, Mali, Mauritania, Madagascar, Niger, Nigeria, Senegal, Somalia, Sudan and Tanzania) in Tables 4 to 16. Such schemes are usually constructed with government funding or have in some cases been acquired by nationalisation. They may be under direct state management or allocated by an irrigation authority to small-scale tenant farmers. A few, especially sugar estates, are under turnkey expatriate management or owned by the private sector. The largest developments are in Sudan (the Gezira Project and its extensions, Rahad, Kenana and New Halfa). Other countries with large schemes are Mali (Office du Niger and Operation Riz Mopti), Senegal (e.g. Boundoum and Dagana), Cameroon (the SEMRY rice projects), Nigeria (various River Basin Development Authority schemes), Ethiopia (Tendaho and others), Kenya (Mwea, Bura), Tanzania (Mbarali, Arusha Chini), and Zimbabwe and Swaziland (various commercial and sugar estates). Most are surface irrigation schemes based on gravity flow diversions or pumping. A few have areas of sprinkler irrigation. Although most are modern schemes with full water control, a few (e.g. Riz Mopti) rely on partial control of natural flooding.

Medium Schemes (50 to about 500 ha)

2.22 Medium-scale schemes are more diverse: they may be established and operated by government agencies, by government-assisted cooperatives or as private commercial estates. Examples are in Niger (various pumping schemes of ONAHA), Senegal (SAED), the Gambia, Tanzania (Kyaka using overhead irrigation), Ghana (Asutsuare), Mauritania (M'Boughé pumping), Burkina Faso (Karfiguéla, gravity), some private schemes in Madagascar, and pump schemes along the Nile in northern Sudan.

Small-scale Developments (below 50 ha)

2.23 This very diverse group includes the following.

- Irrigation based on use of receding or advancing floods in river flood plains, inland valleys, lake shores and coastal swamps; although the area planted by each individual or group may be small, aggregate areas under such largely traditional systems are very substantial.

- Small earth dams using gravity-flow distribution, or sometimes pumping or manual methods to apply the water.

- Small run-of-the-river diversions.

- Small-scale developments from wells or open water using manual labour, animal power or motorised pumps to lift the water.

- Water harvesting or spreading, usually by simple bunding, in areas where seasonal spates or flash floods discharge onto flatter land.

2.24 Frequently these small-scale developments have only partial water control and a lot of those which rely on natural flooding can be cropped fully only in favourable years. Many of the systems have been constructed and are operated using traditional methods and with local materials, by private individuals with little or no government support. Works may be temporary or rebuilt annually. About a half of the irrigated area of SSA consists of such small-scale developments by traditional irrigators. The various systems have been well described by Underhill (FAO, 1984) from whom the next paragraphs are derived. More details of the more common systems of Francophone West Africa are given in Annex 1.

2.25 Coastal swamps and estuaries are used for rice production along the West African coast from the Gambia River to Liberia, and to a lesser extent further east. Production is most commonly in the hands of smallholders using traditional methods, who make a substantial contribution to national rice production in the Gambia, Senegal, Guinea, Guinea Bissau and Sierra Leone. Dykes, canals or gates may be used to exclude seawater and maximise the retention of fresh water.

2.26 Inland swamps and flood plains are also widely used for small-scale irrigation, with partial water control. The oldest production technique in Mali is the flooded system in the Inland Delta of the Niger and Bani Rivers around the city of Mopti, along the flood plains of the Niger toward Ségou and of the Bani towards San; traditional flooded rice is grown in this region in holdings of about 1.5 ha, over a total area of 80,000 ha. The only water control is the construction of earth dykes to prevent too rapid entry of water onto fields of immature plants. In the more deeply flooded fields, floating rice varieties are grown and may be harvested from boats. More details of such systems are given in Annex 1.

2.27 The Sierra Leone bolilands are low, saucer-shaped swamp grasslands associated with the Rokel River and its tributaries. It is estimated that 30,000 ha of bolilands are suitable for rice cultivation, and about 60% of this area is cultivated. Heavily subsidised mechanization has been introduced in this area but cropping is still in the hands of small farmers. Similar areas of rice production are common in Guinea, Burkina Faso, Ivory Coast and Ghana.

2.28 In Tanzania, swamp rice is grown by traditional cultivators south of Lake Victoria, on the northern shores of Lake Malawi and in the Pangani, Ruvu and Rufiji basins. In Kenya too, individual cultivators grow rice and sugar on the banks of the Tana River, on the shores of Lake Victoria and in the swamps near Mumias in Western Province. In these areas rice is planted on the banks as the annual floods subside, and the water is retained to a certain extent by bunds. In Zimbabwe, some 70 non-formal irrigation schemes from 10 ha upwards and totalling 4,500 ha have been implemented for subsistence farmers. It has been estimated that the country has three million hectares of marginal and wet lowlands where small-scale irrigation could be developed if appropriate water conservation measures were practiced.

2.29 Likewise small streams have been developed for local irrigation by peasant farmers throughout the continent. In the Ivory Coast nearly 19,000 ha of valley bottom lands are irrigated by diversion of water from small streams, in some cases with the construction of small dams. These developments are mostly of only 10 to 15 ha each and, except for the dams, are relatively inexpensive, rely heavily on farmer participation, and are widely dispersed. The construction of small dams is fairly expensive but can be justified if groups of families are prepared to cooperate in cropping several hectares under irrigation, and provided that a suitable dam site can be found. Furrow irrigation from rivers has long been practiced by the Wa-Chagga on the slopes of Mount Kilimanjaro. Cases are also found in Kenya, Zambia and elsewhere.

2.30 An alternative method of exploiting seasonal river flow is by pumping either by hand, usually using the traditional shaduf, or mechanically. Shaduf irrigation from surface water sources is still common in many parts of Africa and has the advantage of depending on local materials and labour only. Small mechanical pumps are now, however, becoming very common, purchased by the farmers on their own initiative or through government-aided schemes. Shallow groundwater is also exploited in many areas for small garden irrigation. Examples can be found in Burkina Faso, Niger, Benin, Togo, Zimbabwe, Botswana and other countries.

2.31 Small-scale irrigation of the sort described above generally arises spontaneously as part of the process of intensification of traditional agriculture in response to rising population pressure. For small-scale vegetable production, in particular, it may also be a response to market access or opportunities, provided inputs and equipment are also available. This is a phenomenon documented by Boserup, Binswanger and others. While such changes occurred, with government encouragement, in many Asian countries in the 1950s and 1960s, only now are land pressures becoming sufficient to induce the same developments in much of Africa. However it is noticeable that in Africa not all opportunities for small-scale irrigation are exploited. One ethnic group may plant crops on the receding flood while another prefers to use similar land to provide natural dry-season grazing for livestock. In addition to population pressure, tradition also appears to be involved. This influence can be seen most clearly in Madagascar. Due to the Asian origins of much of the population rice cultivation is a central feature of the national culture. The 800,000 ha of rice grown by small-scale methods in Madagascar represent one third of the total area of traditional irrigation in SSA.

2.32 Small-scale traditional irrigation is usually only a part of the farmer's agricultural enterprise, being integrated with rainfed cultivation and/or livestock rearing. In the case of swamp rice, in particular, it may be the special responsibility of women. Except for commercial vegetable growers, traditional irrigators tend to minimise capital and input costs and attempt to maximise returns on labour. Some typical cropping systems of small-scale irrigators are summarised below.

Main Cropping Systems of Traditional Irrigators

| | |
|---|---|
| Wet Season | |
| River valleys, receding flood | Sorghum, millets, wheat, maize, grain legumes, some vegetables |
| River valleys, advancing flood | Rice |
| Inland and coastal swamps, flooded depressions | Rice |
| Surface diversions, small dams and wells | Cereals, grain legumes, vegetables |
| Dry Season | |
| Inland and coastal swamps, flooded depressions | Vegetables or staple foodcrops on residual moisture |
| Surface diversions, small dams and wells | Vegetables (occasionally emergency staple foods) |

## Areas Irrigated and Remaining Potential

2.33 Estimates of irrigated areas for 1965, 1974 and 1982 are given for each country in Table 3. Tables 4 to 16 give some indication of the breakdown of areas between major and smaller-scale or traditional developments for Burkina Faso, Ethiopia, Ghana, Kenya, Madagascar, Mali, Mauritania, Niger, Nigeria, Senegal, Somalia, Sudan and Tanzania. Table 17 gives a briefer summary of the composition of 1982 estimates for all countries. In addition Table 3 estimates the percentage of total cropped area which benefitted from irrigation in each country in 1982, and the number of people per hectare of irrigated land.

2.34 The 1965 and 1974 figures are, except for Nigeria and Madagascar, taken directly from Rydzewsky, whereas the 1982 figures are the study team's best estimates compiled from a wide variety of sources, including many unpublished reports and personal communications. Written sources are listed in Annex 3 (bibliography), and a full listing is given in abbreviated form in footnotes to Table 17.

2.35 The quality of data reviewed was extremely variable and estimates for some countries were reached only by personal judgement after comparing irreconcilably conflicting sources. A major problem is the definition of irrigation. Rydzewsky used a fairly comprehensive definition including a probably large proportion of traditional flood and recession irrigation. Nevertheless the apparently dramatic increases in irrigated areas for some of the wetter countries between 1974 and 1982 (e.g. Burundi and Zaire) probably result from the inclusion in the 1982 figures of areas of flood irrigation which were not included by Rydzewsky. Other sources (e.g. the World Bank for Ghana) have tended to limit themselves largely to modern fully-controlled irrigation. Even in this case there is a tendency for government statistics to include areas still under construction, or even (e.g. Nigeria) at the planning stage, rather than those capable of production. It is doubtful whether areas of modern irrigation abandoned due to salinity, dilapidation or social problems are systematically removed from statistics, although in Burkina Faso and Niger, for instance, it is alleged that the rate of new construction is close to the rate at which older areas are being abandoned.

2.36 Further difficulties arise due to confusion between irrigable, annually planted or annually harvested areas. This study has attempted to estimate areas available for planting - either on modern schemes at their 1982 stages of construction or, for naturally flooding systems, in years of average flood. Yield estimates attempt to discount the effects of areas which are prepared or planted, but lost before harvest. FAO country statistics, however, start from the opposite position: areas under irrigation are inferred from statistics on the annual harvested areas of irrigated crops. For these reasons the 1982 figures in this report should not be held as definitive nor as official FAO estimates. They are neither.

2.37 The table on page 14 shows 1982 estimated irrigated areas divided between modern systems with substantial or full water control, and small-scale irrigation plus traditional systems with only partial or no water control. The totals are then expressed as a percentage of irrigation potential as given in Table 3.

2.38 It is estimated that the total irrigated area in the region in 1982 was about five million ha, composed as follows:

| | | Million ha |
|---|---|---|
| Modern Irrigation: | | |
| - Very large schemes | (over 10,000 ha) | 1.74 |
| - Large and medium schemes | (500 to 10,000 ha) | 0.90 |
| Sub-total | | 2.64 |
| Small-scale and traditional irrigation, including uncontrolled flooding | | 2.38 |
| Total, Sub-Saharan Africa | | 5.02 |

2.39 Division of these areas between different types of operators is hard to estimate but appears to be approximately as shown below.

| | | Million ha |
|---|---|---|
| Modern schemes over 500 ha | | |
| Government-controlled | - allocated to settlers or small farmers | 1.60 |
| | - estate operation | 0.54 |
| Private sector, estates or individuals | | 0.50 |
| Sub-total | | 2.64 |
| Small-scale and traditional irrigation | | |
| Modern/intensive private operators | | 0.20 |
| Traditional private operators | | 2.18 |
| Sub-total | | 2.38 |
| Total, Sub-Saharan Africa | | 5.02 |

2.40 The countries with the largest irrigated areas are Sudan with 1.75 million ha, Madagascar (960,000 ha) and Nigeria (850,000 ha). Only four other countries (Senegal, Mali, Tanzania and Zimbabwe) are estimated to have over 100,000 ha under irrigation. In Sudan over 95% of irrigation consists of large government projects and this country has over 65% of the total of modern irrigation for the region. The residue of just under 0.9 million hectares of modern irrigation is divided between 31 other countries, only nine of which (Ethiopia, Ivory Coast, Madagascar, Mali, Mozambique, Nigeria, Somalia, Swaziland and Zimbabwe) can claim more than 40,000 ha. In the other two major irrigating countries small-scale and traditional flood irrigation are predominant, making up 83% (800,000 ha) of the total in Madagascar and 94% (800,000 ha) in Nigeria. Other countries with over 40,000 ha of small-scale or traditional irrigation include Burundi, Chad, Sierra Leone, Mali, Senegal, Somalia and Tanzania.

Sub-Saharan Africa: Estimates of Irrigated Areas, 1982, in Relation to Irrigation Potential

| Country | Irrigation Potential ('000 ha) | Area Developed 1982 ('000 ha) Modern | Small-scale or Traditional | Total | Developed as % of Potential |
|---|---|---|---|---|---|
| Angola | 6,700 | 0 | 10 | 10 | < 1 |
| Benin | 86 | 7 | 15 | 22 | 26 |
| Botswana | 100 | 0 | 12 | 12 | 12 |
| Burkina Faso | 350 | 9 | 20 | 29 | 8 |
| Burundi | 52 | 2 | 50 | 52 | 100 |
| Cameroon | 240 | 11 | 9 | 20 | 8 |
| Central African Republic | 1,900 | 0 | 4 | 4 | < 1 |
| Chad | 1,200 | 10 | 40 | 50 | 4 |
| Congo | 340 | 3 | 5 | 8 | 2 |
| Equatorial Guinea | n.a. | n.a. | n.a. | n.a. | n.a. |
| Ethiopia | 670 | 82 | 5 | 87 | 13 |
| Gabon | 440 | 0 | 1 | 1 | < 1 |
| Gambia | 72 | 6 | 20 | 26 | 36 |
| Ghana | 120 | 5 | 5 | 10 | 8 |
| Guinea | 150 | 15 | 30 | 45 | 30 |
| Guinea Bissau | 70 | n.a. | n.a. | n.a. | n.a. |
| Ivory Coast | 130 | 42 | 10 | 52 | 40 |
| Kenya | 350 | 21 | 28 | 49 | 14 |
| Lesotho | 8 | 0 | 1 | 1 | 13 |
| Liberia | n.a. | 3 | 16 | 19 | n.a. |
| Madagascar | 1,200 | 160 | 800 | 960 | 80 |
| Malawi | 290 | 16 | 4 | 20 | 7 |
| Mali | 340 | 100 | 60 | 160 | 47 |
| Mauritania | 39 | 3 | 20 | 23 | 59 |
| Mauritius | n.a. | 9 | 5 | 14 | n.a. |
| Mozambique | 2,400 | 66 | 4 | 70 | 3 |
| Niger | 100 | 10 | 20 | 30 | 30 |
| Nigeria | 2,000 | 50 | 800 | 850 | 43 |
| Rwanda | 44 | 0 | 15 | 15 | 34 |
| Senegal | 180 | 30 | 70 | 100 | 56 |
| Sierra Leone | 100 | 5 | 50 | 55 | 55 |
| Somalia | 87 | 40 | 40 | 80 | 92 |
| Sudan | 3,300 | 1,700 | 50 | 1,750 | 53 |
| Swaziland | 7 | 55 | 5 | 60 | >100 |
| Tanzania | 2,300 | 25 | 115 | 140 | 6 |
| Togo | 86 | 3 | 10 | 13 | 15 |
| Uganda | 410 | 9 | 3 | 12 | 3 |
| Zaire | 4,000 | 4 | 20 | 24 | 1 |
| Zambia | 3,500 | 10 | 6 | 16 | < 1 |
| Zimbabwe | 280 | 127 | 3 | 130 | 46 |
| Total | 33,641 | 2,638 | 2,381 | 5,019 | 14.9 |

Sources: Study team estimates of areas developed; irrigation potentials from FAO Land and Water Division, 1985 (provisional estimates).

2.41 Irrigation represents only about 3.5% of total cropped area. However, as Table 3 shows, there are large variations between countries. The countries in which irrigation is most widespread are Madagascar (32% of total cropped area), and Swaziland (44%). Over 10% of cropped land is irrigated in Sudan, the Gambia, Mauritania and Mauritius.

2.42 The total irrigated area in SSA grew by an average of 148,000 ha/yr between 1965 and 1974 and by about 157,000 ha/yr between 1974 and 1982. Despite the rise in absolulte terms the figures represent a decline in the annual rate of growth, from 5%/yr before 1974 to a little under 3.7%/yr subsequently. Exceptions to the decline in percentage terms were Burkina Faso, Chad, Madagascar, Mozambique, Niger, Nigeria, Senegal, Somalia, and Tanzania. In a few countries, notably Sudan, irrigated areas appear to have declined, due to a combination of technical factors such as salinisation and various institutional and financial problems. Within the region, the eight countries with little further potential for rainfed expansion (Senegal, Burkina Faso, Niger, Mauritania, Somalia, Kenya, Botswana and Mali - see para 2.7) showed a growth rate of about 5.2%/yr (an average of 20,000 ha of new irrigation annually) between 1974 and 1982. For the remaining countries the figure was about 3.5% (an average of 137,000 ha) per year.

2.43 Due to recent budgetary limitations it seems doubtful whether rates of expansion, at least of publicly-financed irrigation, have been maintained since 1982. Although several governments have proposals for major new dams which could substantially increase irrigated areas most plans are at present shelved for lack of funds. Among the few major on-going works for which firm completion targets still exist are the Diama and Manantali dams on the Senegal River.

2.44 The estimated 1982 regional population of 378 million is equivalent to an average of about 75 people per hectare of irrigated land. This compares to 11 to 12 people per irrigated hectare in India <1> . From Table 3 it can be seen that Madagascar, Sudan and Swaziland also have ten to twelve people per irrigated hectare. But among the remainder of African countries none has less than 20, and only the Gambia, Mali, Senegal, Sierra Leone, Somalia and Zimbabwe have under 65 persons per irrigated hectare.

2.45 The irrigated area so far developed in SSA represents only about 15% of the area potential provisionally estimated by FAO, although for the eight countries with little further rainfed potential the figure already averages about 40%. However about a half of what currently exists is traditionally irrigated at far below its technical potential, and much of the modern sector also operates at low irrigation efficiency. Nevertheless the major irrigating countries, Sudan and Madagascar, appear to have developed over half their area potential and Somalia and some of the Sahelian countries are in the same category.

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<1> This comparison assumes an Indian population of 700 million and a total irrigated area of 60 million hectares. However it does not take into account cropping intensity on existing irrigation schemes nor productivity per unit of irrigated land, which are both likely to be greater in India than in Sub-Saharan Africa.

2.46 Major unused reserves remain in Zaire, Zambia, Tanzania, Mozambique, Sudan, Nigeria and Chad, each with over one million hectares. Burkina Faso, Kenya, Ethiopia, Madagascar and Malawi also have sizeable unexploited irrigation potential. However in practice it is necessary to exclude from this potential the wetter areas where irrigation is unlikely to be necessary, (e.g. Zaire), and to separate the more from the less economically attractive possibilities. Furthermore the effects of competing interests must be borne in mind. For instance further development in Sudan would be to the detriment of Egypt, which already uses all the Nile water which it receives. Development of much of the limited remaining potential of Somalia would only be possible by construction of dams in Ethiopia, and further irrigation on the Zambezi below the Kariba dam would depend on overcoming the present reluctance of the hydropower authorities to release water in schedules appropriate for irrigation.

## Numbers and Types of Irrigator

### Small-scale and Traditional Irrigators

2.47 Although small-scale, largely traditional, irrigators operate about half the irrigated area in the region it is difficult to estimate their number. If it is assumed that on average each cultivates around one hectare, then there are probably up to 2.5 million families (or family sub-units) involved part or full-time in small-scale or traditional irrigation, representing a total of perhaps 15 million people.

### Small-Scale Irrigators On Public Projects

2.48 Small-scale irrigators on public schemes operate about 1.6 million ha, equivalent to about 60% of modern irrigation and 33% of the total irrigated area in SSA. Assuming an average farm size of approximately two hectares, they number around 800,000 families, or some five million people.

2.49 Many are in fact quite recent recruits from traditional irrigation. Settlers on most of the public perimeters in Senegal, Mali, Niger and Nigeria on the Senegal and Niger Rivers come into this category. In Kenya, in contrast, Mwea and the other early public irrigation projects were settled by landless people without irrigation experience. New Halfa and most other major projects in Sudan were settled largely by pastoral nomads who previously grazed their stock on the project areas. The Gambia rice development schemes have involved a change from low-input, subsistence rice cultivation by the women of the family to its intensive commercial cultivation by the men. On the Sudan Gezira Project, in contrast, farms may be occupied by the descendants of the original tenants who were recruited in the 1920s when the project began, so that the family may have several generations of experience. Increasingly in the Sudan, however, the cultivator may be a short-term sharecropper brought in by the tenant on public schemes, or by the owner of privately-irrigated land. A final category of small-scale irrigator on government land is the outgrower linked to a nucleus estate and processing unit, generally for sugar but sometimes growing cotton, fruit or vegetables.

Public Sector Estates

2.50 Large-scale estate or state farming operations sponsored by governments total about 0.54 million hectares, or 20% of modern irrigation in SSA. Most estates grow sugar but some produce cotton, cereals, other food staples or vegetables. They are run either directly by parastatals, by imported management teams, as joint local/foreign ventures or under foreign turnkey contracts. Examples are found in Swaziland, Malawi, Zambia, Ethiopia, Sudan, Ivory Coast and various other West African countries.

Modern Irrigators in the Private Sector

2.51 The total area of modern irrigation under private operation, including both estate and small-scale installations, probably amounts to some 0.7 million ha. A wide range of crops is involved. There are many quite small private perimeters with a substantial degree of water control on the Senegal river and on the smaller still un-nationalised Nile Pump Schemes in northern Sudan. They may be operated by one owner, a community, a group of tenants or sharecroppers and often produce coarse grains or rice. Individual small-scale irrigation using motorised pumps has recently expanded rapidly for vegetable production in Northern Nigeria, developing out of an existing traditional system. Typical larger-scale private operations include:

- individual farmers in East and Southern Africa growing wheat, maize, tobacco, grain legumes, or supplementing natural rainfall for coffee or tea, using sprinkler irrigation from a farm dam or local stream;

- specialised fruit and vegetable growing companies who process their product or specialise in off-season exports to northern countries;

- private meat and dairy operations based on irrigated cereal feeds or fodders;

- private companies growing industrial crops such as sugar cane or cotton.

Many of these larger-scale operations have some foreign management or ownership. There also appears to be increasing interest among local entrepreneurs in some West African countries in establishing modern irrigated farms on land soon expected to be brought under command of major dams such as Diama and Manantali.

## Operating Efficiency and State of Maintenance

2.52 Modern fully-controlled schemes have generally been designed with conventional targets for overall efficiency, usually 40 to 60% for surface irrigation and up to 80% for sprinkler systems. Most schemes are the initial parts of longer-term plans to develop a water resource, hence have had excess water reserves to draw on and have not been under great pressure to optimise irrigation efficiency. Partly due to this, but also as a consequence of poor operation and maintenance of many government projects, actual irrigation efficiencies have tended to be low - usually only 20 to 30% overall for surface distribution schemes, although few precise measurements have yet been made. Studies to relate crop output to the quantity of water applied are now in progress on the Sudan Gezira project, and have been proposed for Zimbabwe, but no published data could be found on the subject for African irrigation schemes.

2.53 The efficiency of much traditional irrigation is hard, if not impossible to quantify. Many structures are temporary and built at minimal cost. Hence water losses are likely to he high. Only in the case of manual or pump lift systems is there a direct incentive for the irrigator to economise on water use.

## Land Allocation for Irrigation

2.54 Much land for traditional uncontrolled flood irrigation is still allocated on a seasonal basis by community leaders according to ancient custom. Land access for fixed, more intensive forms of irrigation, especially for vegetable production, has however been subject to the same trends which have affected land access for the rainfed cultivator. Due to population pressure and commercialisation of agriculture individuals have increasingly attempted to claim long-term rights of occupation or personal ownership. In northern Nigeria, for example, arrangements for vegetable production on fadama land are very complex; one person may own the land, another the growing crop, a third is a specialist brought in to raise the crop while a fourth - who finances the whole operation - will have purchased the produce in advance.

2.55 Land for government reservoirs or irrigation projects must either be purchased or, if it is already nominally state property, the occupants and users must usually be compensated for past improvements and lack of future access. As will be seen, land acquisition for government schemes can be a major problem and in many cases land transfer has not been regularised.

## Contribution of Irrigation to Staple Food Supply

2.56 Rice is the main foodcrop produced under irrigation in SSA. To this must be added lesser amounts of coarse grains and some root crops grown mainly under traditional forms of flood irrigation, and some vegetables which may be important for their dietary contribution though not in calorie terms. Less significant are sugar, grain legumes and small amounts of wheat. Taking account of the total areas of cotton, other non-food crops, sugar cane and miscellaneous non-cereal crops, it is estimated that cereals occupy only about 50% of irrigated land. Estimates of typical yields under the main cereal production systems are given below. As indicated earlier, they are expressed per hectare of irrigable land, and include allowances for areas which for one reason or another fail to reach harvest.

| Irrigation Type | Paddy | Coarse Grains |
|---|---|---|
| | ......Yield, | t/ha...... |
| Traditional | | |
| - receding flood | 0.2-1.2 | 0.5-1.5 |
| - rising flood, swamps etc. | 0.8-2.0 | - |
| Modern | | |
| - partial water control | 1.5-2.5 | 1.0-2.0 |
| - full water control | 2.0-5.0 | 2.0-4.0 |

2.57 The total contribution of all the above forms of irrigation to food supply in Sub-Saharan Africa is, however, relatively small. Figures from FAO in Table 18 show that in 1982 irrigation contributed about 3.8 million tons to the regional rice output of 6.45 million tons. Irrigated rice represents only some 7% of total grain demand. Coarse grains, mainly grown under relatively low-yielding traditional irrigation, may have added a further 1.5 million tons, which would make an aggregate contribution to cereal supply from irrigation equal to about 10% of grain consumption, or 12.3% of local production. This does not differ appreciably from FAO's estimate of the contribution of irrigation to regional cereal production for 1975/1976, which was 12.4%. At that time it was estimated that irrigation also contributed 6.0% of root production (5.8% from naturally-flooded areas) and 12.8% of vegetables (7.5% from fully-controlled irrigation).

2.58 Published sources do not indicate the calorie contribution of irrigated crops to regional food supply.

## III. GOVERNMENT APPROACHES TO IRRIGATION

### Rationale for Government Involvement

3.1 Government support for irrigation has been of two main types:

- investment in major modern irrigation schemes;

- promotion of smaller-scale irrigation, often as a component of rural development projects with multiple aims.

3.2 In terms of areas developed and resources committed, major irrigation schemes have been the most important. The rationale for these investments has typically been as follows.

- In response to a combination of rapid population growth and a sluggish or static performance by the agricultural sector, per caput food supply is found to be falling and/or food imports rising.

- Large reserves of potentially irrigable land are shown to exist within the country.

- Relieved of the rainfall risks, it is known that very high yields of foodcrops (or export crops with a foreign exchange earning capacity) are possible.

- Irrigation is therefore seen as a tempting solution to the national problem of food self-sufficiency (or as a path to greater earnings of foreign exchange with which to finance food imports).

- But to have the necessary impact and to obtain economies of scale, a substantial area usually needs to be developed for irrigation, and it must be cropped intensively.

- Furthermore the benefits of such an expansion of modern, irrigated agriculture should as far as possible reach the poorer sectors of society, and especially any people who have been disposessed of their land by the project; hence the newly-irrigated land should be allocated in small plots to the rural poor;

- By creating employment in rural areas, urban drift may at the same time be discouraged.

3.3 The places available for new, large schemes are often isolated, devoid of social infrastructure, and lack agricultural support services and marketing channels. The intended beneficiaries often do not know how to irrigate in an intensive, modern way, if at all. And the private sector usually has alternative priorities and cannot or will not put up the money for this sort of development on such a scale. In order to initiate the necessary economic and social development the government therefore acquires the project land, and takes the leading role in all aspects of scheme planning, construction and operation, as well as providing production and social support services and inputs, and marketing the project output.

3.4 Governments have usually adopted a different approach in the case of irrigation components of rural development projects. The stress has usually also been on the introduction of modern, technically advanced, methods, but state involvement has more often been limited to providing the existing population of an area with credit and technical advice. Alternatively governments have constructed works for drought relief. But operation of these installations and choice of crops in irrigation components of rural development projects has usually been left to the beneficiaries themselves. Land has seldom been redistributed by the state.

## Institutional and Financing Arrangements

3.5 Five of the major river basins of Africa (the Nile, Niger, Zaire, Zambezi and Lake Chad) are shared by six or more countries and few are confined to only one. Most basins have potential to supply hydroelectric, urban and industrial water as well as irrigation. Inter-governmental commissions or planning agencies have been created for many of the major basins - e.g. the Nile, Senegal, Niger, Gambia, Chad and Kagera - to integrate and coordinate development. Responsibilities have sometimes been modelled on river basin development authorities of France or the USA, but range from largely advisory functions, through development of masterplans for hydro-power, water and land allocation, to the construction of dams, generating stations and irrigation works.

3.6 At national level the form of the state institutions given responsibility for irrigation has tended to evolve over the years, as the scale of government irrigation targets and the area actually in operation has expanded. There is often also a division depending on the type of development. Major modern schemes tend to be in the hands of specialised irrigation agencies. Irrigation components of rural development projects are more often handled by ministries of agriculture or rural development with general responsibilities for agriculture. Several countries - for instance Ethiopia, Mali, Niger, Sierra Leone, Kenya and Zimbabwe - now have special government services to support small-scale irrigation and drainage development.

### Planning

3.7 National planning of irrigation has at its simplest been done by technicians from the ministries of agriculture, sometimes in a separate irrigation department. Alternatively it may be the responsibility of a ministry of water (and other natural) resources. However once there is a substantial commitment to irrigation a separate irrigation ministry, or one or several river development boards may be established. In the latter case responsibility for the setting of irrigation targets and planning has often been integrated with responsibility for project execution.

### Financing

3.8 Few governments have been able or willing to finance major irrigation projects entirely with their own resources. Almost all large projects therefore have some form of external capital funding. Sources for some major projects are listed in the country tables in Tables 4 to 14. The World Bank, the African Development Bank and EEC have been important multi-lateral lenders for irrigation in SSA, followed more recently by IFAD and Arab funding agencies. Bi-lateral loans have been received over the last 25 years from France (CCCE) and the United Kingdom (including CDC). For sugar projects, especially, there has also been private-sector participation, usually mobilised through an external partner who has taken responsibility for the project as a turnkey operation.

3.9 There do not appear to be any comprehensive estimates of the resources committed by African governments to irrigation. However irrigation is likely to have played a significant part in the roughly seven-fold increase in public debt - from US$11.1 billion to US$79.8 billion - recorded by the World Bank for Sub-Saharan Africa between 1972 and 1983.

3.10 Grant financing, usually for technical assistance but sometimes also for construction of works and other capital items, has been received by irrigation projects from a wide variety of sources - e.g. UNDP/FAO and the bi-lateral assistance programmes of such countries as France, the United Kingdom, Holland, Belgium, Italy, Germany, Sweden, the USA, Canada, China and the USSR. More recently contributions have been made by Middle Eastern, other Asian, and Latin American countries.

## Construction

3.11 Financing agencies have generally insisted that government project executing units employ external consultants for surveys, designs and sometimes also for supervision of construction of major irrigation projects, and that only internationally qualified and recruited contractors should build major works. Where local contractors exist (e.g. in Sudan and Madagascar) they have been encouraged by the offering of smaller contracts and have sometimes been given more favourable terms on which to compete for bids. Construction on force account has only been accepted for small and/or scattered items. In this case work may be undertaken by the irrigation project entity itself, or by another government agency such as génie rural or a ministry for public works. Force account construction has been more common for works which have been executed without external funding - for instance by the Nigerian river basin development authorities. Participation of potential beneficiaries in construction, sometimes linked with food-for-work programmes, has been strongly encouraged for smaller works and on-farm development, especially in the irrigation components of rural development projects. People's participation has been less, and often negligible, in major modern schemes.

## Operation and Maintenance of Works

3.12 Operation and maintenance (O & M) of main irrigation and drainage works on large government schemes is almost always a continuing responsibility of the executing institution. Typically there is a government-funded unit with its own pool of maintenance equipment, vehicles, workshops and staff. They operate and maintain pumps, intakes, main canals and drains so as to issue water according to schedules previously notified to or agreed with farmers. Maintenance of minor channels may initially be undertaken by the state but irrigators have generally been encouraged to take over. The aim in the case of irrigation components of rural development projects has usually been to transfer the maximum of, if not all, O & M responsibility to the community or individual beneficiaries.

## Production Support Services and Marketing

3.13 Since credit, machinery services and input supplies are seldom already available at the site of a major new project on the scale demanded by irrigated agriculture, the project may reinforce the local state agencies (banks, tractor or trading corporations, cooperatives) which are intended under government policies to provide these services. More often, however, for major schemes the irrigation project authority itself takes over, and has also often become the marketing and crop processing agent of central government. Production credit, whether distributed to irrigators in cash or kind, is usually recovered by deduction from crop sales. Rural development projects, by contrast, normally contain separate production support and marketing components intended to serve all types of farmer.

3.14 Governments are almost always responsible, as well, for irrigator training, extension and applied agricultural research on major projects. Where irrigation is new or limited, these functions may remain with the agencies with general agricultural responsibility in the area such as the extension and research services of the ministry of agriculture, or they may be the function of a multi-purpose regional development agency. However once a specific irrigation project authority exists it is usually structured so as to take over these services itself.

## Cost Recovery

3.15 Few African governments make direct water charges. Most instead aim to recover the costs of scheme operation and maintenance from irrigators indirectly by deduction from the value of crop sales along with credit recoveries and other charges. As will be seen later, both the initial allocation of government funds for scheme operation and maintenance and their recovery has in practice been a major source of difficulty. The project authority is normally responsible for collection.

## Land Tenure

3.16 Once developed for a major irrigation scheme, land is often re-allocated to the existing occupants or users of the area, although for underpopulated sites (e.g. on the lower Tana River in Kenya), settlers may be brought in from elsewhere. In most cases farms are of a size (0.5 to 5 ha depending on whether manual labour, animals or tractors are intended to be used for land preparation) which is expected to absorb the whole productive capacity of the individual family. Plots are almost always leasehold, with tenancy conditions which specify intensive production of the crops given government priority. Leases typically allow the project authority to determine the cropping pattern, timing of operations and all cultural practices. The tenant's contribution is likely to include the sowing/transplanting of crops, weeding, irrigation and application of fertilizers and other inputs, according to a defined schedule, plus the harvest and preparation of the crop for transport. At harvest the tenant is frequently obliged to sell his crop to a specified government agency, which decides the price. The tenant may also be required to maintain field irrigation and drainage channels or provide the project authority with labour for the purpose. Penalties for failure to comply with these conditions include fines or, for repeated or serious offenders, expulsion from the plot.

## Social Infrastructure and Settlement

3.17 To develop the often distant sites of major public irrigation schemes governments have had to provide or improve access, set up education and health services, and often install a public water supply. In addition settlers have frequently been provided with houses or housing materials. The basic urban infrastructure needed to receive settlers, project staff and others attracted by work or business opportunities has also been constructed by governments. The original plan for the Bura Project in Kenya, for instance, assumed the establishment of a new town with 65,000 inhabitants, associated with 6,700 ha of irrigation. Staff housing and some social facilities are usually also necessary to encourage local government project teams, and especially expatriate staff, to reside in the area.

## Comments on Government Approaches to Irrigation

3.18 By choosing in most cases to put their major emphasis on large-scale modern schemes, and then settling the irrigated land with peasant farmers, governments have sought to combine economic growth with social equity. There have been important consequences for both governments and farmers.

> Governments have had to mobilise substantial resources to finance project construction. To allow inexperienced irrigators to achieve the levels of output needed to pay for these investments they have furthermore had to establish and operate extensive and costly support services. In so doing they have become involved in commercial activities - input supply and sales, tractor hire services, crop marketing, rice milling etc. - which are often difficult to run efficiently. To distribute project output in the manner intended and to recover operating costs they have had to control marketing. And to maintain farmer discipline in production and disposal of output they have had to make the continuing occupation of the farmer's plot conditional on him doing what is demanded by government priorities.
>
> Farmers have had to abandon the traditional African risk-spreading strategy of a mix of agricultural activities, in favour of full-time work on the irrigated plot provided by the government. On this plot they have had to adopt a system of production which demands more time and cash than they have been accustomed to commit to traditional agriculture, and new skills. They have had to become dependent on advice, services, and unfamiliar inputs provided by officials. They have had to grow the crops which the government wanted at the times specified, sell their output to the government, and accept the levels of cost recovery which the government demands. They have had to accept that if they fail to perform as their tenancy agreement stipulates they may lose their land, and also, on many schemes, that at the end of their working lives their plots will revert to the state rather than pass to their heirs.

3.19 The choice of intensive modern irrigation has therefore created a series of potential conflicts of interest between irrigation agencies and irrigators, which by inference from Asian experience in the 1950s and 1960s require considerable periods of social adjustment, institutional development and learning by government staff and farmers, before they are resolved. The next chapter examines the degree to which African governments have succeeded in resolving such conflicts in their projects, through a review of a series of externally-funded irrigation schemes.

3.20 Government approaches to smaller-scale irrigation development, as in rural development and drought relief projects, appear at first sight to be less demanding on both institutions and farmers. However, as in the case of large schemes, they have tended to stress modern, technically unfamiliar methods. And small-scale irrigation components have often relied on government staff even less experienced than those of the specialised agencies which handle major irrigation projects.

3.21 Meanwhile relatively minor attention has been given by governments in any projects to the less glamorous possibilities of developing small-scale or traditional irrigation at lower cost, in technically simpler ways demanding less radical institutional and socio-economic change, but with less potential for conflicts of interest.

# IV. A REVIEW OF PROJECT EXPERIENCE

## A. Introduction: Quality of Data Reviewed

4.1 This chapter is based on a review of some forty major government-financed irrigation projects, and 12 rural development or drought relief projects with small or medium scale irrigation components. The data come largely from unpublished sources, principally the World Bank, as well as from case studies compiled by FAO consultants and from personal communications. Published symposia, books and academic studies provided supplementary information. Sources are listed in Annex 3.

4.2 The data on major schemes give two almost conflicting impressions. Only for six projects, all executed with World Bank participation, is the information sufficient for a detailed comparison of planned with actual results. The impression given by these six projects is considerably more favourable than the conventional rather unhappy image of the results of large-scale irrigation in SSA. This appears to be because the six projects were more carefully chosen, planned and supervised than the average. Furthermore they were implemented at a time when construction costs, even inflated to current terms, appear to have been lower, and they benefitted from improvements in commodity prices between planning and execution. Most of the remaining projects, which constituted the majority, give a far less satisfactory general impression. But most of them are much less comprehensively documented. References to less successful projects tend, therefore, to be based on more fragmentary sources or personal communications.

4.3 There is a risk, in the evaluation of state institutions which follows, that due to the pervasive presence of governments some problems may have been attributed to the wrong causes. Problems are often interrelated. For instance, when farmers are reported as not having used planned amounts of fertiliser it may have been because the project authority did not lay in stocks; but it may have been prevented from doing so by a central ban on imports; or there may have been no farmer demand for fertiliser due to pricing policies, or due to farmers' concern over possible crop failure because of unreliable water deliveries.

## B. Performance of Governments

### Resource Allocations

4.4 Once committed to major modern irrigation projects governments have frequently found it difficult to allocate the necessary resources. This has been particularly true after the politically "visible" construction phase is over, and the more mundane costs of continuing operation and maintenance have to be met. Reports of funding agencies note:

- frequent insufficiency of counterpart funds to match external loans;

- allocation of inadequate budgets to irrigation agencies or failure to release budgets on time;

- failure to authorise foreign exchange expenditures on time even when specific commitments exist in loan agreements;

- unwillingness to authorise the purchase of, or to allocate to the project authority, the imported materials, fuel and inputs essential for scheme operation and maintenance or crop production, and sometimes even for construction;

- unwillingness of central governments to adjust procurement or input prices so as to maintain producer incentives.

All of these failings have made operations significantly more difficult for project executing agencies, contributing to the deficiencies at project level reported later.

## Planning

4.5 As in other regions, most of the irrigation agencies in SSA have a bias towards engineering and construction. Hence planning of major, as well as of many minor, schemes has tended to focus on achieving the most technically efficient system of water distribution on the project perimeter, taking less account of (a) the managerial and social factors which will determine whether this later leads to efficient agricultural production and (b) in the case of major schemes, effects on areas outside the perimeter. Thus little thought has been given to the staff changes and other reshaping of project units which are needed when construction ends and crop production begins to become the priority. Inadequate socio-economic investigations have caused irrigation planners to fail to allow for competition for farmers' time between cultivating project land and other rural activities, and due to this competition crop calendars have proved unrealistic and construction or farm labour has proved unexpectedly scarce. Losses of previous, traditional, production due to takeover of land for reservoirs and project perimeters and to downstream changes in flood regimes, have been regularly underestimated.

4.6 In showing that the large sums of money committed to modern irrigation are justified, planners have assumed relatively rapid construction and efficient, intensive crop production. While in principle attainable under favourable circumstances, in practice events have often shown such forecasts to be unrealistic. Poor performance against stated targets has tended to erode political commitment to projects. In the now increasingly frequent atmosphere of economic crisis, this has caused their budgetary priority to be reduced, leading in turn to a further deterioration in performance due to inadequate allocation of operating funds.

## Design and Construction

4.7 Design and construction problems have arisen in many projects because of the inexperience of government project units in supervising design consultants and contractors. The consultants and contractors themselves have sometimes contributed to these problems by proposing inappropriate, over-sophisticated, techniques without much appreciation of the local realities and requirements. In other cases the rigid terms of reference given by governments - often with the encouragement of financing agencies - have prevented consultants from offering what might have been cheaper or more appropriate designs. One of the main reasons for the cancellation and subsequent reformulation of the original Amibara project in Ethiopia was, for instance, the gross initial underestimation of costs during the preparation of the project by expatriate consultants.

4.8 A recent review in Ghana notes that lack of experienced design personnel and lack of standard design practices resulted in unnecessarily expensive structures. Highly mechanized construction methods were adopted leading to considerable delays due to problems with erratic fuel supply and lack of spare parts; labour-intensive construction techniques would have been more workable. Major design errors have also occurred. In the Madagascar Lake Alaotra project, for instance, some canals were built at a level lower than the fields they were intended to irrigate. Elsewhere canals have been designed with incorrect slopes or inadequate controls, or it has proved necessary to discard a part of the original project area due to soil or drainage limitations which were not recognised at the design stage, often for lack of adequate site surveys.

4.9 Design and construction problems appear equally, if not more, likely with smaller-scale developments or with irrigation components of rural development projects, since they do not get the same management attention as a major development and are frequently entrusted to inexperienced government staff rather than consultants and contractors. For instance on the Tara Project in Niger, with a command area of about 200 ha and executed by local institutions, the main pump intake was built above the level of dry season river flow, thus defeating the project objective of dry season cultivation. It is generally believed that consultation with the local people who live along the banks of the river would have avoided this problem. The irrigation component of the Maradi Rural Development Project, also in Niger, performed very poorly with items omitted, costs underestimated and frequent changes of specifications. In Mali scattered small-scale drought relief works were more successfully executed, but only when given intensive management attention from design through to completion. And in the same country, after state capacity for construction of small schemes had been successfully created with the aid of external funding, the agency concerned was not allocated any more work after the project ended.

4.10 Lack of adequate planning and design as well as poor construction caused problems in all the six major projects of which the economic results are reviewed in detail. Lack of detailed designs at appraisal made modification necessary during construction of the Sudan Rahad and Madagascar Morondava projects, with consequent delays and cost overruns. Defective construction in Cameroon SEMRY I and SEMRY II (dikes), and at Rahad (cracks in the lining of the discharge stilling basin) had to be repaired before the start of agricultural operations. On-farm works were temporarily abandoned at Mali Riz Mopti when a contractor stopped deep ploughing, preferring to pay the statutory penalty. At Madagascar Lake Alaotra, SOMALAC abandoned part of the on-farm works because of financial difficulties. Even at completion, some of these projects were left with problems arising from poor original designs or construction. The Lake Alaotra project had difficulties with siltation caused by erosion upstream. In Mopti the capacity of some canals and drains was insufficient and intakes suffered from continuing problems of instability and erosion.

## Project Management

4.11 Few of the institutions responsible for large irrigation perimeters are adequately structured for the non-engineering part of their tasks, but they are nevertheless usually required to become financially self-supporting once project construction is over. They have therefore tended to give priority to revenue-generating activities for which they are poorly suited, often at the expense of cost-cutting on the operation and maintenance of the irrigation system itself.

4.12 A striking example is given by SODEMO in its management of the Morondava project in Madagascar. SODEMO was required to settle rice growers, provide agricultural services and manage the irrigation network as well as producing cotton, groundnuts and tobacco on land allocated to it. It was expected to become financially self-sufficient from the crops grown and from the land and water charges paid by farmers. Although already facing difficulties in securing a sufficient number of qualified staff, its activities were further expanded to include regional commodity marketing, construction of buildings and manufacture of tools and furniture. The tasks were beyond the capacity of the management. SODEMO made a loss on its own farms and failed to recover water charges from farmers, who were anyway not encouraged by the Government to pay. The combination of poor managerial performance and lack of funds led to declining standards of operation and maintenance, and the progressive degeneration of the whole irrigation system.

4.13 Apart from the complexity of management tasks, shortage of qualified personnel is another major cause of poor management performance. For instance, it has been estimated that a single project, the Kano River Project in Nigeria, will absorb all the agricultural graduates from Kano State for the next twenty-five years. Without a greatly expanded training programme, therefore, this one development could jeopardise the management of the whole of the state's agricultural sector for the foreseeable future.

4.14 Problems of management have been further compounded by political and social pressures. Managers, due to the large investments involved in modern irrigation projects, have often been pressed by politicians, local authorities or relatives to allocate contracts, services or resources in ways which may be counter to the efficient construction and running of the project. Such pressures can be almost irresistible when, as is sometimes the case, the pressure groups concerned have sufficient influence to have uncooperative government employees removed from their jobs.

## Operation and Maintenance

4.15 Many major projects in SSA have serious operation and maintenance problems. Main causes are weak management, lack of qualified and trained technical personnel, competition from the many other activities for which the institutions are responsible and lack of funds. Lack of funds can itself be due to several factors including inadequate central allocations of operating budgets, poor cost recovery on services provided to irrigators, or low returns from processing and marketing. The multiple responsibilities of irrigation agencies in SSA are in conflict with the findings of a World Bank review of 26 projects (mostly outside the region), which showed that good irrigation system O & M is most often associated with experienced and specialised irrigation agencies having no other responsibilities. As a result of inadequate planning during project formulation few projects in SSA have a manual for system operation, and even if one exists it is seldom followed. Furthermore, as in other regions, projects tend not to have adequate facilities to maintain O & M equipment. The generally short-sighted approach to project O & M has caused many systems to deteriorate to the point where complete rehabilitation has become necessary.

4.16 Specific examples of poor operation and maintenance in the projects reviewed include the Lake Alaotra project, in which poor control of the level of the water in the main drain endangered agricultural development by allowing the peat soil to dry out, leading to burning and excessive settling. In the Senegal River Polders Project inefficient operation of the downstream water level gates induced farmers to by-pass the inlet system, contributing to an accelerated deterioration of the tertiary irrigation network. Doubtful engineering designs and construction have further increased the maintenance problems of the Senegal River Polder Project by leading to the partial collapse of one dike and water percolation along dikes in another sector. Rice production on the Gambia Agricultural Development Project has declined because pump and machinery repair facilities are inadequate and funds are insufficient to buy fuel and spares. The Bura Project in Kenya reports a series of problems due to pump breakdowns, apparently caused by a complex of shortcomings in design, fuel supply and maintenance.

## Production Support Services

### Access and Transport

4.17 Transport of project equipment, materials and inputs has proved difficult due to bad access roads, with items arriving late or damaged (e.g. Nigeria). The need to move project output long distances (e.g. SEMRY rice) has added to costs, leading to reduced farm-level returns or a requirement for government subsidies to maintain producer incentives. Isolation has been a disincentive to recruiting or retaining qualified staff and managers, whether African or expatriate (Niger). Where the project authority was responsible for transporting output in its own vehicles, movements have been affected by the general problem of low serviceability of motorised equipment (Sudan).

### Credit

4.18 Distribution of credit does not seem to have been a major problem in most of the projects reviewed. In Senegal, however, it was noted that rice credit distributed by cooperatives did not reach paddy producers since they were mainly women, but was diverted to groundnuts, a cash crop grown by men. Government success in credit recovery was variable. Recoveries of 85% or more are reported from Senegal and Sudan, in Senegal by means of village associations of producers. In the Sudan case good recoveries were achieved despite the need to deduct all dues from sales of the only one of the farmers' crops (cotton) which was bought by the project authority; however linking repayments solely to cotton has been a considerable obstacle to cost recoveries in other projects in the Sudan. In the Gambia Rice Project credit was used as intended but paddy was sold privately and repayments were poor. Low credit recoveries are also reported from projects in Nigeria.

## Input Supplies and Machinery Services

4.19 It is difficult to separate the effects of badly organised or limited supplies of inputs from the possible results of a lack of demand due to inappropriate government price policies. For example when the Niger Maradi Rural Development Project started the authorities successfully distributed subsidised fertilizer imported from Nigeria. Demand slumped when this supply ceased and the price was raised. In Mali neither the Office du Niger nor Operation Riz Mopti have been very successful in assuring input supplies but in the Mopti case irregular and at times inadequate water supply made farmers anyway reluctant to use fertilizers. The Cameroon SEMRY and Kenya Mwea projects, however, have a good record in input distribution. Several projects experienced problems in rice seed supply; either projects failed to receive sufficient, or they did not succeed in growing their own as intended, or the seed which they did have was of poor quality or of varieties unadapted to local conditions or consumer taste.

4.20 Machinery services have been a frequent source of difficulty. There are reports of too few tractors at the outset (Somalia), inappropriate models for part of the work required (Sudan), that tractors were used to pioneer a system of mechanised production which proved financially unviable (Cameroon), or that the work done was to an unsatisfactory standard (Gambia). A progressive decline in serviceability of government tractors is noted in many projects through lack of spares, workshops or qualified mechanics. Problems have often been compounded by lack of fuel. Similar problems have affected pumps provided or operated by government agencies, whether the installations were large and fixed (Kenya, Sudan) or smaller and/or mobile (Gambia). Despite many commendable examples of improvisation by field staff, the end result of such problems has frequently been a reduction in planted or harvested areas, reduced cropping intensity or loss of growing crops for lack of water.

## Agricultural Research and Extension

4.21 Several projects include components for applied research, either by the project agency or some other national institution. During the timespan covered by supervision and evaluation by financing agencies - which may admittedly be too short in some cases for an applied research programme to mature - results were usually limited. In some cases the component failed to perform at all, with equipment not being procured or staff remaining unrecruited (Mali). In others the project failed to formulate an appropriate research programme or, if given one, executed it only partially. Although most research components were intended to select better adapted rice varieties (Burkina Faso, Gambia), the lack of appropriate cultivars remained a continuing complaint, in the case of the Gambia even several years after the end of disbursement. Little or no progress seems to have been made on two other major topics which have hindered the implementation of projects according to their original designs - weed problems, and the need to modify intensive cropping schedules so that farmers can follow them more easily.

4.22 Agricultural extension seems to be one of the weakest of government services. Poor performance is noted in Mali, Somalia, Madagascar and Nigeria. Extension agents were sometimes altogether lacking, or variously described as insufficiently qualified, poorly trained, uninformed, lacking in mobility, authoritarian or corrupt. Insufficient use was made of practical instruction and demonstration plots. Only in tightly-managed projects such as Cameroon SEMRY I and II and Kenya Mwea does extension advice appear to have had the hoped-for impact. On those projects the pre-requisites for extension impact (machinery services, inputs, incentives) were also present, and assured by the same management.

### Cooperatives

4.23 Many projects include in their design the creation of irrigator groups or cooperatives for credit and input distribution, machinery or pump operation, marketing, or system O & M. Some successes have been noted - for instance the recovery of credit in Senegal by village associations. The tenants' associations in the Sudan have over the years become an effective voice on behalf of their members in influencing government policies on crop price and cost recoveries. At the individual project level, also, such groups have provided useful feedback from irrigators to the project management (Senegal Casamance). Elsewhere, however, associations and cooperatives have failed to become established or collapsed (Gambia, Niger, Nigeria, Somalia). Reasons have varied: in some cases settlers were from too diverse a background; some associations became dominated by individuals who used them for their own ends; illiterate farmers often distrusted the system since they could not read the cooperative's accounts; low prices, mismanagement or dishonesty led to bankruptcy of the association; or the conditions of tenancy caused irrigators to consider themselves as labourers without any opportunity to influence events in any way.

### Marketing and Prices

4.24 Governments have usually set farm-gate prices assuming that projected production efficiencies and yields will be achieved. At the often lower levels encountered in reality the government price has not always given farmers an adequate return on their costs (e.g. Mali and Nigeria rice, Sudan cotton). Farmers have then either neglected their fields or sought to grow other crops giving better returns. Elsewhere private buyers have offered better prices, thus creating disputes between the government buying monopoly of the project authorities and those irrigators who sell on the unofficial market. Credit recoveries have been undermined and the authorities have been deprived of raw material for their processing or storage facilities, which are consequently underutilised. In other cases the proportion of marketed output has been unexpectedly low (e.g. Senegal), with a similar negative effect on the throughput of government marketing and processing facilities, and hence on the financial status of the project authority.

4.25 At their worst these difficulties have on the one hand caused farmers to abandon the project, while on the other they have bankrupted the project agency. Strong government involvement in marketing and processing has also been noted to lead to recruitment of excessive numbers of office staff with ill-defined responsibilities, as well as unusually high losses in processing or storage.

## Settlement and Social Support Services

4.26 Where project authorities have offered settler housing it has been an important attraction. However designs have not always been adapted to local preferences, in which case houses tend to be abandoned in favour of traditional ones built nearby, or on the farmer's plot. It is not clear in this context to what extent the provision simply of housing materials by project authorities has been acceptable to settlers. But where housing and social infrastructure have been totally omitted from designs, projects have tended to create insanitary rural shanty-towns with no advantages over the primitive conditions in which the inhabitants lived previously. The success with which new settlements have absorbed new populations of irrigators has varied. Nomad pastoralists from East or West Africa have tended to make only a provisional commitment to irrigation and to continue a partly nomadic life, living outside official settlements for part or all of the time. Social conflicts have arisen where project recruits from different groups or clans have been settled on the same site.

4.27 Access to schools, clinics and clean public water supplies may also be an initial attraction to the potential irrigator. Very often, however, these facilities, once constructed by the project authority, have not functioned very efficiently. Their operation has often been entrusted to a different government department with little or no other activities in the (usually isolated) project area; or they may remain a project responsibility but get low management/budget priority. Very often, therefore, settlers have had to use more distant facilities at least for education above the primary level or to see a doctor. Sometimes project social services have ceased to function altogether.

## Financial Performance of Irrigation Agencies, Subsidies and Cost Recoveries

4.28 It is perhaps not surprising that few irrigation project authorities have become financially self-sufficient as intended, given their wide-ranging responsibiities and the budgetary, management and operating problems already described. Their often poor financial status is also a reflection of the basically incompatible requirement to produce cheap food (often at less than import parity prices), while remaining dependent on usually rather inefficient or reluctant irrigators who must receive at least a minimum incentive price if they are to continue to grow the crops required by the state. When faced with inadequate or declining cash flows, governments and project authorities have been naturally reluctant to offer prices which adequately compensate irrigators. Meagre farm-level margins have then been insufficient to allow irrigators to repay the full cost of state-provided services and inputs, leading to further deterioration in the finances of the project authority.

4.29 Governments have usually reacted to such situations either by waiving cost recoveries, subsidising producer inputs and services, paying a direct subsidy to the project authority, or a combination of all three. However farm profitability has generally remained low. And this, especially when combined with subsidies on the input side which have given government agencies a commercial advantage, has been a powerful disincentive to the establishment of private sector agricultural support services on irrigation projects. Furthermore subsidies, wherever applied, have proved extremely difficult to contain and virtually impossible to eliminate. Only recently, for instance under new policies in Senegal and Niger, are irrigation agencies taking serious steps to improve their efficiency, divest themselves of unnecessary staff, privatise services and O & M to the extent possible, and thus remove their dependence on continuing subsidies.

4.30 Data on the financial performance of a selection of irrigation project authorities are reviewed below.

4.31 On the Gezira and other major projects in Sudan revenues from cotton, the main cash crop, have been divided between the Government to cover land rent, maintenance of main works and provision of water (36%), the project corporation for overhead costs (10%), and the tenants (47%). The remaining 7% are set aside for taxes and a reserve fund. A gradual increase in the tenant's share from an original 40%, plus the transfer of increasing responsibilities to the project corporations, have starved the corporations of funds to carry out their responsibilities. On the Gezira scheme charges are now levied for all crops, and no longer solely on the basis of cotton output. But the corporations have still been unable to raise their share of revenues due to the likely disincentive effects on tenants, at a period when cotton prices have remained low. As they stood in 1982/83, therefore, charges in the Sudan were considered to represent full cost recovery for gravity schemes such as the Gezira, but to include a large element of subsidy for pumped schemes such as Rahad. This situation appears relatively favourable, however, compared with that of ONAHA in Niger, which in the five years from 1980 to 1985 received an average annual operating subsidy of US$0.5 million while revenues averaged only US$0.4 million. It still made an operating loss in three of the five years.

4.32 Even in the case of a successful project such as SEMRY I the share of returns required to finance the operations of the project authority itself can be substantial, as shown below.

SEMRY: Distribution of Project Earnings by Participant (%)

| | Percentage |
|---|---|
| Payment for SEMRY Operations | |
| - recurrent costs | 26 |
| - amortisation | 21 |
| Sub-total | 47 |
| Purchase of paddy from tenants | 35 |
| Margins to traders | 18 |
| Total | 100 |

Source: FAC Evaluation Service

In addition to its 47% share of returns SEMRY also received a government subsidy equivalent to a further 19%. Since the same source calculated that the tenants contributed 46% to value added in exchange for their share of only 35% of net returns, it can be legitimately questioned who the project is intended to benefit - the small farmer, or the government itself.

4.33 The FAC Evaluation Service reviews of other projects in West Africa paint an even more sombre picture.

> The Mopti II Rice Project, which aimed to improve water control for traditional rice irrigation in Mali, raised the government contribution to the cost of producing a ton of paddy by 20% and the foreign exchange cost by 25%. Value added fell by 4% and farmer gross returns by 13% compared with the without-project situation. Furthermore the project almost completely failed in its main objective, which was to generate a marketable surplus of rice to supply government institutions.

> In Senegal in 1983 it was calculated that the government was spending the equivalent of about US$12.1 million to produce 54,000 t rice (US$225/t). Plans to increase output to 150,000 t in 1990 would lower the unit cost to US$195/t, but raise the total cost to US$29 million. Meanwhile in 1983, for each kilogramme of paddy purchased from tenants at US Cts 16, the government was paying a subsidy equivalent to US Cts 6 for production on village schemes or US Cts 10 for major schemes.

In 1983 SODESUCRE in Ivory Coast was producing irrigated sugar at US$1.07/kg. FAC estimated that despite a period of much lower world sugar prices, the local market could support a price of up to US$0.34/kg. However even this would only allow SODESUCRE to meet its operating costs and offered the company no prospect of ever repaying its loans.

## C. The Influence of Donors

4.34 The river basin surveys and masterplans which were supported by external agencies mainly in the 1960s were often largely technical exercises which did not concern themselves to the same extent with the managerial and social constraints to development. In the political climate of the time the likely importance of these constraints was overlooked by many African governments. The studies therefore raised expectations of rapid, massive increases in cheap hydropower and agricultural production. The frequent necessity for a highly visible structure such as a dam as the starting point for such developments made them politically attractive as symbols of modernisation. Surveys of groundwater, which could have had an important localised irrigation impact but which would have involved only inconspicuous works more suited to community or private development, were often followed up only to the extent needed to locate sources for domestic and livestock use.

4.35 With the benefit of hindsight it appears that the lending agencies which subsequently financed some of the major developments in basin masterplans were also inclined to excessive optimism. Some lenders did have a beneficial influence by stressing phased project expansion and by focussing attention on how projects were to be executed and who they would ultimately benefit, although others were inclined to fund the technical proposals at their face value. The result has been some useful projects and some white elephants, but all at the expense of a considerable increase in the indebtedness of the region. It has taken a further 10 to 20 years for the major lenders to bring governments to face the additional needs for training, institution building, improved management, farmer incentives and - latterly - system rehabilitation. This more recent orientation has also at times run into difficulties, due to the differing approaches of agencies. Agency A may consider one set of policy or institutional changes as a necessary adjunct to physical rehabilitation while B presses for others; meanwhile C finances the works without demanding any changes.

4.36 It has also been claimed that by insisting on expatriate design consultants, supervision and contractors, financing agencies have unnecessarily raised construction costs. While often true, it is difficult to see how else the agencies could have protected their investments in the absence, as yet, of any local capacity in most of the countries of the region.

4.37 At perimeter level external support has often reflected the donor's own traditions. Thus projects supported by France, Britain, Holland, the USA or China have each tended to embody a different approach to system design, construction and operation which may or may not have been well adapted to Africa. Such projects have shown that high productivity can be achieved under irrigation. For instance a Dutch team in Senegal doubled rice output when they took over the operation of a 600 ha polder, and Chinese projects built and operated largely by expatriate staff, have produced 10 t paddy/ha/yr in Burkina Faso, the Gambia and elsewhere. However at times works have been unnecessarily costly, or in the case of western designs have incorporated systems for automatic labour-saving operation when in the African context simpler manual methods would have been better. At its worst such assistance has created enclaves with no external or multiplier influence, which have continued to operate only while expatriates remain. For instance the Kou project in Burkina Faso (1,250 ha) is reported at one time to have had 60 expatriates, while in five years no African staff had yet received any training. In another case the exemplary technical efficiency of such an enclave project caused it to be adopted as the model for a larger investment project before its longer-term durability had been confirmed. The larger-scale project and its model both subsequently failed, because of the unwillingness of the local population to commit themselves to the new methods which the technical assistance team had successfully demonstrated. Lack of lasting impact is also a risk with multilateral technical assistance.

4.38 Similar problems arise with gifts of equipment. Items are of little use unless they are fully appropriate for the intended purpose, able to withstand local conditions and supported by adequate local arrangements for servicing and for distribution of spares. An external assistance project based on import of a particular model of pump to the Sahel became a logistical nightmare due to servicing and procurement problems, compounded by bureaucratic import procedures; it failed when the chosen model was discontinued by the manufacturer. On the other hand other types of pumps have been widely and successfully adopted by vegetable growers in northern Nigeria because (a) they have the same motors as generators and motorcycles which are already widespread in the area so that a servicing capacity already exists, and (b) they are fully portable hence can be kept indoors at night, safe from theft. In Somalia, in contrast, project tractors rapidly became immobilised when a change of national foreign policy broke contacts with the supplier country.

4.39 Expatriate technical assistance during project execution has, however, also made some very positive contributions to the management of irrigation projects. The technical success of the Cameroon SEMRY projects still depends considerably on use of a team of French expatriate managers. Partnerships or management contracts with the UK's Commonwealth Development Corporation have contributed to the efficiency and profitability of sugar and other agro-industrial projects in Swaziland, Malawi and Zambia. Turnkey contracts with various private companies have also given good results. In most of these cases, however, the originally planned transfer of responsibility to African managers has either been inordinately slow and difficult, has not taken place at all, or if it has taken place as scheduled it has been followed by a decline in project performance. In a typical example cane yields on a sugar estate were almost halved two years after the external management contract ended. Moreover expatriate support is expensive. For instance it comprised some 20% of the total costs of the SEMRY rice projects over their five-year construction periods.

4.40 External assistance has tended to have rather less impact when expatriates have been recruited individually by Governments. In a number of projects financed by the World Bank specialists failed to settle or perform adequately and had to be replaced. Sometimes delays in recruiting have turned what was supposed to be a team of experts into a procession. Failure to synchronise their arrival with procurement of project vehicles and equipment has at times left expatriates idle, or lack of government counterparts has prevented their leaving a lasting impact. In the view of one observer the presence of 80 foreign irrigation engineers in one African country for three years brought no discernible benefits to the irrigation sub-sector.

## D. Results of Major Irrigation Projects

### Crop Production and Yields

4.41 The principal crops of major government-financed irrigation projects in SSA are rice, sugarcane and cotton. Much smaller areas are devoted to other staple foodcrops, fodders, vegetables and fruits.

Rice (Table 18)

4.42 Of the total of 6.45 million tons of rice produced in the region in 1982 1.1 million tons (17%) are estimated by FAO to have originated from modern irrigation schemes and 2.8 million tons (43%) from traditional wetland irrigation. This compares with 2.55 million tons of upland rice. Table 18 gives details for the main rice producing countries. The major producers under modern irrigation are listed below.

| Country | 1982 Rice Production under Modern Irrigation ('000t) | Percentage of National Total | Percent of SSA Total |
|---|---|---|---|
| Madagascar | 600 | 30 | 9.3 |
| Mali | 150 | 60 | 2.3 |
| Nigeria | 140 | 10 | 2.2 |
| Mozambique | 47 | 76 | 0.7 |
| Kenya | 32 | 74 | 0.5 |
| Cameroon | 30 | 50 | 0.5 |
| Ghana | 19 | 21 | 0.3 |

Source: FAO

4.43 Paddy yields and cropping intensities for five major government projects are shown in Table 24. Yields ranged from 0.9 t/ha/yr with partial water control (Mali, Riz Mopti) to between 2.3 t/ha/yr (Madagascar, Mondorava) and 10.0 t/ha/yr (Cameroon, SEMRY II) with full water control. Elsewhere the Kenya Mwea project has maintained around 5 t paddy/ha/yr over the past ten years. Dry-season yields of 5 t/ha are also reported on the Gambia rice projects, although in the wet season only about 2.5 t are obtained per hectare. Yields in Senegal have ranged from about 2.5 to 4 t paddy/ha. In government projects in Niger yields of 5.5 t paddy were obtained on newly-developed land but fell to 3.5 t/ha by the fourth crop, and 3 to 4 t/ha were obtained on Nigerian rice projects.

4.44 However in the less successful government irrigation projects of West Africa, where the problems of input supply, machinery breakdown and system degeneration have been most acute, paddy yields have sometimes been no better than those for unimproved swampland cultivation. And in the more heavily degraded government perimeters in the Senegal and Niger river valleys yields are often, at 0.8 to 1.5 t/ha, scarcely above those for traditional flood irrigation. Irrigated crops planted outside traditional production seasons have been particularly vulnerable to bird damage. Allowing for the proportion of government schemes with only partial water control and the significant areas of some perimeters which are not regularly harvested or are abandoned, overall average paddy yields from major schemes are estimated to be around 2.0 t/ha per crop.

4.45 Cropping intensity has generally been disappointing. Of major projects designed for two crop seasons the Cameroon SEMRY projects achieved 170 to 180% intensity but Madagascar Lake Alaotra only 100% and Morondava 90%. The Gambia rice projects had achieved 120% by the end of World Bank loan disbursement but this fell to only 41% five years later.

Sugarcane (Table 19)

4.46 An estimated 41 million tons of sugarcane are harvested annually in SSA of which 31 million tons are from only 13 countries, information for which is given in Table 19. Of the 31 million, almost 20 million tons (65%, or nearly half the total cane output of SSA) are grown under modern irrigation, mainly under industrial-style management. Yields on such estates are in the region of 100 to 125 t cane/ha/yr. On the Bacita project in Nigeria and on state farms in Somalia, however, yields are currently only about 60 t/ha and on the Ghana Asutsuare project 37.5 t/ha were recorded in 1981, compared with 100 t/ha on a pilot farm. The most important countries which produce irrigated cane are listed below. Although Mauritius, with 6.5 million tons cane/yr, is the largest regional producer, only some 15% of its output (one million tons) is irrigated.

| Country | 1982 Irrigated Cane Production ('000t) | Percent of National Cane Total | Percent of SSA Total |
|---|---|---|---|
| Zimbabwe | 3,420 | 95 | 8.3 |
| Swaziland | 3,135 | 95 | 7.7 |
| Sudan | 2,500 | 100 | 5.9 |
| Ivory Coast | 2,280 | 95 | 5.6 |
| Malawi | 1,800 | 100 | 4.4 |

Source: FAO

Cotton

4.47 FAO data show that a little over half of the estimated 1.8 million tons of seed cotton produced annually in SSA come from only six countries. In three of these - Ivory Coast, Tanzania and Mali - cotton is largely rainfed. The remaining three major producers are Sudan, Zimbabwe and Ethiopia which produce respectively 17, 8 and 5 percent of the regional total. In all three the majority of output comes from modern government-sponsored irrigation schemes.

4.48 In the Sudan both cotton output and irrigated yields declined between the early 1970s and the early 1980s, mainly due to poor management of the larger Nile Pump Schemes after they were nationalised and a general decline in producer returns. Seed cotton yields which were about 1.5 t/ha fell to only 0.7 t/ha, but have since responded to improved incentives and risen to around 1 t/ha. This compares with average yields of about 0.3 t/ha for rainfed cotton in Sudan. In Ethiopia estate averages of 2.5 t/ha have been obtained. In successful pilot developments in Zimbabwe small-farmer yields are reported to be 4 t/ha. However current mean yields in Ethiopia are probably 1.5 to 2 t seed cotton/ha and in Zimbabwe about 2 t/ha.

### Other Crops

4.49 A very wide range of other crops is grown on government irrigation schemes on a smaller scale. In Sudan the crop rotations with cotton include sorghum for subsistence and to pay hired labour, plus fodders for draft animals and other livestock. Wheat and groundnuts have also entered the system as alternative cash crops. The proportion of these non-cotton areas has risen - against the will of the Sudanese government - in periods when cotton returns have been low. In Senegal, dry-season tomatoes are rotated with rice in suitable areas, the government providing inputs and operating a processing factory. In Somalia irrigated bananas for export are an important crop on state farms. In Nigeria significant areas of wheat and coarse grains are grown on state projects. Several government perimeters in eastern and southern Africa grow maize, groundnuts and other staple foods as a commercial objective.

4.50 Where projects provide the settler with a separate subsistence or houseplot the family crops may include maize, sorghum, rice and grain legumes as well as fruits, vegetables and condiments. At times the market opportunities for the horticultural crops may attract the irrigator to give priority to this part of his enterprise, to the neglect of his "government" crop.

4.51 For most of these crops yields are difficult to ascertain. In Sudan sorghum yields, at between 1.2 and 2 t/ha, are similar to those from mechanised rainfed production. Wheat, for which the climate is unfavourable, is reported to yield only 0.7 to 1.2 t/ha. Groundnuts are quoted at 1.9 t/ha. Elsewhere maize yields have usually ranged between 2 and 5 t/ha. Tomatoes in Senegal yield around 20 t/ha. A yield of 16 t/ha is quoted for bananas in Somalia.

## Costs and Economic Returns

### Costs and Trends

4.52 Costs of irrigation in Africa are higher than in most other regions. Inter-regional comparisons made by the World Food Conference in 1974 estimate that new schemes in Africa cost 64% more than in the Far East, 55% more than in Latin America but 3% less than in the Near East. Rehabilitation is estimated to cost 20% more than in the Far East and Latin America but 11% less than in the Near East.

Estimated Costs of Irrigation Development

| Region | Renovation and Improvement of Existing Irrigated Areas | | New Irrigation | |
|---|---|---|---|---|
| | 1974 Prices | 1985 Prices (a) | 1974 Prices | 1985 Prices (a) |
| | . . . . . . . . . . . (US$/ha). . . . . . . . . . . . . . . | | | |
| Far East | 418 | 674 | 1,466 | 2,366 |
| Near East | 560 | 904 | 2,467 | 3,982 |
| Africa | 500 | 807 | 2,400 | 3,874 |
| Latin America | 420 | 678 | 1,500 | 2,420 |

Source: Secretariat Proposals. UN World Food Conference, Rome, 1974; cited by Carruthers and Clark, 1981.

(a) Brought to 1985 prices using the World Bank Manufacturing Unit Value Index.

4.53 The UN Water Conference in 1977 estimated similar orders of costs per hectare for Africa but less difference between regions, as shown below. The figures suggest that new irrigation systems in Sub-Saharan Africa cost an average of around US$4,500/ha (1985 dollars) with major improvements costing US$1,400/ha and minor improvements US$600/ha.

Average Capital Investment for New Irrigation and Improvements by Region, 1975 and 1985 Prices (a)

| Region | New Irrigation | | Major Improvements | | Minor Improvements | |
|---|---|---|---|---|---|---|
| | 1975 Prices | 1985 Prices | 1975 Prices | 1985 Prices | 1975 Prices | 1985 Prices |
| | . . . . . . . . . . . . . (US$/ha) . . . . . . . . . . . . . | | | | | |
| Africa (excluding Northeast) | | | | | | |
| North of Sahara | 2,500 | 4,035 | 900 | 1,452 | 400 | 646 |
| South of Sahara | 2,800 | 4,519 | 900 | 1,452 | 400 | 646 |
| Latin America | | | | | | |
| Central America and Mexico | 2,400 | 3,874 | 800 | 1,291 | 300 | 485 |
| Caribbean | 2,400 | 3,874 | 800 | 1,291 | 300 | 485 |
| South America | 1,900 | 3,066 | 600 | 968 | 200 | 323 |
| Near East | | | | | | |
| Northeast Africa | 3,100 | 5,003 | 900 | 1,452 | 500 | 807 |
| Middle East | 2,600 | 4,196 | 900 | 1,452 | 500 | 807 |
| Asia | | | | | | |
| South Asia | 2,900 | 4,681 | 700 | 1,130 | 300 | 485 |
| Southeast and Far East | 3,000 | 4,842 | 700 | 1,130 | 300 | 485 |

Source: United Nations Water Conference, "Water for Agriculture", (E/Conf.70/11), 1977; cited by IFPRI, 1979.

(a) Brought to 1985 prices using the World Bank Manufacturing Unit Value Index.

4.54 Annex 1 examines the cost of irrigation works in the Sahelian countries of Francophone West Africa, which have tended to be among the highest in the region. A summary of these figures is given below and more details can be found in Annex 1, Table 2. By comparison with the World Food Conference and UN Water Conference estimates given above, they suggest that costs for major surface irrigation schemes in West Africa may be about 1.5 times the regional averages.

Estimated Construction Costs for Irrigation Systems in Francophone West Africa (1985)

| Type | Earthworks | Concrete Structures | Land Levelling | Pumps | Total |
|---|---|---|---|---|---|
| | ................. | ................. | US$/ha | ................. | ................. |
| Controlled flooding, depth 1.3 m | 800 | 200 | - | - | 1,000 |
| Controlled flooding, depth 40 cm | 1,350 | 350 | - | - | 1,700 |
| Controlled flooding, depth 15 cm | 3,000 | 800 | - | - | 3,800 |
| Receding flood (River Niger) | 300-800 | 80-200 | - | - | 400-1,000 |
| Swampland development, simple | - | - | - | - | 200 |
| Swampland development, improved | - | - | - | - | 800 |
| Surface irrigation, full control | | | | | |
| - village schemes, river terraces | 1,000 | 700 | - | 1,500 | 3,200 (a) |
| - village schemes, lowlands | 2,600 | 1,800 | 400 | 1,000 | 5,800 |
| - large schemes, river terraces | 2,400 | 800 | 400 | 1,200 | 4,800 |
| - large schemes, lowlands | 4,600 | 1,200 | 1,600 | 1,000 | 8,400 |

Source: Annex 1, Table 2.

(a) Plus labour by beneficiaries.

4.55 None of the above estimates include costs of supervision, nor of essential supporting items such as offices, workshops and staff houses for the project authority. Nor is maintenance equipment provided for. Such items would typically add 10 to 15% to project costs in Africa, and in some circumstances considerably more. The total of these costs for the productive elements of the project may be further increased by the costs of settlements, urban infrastructure or social services provided for the irrigators and their families. Finally the government may incur high costs to create or improve road access.

4.56 When all the productive and non-productive items of the project are added together they tend to confirm general statements that irrigation in Africa "now costs US$15,000 to US$20,000/ha" - provided, however, that the definition of "irrigation" includes full water control with pumped supply, on a site requiring a complete range of technical and production support services as well as all social infrastructure. For the Kenya Bura project, regarded as one of the more costly in Africa, non-productive infrastructure has contributed an estimated US$12,000/ha to the total cost of US$20,000/ha. And a recent World Bank review in Ghana has shown that some projects, in dollar terms at the official rate of exchange, have cost as much as US$40,000 to US$50,000/ha.

4.57 The causes of these high dollar costs of irrigation projects in Africa are discussed in Annex 1. In summary they arise from:

- overvalued exchange rates and high taxes;

- high transport costs due to long distances and poor roads;

- the tendency for contractors to add to their bids an element to protect themselves against the perceived risks of commercial operations in the region;

- the absence of local manufacturers, assemblers, dealers or repair services for mechanical equipment;

- the scarcity of local managers and trained technicians, resulting in either inefficient operations or a need for costly expatriate supervision;

- the complexity of organisation and of administrative procedures often demanded by external financing agencies;

- the frequent lack of access roads or social infrastructure, or of any existing main irrigation works below which new perimeters can be constructed by simple expansion;

- a severe climate and violent flood regimes, necessitating the adoption of high irrigation duties and wide safety margins in the design of works.

The effect of some of these factors can be seen in the comparison below between Africa and India for the unit costs of some common items.

| Item | Mauritania | Burkina Faso | Niger | Cameroon | Malawi | India |
|---|---|---|---|---|---|---|
| | | ..............US$/unit............. | | | | |
| Cement (t) | 200 | 120 | 140 | 105 | 115 | 80 |
| Steel (t) | 2,300 | 1,090 | 760 | 850 | 1,000 | 560 |
| Diesel fuel (l) | 0.45 | 0.55 | 0.45 | 0.36 | 0.60 | 0.32 |
| Unskilled labour (man day) | 2.50 | 2.20 | 2.20 | 8.00 | 0.43 | 1.35 |
| Civil Engineer (yr) (5-10 yrs experience) | 10,000 | 10,000 | 10,000 | 12,500 | 4,600 | 2,700 |

## Costs of Six World Bank Assisted Projects

4.58 As already noted, the six World Bank assisted projects reviewed in detail in this chapter give an impression which contrasts somewhat with the general cost picture given above. Main features of the projects are given in Tables 20 to 27 and are summarised below. All but Riz Mopti have full water control. Of the remainder, Rahad was designed for 85% cropping itensity and the others for between 134% and 160%.

| Country | Project Name | Type of Irrigation | Irrigated Area (ha) | Construction Period |
|---|---|---|---|---|
| Madagascar | Lake Alaotra | Gravity | 10,000 | 1970-75 |
| Mali | Riz Mopti | Flood Control | 26,100 | 1972-80 |
| Cameroon | SEMRY I | Pump | 4,075 | 1972-76 |
| Madagascar | Morondava | Gravity | 3,800 | 1973-81 |
| Sudan | Rahad | Pump | 126,000 | 1975-83 |
| Cameroon | SEMRY II | Gravity | 7,000 | 1978-86 |

4.59 Apart from their agricultural objectives four projects also had settlement components, the two exceptions being Mopti and SEMRY I. All except Rahad, where the major crops are cotton, groundnut and sorghum, are based on rice production and all were implemented through project authorities or parastatals. All but Morondava broadly achieved their main aims although their performance differs widely, as shown below. It is important to note, however, that rates of return were estimated only at the end of the construction period, supposing that the output levels then achieved would be maintained or even increase further for the remaining 20 years or so of project life.

Project Achievements as Percentage of Appraisal Estimates

| Item | Lake Alaotra | Riz Mopti | SEMRY I | Morondava | Rahad | SEMRY II |
|---|---|---|---|---|---|---|
| Development area | 100 | 84 | 95 | 41 | 100 | 100 |
| Cropping intensity | 67 | - | 129 | 56 | 98 | 114 |
| Yields | 90 | 50 | 150 | 65 | 100 | 115 |
| Incremental production | 95 | 84 | 200 | 49 | 100 | 113 |
| Number of beneficiaries | 97 | 107 | 103 | 136 | 88 | 107 |
| Economic rate of return (a) | 200 | 121 | 209 | - | 148 | 133 |
| Total cost | 109 | 139 | 125 | 207 | 318 | 124 |
| Implementation period | 82 | 133 | 100 | 170 | 125 | 133 |

Source: Tables 20 to 26.

(a) As estimated at the end of the construction period.

4.60 Nevertheless, all projects had investment cost overruns, despite including price and physical contingencies in the original estimates. Main reasons were:

- delays in implementation, often caused by a lack of detailed studies and designs before project execution, which in turn led to a need to redesign during the construction period (Mopti, Morondava, Rahad);

- underestimate of original costs (Rahad);

- poor quality of initial works, which required additional expenditure on repairs during the construction period (SEMRY II);

- high cost inflation as a consequence of rising oil prices during the implementation period.

The most serious overruns were triggered by poor or incomplete designs at the appraisal stage. The resultant delays and cost increases at Mopti and Morondava made it necessary to reduce the project size; when combined with cost overruns, these reductions raised costs per hectare still further.

4.61 Total costs at completion are shown below in 1985 US Dollars. Only one project is in the US$15,000 to 20,000/ha range cited above, although there may be some underestimation of dollar equivalents because the Manufacturing Unit Value Index was applied to both foreign exchange and local costs, the latter not being separately identified in project audits.

| Project | Construction Cost (US$/ha, 1985) |
|---|---|
| Lake Alaotra | 1,250 |
| Riz Mopti | 650 |
| SEMRY I | 2,930 |
| Morondava | 15,030 |
| Rahad | 3,200 |
| SEMRY II | 9,600 |

4.62 The most costly scheme, Morondava, suffered special problems; its start coincided with the overthrow of the Government in 1972 which made its fate unclear, and its objectives were anyway more towards rural development than straightforward irrigation. The other costly project, SEMRY II, required repairs before it started operating. The remaining fully-controlled irrigation projects (Lake Alaotra, SEMRY I and Rahad) have costs which compare very favourably with those quoted earlier for other regions, and with the Francophone West Africa data in Annex 1 and para 4.54. Furthermore, as shown below, much lower figures are obtained for the above six projects if the costs of non-productive items such as settlement and social infrastructure are excluded. About 40% of the cost of Rahad and over 20% of that of SEMRY II were incurred in settlement, social and other infrastructure, and for farmer services.

Proportion of Major Cost Items at Completion

| Project | Total Cost Per Ha (1985 US$) | Irrigation Works | Administrative Overheads | Technical Assistance | Settle-ment and Others |
|---|---|---|---|---|---|
| | | . . . . . . . . . . . | (%) | . . . . . . . . . . . | |
| Lake Alaotra | 1,250 | 80 | n.a. | 8 | 12 |
| Riz Mopti | 650 | 51 | 34 | 5 | 10 |
| SEMRY I | 2,930 | 69 | 5 | 22 | 4 |
| Morondava | 15,030 | n.a. | n.a. | n.a. | n.a. |
| Rahad | 3,200 | 56 | 2 | 4 | 38 |
| SEMRY II | 9,600 | 51 | 8 | 20 | 21 |

Source: Table 27.

## Operation and Maintenance Costs

4.63 In its 1981 worldwide review of water management in 26 irrigation projects (only five of which are in Sub-Saharan Africa) the World Bank showed annual average O & M costs of US$145/ha for pump systems, US$31/ha for gravity systems with full control, and US$15/ha for projects with partial water control. The audits of the six African projects examined here provide only total overhead costs, hence O & M costs cannot readily be isolated. Furthermore since structures are relatively new at completion the full costs of operation and maintenance have yet to be incurred. Nevertheless, dividing total overheads during construction by the length of the construction period shows very little correlation with the figures in the Bank's review. The SEMRY I and Rahad pumped schemes are both less than 25% of the expected average: SEMRY II is almost five times the review average for gravity schemes and Mopti is twice the average for projects with partial water control.

4.64 The very high figure for SEMRY II may be explained by the fact that it includes fisheries and livestock components as well as by the costs of a heavy expatriate presence. The low cost for Rahad appears mainly due to lack of adequate funding. Even at completion it was reported that the Rahad Corporation was facing serious financial difficulties and that it lacked competent staff; the low expenditures suggest that the system could degenerate rapidly if more O & M funding is not provided. The low costs of SEMRY I appear due to inadequate initial maintenance works since it is reported that before 1975 the project agency lacked the necessary staff and equipment. Subsequent information on O & M costs for SEMRY I is unfortunately not available. In addition the Lake Alaotra and Morondava projects also faced serious operating and maintenance problems because the operating institutions lacked equipment, funds and managerial capacity. Lake Alaotra subsequently required a major rehabilitation programme with further assistance from the World Bank.

4.65 From these examples it is clear that low O & M costs are not necessarily an indicator of efficiency. On the contrary, they may indicate inadequate maintenance. This appears to have been the case in four of the six projects reviewed.

Returns on Investment

4.66 All projects except Morondava gave economic rates of return, as re-calculated at the end of disbursement, which were higher than those estimated at appraisal. But this was mainly due to higher international crop prices rather than greater than expected output, as can be seen below. Only the two SEMRY projects exceeded their physical production targets.

Production and ERR Estimates at Project Appraisal and Completion

| Project/Crop | | ....Appraisal.... Production (tons/yr) | ERR (%) | ....Completion.... Production (tons/yr) | ERR (%) |
|---|---|---|---|---|---|
| Lake Alaotra | - Paddy | 25,900 | 11 | 24,500 | 22 |
| Riz Mopti | - Paddy | 35,000 | 14 | 29,400 | 17 |
| SEMRY I | - Paddy | 15,960 | 11 | 31,835 | 23 |
| Morondava | - Paddy | 32,500 | 16 | 15,800 | negative |
| Rahad | - Cotton | 119,000 ) | | 114,000 ) | |
| | - Groundnut | 84,000 ) | 13.5 | 43,300 ) | 20 |
| | - Sorghum | 0 (a) ) | | 37,370 ) | |
| SEMRY II | - Rice | 47,000 | 15 | 53,000 | 20 |

(a) Not foreseen at appraisal.

4.67 Experience suggests, however, that some schemes which are considered economically successful at audit may fail to maintain their performance after the end of loan disbursement, either because of the cumulative effects of the inadequate O & M expenditures noted earlier, falling crop prices, or due to managerial decline in production support services. Thus a re-examination of the Lake Alaotra project by the World Bank after four years found that incremental annual production had dropped to only 10% of appraisal targets without any of the expected crop diversification or double cropping. The original ERR estimate of 22% became negative. Results of the Bank's Gambia Agricultural Development Project were also considered satisfactory at the end of disbursement, but cropping intensity deteriorated sharply thereafter. The Sudan Gezira project, after several decades of successful operation, deteriorated during the 1970s to the point of needing major rehabilitation; low cotton prices at that time initiated a vicious circle of lower project earnings, under-funding of O & M and declining crop production.

## Financial Results on Some Major Schemes

Farm Incomes

4.68 This section reviews the impact on farm incomes of four World Bank assisted irrigation projects implemented between 1970 and 1978. Results are summarised below. Values have been converted to US dollars at the time of project completion using exchange rates as quoted in the audit or impact evaluation reports, then updated to 1985 US dollars using the Manufacturing Unit Value Index.

Expected and Actual Annual Net Farm Incomes from Four Projects
(1985 US$)

| Project | Farm Size (ha) | Appraisal Estimate Without Project | With Project | At Completion | After Completion |
|---|---|---|---|---|---|
| Lake Alaotra | 3.6 | 511 | 1,888 | 1,149 | 636 |
| Riz Mopti | 3.3 | 498 | 657 | 261 | - |
| SEMRY I | 1.4 | 300 | 808 | 1,147 | - |
| Gambia ADP | 0.5 | 653 | 822 | 668 | 269 |

4.69 At completion all projects except Riz Mopti show increased farmer incomes compared to the without-project estimates. SEMRY I exceeded the predicted income at full development by about 40% in constant price terms, because of higher paddy yields (4.5/ha as opposed to 3.0/ha) and cropping intensity (163% as opposed to 135%). For the two other projects incomes at completion, although better than without-project estimates, were much below appraisal targets. Furthermore, as can be seen from the two projects for which later information is available, they tended to decline subsequently. In the case of Lake Alaotra, the estimated farm family income four years after completion fell to almost half of that estimated at completion, although it remained about 25% higher than the without-project situation. In the case of the Gambia Agricultural Development Project, family income seven years after completion was less than half of the without-project income calculated at appraisal.

4.70 Lake Alaotra project incomes fell short of predictions mainly because anticipated yields - 3 tons of paddy/ha at completion and 3.35 t/ha at full development - were not attained; they averaged only 1.6 to 2.3/ha. Use of herbicides and fertilizer was much lower than anticipated. Partly due to lower than expected flood levels, resulting from climatic deterioration, average paddy yields achieved in Mopti at completion were only about 70% of the appraisal forecast during years of good flooding and 50% during years of poor flooding. Furthermore, the improved farming practices foreseen were not adopted, and the paddy area per farm averaged only 2 ha against appraisal predictions of 4 ha. In the case of the Gambia ADP, incomes declined because most farmers did not double crop as was envisaged at appraisal.

Returns to Labour

4.71 Return to labour is often given at least as much importance by the African farmer as return on capital or land. Information on returns to labour on government irrigation schemes is unfortunately very limited. Where returns have been estimated they have seldom been compared with returns on other farming activities outside the irrigated perimeter. There are, however, limited data which suggest that on successful government schemes return to labour has been higher from modern irrigation than from non-project crops. In SEMRY I for instance, returns per man-day on labour for rice exceed those from outside rainfed crops by about 60%. In Niger, irrigated crops gave returns per man-day of FCFA 1,700 for sorghum and maize, and FCFA 2,500-3,000 for onions, while rainfed crops gave only FCFA 500-700 per day. An FAO study for the Gambia shows returns to be better for irrigated rice than for rainfed rice, although it also shows lower returns for wet season irrigation than for dry season, because of poorer growing conditions during the rains.

4.72 A comparison of labour returns to rice cultivation in Northern Sierra Leone, however, shows no marked difference between intensive swamp irrigation as promoted by the government, traditional swamp irrigation, or rainfed farming, as expressed in paddy output per day worked. This was despite the fact that farmers with intensive swamp irrigation benefitted from inputs and advice from an externally-funded area development project while traditional and rainfed producers did not. The better returns in the table below for the Bumban area were attributed not to the production system itself, but to favourable topography and greater skills due to a century-old tradition of rice cultivation.

Sierra Leone: Comparison of Labour Input and Paddy Output for Three Production Systems

| | Total Workdays Per Ha | Net Paddy Production/ha | Return per man-day |
|---|---|---|---|
| | | ...............kg | .............. |
| Intensive Swamp Irrigation | | | |
| Bumban | 198 | 1,090 | 5.5 |
| Matotoka | 426 | 1,280 | 3.0 |
| Gbendembu | 379 | 1,010 | 2.7 |
| Traditional Swamp Irrigation | | | |
| Matotoka | 451 | 1,220 | 2.7 |
| Upland Farming | | | |
| Bumban | 395 | 820 | 2.1 |
| Gbendembu | 380 | 1,030 | 2.7 |

Source: IUC, 1980.

4.73 A further comparison between returns from irrigated and rainfed cultivation, in this case in the Senegal Valley, is shown below. These data came from ORSTOM and FAO sources, with some interpolation. The Bakel region has a higher rainfall than Matam, which presumably explains the higher returns to labour from rainfed farming. The most important comparison is, however, between rainfed farming and large-scale controlled irrigation. Farmers' operating costs at the time of the survey quoted were heavily subsidised by the government, which made controlled irrigation of rice far more remunerative. However, without subsidy the return to labour drops almost to zero. Clearly only the government subsidy induced farmers to continue irrigation.

Returns to Labour From Three Production Systems in Senegal Valley, 1982

| | Net Value of Production (FCFA/ha) | Labour Requirement (workdays/ha) | Returns to Labour (FCFA/workday) |
|---|---|---|---|
| Rainfed | | | |
| Millet (Matam Region) | 16,960 (a) | 65 | 260 |
| Millet (Bakel Region) | 31,880 (a) | 65 | 490 |
| Receding Flood Irrigation | | | |
| Sorghum (Matam Region) | 6,530 (a) | 65 | 100 |
| Controlled Irrigation | | | |
| Rice and some vegetables: | | | |
| - with subsidy | 202,000 (b) | 107 | 1,887 |
| - without subsidy | 2,000 (c) | 107 | 20 |

(a) After deduction of cash expenditures, assumed to be 10% of gross value of production.
(b) After deduction of farmer's own cash expenditures but with incomplete cost recovery by SAED, calculated to be equivalent to a subsidy of FCFA 50/kg paddy, on 4 t/ha.
(c) Assuming full government cost recovery.

4.74 Even where, in the range of examples given above, modern irrigation gives better returns to labour this normally necessitates sharply increased input costs and greater dependence on the project authority. Hence risks, as perceived by the farmers, are also likely to increase. The wish to reduce risks may explain why, despite government rice subsidies, the farmers in the Senegal Valley are reported to neglect their irrigated areas to cultivate rainfed crops in years when there is abundant rainfall, even though these crops give lower returns to their labour. Another factor acting against irrigation could be a wish to secure traditional food supplies of millet and sorghum for home consumption. Only in years of low rainfall do farmers commit their labour fully to irrigated rice.

## Social Effects and Land

4.75 As noted earlier, most of the requirements of modern irrigation are in sharp contrast to the traditional approach to agriculture in Africa, and to become an irrigator on a major scheme therefore usually implies a profound social change. Government irrigation agencies have not, so far, been particularly successful in bringing about this change. Incompatibilities between the traditional outlook and project designs have frequently been aggravated by the fact that staff responsible on the government side have also been poorly trained and inexperienced, and by the failures of government agencies to provide the external services on which the transition from traditional farmer to modern irrigator depends. The principal areas of conflict between traditional attitudes and the demands of modern irrigation schemes relate to allocation of family labour between irrigation and other activities, choice of crops and market outlets, conditions of acquisition and occupation of land, and the uses made of project credit and inputs.

## Conflict with other Rural Activities

4.76 Project records contain many examples of the negative effects on irrigation efficiency of attempts by irrigators on major government projects to maintain the traditional diversity of their rural activities. On projects in Sierra Leone, the Gambia and Madagascar planting of wet-season irrigated rice was delayed until labour was released from work on rainfed crops elsewhere, thus reducing potential yields and overall irrigation intensity. Destitute pastoral nomads settled on small-scale government irrigation perimeters in Northern Kenya remained only until they had accumulated enough money to re-establish their herds and resume a nomadic life; plots were then left with women or sharecroppers. Many of the nomad tenants on the Sudan New Halfa scheme return to their plots only to grow cotton, or hire out their plots so that they do not need to return at all. Attempts by project authorities to control the number of animals owned by irrigators in the Sahel and Sudan have led to disputes, and animals have grazed standing crops and trampled irrigation channels.

## Conflicting Crop Choices and Markets

4.77 The farmer's priority to secure his traditional food supply has at times conflicted with government's wishes to promote unfamiliar foodcrops such as rice, or to produce cotton and sugarcane. In times of low cotton profitability in the Sudan irrigators have insisted on increasing the proportion of foodcrops, in conflict with state priorities for cotton production. Even in rice-eating areas the total of the paddy needed for family subsistence during the current year, stocks held over for the future, amounts used as payment for labour, and paddy distributed to kin in other places - especially in towns - can be substantial. Government procurement may be further reduced where there is reluctance to sell paddy because of the social implication that the family has fallen on hard times (e.g. in Sierra Leone), or due to leakage into parallel markets when official prices are low. Where the tenant is allowed to plant a part of his area with a higher-value crop of his own choice he has tended to concentrate his resources there, to the neglect of the "government's" crop. Although the governments of countries as different as India and the USA have left their farmers free to exploit the crops with comparative advantage in their particular region - leading to the establishment of corn, cotton or wheat belts - few African governments have so far felt able to allow this free play of market forces on their major irrigation projects.

## Land Acquisition and Distribution

4.78 Government acquisition of land for irrigation projects has often been a source of delay, expense and sometimes open conflict. Cadastral records seldom exist and frequently the identity of the ultimate rightholder has been hard to determine. The local leadership or individuals who present themselves as the owners may turn out to hold the land only by permission of some more distant power group, due to past transactions or conquest. Confusion has also arisen due to government statements that it has replaced the traditional system with modern land laws under which the central authorities now own all land. Even where this is legally the case there have still been disputes with local residents over compensation for loss of improvements, or of any past uses - e.g. flood irrigation or dry season grazing - which they have previously made of the project site. The offer to let them become settlers on the new perimeter has not always been accepted as an appropriate compensation.

4.79 With the arrival of the irrigation authority as a new centre of power in the project area, the right to allocate land passes from the traditional authority to the project agency. At times (e.g. in the Senegal Valley) attempts by local communities to irrigate on their own initiative have been prevented, or taken over, by the agents of central government. Violent social conflicts have also occurred - for instance in Northern Nigeria, when a community protested against being prevented from cropping project land after takeover by the project authority, but before construction work began. The river valley development authorities in Nigeria now only give priority to projects in places where the local community requests the installation of irrigation.

4.80 Other projects have been seen by local elites as a chance to divide the spoils of power with the central government, through preferential allocation of land to themselves and their kin. It has proved difficult to prevent powerful individuals from obtaining the better plots or from accumulating land under a series of family nominees. Such holdings can also be expanded de facto if an irrigator, anxious to comply with the costly production practices specified by the project authority so as not to lose his plot, but unable to get official credit, takes out a private loan from another individual and then finds himself unable to repay. A series of unofficial sub-tenancies or sharecropping arrangements then builds up, counter to the original intention of the project. In the Sudan Gezira project it is estimated that about half the tenants no longer take any part in the farming of their plots. All of these tendencies are counter to the aims of project designs, which usually specify the operation of each irrigated plot by a separate and independent tenant family. Their overall effects have often been to the detriment of project success.

## Conditions of Tenancy

4.81 The conditional tenancy arrangements on most government irrigation schemes have caused tenants to feel and behave as if they are little more than government labourers. Government staff have at times abused their considerable powers by unfair or corrupt allocation of land, water, services or inputs. The lack of full commitment to modern irrigation by farmers on many government schemes in Africa is in part a result of this contractual arrangement and the ways in which it is liable to abuse.

4.82 Freehold occupation has generally been rejected because governments would lose control over land use and crop production. In the Sudan, however, tenancy of the undivided farm can be inherited by one of the irrigator's family. Attempts have been made to reduce irrigators' feelings of external dependence by forming groups to take over water issues, maintenance, purchasing, services or marketing. However, so far few successes are reported. The World Bank notes the apparent reluctance of the authorities to attempt this transfer in the case of Cameroon SEMRY I, the Mali Riz Mopti project or on the Senegal Polders. It is difficult to tell whether this might be due to genuine concerns over a possible fall in project efficiency, lack of evidence that the irrigators themselves were interested or capable, or simply reluctance of the bureaucracy to abandon power and influence.

4.83 So far as is known no government schemes in the region incorporate specific arrangements for tenant appeal to an independent authority against arbitrary or corrupt actions by the project management. The possibility of such redress could do much to reduce tenants' feelings of vulnerability and hence increase their commitment to modern irrigation projects.

Differing Priorities in the Use of Credit and Inputs

4.84 To obtain a plot on a government irrigation project may give access to a useful range of subsidised inputs and credit. These can be diverted by the already well-off individual into a variety of business interests, while the plot can generate income from the sharecroppers who in fact farm the land. A study in Zambia showed that village elders tended to divert resources and effort into other activities to the detriment of the small irrigated plots which they were allocated, while young or poor tenants without other interests obtained better output by using government support in the way intended.

Effects on Women

4.85 In many parts of SSA women are financially semi-independent within the family. Neither they nor their own children, who they are responsible for feeding, will automatically share in the project benefits if their husbands become commercial irrigators. In some cases they may in fact become worse off. For instance in the humid zone in parts of West Africa women traditionally cultivate rice in inland swamps for subsistence, while men cultivate upland rice and rainfed cash crops. Several projects have sought to develop swamps to produce rice as a cash crop. Since only men are eligible for production credit, it is they who have been encouraged to occupy the best swamplands once used by women. Women have as a result been left with only marginal areas, or the possibility of working as labourers on men's crops.

Effects on Surrounding Areas

4.86 Apart from the demolition of indigenous settlements to make way for project works, government irrigation projects have resulted in:

- loss of large areas of traditional flood irrigation, especially in West Africa, not only on the project site itself but on upstream reservoir sites and on downstream land affected by changed river flows;

- reduction in the areas of, or loss of access to, riverine dry-season pasture;

- changes in natural populations of fish ;

- competition for fuelwood and consequent deforestation, due to the demands of the suddenly increased local populations;

- conflicts due to grazing, accidental or at times deliberately arranged, by the livestock of local or transhumant pastoralists on irrigated crops.

Social Impact - Conclusions

4.87 The end result of the difference in attitudes, aims, and priorities between governments and tenants on modern irrigation projects has very often been lower-than-planned scheme efficiency due to lack of commitment by the irrigators. While governments and funding agenices have seen modern irrigation as a major means of reducing agricultural risks, the irrigator has often approached it as an exchange of one risk (inadequate rainfall) for another set which may be equally threatening - i.e. dependence on government agencies and their officials which he sees as alien to his community, not necessarily sympathetic to his family interests, and unreliable in fulfilling their promises. Poor performance of state agencies has confirmed his fears so that he has preferred to retain a traditional diversity of activities where possible.

4.88 A frequent consequence has been a downward spiral of scheme degeneration. Unscrupulous individuals have seized opportunities to exploit positions of responsibility or power to their own advantage. Irrigators have become frustrated or disillusioned and water discipline has declined. Only in a relatively few cases has the fundamental conflict between traditional African attitudes to agriculture and the intensive demands of modern irrigation been satisfactorily resolved. Where acceptable commitment of the irrigators has been obtained it has usually been where good commercial opportunities have provided a strong incentive or where few other options exist for the irrigator, and above all where scheme management has been capable, consistent and firm.

## Health and Nutrition

4.89 The substantial bodies of standing or moving water created by the construction of major government irrigation schemes have provided new breeding grounds for the vectors of malaria, yellow fever, ochocerciasis, schistosomiasis and several other diseases. Flooded rice has created especially favourable vector habitats. The gathering on project sites of large numbers of people, some already infected with these diseases and others with little or no natural resistance, has provided the potential for their epidemic spread. Seldom in project documents is there specific reference to limiting vector breeding by appropriate design of works - e.g. by the minimisation of open stagnant water and use of steep shore lines which limit weedy habitats - or to locating villages well away from open water. It is doubtful whether such steps have often been taken in practice. In addition there are seldom at first any sanitary facilities at project sites, bringing additional risks due to contamination of water sources with gastro-intestinal diseases.

4.90 The success of projects in avoiding these problems has been variable. In most major investments there has at least been financial provision for health monitoring, prophylaxis and vector control for mosquito-borne diseases and schistosomiasis. Whether these components have succeeded appears to relate to whether, in the face of often competing needs, the funds were actually released for these purposes and how successfully the facilities, if installed, were managed. In Kenya many cases of malaria and schistosomiasis were reported initially at both the Mwea and Bura projects. At the former they have since been contained by determined public health campaigns. At Bura, so far, they have not. Failure to construct public sanitation at the Bakalori project in Nigeria made it necessary for the population to rely on canals for water supply, which soon became contaminated and greatly increased schistosomiasis. On the Sudan Gezira project the incidence of this disease was estimated at 9% in the 1940s but is now thought to have reached 50%. Various projects have recorded outbreaks of gastro-intestinal disease where no domestic water supplies were provided. And it seems likely, although this is not documented, that unless the current poor maintenance of government irrigation projects can be reversed there will be, through proliferation of weedy, badly-drained areas, further rises in vector-borne diseases among irrigators and project staff.

4.91 Effects of public projects on the nutrition of irrigators and their families have not been systematically assessed. It seems fair to suppose, however, that there would be a strong correlation with changes in income, as discussed in paras. 4.68 to 4.70. Complicating factors are the compulsion, on some government projects, to concentrate on non-food crops, or on rice which may not be the preferred staple of the irrigator. Low yields or prices in such cases can leave the irrigator with neither his subsistence food supply nor the money with which to buy what he needs. A further complication is the semi-independence of the sub-units of the African family. In the example of swamp rice development already cited the income lost by women was presumably reflected in a poorer diet for them and their children. One observer has described the irrigators on unsuccessful irrigation schemes in Somalia as some of the poorest, worst fed people in the country.

## E. Results of Government Investments in Small-scale Irrigation

4.92 The final section of this chapter compares the results of some small-scale irrigation components of externally-financed government rural development and drought relief projects with the results of major schemes. An initial comparison suggests that in many cases "small-scale irrigation" was in fact simply a miniature version of the technically sophisticated, fully-controlled irrigation promoted in larger projects. Institutional arrangements were generally the more important difference. In drought relief projects crop choices were usually left to the farmer although in rural development projects governments often aimed, as on major schemes, to produce foodcrops (usually rice) considered essential for national food self-sufficiency.

### Physical Achievements

4.93 A small-scale irrigation target of 500 ha was achieved in Burkina Faso in a project where government supervisory staff were double the number originally planned, and where farmers had a market for vegetables; but in another project a similar component failed, largely for lack of competent staff to promote development. In Senegal only 23% of an intended 1,650 ha of small-scale irrigation were built. Constraints were a lack of technical advisers, inadequate physical surveys and failure to recruit a competent contractor. In the same area, however, farmers made good independent progress with protective works against salt intrusion, their main immediate problem, although receiving only technical advice from project staff. In Mauritania farmers showed little enthusiasm to rehabilitate or construct new small-scale, fully controlled irrigation for rice production since flood-recession cultivation of coarse grains was their main priority. The project barely reached a half of its construction target.

4.94 Results of swamp or lowland development have been, if anything, even more variable. In one case in Burkina Faso it is reported that farmers believed bottomland development to be to their immediate benefit. They contributed their labour freely and the component target was exceeded by 15%. In a second case, however, only 50 to 70% of targets were achieved due to land tenure problems, poor site selection, and input supply and marketing constraints. In a third case swamp development was scrapped altogether due to cost overruns on other project components, which were given priority in use of funds. In one project in Sierra Leone negligible progress was made with bottomland development in four years, mainly because soils were found to be too sandy for good water retention, plus the fact that the supervising engineers were withdrawn by the project authority when progress was found to be too slow. Elsewhere a good project manager exceeded physical targets, but swamps tended to be abandoned later in the face of labour competition from upland crops and because of government insistence that rice should be purchased at only a half of the price obtainable on the free market. In Liberia good progress was made with lowland development in places with population densities over about 70/km2, but not in less populated areas. Attempts to upgrade existing swamps in Liberia were abandoned when the full extent of the works which were needed became evident.

## Costs

4.95 It is often said that per hectare costs of small-scale irrigation are less than for large, modern schemes. Certainly the beneficiaries, by their contribution of labour or other resources, usually relieve government budgets of a larger proportion of construction and O & M costs. In an economic assessment, however, the costs of beneficiary contributions should also be included. And considering the strong competing opportunities which in reality often exist for farmers' labour, the economic value of these contributions may be considerable. Unfortunately beneficiaries' contributions were not recorded in any of the evaluations of small-scale irrigation reviewed, which quote only financial costs to the government budget.

4.96 Where small-scale projects have involved concrete structures and mechanised construction methods they have inevitably incurred diseconomies of scale and high positioning costs. Due to the small jobs concerned they have often attracted only second-rank contractors. Government supervision costs, which are also not always included in quoted expenditures, are furthermore likely to be higher than for large, concentrated developments.

4.97 Many of the quoted figures for government costs of small-scale irrigation nevertheless tend to be lower than the hectare costs for comparable large projects. In Annex 1 US$3,200/ha is estimated for village schemes with fully-controlled surface irrigation on river terraces, in comparison to US$4,800/ha for large schemes on similar sites. Simple low-pressure sprinkler systems suitable for individual small farmers cost an estimated US$3,200/ha, while the high-pressure equipment necessary for large estates is likely to cost US$4,400/ha or more. A recent unpublished review by FAO gives figures of around US$2,500/ha for small low-lift pump systems, and substantially lower costs for simplified systems. Small-scale developments have the further advantage that they have not required costly associated investments in roads, settlement or social infrastructure.

4.98 Where dug wells, boreholes or small dams are involved, however, hectare costs may be higher than for most large-scale surface irrigation works. In Annex 1 figures of up to US$20,000/ha are estimated for tubewell development in Francophone West Africa, and although these may be overestimates the FAO source quotes US$5,000/ha (Niger) and US$8,750/ha (Burkina Faso). On a more hopeful note, BRGM considers that with more widespread adoption of tubewell technology and a growth in local manufacturing and support services, capital installation costs of tubewells could fall to around US$3,000 to 4,000/ha. But to this must be added the often substantial costs of pump operation and maintenance. Government costs for construction of irrigation systems under small dams are also substantial - for vegetable production in Burkina Faso FAO quotes from US$4,100 up to US$8,900/ha.

4.99 Finally, it has been calculated that between 1966 and 1983 the accumulated costs to the government, donors and external technical assistance agencies of a small drought relief scheme for nomads in northern Kenya reached a combined total of US$63,140/ha.

## Crop Yields and Production

4.100 Crop yields and intensities on small-scale schemes appear to span the same very wide ranges that have already been reported for major projects. Because they are smaller and scattered, however, small perimeters may have even greater problems in securing inputs, services and timely technical advice than their large-scale equivalents. Hence project strategies based on introducing intensive, modern techniques are even more vulnerable. This is reflected in some project results. In Burkina Faso, for instance, bottomland paddy yields ranged down to only 50% of the appraisal estimate of 1.5 t/ha due to inadequate fertilizer supply and training. In Liberia the appraisal estimate of 3.5 t paddy/ha was exceeded by the few farmers who obtained all the recommended inputs, but most did not succeed in doing so and hence average yields fell short of expectations.

4.101 Production estimates were more often achieved where the project design involved smaller technical changes, where existing types of irrigation were expanded rather than more intensive new methods being introduced, where population pressure or climate gave the farmers few other options, or where small-scale irrigation allowed highly profitable crops such as vegetables to be grown.

## Institutional Performance

4.102 Small-scale irrigation components have generally been the responsibility of a multi-purpose project unit, or executed through the coordinated action of a group of separate institutions. This contrasts with the single, specialised irrigation agencies which usually implement major schemes. Because the success of small-scale irrigation has generally depended on the cooperation of a larger range of government institutions and individuals - for instance the departments of irrigation, extension and rural works, as well as banks - budgetary and institutional problems have tended to be even more common than for major schemes. Several project evaluations also mention lack of counterpart funds and budgetary delays, often aggravated in the case of small-scale irrigation by competition for funds and staff between project components. Government staff generally have had even less training in and experience of irrigation than those allocated to major schemes. Staff problems have been compounded by the difficulties of giving sufficient attention to often scattered irrigation sites.

## Socio-economic Factors

4.103 Due to the often considerable technical sophistication incorporated into the designs of small-scale irrigation components and the tendency, as for major schemes, for governments to try to control output prices and marketing, many of the same conflicts have arisen between farmers and governments. As on major schemes, farmers have neglected or abandoned irrigation when there were better returns to be had from their labour elsewhere. As one evaluation of a rural development project in Burkina Faso observes, farmers' participation is "a sound principle but it should be recognised that farmers may have different priorities".

4.104 In contrast to major schemes, few small-scale developments have involved land expropriation. Nevertheless they have not always been free of tenure problems. Failure by communities to agree among themselves on land release or allocation has been a limiting factor for swampland development in several projects. Proposals to distribute credit to individuals appear in some cases to have raised opposition from local leaders, who may have feared that their holding of small farmers in semi-serfdom would be broken. Distribution of credit to women farmers has proved as difficult as for other forms of agricultural development, and there has been the same tendency for women to be the losers when projects seek to commercialise what was originally subsistence food production.

# V. CONCLUSIONS AND RECOMMENDATIONS

## A. Opportunities and Constraints for the Future

### Technical Needs

5.1 Chapter II shows that there is considerable technical potential for further development of irrigation in Sub-Saharan Africa. As the review of project experience makes clear, the constraints to its exploitation are mainly institutional, economic or social, and not technical. Nevertheless further technical development and solutions to some specific technical problems could improve future prospects. Agronomic developments such as:

- better weed control (especially of wild rice and sorghum species, sedges - especially Cyperus rotundus - and water weeds);

- clean, high-quality seed of rice varieties better adapted to project cropping schedules and local consumer preference;

- improved control of or resistance to problems such as rice blast, the cotton pest complex and vegetable pests and diseases,

would all facilitate the intensive irrigation desired by governments, and would raise farmers' returns as well as improving the lot of the small-scale or traditional irrigator. Since foreign exchange allocations for import of inputs and fuel are likely to remain restricted, there is also an urgent need to develop production systems with lower demands for imported inputs, and which in the case of pumped systems using imported fuel, maximise water efficiency.

5.2 Better scheme designs and equipment would allow irrigation in future to be adapted to the African farmer, rather than vice versa as in the past. If more of the O & M of major government projects is to be successfully handed over to irrigators, it will be necessary to adapt irrigation system designs. Schemes need to be laid out as a series of modules each capable of operating semi-independently, each module being matched in size to the number of irrigators in a group (see Annex 1, para 45). Designs are required which can be maintained by relatively unskilled local contractors hired by the irrigators, or by irrigators themselves, and which can if necessary continue to operate reasonably well even under sub-optimal maintenance. In some cases it may be appropriate to accept higher capital costs in order to secure cheaper maintenance requirements, on the grounds that investment funds may in future be easier to obtain than a long term guarantee of operating budgets. More systematic provision should also be made for drainage in the design of large-scale projects. Either drains should be built at the same time as the irrigation network; or else protected drainage reserves, groundwater monitoring arrangements and a secure future supply of funds should be included in the original project design, so that drains can be built immediately the need subsequently becomes evident. Improved base data - on soils, topography, climate, hydrology and crop water requirements - are likely to be needed if many of these changes are to be successfully introduced.

5.3 Other technical needs include:

- simple designs of pumps and other items of small-scale equipment, suitable for local manufacture and capable of being repaired and maintained by the farmer or village mechanics;

- further progress with the challenging problem of lowering the cost of solar-powered pumps, so as to make small-scale irrigation independent of outside fuel supplies;

- low-cost irrigation systems or methods which can give acceptable returns when used only for supplementary watering of traditional crops.

5.4 More groundwater surveys could:

- accelerate the spread of small-scale subsistence irrigation to semi-arid areas where it can provide a lifeline for populations at risk;

- facilitate the expansion of small-scale vegetable production and other high-return activities;

- facilitate the introduction of conjunctive use of surface and groundwater on major African irrigation schemes;

- if groundwater recharge is limited, warn of over-exploitation of aquifers.

5.5 Finally, more systematic attempts could be made to adapt some of the low-cost small-scale systems of Asia and North Africa to local conditions and materials, to arrive at irrigation methods which are more readily accepted by individuals or communities as components of rural development projects.

## Economic Considerations

5.6 The economic viability of further government investment in modern irrigation schemes is constrained by the high current costs of construction, operation and maintenance, and the low import parity prices of most of the crops for which there is an adequate market.

5.7 These aspects are examined in more detail in Annex 2. The annex shows that for an irrigation scheme constructed over eight years and reaching full production in year 12 - a scenario fairly representative of past results - it is necessary to generate a net annual benefit at full development of about US$150 on each US$1,000 invested in irrigation works to give a return of 12%. If a return of only 7% is regarded as acceptable the net annual benefit must still be around US$100. Taking rice as a representative crop and assuming that, under relatively efficient production, government and on-farm operating costs absorb only 30% of the gross value of output, it is possible to calculate the incremental annual production needed to justify some typical costs of irrigation works. These figures are shown below. Two import parity rices are given for rice. The figure of US$180/t represents a project located near to a major port and supplying its urban population as an alternative to food imports. US$300/t is taken to represent the price which would be incurred by the state to supply food to people living in the distant interior of the Sahel.

Incremental Paddy Output to Justify Typical Investment Costs of Irrigation (assuming 68% milling efficiency and operating costs equal 30% of gross output value)

| | | ......Desired Rate of Return....... | | | |
|---|---|---|---|---|---|
| | | ....12%.... | | ....7%.... | |
| Rice Price (US$/t) | | 180 | 300 | 180 | 300 |
| New Irrigation | | ...........t paddy/ha/yr........... | | | |
| - Partial control | (US$4,000/ha) | 7.1 | 4.3 | 4.7 | 2.8 |
| - Full control | (US$8,000/ha) | 14.2 | 8.5 | 9.4 | 5.7 |
| Rehabilitation (a) | | | | | |
| - Major repair | (US$1,500/ha) | 2.7 | 1.6 | 1.8 | 1.1 |
| - Minor repair | (US$ 750/ha) | 1.3 | 0.8 | 0.9 | 0.5 |
| Traditional Systems | | | | | |
| - Rising flood | (US$1,500/ha) | 2.7 | 1.6 | 1.8 | 1.1 |
| - Swamp | (US$ 500/ha) | 0.9 | 0.5 | 0.6 | 0.3 |

(a) This case assumes works over three years and full benefits in year six.

5.8 The figures show clearly the combination of high yields and cropping intensities which would be necessary to justify new investments in fully-controlled irrigation. Even the most successful of the six projects reviewed earlier could reach only the lower of the two rates of return at the higher of the two rice prices. This implies that while new, fully-controlled irrigation costing US$8,000/ha might perhaps be justifiable in, say, Chad, it is unlikely to be economically viable in the lower Senegal Valley nor in many other parts of Sub-Saharan Africa. Bearing in mind that with incomplete water control only one crop is likely to be possible per year, the figures for new partially-controlled irrigation are almost as unfavourable despite the lower capital cost. On the other hand the figures suggest that there is a much better economic case for more limited capital investments in rehabilitation, and in developing traditional forms of rice cultivation on the rising flood or in swamps.

## Social Factors

5.9 Much could be done in theory to make participation in major irrigation projects more attractive to farmers. Perhaps the most important change would be to minimise the dependence of the proposed farming system on external factors or agencies, particularly imported machinery and materials (see also under technical needs), as well as on state support and marketing services which the irrigators distrust. Participation would also be made more attractive to farmers if the project authorities could:

- allow a freer choice of crops, to the extent that system design and availability of water allows;

- design projects to be compatible with a greater diversity of other agricultural activities outside the irrigated plot;

- make more specific provisions to secure all food needs from the irrigated farm, including both the quantities required for family subsistence and for all other uses;

- promote production practices and systems of project organisation which minimise cash costs and indebtedness, and hence lower the risks of modern irrigation as perceived by farmers;

- design cropping systems on major schemes to maximise returns on labour rather than on land or cash committed;

- give greater security of land tenure, at least by the wider issue of inheritable tenancies and preferably linked with the introduction of an independent appeal mechanism against the arbitrary application of sanctions by the project authority.

Above all, since the social changes in adopting intensive modern irrigation on a government scheme are often profound, irrigation agencies should allow more time for communities to become adapted.

5.10 Such changes might make individuals or communities more prepared to release land to the government for project construction. The diversity of agricultural activities would reduce the tendency for non-participating sections of the family to become poorer as a result of irrigation, as well as tending to improve diet and nutrition. Conflicts with livestock interests are also less likely if livestock needs have been provided for at the outset in project design, rather than emerging later as a social problem to be solved.

5.11 However the diversity of crops which the farmers would probably want to grow would make the scheduling and efficient operation of the existing type of modern irrigation system extremely difficult, raising the need for a new approach to design (see above). In addition, with more non-irrigated activities competing for labour, the standard one to five hectare plots of modern schemes would probably be too large for one family, even with mechanical land preparation. In practice, therefore, the full adoption of this package comes closer to a recipe for expanding traditional or small-scale private irrigation, rather than modern irrigation.

## Health Hazards

5.12 Various measures could be taken which together stand a good chance of containing the health hazards due to large-scale irrigation at tolerable levels. They include:

- vector control;

- appropriate siting of human habitations;

- installation of clean public water supplies and sanitation;
- monitoring of disease levels, linked with quarantine, prophylactic or curative measures;
- health awareness campaigns.

5.13 The necessary health and public water supply infrastructure is variously estimated to cost between 1 and 2.5% of total project cost. Adequate scheme maintenance, which will tend to reduce areas of stagnant water, and where feasible the operation of the system also to minimise the multiplication of vectors, can contribute further to lower risks. Although there are few technical obstacles to this combined approach it requires technically proficient staff, and above all considerable vigilance by the project management.

## The Need for New Policies, Institutional Change and Management

5.14 Policy change and improvement of institutional performance by governments are essential for many of the opportunities indicated above to be turned to realities. A fundamental need is to improve the overall profitability of irrigation, so as to raise farmer commitment, and to attract private sector participants both into production and supporting activities. The problems to be overcome in doing so are formidable. They include adjustments in the terms of trade between rural and urban areas, better producer incentives, improved selection of project objectives, more realistic project designs, a lowering of government costs, withdrawal from activities more appropriate to the private sector and improvement of cost recoveries.

5.15 Manpower constraints, and particularly a lack of capable managers, are likely to be met at many levels. Even if governments can bring themselves to make the hard policy decisions and difficult institutional reforms which are needed, they will frequently lack managers with the necessary executive abilities, especially in the case of complex or large-scale projects.

## B. Future Development Strategies

### At National Level

5.16 Irrigation and other forms of agricultural intensification will eventually expand in Sub-Saharan Africa in response to population pressure as they did in similar circumstances in Asia. However, as the Asian experience shows, this will take time. If large modern irrigation schemes are to be constructed it will also be costly. Few African countries still have time on their side. Many are now critically short of resources, heavily in debt, and already faced with exponential rises in their food imports.

5.17 Meanwhile, as the data on growing periods in Table 1 show, two-thirds of the countries in the region have at least part of their area with a growing period of over 200 days. In the absence of detailed rainfall probability data, this can be considered as the likely threshold for commercial, rainfed cultivation of staple foodcrops. Twenty-two of these countries are calculated by FAO to have not yet reached their full population-carrying capacity for low-input rainfed farming. Another 12, although they have already exceeded their population carrying capacity at low input levels, have a growing period of over 200 days throughout their territory. In all of these countries, which between them contain over 85% of regional population, intensification and in some cases expansion of rainfed agriculture is likely to be still possible. Rainfed development demands fewer scarce government financial or managerial resources; less imported materials, fuel and equipment; does not require profound social change; and has a quicker impact. Irrigation may eventually be essential in these countries and pilot projects to evolve an institutional framework and to acquire the necessary skills may be justified. But in the short and medium term in these countries rainfed development is likely to be a better national strategy for food supply than large-scale modern irrigation.

5.18 As shown in para 2.7 only eight countries, containing the remaining 14% of regional population (Senegal, Burkina Faso, Niger, Mauritania, Somalia, Botswana, Mali and possibly Kenya) have seriously restricted future rainfed opportunities. For them, irrigation in some form may be the only short or medium-term alternative to ever-rising levels of food imports. In some places, where populations are remote from possible points of food import, the import parity prices of locally-grown cereals may justify the construction of new schemes; but most of these countries face the same economic limitations on new irrigation as the rest of the region. Many, however, have existing areas of modern irrigation which could benefit from relatively less costly and more profitable rehabilitation. In some other cases schemes could be expanded below existing main works at low cost. In Senegal and Mauritania, for instance, completion of the Diama and Manantali dams will allow full water control on greatly increased areas of existing irrigation. Where the chance exists, rehabilitation of major schemes is likely to be a more appropriate strategy than building new ones.

5.19 These eight countries also have further potentials for small-scale or traditional irrigation which, although they might not on their own satisfy all national food needs, could also respond fairly quickly to improved government support and make a useful additional contribution to food supply. But if the contribution of small-scale irrigation is to be maximised a simpler and less costly approach will be needed than in the irrigation components of many previous rural development projects. Experience stresses the needs, as in Asia in the past, to:

- regard willingness by the intended beneficiaries to allocate land, as well as their financial participation, as pre-conditions for any major government involvement in development;

- allow small-scale irrigation to find its own place among the various activities from which rural people make their living;

- allow the irrigators to determine their own cropping patterns on the basis of local comparative advantage;

- limit government interventions to technical support and supply services, with the addition of credit if the aim is commercial production.

In the African context it would also seem desirable, on the evidence of Boserup and others, to plan for stepwise modernisation of small-scale irrigation starting from a low base, rather than promoting the immediate adoption of highly intensive methods which are not yet justified by existing land shortage and demographic pressures.

5.20 Opportunities also exist in most of these eight countries to make smaller improvements in the productivity of traditional, often uncontrolled, swamp and flood irrigation. Since the areas are in some cases substantial, the aggregate contribution of even a low percentage increase in average yields could be significant. However costs would have to be minimised. For flood and swamp irrigation countries should consider an approach similar to rainfed rural development projects, seeking opportunities to introduce simple improvements to cultural practices, better adapted varieties or a very few purchased inputs, and giving technical advice to communities or individuals on how to develop local water resources at low cost. No land distribution should be attempted here, the social system should be accepted as it stands, and government involvement in the construction of works should be minimised. Cost per beneficiary would have to be kept low.

5.21 For countries outside the above group of eight, even though they may be in a position to adopt rainfed development as their main shorter-term national agricultural strategy, the rehabilitation of modern schemes and support for small-scale and traditional irrigation can also make a useful, if supplementary, contribution to national food supply.

5.22 With regard to rehabilitation, few governments can in practice discard substantial past investments in irrigation infrastructure simply because they have become inefficient, nor abandon large numbers of existing irrigators, nor accept the consequences for food imports or export earnings. Only where there are overwhelming technical or social limitations is it likely to be preferable to abandon an existing irrigation perimeter. It is, however, essential that rehabilitation, wherever located, should also tackle the underlying institutional, financial and social causes of past scheme degeneration. Otherwise the benefits of physical reconstruction will be only transient.

At Local Level

5.23 Twelve countries (Mauritania, Niger, Burkina Faso, Mali, Chad, Sudan, Ethiopia, Somalia, Kenya, Tanzania, Zimbabwe and Botswana) have a rainfed growing period of less than 120 days on over a quarter of their territory and a further ten have up to a quarter of their area in the same semi-arid zone. In the high risk tracts of such countries, whether or not rainfed development is the overall national priority, localised government investments in irrigation are likely to be needed as a means of increasing food security. Special prominence needs to be given to small-scale developments or improvement of traditional methods, along the lines already described. Distribution of works should be matched to the distribution of the population at risk.

5.24 Such irrigation needs to be designed from the outset to complement other rural activities. It could be based on wells, earth dams, stream diversions or water harvesting depending on local circumstances and is likely to be used mainly for subsistence crops and some vegetables. It could do much to reduce rural suffering and the costs of periodic drought relief. It could help to feed people in remote areas to which it is difficult and costly to transport food, and for whom the only alternative is resettlement - at considerable cost - elsewhere. Due to the distant locations, the economics of such developments are likely to be favoured by the high import parity prices of any food which they produce. However the financial resources of the beneficiaries are likely to be very limited, raising the possible need for capital costs to be grant-funded by governments if development of this sort is to take place on any scale.

## C. The Justification of Irrigation Project Proposals

5.25 It is natural that a nation with a dry climate should feel deeply about development of water resources; this urge has been followed throughout human history in arid areas - without the benefit of economic analysis. Capture of large rivers has been seen by governments not just as the means to irrigate but also as an eventual source of hydro-electric power for new industrial development. If the country has few other obvious resources to exploit, the political case for investment in a large multi-purpose dam becomes very powerful.

5.26 In this situation it may be difficult for government planners to reach a fair assessment of the real benefits and costs of the venture. Projects given prominence in national development plans have not always proved economically acceptable to the prospective funding partners. There are also cases when consultant companies who are engaged to undertake feasibility studies have given full attention to the technical aspects of the scheme, but out of respect for the government's anxiety to start the project, have made light of serious economic and social constraints. The financing agency has then also challenged the conclusions of the consultants.

5.27 Understandably, a government which has publicly committed itself to an important scheme may be impatient of objections on economic grounds by financing agencies. Controversy often centres on the internal economic rate of return on the investment. Although that percentage figure is only one of the indicators of the project's merits, in practice it is often believed to be the definitive test which decides whether the investment is justified or not.

5.28 In fact the economic rate of return is only concerned with those effects of the project which can, theoretically at least, be measured in monetary terms. There are inevitably other effects to be taken into account in making a responsible judgement on whether the project should proceed. A major irrigation project usually brings substantial changes in the environment and in the way of life of the people in the project area. The more direct economic costs and benefits - expenditures on civil works, equipment, inputs and services, and the increased output of crops - can readily be estimated and are the core of the economic analysis. But there are also indirect effects inside the project area which can be assessed with less confidence, such as the influence on local fishing, livestock husbandry or fuelwood collection. Furthermore there may be effects on agriculture and economic activities outside the project area, particularly losses of flood irrigation due to altered river regimes. Beyond this again are other effects, which may be only vaguely perceived but are still of great importance, and which directly affect the quality of people's lives rather than their incomes and material welfare. While some of these various effects are negative - and planners have been justly criticised for under-estimating or ignoring them in the past - others may be positive. Major irrigation projects, because they create many forms of employment and stimulate demand for a wide range of goods and services from both rural and urban sources, tend to have substantial multiplier effects. This may be considered an economic advantage over other development options, even though their calculated rates of return are the same.

5.29 Because of these considerations the basic economic rate of return calculation of every irrigation project needs to be supplemented by a systematic review of all other important effects than can be foreseen. The tendency to play down effects which cannot be evaluated, but which may be important, needs to be resisted. The more significant of these effects are likely to be found among the following:

- changes in non-irrigated production and employment opportunities inside and outside the project area, not only in crop production which is normally measurable, but also in fishing, livestock grazing, fuelwood collection, or non-agricultural activities;

- social effects of displacing people from the area taken by the reservoir;

- contribution of the project to reduction of special famine relief expenses in drought years and to the saving of lives in extreme cases (justification for nineteenth century irrigation schemes in India rested heavily on these grounds and the same consideration may be relevant to irrigation in Sahelian countries);

- contributions to the development of depressed or disadvantaged regions;

- the possibly greater multiplier effects of major irrigation investments in comparison to, for instance, rainfed agricultural development;

- contributions to national food security;

- occupation of politically insecure or frontier areas;

- dietary changes for the beneficiaries;

- effects on health, risks of disease and costs of disease control;

- special effects on the welfare, work and leisure of women;

- sociological effects concerned with changes in way of life, effect on traditional authorities, community relations, etc.;

- effects on the native fauna, flora or the environment;

- in extreme cases, the ability of irrigation to reduce the risks of massive migrations of population, famine, riots or war.

A simple statement of all such effects in plain language is essential. If project alternatives are being compared it may be possible to rank the unquantifiable effects in order of importance to the nation, and then grade each project option according to its likely contribution under each heading.

5.30 In addition there is the problem of costs and benefits which do not fit the time-scale of conventional project analysis. For instance, for many African countries in addition to the eight listed in para. 5.18, irrigated farming is likely to become a long-term national necessity for the feeding of their populations in the twenty-first century. The building of the institutions, services and traditions necessary for highly organised irrigation takes many years, and this fact will clearly add to the justification for starting irrigation development - at least at pilot level - long before the schemes become a necessary protection against large-scale starvation. On the costs side, a scheme in which soil erosion into the reservoir is negligible is clearly preferable, other things being equal, to one where the reservoir will silt up in fifty years, even though the cost of this event would not be fully reflected in a conventional project analysis, which has a time horizon of only twenty-five or thirty years. Very long-term costs and benefits of this type may often be associated with irrigation projects which cause important changes in the environment. The "intergenerational effects" of environmental changes also deserve greater attention in analysis of irrigation projects.

5.31 A major irrigation scheme, especially if it involves a large river dam, is likely to be planned as an all-or-nothing affair and is hence a "lumpy" investment. For a small country the investment may be so large that it not only pre-empts resources that could otherwise be used for several other competing projects, but it may also commit the country to a heavy load of debt servicing. Projects which offer the alternative of phased development may make it possible to reduce these difficulties. In addition phasing allows practical problems which only become clear during development to be progressively assessed and dealt with over time. The advantages of flexibility are likely to apply particularly to the development of small-scale irrigation, where the main investments may be numerous wells, weirs or simple dams that can function independently. Furthermore the effects of small-scale projects on the national economy, the environment and the community are likely to be less dramatic; consequently those costs and benefits which cannot be covered by basic economic analysis are likely to be more manageable.

## D. Improving the Chances of Success

5.32 The review indicates a number of items which must receive attention if the rate of success of major irrigation projects in Africa is to be improved. Action on most would also benefit small-scale and traditional irrigation, which should in future receive higher development priority. Key items are listed below.

A shift in national terms of trade in favour of rural producers, leading to more favourable production incentives for agriculture in general and improved profitability for irrigation in particular.

Creation of local private sector capacity for construction of irrigation works, production support services and input supply, and the local manufacture, sales and service of irrigation equipment.

Institutional reform and better management at all levels of government involvement with all types of irrigation, starting with sectoral planning and financial control, going down to the operation and maintenance of individual government perimeters, and including the planning and implementation of projects for the promotion of small-scale and private irrigation.

Manpower development, to give governments the human resources needed to implement the reforms and improvements indicated above.

Development approaches and designs (or re-designs) of major irrigation projects which are better adapted to the needs and aspirations of those who are intended to operate the systems, demand less profound social change, and hence are more easily implemented; in particular, a reduction in the dependence of irrigators in public schemes on inefficient government support services in which they have little confidence.

Designs and construction methods for both major and small-scale works which are cheaper, less demanding in imported materials and better adapted to local capacity for operation and maintenance.

Crop production systems which are also less dependent on imported items.

Allocation of sufficient local resources and foreign exchange to keep existing government schemes operating and adequately maintained, and to ensure that the necessary fuel, spares and inputs are available to all types of irrigator.

## E. The Role of Governments

5.33 Whether or not these changes come about will depend largely on governments. Assuming that national circumstances justify promoting irrigation in one form or another, a number of actions can be taken.

5.34 The first need, already flagged above, is for policy adjustment intended to improve the profitability of the agricultural sector as a whole. An increase in farm-level profitability is essential for future and existing large-scale government irrigation schemes to achieve their production targets. It would do much to secure full-time farmer commitment to "government" crops in cases where this is lacking, especially if linked to changes towards less precarious conditions of land occupation. Only if farm profits are sufficient will the private sector be attracted to take over agricultural supply and service functions, as many governments already wish, or take up the local fabrication, sales and service of pumps and other equipment. Improved profitability would also encourage more small-scale and traditional irrigators to turn to commercial production instead of growing crops only for subsistence. Stability of the incentive package is particularly important in the case of irrigation. Because many systems are designed for a single crop (e.g. rice or sugarcane), farmers often cannot adapt their production plans to market changes like their rainfed counterparts.

5.35 The measures used to adjust and maintain incentives will vary from country to country. Whether it is more appropriate to manipulate controlled prices or adopt a free market, for instance, will depend on macro-economic considerations which go beyond the irrigated sub-sector and are not discussed here.

5.36 Government policymakers and planners also need to be more realistic in their expectations. Experience shows that throughout the world irrigation development is a long-term process. This is especially true for Africa since the approach so far favoured has usually also required profound social changes. The full impact of a new, major irrigation scheme is unlikely to be felt for 10, 15 or even 20 years. Such schemes therefore, (a) cannot immediately overcome food shortages or other economic crises and (b) require long periods of official funding before there is any payback. If they are to succeed, continuity of government commitment, adequate feedback and learning from initial results, and patience, are essential.

5.37 National planners who commit scarce resources on the supposition that irrigation will give instant solutions may be pre-empting other more relevant projects. On the other hand to cut off government funds prematurely because results are slow to appear will jeopardise all the previous investment. It must also be realised that projects which unjustifiably favour irrigated wheat, and in some circumstances also irrigated rice, may tend to turn public taste away from traditional staples such as coarse grains and root-crops, which in many African countries can be produced more cheaply under rainfed conditions.

5.38 Governments need to review the activities and terms of reference of the national or international river basin development authorities. The past concern of these authorities with major dams and hydropower has in many cases resulted in excess generating capacity. Meanwhile water which could be used for traditional or modern irrigated agriculture is denied to farmers. The authorities should be encouraged to:

- review their present priorities for new dam construction and water allocations against existing urban and industrial demands, taking account of the probability that future growth in these sectors may be less than assumed in earlier masterplans;

- re-assess the losses to traditional and small-scale irrigation caused by past hydropower developments;

- reformulate priorities for future dam construction and water allocation to take account of the above findings, and to reflect the probably greater emphasis in future on rural growth as part of national development strategies;

- include the development of small-scale and existing traditional irrigation, as well as rainfed agriculture, among their development objectives for river basins.

Once specific irrigation developments are launched below major dams, the international or national authorities which operate the dams must be encouraged to cooperate fully with national irrigation authorities in the timely release of water for agricultural purposes.

5.39 If major projects are to be better adapted to the needs and aspirations of the intended beneficiaries, planning will have to be based on better socio-economic information. More use could also be made of pilot projects to give confirmatory data on institutional, social and technical feasibility before plans for the main perimeter are finalised. To the extent possible the development of major projects should be in phases, to allow the results of accumulated experience on one stage to be applied to the next. Projects might respond better to local needs if they initially allocated families only a small, inheritable, houseplot for subsistence, on which they could gain experience of irrigation. The lease of a larger holding could be offered on the next phase, only to those interested in and capable of becoming commercial irrigators. The findings of such experiments need to be systematically incorporated into future irrigation policy, otherwise the old conflicts of interest between governments and irrigators will persist.

5.40 Reform of the government agencies responsible for major irrigation projects is needed in many cases. While such changes have begun in some African countries they need to be pressed home, and could with advantage be adopted in many more. Reforms should aim particularly towards:

- cost reductions, by elimination of overstaffing and other wasteful expenditures, linked where practicable to the privatisation or transfer to irrigators of scheme O & M and other government support services;

- ensuring more timely and stable budget allocations, better matched to the scale of the agencies' programmes and responsibilities;

- improved recovery of government costs, to the extent that irrigators are able to pay;

- introduction of improved internal planning, budgeting and financial control;

- improved scheduling and organisation of scheme O & M;

- replacement of unserviceable plant, equipment and vehicles;

- improved workshop and repair facilities and the stricter application of preventive maintenance procedures;

- better management information systems and means of monitoring the economic and social impact of projects.

5.41 It is important that governments link such institutional reforms to expanded training and manpower development. The present external, usually academic, training to produce a small number of graduate irrigation specialists needs to be supplemented by more practical, on-the-job learning for staff at other levels of responsibility. The aim should be to supplement the graduate cadre with larger numbers of irrigation technicians, as well as generalists skilled in field-level operations. Regional interchange of experience and the reinforcement of regional training capacity are urgently needed. Attractive conditions of service will be needed if staff, once trained, are to remain in the field, where they are likely to be most needed.

5.42 Increased future emphasis on the improvement of small-scale and traditional irrigation also brings a need for institutional change. There is an urgent need to create more groups specialised in promoting small-scale and traditional irrigation in the context of general rural development. Whether this responsibility is best transferred to a specialised irrigation agency or created in a department of agriculture will depend on the country and the present state of its institutional development. In either case, however, the solution will have to allow for the fact that such developments are likely to be too small and scattered to allow the regular presence of government staff at acceptable cost. The idea of partnership with non-governmental organisations or private charities is appealing, but raises the question of whether such organisations will wish to associate themselves so closely with governments, as well as how funds would be channelled, administered and recovered and goods procured through non-government intermediaries.

5.43 Privatisation or transfer of responsibilities to irrigators needs appropriate government support, not only in the form of financial incentives and access to imported materials and equipment as already mentioned: training and credit may be needed and means must be found to form stable and effective irrigator groups. It must be accepted, too, that successful government disengagement, like the establishment of irrigation itself, is likely to be a long process. Even when the process is complete there may still be continuing needs for government support; and perhaps also capital grants and subsidies, especially in the case of developments aimed to support small-scale irrigators in drought-risk areas. Governments need to take full account of these budgetary implications and decide how to mobilise the money. Unless all these aspects are given full attention there is a risk, in the case of privatisation, that the withdrawal of the government will leave behind a vacuum, and projects will remain as inefficient as before.

5.44 Government action is also appropriate to fill a number of technical gaps. Resource survey departments will often need to be strengthened and more attention may need to be given to maintaining the quality and continuity of meteorological and hydrological records. If irrigation is to be expanded for the support of people in semi-arid areas, for the supplementary irrigation of rainfed crops, and to permit the conjunctive use of underground and surface water on modern irrigation projects, more surveys of groundwater potential will be especially important, as well as the monitoring of water tables. There may be opportunities for expansion of rural electrification which can relieve large and small-scale pump schemes from their dependence on transported fuel. By inference from Asia, electrification can greatly stimulate the expansion of small-scale pumped irrigation both from subterranean or surface water.

5.45 Adaptive agricultural research is potentially needed by all irrigators, particularly to provide them with improved methods of on-farm water management, better varieties, improved weed and pest control, and cropping systems which optimise the use of scarce inputs and pumping costs. To facilitate small-scale development and to permit new approaches to the design of major projects, agronomists also need to give more attention to evolving systems which integrate irrigation with rainfed cropping and livestock activities, rather than starting from the assumption that the user will be a full-time irrigator. Adequately trained and equipped extensionists are needed to bring research results to farmers, both on major schemes and smaller-scale developments. Again, there is a need for more effective regional cooperation and pooling of resources in the face of common problems, through regional organisations such as WARDA.

5.46 Almost all the above government actions require capable and enterprising managers, who are at present likely to be extremely scarce. The selection and training of managers, and the creation of appropriate career and salary incentives, must therefore be given highest priority in any plans for irrigation development. To raise management salaries or adopt production-linked bonus incentives will seldom add appreciably to the total cost of a modern scheme, but can have a dramatic influence on management quality, performance and production. Even so, in the case of major schemes governments are still likely to have to choose between the risks to a costly investment of possibly inadequate local management, the continuing presence of an expensive expatriate technical assistance team, or the re-design of the whole project to simplify the management task.

5.47 Under this last option governments should experiment with alternative, less monolithic models for project organisation. Options include a cluster of semi-independent units each with a larger irrigator participation in management decisions, or group leasing in lots of 10 to 50 ha to kinship groups or private individuals. Alternatively if, as in some Sahelian countries, assured output is of paramount national concern, there may be circumstances when rather than land distribution to small-scale irrigators, agro-industrial farming is the best option. A management contract, joint venture or turnkey operation may be appropriate. Or it may be appropriate for governments to lease irrigated land in larger blocks to entrepreneurs, subject to their financial participation in on-farm development and a guarantee that technically competent management will be hired. In all cases, however, the prospect of improved profitability may be needed to attract private-sector participants.

## F. The Role of Donors and Technical Assistance

5.48 International lenders and donors can do much to help governments to make the changes listed above. Principal areas where assistance is likely to be needed are:

- in devising the policy and structural adjustments needed to improve agricultural profitability and improve financial returns to irrigation;

- in sectoral dialogue to decide with governments on the agricultural development policies and priorities which are appropriate to the specific circumstances of the country, especially the balance in strategy between rainfed and irrigated agriculture, and the relative emphasis to be given to the various alternative forms of irrigation;

- in substantial programmes for training and manpower development, perhaps on a regional basis;

- in devising appropriate uses for food aid, so as to

  a) avoid creating disincentives to local food production;

  b) support irrigators' participation in construction or maintenance through food-for-work campaigns;

  c) finance the government support or subsidies needed to promote or sustain increased local food production under irrigation;

- in developing local consultant skills for irrigation project design and the capability of local contractors for scheme construction;

- in developing national or regional capacity for the assembly or manufacture of irrigation equipment;

- in irrigation research and technical development, either through national projects or by support of regional research institutions.

Loans, grants or technical assistance in kind can all make contributions.

5.49 Loans are appropriate to support structural adjustment of the sub-sector, to finance rehabilitation of modern irrigation or (where justified) new construction, to promote the expansion of small-scale irrigation, and for projects based on the improvement of traditional methods. In most cases institutional support and training are likely to be important loan components, linked as appropriate to institutional reform or rebuilding. In some cases, particularly to build irrigation infrastructure in poorer countries which would otherwise remain indefinitely dependent on gifts of food aid, grant funding may be more appropriate.

5.50 A flexible, programmed approach is needed to irrigation lending and grant funding, to match the less rigid approaches to project design which are proposed earlier. It is important to accept that, if major projects are to achieve sustainability, support may be needed over ten years or even more. When institutional and social change are part of the programme the lender or donor and the government could, following the example of a recent World Bank project, agree on criteria (e.g. extent of time delays, cost overruns, production short-fall, settler turnover or farm credit overdues) on which a decision would automatically be taken to call "time out" for reflection, discussion and reformulation of the project approach. Release of funds, on the other hand, could be in tranches each conditional on achieving previously agreed targets for improved institutional efficiency or transfer of responsibilities. For this to work, however, lending agencies are likely to have to allocate more time to loan supervision and take greater care with the composition and continuity of supervision teams than in the past.

5.51 Technical assistance is particularly needed for training, and with the management and administration of all aspects of irrigation planning and execution. Assistance is also likely to be needed for resource and socio-economic surveys, scheme design and construction, system operation and maintenance, water management, agronomic research, extension, health aspects, monitoring and evaluation. Regional technical assistance to standardise and document design coefficients for Africa would help reduce the frequency of basic design errors. Regional assistance would also be appropriate to help establish local assembly or manufacture of irrigation equipment.

5.52 Among the above, training - at all levels from managers and planners down to farmers - is the most important technical assistance task. A practical approach, emphasising on-the-job learning, is essential. Three other major challenges can also be specially noted. First, the necessity to develop and promote only those irrigation techniques which can be self-sustaining after expatriate technicians leave; second, the need for better means to create effective and durable irrigators' organisations which can truly serve their members and eventually take charge of their own destiny; and third, the difficulty, in practice, of securing the emergence of private sector agricultural supply and equipment manufacturing industries in Africa, whether on a national or regional basis.

5.53 It is essential that the various lenders and donors coordinate their activities, to avoid giving the conflicting advice or incompatible support which have been seen in several African countries in the past. Coordination is also necessary so that governments can allocate scarce local counterpart funds and manpower between the projects of different donors, to maximise the national impact of the external support which they receive.

## G. Prospects to the Year 2000

5.54 The study team's review of past irrigation experience and a consideration of the present and likely future economic and social trends in Sub-Saharan Africa suggest that the following future rates of irrigation development might be obtainable up to the year 2000.

- In the eight African countries, five of them Sahelian, having little or no further rainfed potential (see para 5.18) the annual rate of expansion of fully-controlled new irrigation schemes could be about 3.5%, equivalent to an average of about 10,400 ha of new installed capacity per year over the rest of the century. This compares with a total rate of increase for all types of irrigation of about 5.2% per year in these countries from 1974 to 1982.

- Construction of modern, fully-controlled irrigation in the remaining countries, all of which still have some rainfed opportunities, may expand at only 1.0%/yr, equivalent to an average of about 26,000 ha new installed capacity per year. This represents only about a third of past rates of increase of irrigation of all types in these countries. The lowered rate is assumed to be due mainly to government funding limitations, discouraging past experience, the fact that many of the best large-scale sites are already developed, and concentration on rainfed opportunities;

- Rehabilitation of existing modern schemes could proceed at an average of 50,000 ha/yr, giving a total of some 900,000 ha rehabilitated by the year 2000.

- In addition, small-scale and traditional irrigation might expand at 4% (about 136,000 ha) per year, a rate slightly above recent overall rates of growth of irrigation in the region.

5.55 On these assumptions irrigated areas in Sub-Saharan Africa would develop by the year 2000 as shown below. The projected expansions would raise irrigated areas in the eight countries with high needs to about 75% of their total estimated irrigable potential. The remaining 32 countries would reach an aggregate level of about 20% of potential, as provisionally defined by FAO.

Estimated Expansion of Irrigated Areas, by Category, to the Year 2000

| | Area, 1982 ('000 ha) | .....Expansion 1982-2000.... %/yr | Average '000 ha/yr | Total Increment ('000 ha) | Area 2000 ('000 ha) |
|---|---|---|---|---|---|
| Modern Irrigation | | | | | |
| 8 countries with little scope for rainfed intensification | 213 | 3.5 | 10.4 | 187 | 400 |
| Remaining 32 countries | 2,425 | 1.0 | 26.4 | 475 | 2,900 |
| Traditional and Small-scale Irrigation | | | | | |
| All countries | 2,381 | 4.0 | 135.5 | 2,439 | 4,820 |
| Total Expansion | 5,019 | 2.7 | 172.3 | 3,101 | 8,120 |
| Rehabilitation | - | - | 50 | 900 | 900 |

Contribution to Food Supply

5.56 Approximately 50% of existing irrigated areas produce cereal crops. It is assumed that this proportion is likely to be maintained on those areas in future; but on new and rehabilitated areas, responding to market needs, the proportion of cereal crops may rise to 75%. Average yields (expressed either as milled rice equivalent or coarse grains) might develop as follows:

| | Average Annual Cereal Yield (t/ha/year) 1982 | 2000 |
|---|---|---|
| Modern Irrigation | | |
| - new | - | 4.0 |
| - rehabilitated | 2.5 | 3.5 |
| - pre-existing | 2.5 | 3.0 |
| Traditional and Small-scale Irrigation | | |
| - new | - | 2.5 |
| - pre-existing | 1.5 | 2.0 |

5.57 Combining the figures above with the projected area expansions gives an estimated contribution to regional cereal production of about 13.9 million tons in 2000, compared with an estimated 5.3 million tons in 1982. However due primarily to expected population growth, this increase would raise the contribution of irrigation to estimated regional cereal demand from the present 10% to only about 14%.

## Financial Requirements

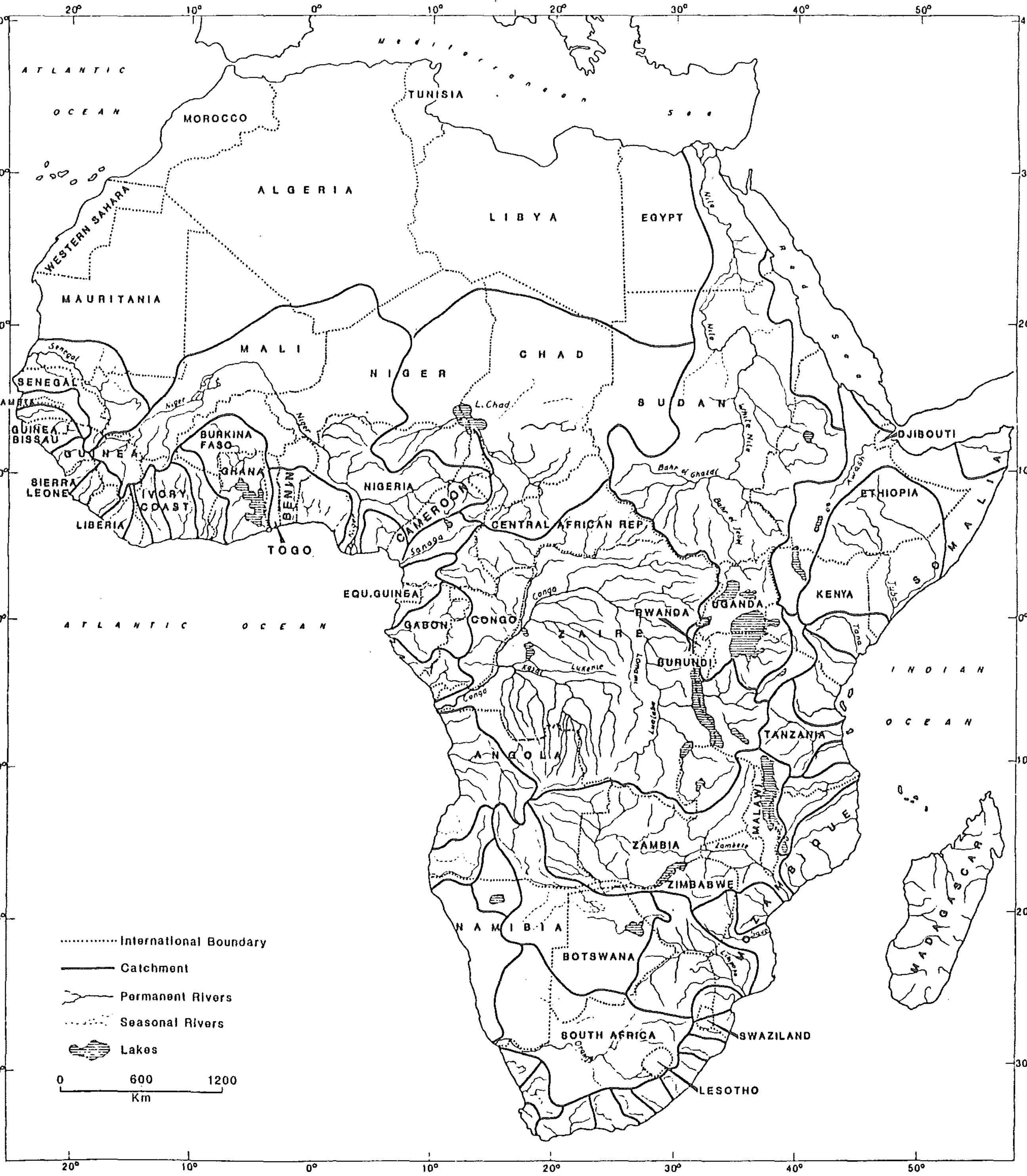
5.58 Capital requirements for such an expansion would be substantial. At an average construction cost of US$8,000/ha for major, new fully-controlled irrigation works or US$1,500/ha for their rehabilitation, the region would have to mobilise an average of nearly US$370 million/yr, or a total approaching US$7 billion (expressed in 1985 dollars) over the period 1986-2000. A substantial proportion of these capital costs, even under policies designed to increase private-sector involvement in modern irrigated agriculture, would be borne by governments. Where necessary governments would also have to find additional resources for access roads, social infrastructure and settlement of new public schemes located in underpopulated areas. A government capital contribution of an average of only US$200/ha to the cost of small-scale village or individual schemes and to promoting expansion of traditional methods would add a further US$27 million/yr to average government expenditures.

5.59 Incremental operating costs for major schemes, at about US$80/ha/yr for new major schemes and US$50/ha/yr for rehabilitated areas, would rise to a total of some US$100 million/yr by 2000. Finally governments would have to mobilise the resources needed to provide extension and research services, and to supply private small-scale irrigators with credit.

5.60 The recoverability of these costs would depend greatly on the degree of the success of governments in adjusting rural terms of trade and producer incentives. But a substantial part of the total is likely to represent a continuing subsidy.

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

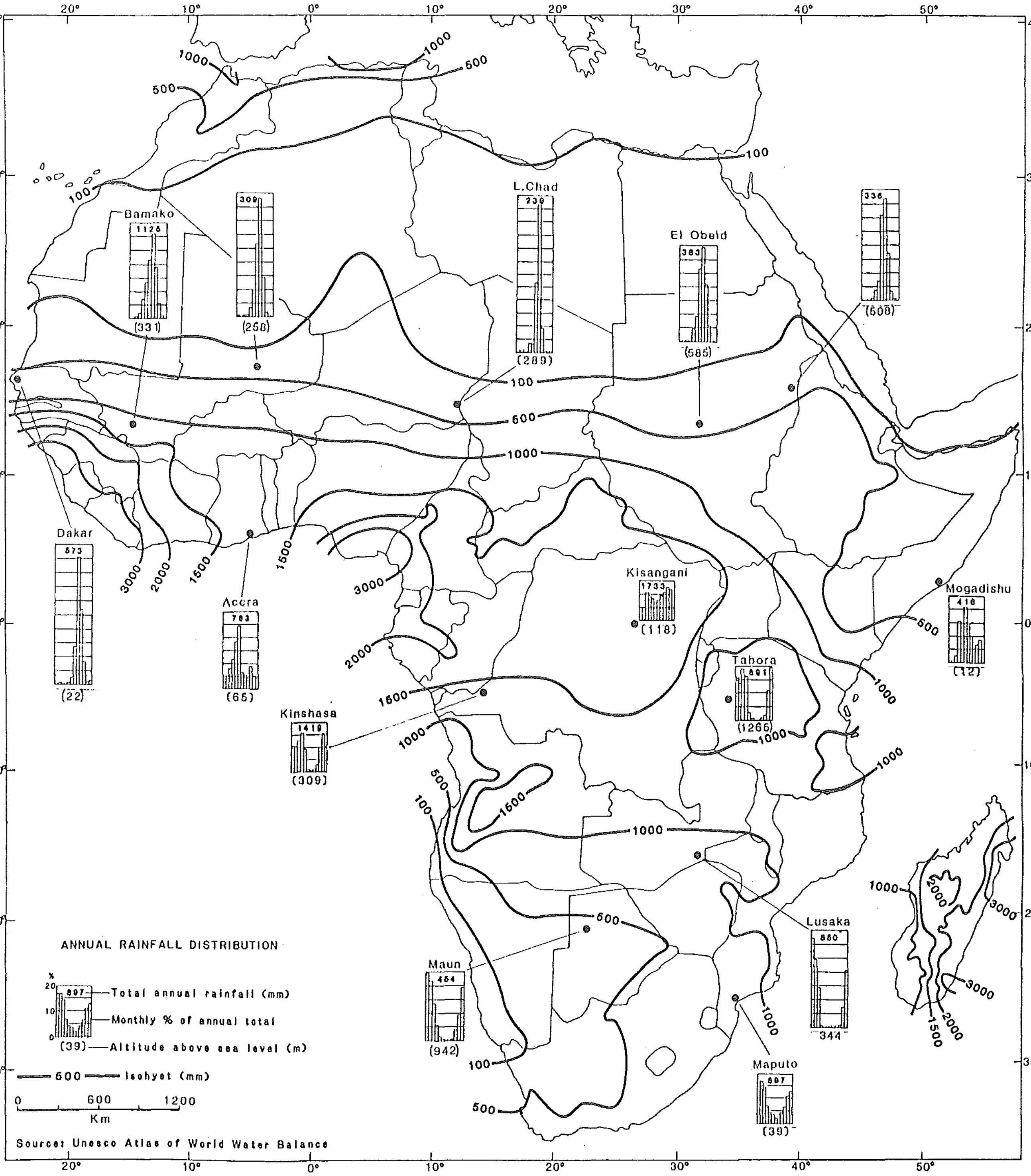
# RIVER AND LAKE BASINS




MAP 1

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

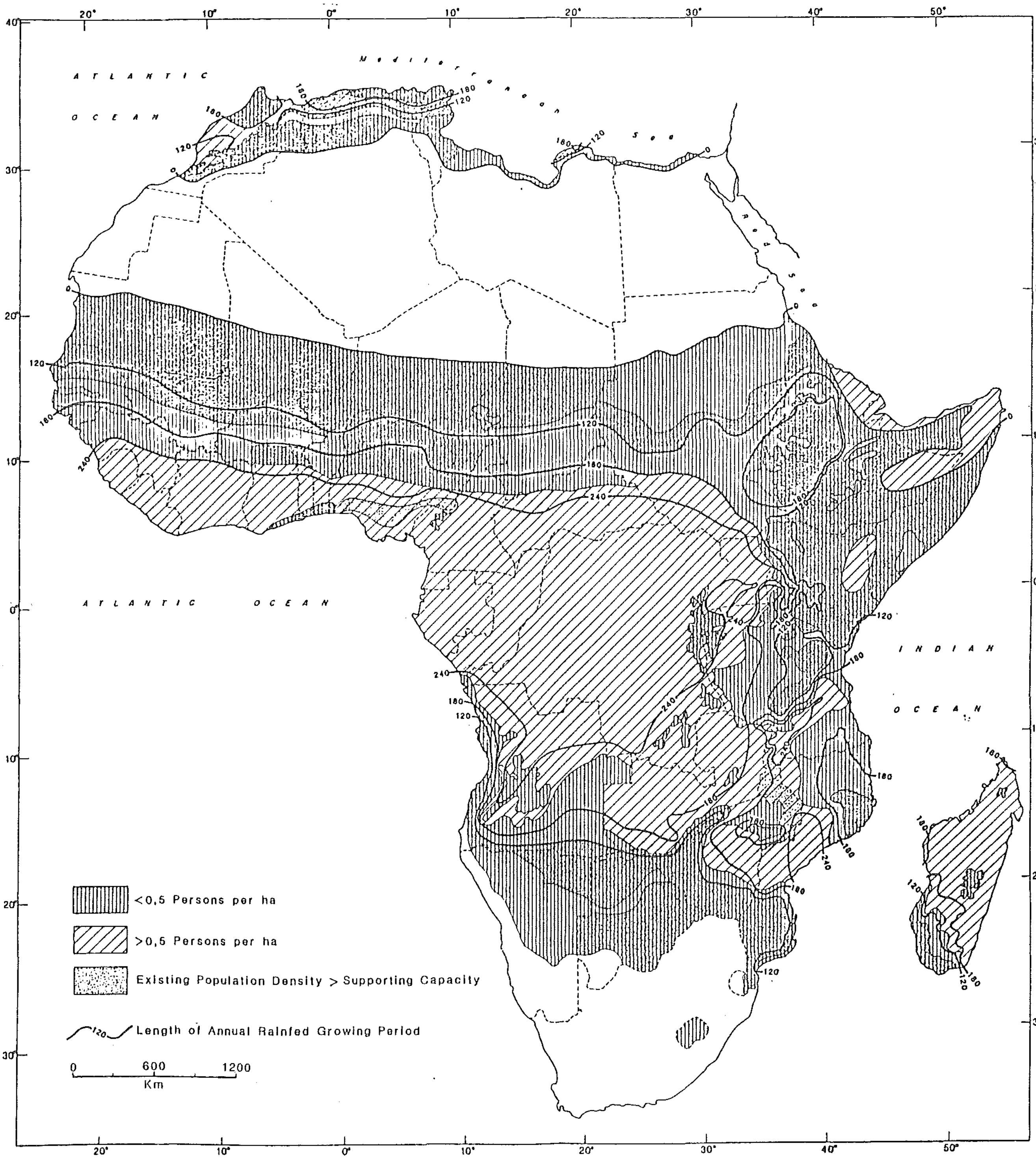
# RAINFALL DISTRIBUTION




MAP 2

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

# POTENTIAL POPULATION SUPPORTING CAPACITY, LOW INPUT LEVELS, RAINFED




MAP 3

Table 1

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Surface Area, Population (1982) and Estimated Length of Rainfed Growing Period for the Countries Covered by the Study

| Country | Land Area (thousand km2) | Population 1982 (million) | Range of Length of Growing Period (days) |
|---|---|---|---|
| Angola | 1,246 | 8.2 | 0-270 |
| Benin | 111 | 3.7 | 120-270 |
| Botswana | 585 | 1.0 | 0-120 |
| Burkina Faso | 274 | 6.5 | 75-230 |
| Burundi | 25 | 4.3 | 240-300 |
| Cameroon | 469 | 9.0 | 75-365 |
| Central African Republic | 623 | 2.4 | 150-365 |
| Chad | 1,284 | 4.7 | 0-220 |
| Congo | 341 | 1.6 | 280-365 |
| Equatorial Guinea | 28 | 0.4 | 330-365 |
| Ethiopia | 1,100 | 34.0 | 0-300 |
| Gabon | 258 | 1.1 | 275-365 |
| Gambia | 11 | 0.6 | 160 |
| Ghana | 231 | 12.1 | 190-330 |
| Guinea | 246 | 5.1 | 190-330 |
| Guinea Bissau | 36 | 0.8 | 180-210 |
| Ivory Coast | 322 | 8.8 | 210-365 |
| Kenya | 570 | 18.2 | 75-270 |
| Lesotho | 30 | 1.4 | 180-270 |
| Liberia | 111 | 2.0 | 310-365 |
| Madagascar | 580 | 9.2 | 75-365 |
| Malawi | 94 | 6.4 | 180-300 |
| Mali | 1,240 | 7.4 | 0-210 |
| Mauritania | 1,030 | 1.7 | 0-120 |
| Mauritius | 2 | 1.0 | n.a. |
| Mozambique | 784 | 12.8 | 150-270 |
| Niger | 1,267 | 5.6 | 0-120 |
| Nigeria | 924 | 86.4 | 120-330 |
| Rwanda | 25 | 5.5 | 240-365 |
| Senegal | 196 | 6.0 | 70-180 |
| Sierra Leone | 72 | 3.4 | 260-350 |
| Somalia | 638 | 4.8 | 0- 65 |
| Sudan | 2,506 | 19.8 | 0-270 |
| Swaziland | 17 | 0.6 | 210-270 |
| Tanzania | 886 | 20.3 | 75-300 |
| Togo | 57 | 2.7 | 180-300 |
| Uganda | 200 | 14.1 | 120-365 |
| Zaire | 2,268 | 30.3 | 210-365 |
| Zambia | 740 | 6.1 | 120-210 |
| Zimbabwe | 386 | 7.9 | 150-210 |
| Total | 21,813 | 377.9 | |

Sources: FAO Production Yearbook, 1983.
FAO Study of Potential Population Supporting Capacities, 1984.

Table 2

## STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA
## Areas and Discharge of the Principal River Basins of Sub-Saharan Africa

| Basin | Principal Countries | Basin Area (km2) | Mean annual discharge (km3) |
|---|---|---|---|
| **Discharge into the Mediterranean** | | | |
| Nile | Uganda, Ethiopia, Sudan, Egypt | 2,800,000 | 84.0 |
| **Discharge into the Indian Ocean** | | | |
| Shebelli | Somalia, Ethiopia | 205,400 | 2.5 |
| Juba | Somalia, Ethiopia | 168,100 | 6.0 |
| Tana | Kenya | 42,217 | 4.1 |
| Athi | Kenya | n.a. | 1.3 |
| Wami | Tanzania | 36,450 | 2.5 |
| Rufiji | Tanzania | 158,000 | 30.0 |
| Ruvuma | Tanzania, Mozambique | 155,400 | n.a. |
| Zambezi | Angola,Zambia,Mozambique | 1,250,000 | 103.4 |
| Save | Zimbabwe, Mozambique | 88,395 | 5.0 |
| Limpopo | Zimbabwe, Mozambique | 412,000 | 5.3 |
| **Discharge into the South Atlantic** | | | |
| Congo | Zaire, Congo | 4,000,000 | 1,325.0 |
| Ogooue | Gabon | 203,500 | 148.9 |
| Sanaga | Cameroon | 131,500 | 65.2 |
| **Discharge into the North Atlantic** | | | |
| Niger | Guinea, Mali, Niger Nigeria | 1,215,000 | 179.8 |
| Volta | Ghana, Burkina Faso | 394,100 | 39.8 |
| Gambia | Gambia,Guinea,Senegal | 77,850 | 5.0 |
| Senegal | Guinea,Senegal,Mali Mauritania | 338,000 | 21.8 |
| **Discharge Inland** | | | |
| Awash | Ethiopia | 113,700 | n.a.(into Danakil Desert) |
| Chari-Logone | Central African Republic Niger,Chad,Nigeria | n.a. | 43.2 (into Lake Chad) |
| Omo | Kenya | 77,200 | 16.1 (into Lake Turkana) |
| Okavango | Botswana | 53,000 | 0.6 (into Okavango Swamp) |
| Gash | Sudan | 23,500 | 0.6 (into Gash Plain) |

Table 3

## STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

### Irrigation Potential, Estimated Irrigated Areas and Area Irrigated in Relation to Population

| Country | Irrigation Potential '000 ha | Irrigation Potential Percent of Land Area | Estimated Irrigated Area ('000 ha) 1965 | Estimated Irrigated Area ('000 ha) 1974 | Estimated Irrigated Area ('000 ha) 1982 | Irrigated Area as Percent Total Cropped (1982) | No. People per ha Irrigated (1982) |
|---|---|---|---|---|---|---|---|
| Angola | 6,700 | 5.3 | n.a. | n.a. | 10 | 0.3 | 820 |
| Benin | 86 | 0.8 | 0.1 | 9.4 | 22 | 1.2 | 168 |
| Botswana | 100 | 0.1 | 3.0 | 9.5 | 12 | 0.9 | 83 |
| Burkina Faso | 350 | 1.3 | 0.1 | 6.0 | 29 | 1.1 | 224 |
| Burundi | 52 | 2.1 | 0 | 5.5 | 52 | 4.3 | 83 |
| Cameroon | 240 | 0.5 | 4.0 | 14.2 | 20 | 0.3 | 465 |
| Central African Republic | 1,900 | 3.0 | n.a. | n.a. | 4 | 0.2 | 600 |
| Chad | 1,200 | 0.9 | 7.0 | 10.0 | 50 | 1.9 | 94 |
| Congo | 340 | 1.0 | 0 | 2.2 | 8 | 1.2 | 200 |
| Equatorial Guinea | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Ethiopia | 670 | 0.6 | 58.7 | 92.6 | 87 | 0.6 | 390 |
| Gabon | 440 | 1.7 | 0 | 0.2 | 1 | 0.2 | 1,100 |
| Gambia | 72 | 6.6 | 25.0 | 33.2 | 26 | 16.3 | 23 |
| Ghana | 120 | 0.5 | 0.2 | 16.1 | 10 | 0.4 | 1,210 |
| Guinea | 150 | 0.6 | 41.0 | 64.0 | 45 | 2.9 | 113 |
| Guinea Bissau | 70 | 1.9 | n.a. | n.a. | n.a. | n.a. | n.a. |
| Ivory Coast | 130 | 0.4 | 6.7 | 32.9 | 52 | 1.3 | 169 |
| Kenya | 350 | 0.6 | 15.0 | 36.6 | 49 | 2.1 | 371 |
| Lesotho | 8 | 0.3 | 0 | 0 | 1 | 0.4 | 1,400 |
| Liberia | n.a. | n.a. | 0 | 2.5 | 19 | 5.2 | 105 |
| Madagascar | 1,200 | 2.1 | 330.0 | 426.0 | 960 | 32.0 | 10 |
| Malawi | 290 | 3.1 | 0.6 | 11.0 | 20 | 0.9 | 320 |
| Mali | 340 | 0.3 | 117.0 | 150.3 | 160 | 7.8 | 46 |
| Mauritania | 39 | <0.1 | 10.7 | 33.0 | 23 | 11.1 | 74 |
| Mauritius | n.a. | n.a. | 12.0 | 21.0 | 14 | 13.1 | 71 |
| Mozambique | 2,400 | 3.1 | 16.0 | 34.0 | 70 | 2.3 | 184 |
| Niger | 100 | 0.1 | 1.9 | 2.9 | 30 | 0.9 | 187 |
| Nigeria | 2,000 | 2.2 | 300.0 | 400.0 | 850 | 2.8 | 102 |
| Rwanda | 44 | 1.8 | 2.6 | 12.7 | 15 | 1.5 | 367 |
| Senegal | 180 | 0.9 | 13.6 | 38.1 | 100 | 1.9 | 60 |
| Sierra Leone | 100 | 1.4 | n.a. | n.a. | 55 | 3.1 | 62 |
| Somalia | 87 | 0.1 | 31.5 | 47.2 | 80 | 7.2 | 60 |
| Sudan | 3,300 | 1.3 | 1,352.0 | 2,064.0 | 1,750 | 14.1 | 11 |
| Swaziland | 7 | 0.4 | 20.0 | 30.0 | 60 | 43.5 | 10 |
| Tanzania | 2,300 | 2.6 | 27.9 | 52.0 | 140 | 2.7 | 145 |
| Togo | 86 | 1.5 | 0.2 | 6.2 | 13 | 0.9 | 207 |
| Uganda | 410 | 2.1 | 3.0 | 16.0 | 12 | 0.2 | 1,260 |
| Zaire | 4,000 | 1.8 | 2.5 | 4.2 | 24 | 0.4 | 721 |
| Zambia | 3,500 | 4.7 | 2.0 | 17.5 | 16 | 0.3 | 381 |
| Zimbabwe | 280 | 0.7 | 36.0 | 65.4 | 130 | 4.6 | 61 |
| Total | 33,641 | | 2,440.3 | 3,766.4 | 5,019 | | |

Sources Irrigation potential: FAO, 1985 (unpublished provisional estimates).
Irrigated areas, 1965 and 1974: Rydzewski, J.R., 1974.
Irrigated areas, 1982: Study team estimates.

## A Preliminary Inventory of BURKINA FASO Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Banfora | 3,900 | sugar | Diversion dam on the Comoe and Yannon rivers. Pumping enegy from the fall at Banfora. Sprinkler irrigation. | |
| Kou (Northwest of Bobo-Dioulasso) | 1,250 | rice some fruits | Kou River (affluent of Black Volta). Diversion dam and canal. Gravity. | Implemented by Chinese technical assistance. Settlement of 1,000 families. |
| Banzon | 585 (450 in use) | rice | Diversion dam, dykes and canals. Gravity. | Chinese technical assistance. |
| Karfiguéla | 300 | rice | Comoe River. Canals, dykes. Gravity. | Chinese technical assistance. |
| Small-scale irrigation | 2,800 | vegetables fruits | Pumping. | |

### Brief Summary

| | |
|---|---|
| Total irrigated area: | 28,700 ha |
| Modern irrigated area: | 8,700 ha |
| Main crops: | Rice, vegetables, coarse grains |
| Main irrigated zones: | Comoe, Haut-Bassin |
| National authority on irrigation: | Office national des barrages et de l'irrigation (ONBI) |
| Estimated cost per hectare: | US$ 6,300-11,000 (1984 price) Full control, diversion dam, canals |

### Sources

FAO/CP: Haute-Volta: Revue du secteur de l'irrigation, 1984

Club du Sahel: Irrigated Development in Upper Volta, 1979

ECA: Land and Water Survey of Africa, Vol. II, 1980

FAO Crop statistics

Table 4

A Preliminary Inventory of

ETHIOPIA Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Amibara/Melka Sadi | 12,000 | cotton<br>groundnuts<br>bananas | Awash River. Gravity. | World Bank, EEC, ADS. |
| Awara Melka | 1,300 | cotton<br>groundnuts | Awash River. Gravity/diversion. | |
| Bilate | 2,800 | | | |
| Lower Gash | 1,000 | cotton | | |
| Tendaho | 10,000 | cotton | Awash River. Canals, gravity, some pumping. | Originally private management. Foreign private/ Government partnership. |
| Maro Gala | 3,500 | | | |
| Mereb Gash | 10,000 | cotton<br>cereals | Gash River. Gravity/flooding. | Local private. |
| Metehara | 9,200 | sugarcane | Awash River. Pumping. | Originally private management. |
| Nura/Era Abadir | 6,200 | vegetables<br>cotton | Awash River. Gravity/diversion, flooding. | Drainage problems. Originally private management. |

| Name & location | Project purpose and land allocation ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Tessenei (Eritrea) | 10,000 | cotton | Tessenei River. Flooding, gravity. | Originally private management. |
| Tibila | 4,500 | cereals | | |
| Wabe Shebelle | 3,800 | cereals | Wabe Shebelle. Flooding. | Local private. |
| Wonji (Shea) | 7,000 | sugarcane | Awash River. Pumping. | Originally private management. Private/Government partnership. |
| Small-scale irrigation | 6,500 | cotton | Awash River. Flooding. | Private. |

**Brief Summary**

| | |
|---|---|
| Total irrigated area | 87,000 ha estimated in operation |
| Main crops | Cotton, sugarcane |
| Main irrigated zones | Awash River, Wabe Shebelle, Blue Nile, Tessenei basins |
| National authority onirrigation | Water Resources Development Commission, Ministry of Agriculture |
| Estimated cost per hectare | Small-scale irrigation: US$ 1,500-2,500 (1983 prices) |

**Sources**

ECA. A Survey of Land and Water Resources of Africa, Vol. II, 1980.

FAO (DDC). Ethiopia: Small-scale Irrigation Development, Preparation Report, 1983.

WRDA/FAO. Irrigation Policy: The Awash River Basin, 1983.

Interviews with DDC and AGL staff familiar with Ethiopia.

A Preliminary Inventory of

GHANA Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| AFIFE (Volta Region) | 800 | Rice | Dam on Balikpa River | Started by the Russians and later assisted by the Chinese |
| Ashiaman (Greater Accra Region) | 150 | Rice and vegetables | | Local finance |
| Dawhenya (near Accra) | 150 | Rice and vegetables | Dam constructed in 1966 | |
| K'Pong (Eastern Region) | 200 | Sugarcane | Pumping; network of canals | ADF |
| Asutsuare | 1,900 | Rice, sugar-cane | Pumping from Volta River controlled by the Akosombo Dam | |
| Tono (Navrongo) | 2,500 | Rice and veg-etables | Earth dam with irrigation and drainage network | |
| Vea (Bdgatanga) | 800 | Rice and veg-etables | Earth dam with canal network | 10% to small farmers; 60% to commercial farmers; 30% to the State |
| Komenda | 400 | Rice and veg-etables | | |
| Weija (Greater Accra Region) | 150 | Rice and veg-etables | Dam | |
| Small-Scale modern irrigation | 500 | Sugarcane, rice, vegetables | Pumping; canals | |

Plus about 50,000 ha traditional swamp and flood recession irrigation for rice and coarse grains

Table 6
Page 2

Brief summary

| | |
|---|---|
| Total irrigated area | 10,000 ha approximately |
| Modern irrigated area | 6,000 ha in operation in 1985 |
| Main crops | Rice, sugarcane, tomato, other vegetables |
| Irrigated regions | The Southern and Northern Savannahs |
| National authority on irrigation | The Irrigation Department under the control of the Central Government |
| Estimated cost per hectare | US$10,000-15,000 per ha (pumping) (1985 prices, from WB Review of Irrigation Sub-Sector, 1985); US$23,000 per ha (relatively high cost) Weija Project |

Sources

ECA. A Survey of Land and Water Resources of Africa, Vol. II, 1980

FAO/CP. Ghana: Irrigation Sector Study, 1975

The World Bank. Agricultural Sector Review, Background Papers, Irrigation Sub-Sector, 1985

## A Preliminary Inventory of KENYA Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Mwea | 6,100 | Rice | Nyamindi River, Thiba River. Diversion canals, gravity | Praised as highly successful |
| Ahero/Wescano | 1,500 | Rice | Nyando River. Pumping and gravity | Double cropping of rice |
| Bura | 3,900 (2,000 in use) | Cotton, maize | Tana River. Temporary pumping station, furrow irrigation | US$50,000 per family settled, 1,850 tenants |
| Bunyala | 354 | Rice | Pump station, gravity set basin | Single crop: 4-7 tons/ha |
| Tana/hola | 864 | Cotton | Tana River. Pump station, gravity | |
| Perkerra | 200 | Onion, maize | Perkerra River. Diversion canals, gravity | Erratic flow of the river |
| Other Large-Scale (private Sector) | 10,000 | Pineapple, coffee, sugarcane, vegetables | Pumping overhead | Private |
| Small-Scale Irrigation (Private) | 26,000 | Coffee, fruits, vegetables, rice coarse grains | Pumps, sprinklers, gravity, flooding | |
| Small-Scale Irrigation (Government) | 2,000 | Experimental | | UNDP/FAO/Government |

Table 7
Page 1

Brief summary

| | |
|---|---|
| Total irrigated area | 49,000 ha |
| Main crops | Rice, coffee, cotton, fruits and vegetables |
| Main irrigated zones | Arid zones, Tana River Basin, Nyando River Basin, Wyamindi River Basin |
| National authority on irrigation | Kenya Irrigation Board (KIB) |
| Estimated cost per hectare | Large schemes: US$7,000-20,000/ha (Bura scheme, 1983 prices), full control |

Sources

ECA. A Survey of Land and Water Resources of Africa, Vol. II, 1980

Post, W.S. Kenya: A Review of Irrigation Development, Nairobi, 1982

Toksoz, S. An Accelerated Irrigation and Land Reclamation Programme for Kenya, Harrod Institute of International Development. Discussion Paper No. 114, 1981

Chambers, R., and Moris, J. Mwea: An Irrigated Rice Settlement, 1973

Interview with W.S. Post on the latest development in Kenya

## A PRELIMINARY INVENTORY OF MADAGASCAR Irrigation Schemes

| Name and Location | Project Purpose and Land Allocation: Ha | Crop | Type of Irrigation | Other Informatio |
|---|---|---|---|---|
| Lake Alaotra (Tanatave) | 30,000 | rice | gravity | Part of the scheme was assisted by the World Bank |
| Marovoay (Majunga) | 20,000 | rice | gravity | |
| Antananarivo Plain | 13,000 | rice | gravity | |
| Ambilobe (Diego-Suarez) | 9,000 | rice and sugar cane | gravity | |
| Morondava (Tulear) | 5,000 1/ | rice and sugar cane 1/ | gravity | Developed with the World Bank's assistance |
| Mongoky (Tulear) | 4,000 | cotton | gravity | |
| Andapa (Diego-Suarez) | 2,000 | rice | gravity | |
| About 130 medium scale schemes | 80,000 | rice, other food and commercial crops | pumping and gravity | |
| About 900 small-scale schemes | 300,000 | rice and other food crops | pumping and gravity | |
| Family rice fields | 500,000 | mainly rice | mainly small river diversions, gravity | |

1/ In 1981 the area irrigated amounted to about 3,500 ha and was mainly under rice (see Table 23)

Table 8
Page 1

| Brief Summary | | Sources |
|---|---|---|
| Total irrigated area | 960,000 ha | The World Bank, Madagascar Agriculture and Rural Development Sector Memorandum, 1983 |
| Main crops | Rice, sugarcane, cotton and other food crops | |
| Main irrigated zones | Irrigation is widely dispersed among different regions and altitudes | The World Bank, Madagascar: Irrigation Rehabilitation Project, Staff Appraisal Report, 1985 |
| National authority on irrigation | Ministry of Agricultural Production and Agrarian Reform | |
| Estimated cost per hectare | US$5,700-9,600 for large schemes (1983 prices) | |

## A Preliminary Inventory of MALI Irrigation Schemes

| Name & location | Project purpose and land allocation ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| **Niger River Basin** | | | | |
| Dounanaba | 1,200 | Cotton, rice | Niger River, controlled flooding | |
| Small Irrigation (less than 1,000 ha) | 3,500 | Cotton, rice | Niger River, controlled flooding, pumps | Private |
| Office du Niger | 56,000 (41,000 in use) | Rice, sugarcane | Markala Barrage, gravity | Pre-independence construction, plus FAC, WB, EEC. Central management |
| Mopti | 40,000 (30,000 in use) | Rice | Niger River, dykes, gravity | FAC, WB, AfDB. Eight perimeters larger than 1,000 ha; 5 perimeters smaller than 1,000 ha. Centrally managed |
| Lacustrine Zone | 18,000 | Rice, wheat (Action Diré) | Controlled flooding of the Niger River; also some pumping | Private. Village perimeters. Also Government scheme |
| Ségou | 36,000 | Rice | Controlled flooding; direct inundation by the river | FAC, EEC. Highly dependent on the level of flooding of Niger River. Central management |
| The Niger Bend | 2,600 | Rice | Pumping from Niger River | |
| Other Small-Scale Irrigation | 17,000 | Rice, vegetables | Natural flooding | Private |
| **Senegal River Basin** | | | | |
| Small-Scale Irrigation | 360 | Vegetables and some rice | Pumping | NGO and rural peasant association |

Table 9
page 1

| Brief summary | |
|---|---|
| Total irrigated area | 160,000 ha |
| Main crop | Rice |
| Main irrigated zone | Flood plains and internal delta of Niger River |
| National authority on irrigation | Génie rural, which coordinates the three main irrigation operations: Office du Niger, Ségou, Mopti |
| Estimated cost per hectare | Controlled flooding: US$600-1,000/ha. Pumping: US$4,000-5,000/ha. The unit cost of development (apart from structural work) is of the order of MF400,000/ha in the Mopti region (1979 prices) or about US$1,000/ha |

Sources

USAID. Prospects for Small-Scale Irrigation Development in the Sahel, 1984.

Club du Sahel. Development of Irrigated Agriculture in Mali.

ECA. A Survey of Land and Water Resources of Africa, Vol. II, 1980.

Notes of and interviews with DDC staff familiar with Mali.

Table 10

## A Preliminary Inventory of MAURITANIA Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| M'Pourié (Near Rosso) | 1,400 | Rice | Senegal River. Dykes, canals and pumping station | Chinese technical assistance from 1971 to 1979. Centrally managed. Single cropping |
| Gorgol Pilot Scheme (Near Kaédi) | 700 | Rice, cereals | Senegal River. Dykes, canals and pumping station | FED. Centrally managed |
| M'Boughé | 850 | Rice | Senegal River. Pumping | |
| Small-Scale Irrigation Perimeters | 1,800 | Rice, corn, wheat | Flood water from Senegal River, mobile pump sets | FED, WB, FAC |
| Independent Private Irrigation | 2,150 | Rice | Pumping from delta of Senegal River | Private |
| Small-Scale Traditional Irrigation | 16,000 | Rice | Flood-fed, Senegal River. Varies from year to year | |

### Brief summary

| | |
|---|---|
| Total irrigated area | 23,000 ha approximately |
| Main crops | Rice, cereals |
| Main irrigated zones | Senegal River Basin |
| National authority on irrigation | Société nationale pour le développement rural (SONADER) |
| Estimated cost per hectare | US$7,000/ha (1979 prices). Dykes, canals and some pumping |

### Sources

ECA. A Survey of Land and Water Resources of Africa, Vol. II, 1980

Club du Sahel. Development of Irrigated Agriculture in Mauritania, 1979

The World Bank. Mauritania: Gorgol Irrigation Project, Staff Appraisal Report, 1980

## A Preliminary Inventory of NIGER Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Birni-N'Konni (Maggia River Basin) | 2,457 | Cotton, sorghum, wheat, vegetables | Maggia River, dam, open canals, gravity | |
| Galmi (Maggia River Basin) | 262 | Onions | Maggia River, dam, open canals gravity | |
| Maradi (Eastern Niger) | 500 | Groundnuts, cotton, sorghum, vegetables | Groundwater, pumping | FAC, WB |
| Small-Scale Irrigation | 7,000 | Vegetables | Fadama, shallow wells (up to 4 m) | Private |
| Maggia River, Maradi River, Komadongo | | Vegetables, sorghum | Pumps or shadouf | |
| **Niger River Valley** | | | | |
| Namari Goungo | 1,500 (840 in use) | Rice, maize | Pumping, canals, dykes | WB |
| Small-Irrigated Perimeters (less than 300 ha) | 3,200 | Rice | Pumping, canals | FAC/FED, FNI/Churi, Belgium |

Traditional flood and recession irrigation for rice and coarse grains, approximately 15,000 ha.

| Brief summary | |
|---|---|
| Total irrigated area | 30,000 ha |
| Main crops | Niger River: rice<br>Maradi, Maggia Rivers: cotton, sorghum, wheat, vegetables |
| Main irrigated zones | |
| National authority on irrigation | Office national de l'aménagement hydro-agricole, Niger (ONAHA) |
| Estimated cost per hectare | Maradi Region: over US$10,000/ha. Groundwater, full control, 1983 prices |

Sources

ECA. A Survey of Land and Water Resources of Africa, Vol. II, 1980

Club du Sahel. Development of Irrigated Agriculture in the Niger

USAID. Prospects for Small-Scale Irrigation Development in the Sahel

Interviews with and notes of DDC and AGL staff familiar with Niger

## A Preliminary Inventory of NIGERIA Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Project purpose and land allocation: Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Bakalori (Talata Mafara) in Sokoto State | 2,300 (800 in use) | Rice, wheat, maize, vegetables | Dam, gravity | |
| Kano River (I and II) | 62,000 (16,500 in use) | Wheat, maize, tomatoes | Dam, gravity | |
| South Chad (I, II and III) | 67,000 (10,000 irrigated) | Wheat, rice | Pumping from Lake Chad | |
| Mada Valley | 20,000 (2,000 irrigated) | Grains, vegetables | | |
| Daden Kowa | 2,500 (300 in use) | Grains, vegetables | | |
| Baga/Kirenowa Polder | 20,000 (500 irrigated) | Grains, vegetables | | |
| Dep River | 80,000 (150 irrigated) | Rice, maize, vegetables | | |

## Small-Scale Irrigation, 1978

| | | |
|---|---|---|
| Upland seasonally inundated depressions | Oyo, Ogun, Ondo, Bendel<br>Cross River | 90,000<br>4,000 |
| Similar with typical hydromorphic characteristics | Gongola, Benue | 23,000 |
| Similar with supplemental irrigation | Kwara, Niger | 60,000 |
| Shallow swamps | Imo-Anambra, Cross River, Kaduna, Bauchi | 90,000 |
| Riverain valley bottom swamps | Middle Belt and Northern States | 507,000 |
| Mangrove swamps | Rivers, Bendel | 31,000 |
| Total | | 805,000 |

Most of this bottomland development has been achieved by the efforts of the farming communities alone, with little help from Government authorities. This underlines the attractiveness of this cultivation system, the potential of which is far from exhausted.

### Brief summary

| | |
|---|---|
| Total irrigated area | Large-scale: 50,000 ha<br>Small-scale: 800,000 ha |
| Main crops | Rice, wheat and vegetables |
| Main irrigated zones | Along the major rivers |
| National authority on irrigation | See Table 10, Page 3 |
| Estimated cost per hectare | US$15,000-20,000/ha for large schemes (1983 prices) |

### Sources

The World Bank. Nigeria: Sector Review, 1979 (for small-scale irrigation)

FAO/AGL Representative in lagos (for large schemes)

## A Preliminary Inventory of SENEGAL Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Bakel I and II (Senegal River Valley) | 2,100 | Rice | Pumping from Senegal River | USAID, Kuwait Fund |
| Boundoum (Senegal River Delta), South Kassac | 2,400 (1,100 in use) | Rice | Pumping from Senegal River | FAC, CCCE |
| Dagana (Senegal River Valley) | 2,900 (1,500 in use) | Rice | Pumping from Senegal River | WB |
| Tellel Large Dam (Senegal River Delta) | 2,200 | Rice | Pumping from Senegal River | FAC/CCCE |
| Matam I and II | 1,500 | Rice | Pumping from Senegal River | CCCE. 1,000 small perimeters |
| Guede Dam (Casamance) | 800 | Rice | | AfDB/CIDA |
| Kam Beul Large Dam (Casamance) | 2,400 | Rice, tomatoes | Gravity from Casamance River | Abu Dhabi |
| Nianga | 1,000 | Rice | Pumping from Senegal River | Federal Repúblic of Germany |
| Thiagar (Senegal River Delta) | 1,300 (700 in use) | Rice | Pumping from Senegal River | FAC |
| N'Dombo Thiago | 700 | Rice, vegetables | Pumping from Senegal River | |
| Sugar Perimeters (Phase I) | 5,000 | Sugar | Pumping from Senegal River | Private funds and Government |

| Name & location | Project purpose and land allocation ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Modern Small-Scale Irrigation | 1,000 | Rice | Pumping from Senegal River | Private, NGO |
| Other Small-Scale Irrigation | 80,000 | Rice | Flood-fed swamp rice (natural submersion) or controlled submersion (mostly in the Casamance) | Private farmers |

Brief summary

| | |
|---|---|
| Total irrigated area | 100,000 ha (assuming that area under natural or controlled submersion has not changed since 1976) |
| Main crop | Rice |
| Main irrigated zones | Senegal River Valley and Delta, Casamance area |
| National authority on irrigation | Société d'aménagement et d'exploitation des terres du delta du fleuve Sénégal et des vallées du fleuve Sénégal et de la Falémé (SAED). The authority for the Casamance area is the Société de mise en valeur de la Casamance (SOMIVAC) |

Sources

ECA. A Survey of Land and Water Resources of Africa, Vol. II, 1980

Club du Sahel. Development of Irrigated Agriculture in Senegal, 1979

FAO/ISP. Projet d'irrigation en Salda-Wala (Identification/Préparation), 2 vol., 1983

M. Siméon. DDC BTO, 1985, Senegal

A Preliminary Inventory of

SOMALIA Irrigation Schemes

| Name & location | Project purpose and land allocation ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| **Shebelle Plain** | | | | |
| Jowhar | 320 | Maize, ground-nuts, cotton, rice, sesame, pulses | Controlled flooding | |
| Jowhar Sugar | 6,200 (4,850 in use) | Sugarcane, citrus | Gravity, furrows | |
| Balad Cotton | 1,000 | Maize, cotton, sesame | Diversion barrage, gravity | North Korea |
| Balad Ardegle | 6,630 | Maize, sesame, pulses/vegeta-bles, cotton, bananas, citrus | Diversion barrage, gravity | |
| Af Gai/Mordiile | 1,500 | Maize, ground-nuts, upland rice, sesame | Pumping | ADF. Problems with silt in canals |
| Janaale/Bulo Marurta | 21,000 (Not all in use) | Maize, sesame, upland rice, bananas, citrus, cotton | Diversion barrage, gravity | Insufficient water |
| Kurten-Waarey | 565 | Maize, upland rice, pulses, sesame, bananas | Swamps, seasonal flooding | |

Table 14
Page 1

| Name & location | Project purpose and land allocation ha | Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Sablaale | 1,000 | Maize, pulses, paddy rice, sesame, sorghum, bananas | | |
| Haawaay | 500 | Maize, rice | | |
| Small-Scale Irrigation | up to 85,000 | Sorghum, maize sesame, vegetables | Flood irrigation, depending on availability of water | |
| **Juba River** | | | | |
| Marurey | 7,700 (4,500 in use) | Sugar | | |
| Small-Scale Irrigation | 3,000 | Bananas | | Private |

**Brief summary**

| | |
|---|---|
| Fully-controlled irrigation | Approximately 40,000 ha |
| Total irrigated area | up to 100,000 ha, depending on availability of water |
| Main crops | Maize, groundnuts, cotton, rice, sesame, vegetables, bananas, citrus |
| Main irrigated zones | Shebelle and Juba River Basins |
| National authority on irrigation | Ministry of Mineral and Water Resources, Ministry of Agriculture |

**Sources**

The World Bank. Somalia: Agriculture Sector Review, Vol. II, Annex 2, 1981

Henry, J.C. Democratic Republic of Somalia, Present and Future Irrigated Agriculture in the Shebelle and Juba River Basins, FAO, Rome 1979

# A Preliminary Inventory of SUDAN Irrigation Schemes

| Name & Location | Project Purpose and Land Allocation: Ha | Project Purpose and Land Allocation: Crop | Source and Type of Irrigation | Other Information |
|---|---|---|---|---|
| Gezira | 468,000 | Cotton, groundnuts, sorghum & vegetables | Blue Nile (Sennar Dam), gravity | Oldest large-scale scheme started - 1920. Now being rehabilitated with the assistance of the World Bank |
| Managil | 397,000 | Cotton, groundnuts, sorghum & vegetables | Blue Nile (Sennar Dam), gravity | |
| New Halfa | 163,800 | Cotton, wheat & vegetables | Atbara (Khashm el Girba Dam), gravity | Recently rehabilitated with the World Bank assistance |
| Rahad | 126,000 | Cotton, groundnuts, sorghum & vegetables | Blue Nile, pumping and Rahad Barrage, gravity | Developed with the World Bank assistance |
| White Nile Nationalized Pump Schemes | 365,000 1/ | Cotton, sorghum & legumes | White Nile, pumping | The nationalized pump schemes are being rehabilitated with the assistance of the World Bank |
| Blue Nile Nationalized Pump Schemes | | Cotton, sorghum & legumes | Blue Nile, pumping | |
| Northern Region Pump Schemes | | Cotton, fruits & legumes | Main Nile, pumping | |
| Essuki | 35,700 | Cotton, groundnuts & sorghum | Blue Nile, pumping | |

1/ Evidence on the actual aggregate area under cultivation is contradictory and the above estimates for 1982 may be subject to a considerable margin of error. Recent reports have indicated the current cultivable area under these schemes as follows: White Nile Nationalized Schemes 183,000 ha; Blue Nile Nationalized Schemes 113,000 ha; and Northern Region Pump Schemes 183,000 ha.

| Name & Location | Project Purpose and Land Allocation: Ha | Project Purpose and Land Allocation: Crop | Source and Type of Irrigation | Other Information |
|---|---|---|---|---|
| Guneid | 35,700 | Sugarcane | Blue Nile, pumping | |
| Kenana | 33,600 | Sugarcane | White Nile, pumping | |
| Tokar Delta | 25,200 | Cotton and sorghum | Baraka River, natural flooding | |
| Gash Delta | 21,000 | Cotton, castor & sorghum | Gash River, natural flooding | |
| Hurga-Nurel Din | 20,600 | Cotton, sorghum & legumes | Blue Nile, pumping | |
| North West Sennar | 20,600 | Sugarcane | Blue Nile, pumping | |
| Elwaha | 16,800 | Fruits, vegetables & fodder | Blue Nile, pumping | |
| Abu Na'ama | 12,600 | Cotton & sorghum | Blue Nile, pumping | |
| Hagar Asalaya | 7,600 | Sugarcane | White Nile, pumping | |

**Brief Summary**

| | |
|---|---|
| Total irrigated area | 1,750,000 ha |
| Main crops | Cotton, sorghum, sugarcane, legumes, vegetables, fruits and some fodders |

**Sources**

The World Bank. Sudan: Agricultural Sector Survey, 1979 and Agriculture Sector Review, 1984.

B.M. Elbashir, Draft Paper, Planning Agricultural Policy Report, Northern Region, Sudan, prepared for FAO, 1985.

| Brief Summary | | Sources |
|---|---|---|
| Main irrigated zones | Central, Eastern and Northern Regions | A. Eltom, Draft Paper, Towards a Long-Term Agricultural Development Strategy and Related Policies for Sudan, prepared with FAO (ESP) Support, 1986. |
| National authority on irrigation | Ministry of Agriculture and Irrigation | Interviews with FAO staff familiar with Sudan. |

Table 16
Page 1

## A Preliminary Inventory of TANZANIA Irrigation Schemes

| Name & location | Project purpose and land allocation: ha | Project purpose and land allocation: Crop | Source and type of irrigation | Other information |
|---|---|---|---|---|
| Borali | 3,500 | Rice | Flood irrigation, gravity | |
| Kilombero | 10,000 (not fully in use) | Sugar | Pumping, sprinkler | |
| Ruvu | 800 | Rice | | |
| Tanganyika Plantation Co. | 5,000 | Sugar | Gravity, diversion, furrow irrigation | |
| Dakawa | 2,000 | | | |
| Small-Scale Traditional Irrigation | 115,000 | Rice, vegetables | Gravity, natural flooding | |
| Village Command Projects | | | | |
| Mitowa | 5,000 | | | |
| Mbarali | 20,000 (8,000 in use) | Rice | Flood irrigation, gravity | |
| Kyaka | 5,000 | Sugar | Sprinkler overhead irrigation, pumping | |

| Brief summary | | Sources |
|---|---|---|
| Total irrigated area | 140,000 ha, of which about 25,000 ha full control and 115,000 ha small-scale or traditional | The World Bank. Tanzania: Agricultural Sector Review, 1983 |
| Main crops | Rice, sugarcane. Total irrigated rice production: 40,000 tons | Tanzania, Ministry of Agriculture and Livestock Development. Tanzania National Food Strategy, Vol. II, 1984 |
| Main irrigated zones | Mbeya, Murogora, Kilimangiaro, Tabora, Mwanza, Ruvuma | ECA. A Survey of Land and Water Resources of Africa, Vol. II, 1980 |

## Inventory of Existing Irrigated Agriculture in Sub-Saharan Africa

| Country | Population 1982 (millions) | Irrigated area 1965 | Irrigated area 1974 | Irrigated area 1982 | Other information |
|---|---|---|---|---|---|
| | | .......... | ha | .......... | |
| BENIN | 3.7 | 100 | 9,400 | 22,000 1/ | Three medium-sized projects based on gravity for rice production. Also small-scale rice production in inland valley swamps, about 10,000 ha. |
| BOTSWANA | 0.9 | 3,000 | 9,500 | 12,000 2/ | Small-scale. Irrigated plots in different climatic regions of the country. There are commercial market gardens for producing vegetables along Limpopo River. |
| BURKINA FASO | 6.5 | 100 | 6,000 | 29,000 3/ | Two large projects and two medium projects using diversion dam and gravity for producing rice. Also some pumping and sprinkler irrigation (for more details, see Table 4). Approximately 20,000 ha traditional flood irrigation.<br><br>2,000 ha of small-scale irrigation using pumps for producing vegetables and fruits. |
| BURUNDI | 4.2 | - | 5,500 | 52,000 1/ | Small-scale irrigation in the form of cultivation of the inland valley swamps (with pent and mineral soils). Mainly rice. Also one large project. Coffee, rice. Full control. |
| CAMEROON | 9.3 | 4,000 | 14,200 | 20,000 | One large project based on pumping. Other small-scale, flood-fed river flood plain, mainly rice. |
| CHAD | 4.6 | 7.000 | 10,000 | 50,000 1,5/ | 3,300 ha under full control and 7,400 ha under partial control. Irrigated production consisting of rice, sugar and vegetables. Three large schemes and four medium-size schemes. About 40 ,000 ha traditional flood irrigation. |
| CONGO | 1.7 | - | 2,200 | 8,000 1/ | Small-scale flood-fed irrigation and an approximately equal area of modern irrigation. |

| Country | Population 1982 (millions) | Irrigated area 1965 | 1974 | 1982 | Other information |
|---|---|---|---|---|---|
| | | ........... | ha | ........... | |
| ETHIOPIA | 40.0 | 58,700 | 92,600 | 87,000 1/ | One very large project. Eleven large projects. Mostly based on gravity and some pumping. Irrigated crops are cotton, sugar and cereals. Also some small-scale flood-fed river flood plains production of cotton (for more details, see Table 5). |
| GABON | 0.7 | - | 200 | 600 | Insignificant irrigation. |
| GAMBIA | 0.7 | 25,000 | 33,000 | 26,050 6/ | Small scale: 3,000 ha pump irrigation, 12,800 ha swamp rice, 10,000 ha marginal swamps. |
| GHANA | 12.2 | 200 | 16,100 | 10,000 1,7/ | Two existing large-scale projects (dams, pumping): full control. Eight medium-scale projects (pumping): full control. Main crops are rice and vegetables. Small-scale irrigation: swamp rice and pumping: 500 ha (for more details, see Table 6). About 5,000 ha uncontrolled irrigation. |
| GUINEA | 5.7 | 41,000 | 64,000 | 45,000 1/ | One very large project. Also extensive traditional swamp rice. |
| IVORY COAST | 8.9 | 6,700 | 32,900 | 52,000 4/ | 30,000 ha of large-scale irrigated sugarcane plantation. 15,000 ha of medium-scale rice operations using small earth dams, or run-of-the-river. Also some swamp rice (mostly in the north), fruit trees and vegetables (urban perimeters). |
| KENYA | 18.1 | 15,000 | 36,000 | 49,000 8/ | Three large projects based on gravity and pumping, mostly for rice. 10,000 ha of medium- and large-scale private irrigation for coffee, fruit, sugar, vegetables, based on overhead irrigation. 26,000 ha of small-scale irrigation using pumps, sprinklers and gravity for producing coffee, fruit and foodcrops (for more details, see Table 7). |

| Country | Population 1982 (millions) | Irrigated area 1965 | 1974 | 1982 | Other information |
|---|---|---|---|---|---|
| | | .......... | ha | .......... | |
| LESOTHO | 1.4 | - | - | 800 | Insignificant irrigation. |
| LIBERIA | 2.0 | 40 | 2,500 | 19,000 1/ | Improved and traditional swamp rice. |
| MADAGASCAR | 9.2 | 330 | 426,000 | 960,000 9/ | 80,000 ha of large irrigation schemes.<br>80,000 ha of medium irrigation schemes.<br>300,000 ha of small water-control development.<br>500,000 ha of family rice fields.<br>(for more details see Table 8) |
| MALAWI | 6.5 | 600 | 11,000 | 20,000 10/ | 15,000 ha of medium- and large-scale private commercial sugar plantations based on surface and overhead irrigation.<br>3,100 ha of government-assisted smallholder irrigated rice schemes.<br>1,500 ha of small-scale self-help farmer schemes mostly for one summer crop of rice (some maize and vegetables).<br>Irrigation is mostly supplementary using gravity, infiltration and water lifting. |
| MALI | 7.1 | 117,000 | - | 160,000 1/ | Three very large schemes: 107,000 ha.<br>Large and medium schemes: 22,000 ha.<br>Small-scale irrigation: 20,660 ha.<br>Main crops are rice, cotton and sugarcane. Vegetables are also produced in the small-scale operations (for more details, see Table 9). |
| MAURITANIA | 1.7 | 10,700 | 33,000 | 22,680 11/ | One large-scale project: 1,400 ha.<br>Two medium-scale projects: 1,280 ha.<br>Small-scale village schemes: about 20,000 ha, mostly of traditional flood-fed irrigation.<br>Main crop is rice (for more details, see Table 10). |

| Country | Population 1982 (millions) | Irrigated area 1965 | 1974 | 1982 | Other information |
|---|---|---|---|---|---|
| | | ........ | ha | ........ | |
| MAURITIUS | 0.9 | 12,000 | 21,000 | 14,371 12/ | 9,122 ha of sugar estates. 5,249 ha of small-scale irrigation. Irrigation methods consist of both overhead (sprinkler and drip) and surface (mainly gravity) irrigation. Main irrigated crop is sugar. |
| MOZAMBIQUE | 12.9 | 16,000 | 34,000 | 70,000 1/ | Large-scale irrigation mostly using sprinkler method. Irrigated crops are rice, maize, tomatoes, tobacco and soya. |
| NIGER | 5.9 | 1,900 | 2,900 | 30,000 1/ | One large-scale project; irrigation through gravity from a dam. Three medium-scale projects; two using gravity and one using groundwater through pumping. 3,200 ha of small irrigated perimeters; pumping and fadama (for more details, see Table 11). About 15,000 ha traditional uncontrolled irrigation. |
| NIGERIA | 90.6 | 300,000 | 400,000 | 850,000 1/ | 200,000 ha of very large-scale schemes (only 50,000 ha are actually irrigated). 800,000 ha of small water-control developments consisting of inland valley swamps, flood and river flood plains, and small-scale pumping from shallow wells; 1965 and 1974 are guestimates based on the rapid growth of small-scale irrigation in Nigeria during the past 10 years. Main crop is rice (for more details, see Table 12). |
| RWANDA | 5.5 | 2,600 | 12,700 | 15,000 | Small-scale swamp rice. |
| SENEGAL | 6.0 | 13,600 | 38,100 | 100,000 1/ | Eight large-scale projects, all based on pumping from Senegal River. One large-scale project using gravity from Casamance River. Total water control covers 20,000 ha. Partial water control in small-scale perimeters or river flood plains covers about 80,000 ha.<br><br>Irrigated crops are rice, sugar and vegetables (for more details, see Table 13). |

| Country | Population 1982 (millions) | Irrigated area 1965 | 1974 | 1982 | Other information |
|---|---|---|---|---|---|
| | | .......... | ha | .......... | |
| SIERRA LEONE | 3.2 | - | - | 55,000 1/ | Small-scale flood-fed river plains and inland valley swamp rice. |
| SOMALIA | 4.5 | 31,500 | 47,200 | 80,000 1/ | One very large project, seven large projects and three medium-scale projects.<br>Irrigation consists of diversion barrage using gravity, controlled flooding and swamp management.<br>Main irrigated crops are maize, groundnuts, cotton, rice, sesame, vegetables, bananas and citrus.<br>Also small-scale flood irrigation along the Shebelle and the Juba Rivers (for more details, see Table 14). |
| SWAZILAND | 0.7 | 40,000 | 56,000 | 60,000 1/ | Annual total depends on availability of water<br>Mostly large estates producing citrus and sugarcane by sprinkler irrigation and flooding. |
| SUDAN | 20.2 | 1,352,000 | 2,064,000 | 1,750,000 1/ | Mostly very large-scale projects using the Blue and the White Nile River for producing both food and export crops (for more details see Table 15). |
| TANZANIA | 19.8 | 27,900 | 52,000 | 140,000 14/ | About 25,000 ha of large-scale irrigation using gravity, pumping and sprinkler to produce rice and sugar.<br>115,000 ha of small-scale flood irrigation producing rice and vegetables (for more details, see Table 16). |
| TOGO | 2.8 | 210 | 6,200 | 13,000 1/ | Largely supplementary irrigation. Rice and maize are the irrigated crops. Some small-scale swamp irrigation. |
| UGANDA | 13.5 | 3,000 | 16,000 | 12,000 1/ | One large-scale project, rice.<br>Small-scale swamp irrigation, fruit trees and sugarcane. |
| ZAIRE | 30.7 | 2,530 | 4,200 | 24,000 1/ | Small-scale. Inland swamp and flood irrigation for rice. |

| Country | Population 1982 (millions) | Irrigated area 1965 (ha) | Irrigated area 1974 (ha) | Irrigated area 1982 (ha) | Other information |
|---|---|---|---|---|---|
| ZAMBIA | 6.0 | 2,000 | 17,500 | 16,000 15/ | One large sugar estate: irrigation by flood and sprinkler. Other small-scale irrigation. |
| ZIMBABWE | 7.5 | 36,000 | 65,800 | 130,000 1/ | 3,000 ha of very large and large private commercial estates producing cotton, sugarcane and citrus. The method of irrigation is both sprinkler and flooding.<br>9,000 ha of State schemes, large-scale, using gravity. Crops are cotton, wheat, barley, rice, beans, tobacco, coffee and tea.<br>About 80,000ha ofsmall-scale irrigated commercial farms. Important supplementary irrigation based on the sprinkler method and also some based on gravity. Cotton, tea, coffee, tobacco, citrus and vegetables.<br>11,000 ha of small-scale settler schemes.<br>5,700 ha of peasant irrigation based on flood-fed river flood plains. Also abstraction of water from streams. Producing cotton, wheat, beans, maize and vegetables (approximately 20,000 ha). |

## Summary of Estimated 1982 Irrigated Area in Sub-Saharan Africa

| | |
|---|---|
| Total irrigated area | 5.02 million ha |
| | |
| Total very large schemes | 1.74 million ha |
| Total large and medium-scale schemes | 0.90 million ha |
| Total small-scale irrigation (mostly traditional) | 2.38 million ha |

## SOURCES

1/ Estimates prepared for the FAO Africa Study (1986 in press)

2/ D. Kraatz, FAO Investment Centre, personal communication

3/ Club du Sahel, 1979; DDC Sector Review, 1985

4/ Adapted from World Bank Irrigation Sub-Sector Review (1985 in preparation)

5/ Club du Sahel, 1984

6/ I. Hill, FAO Investment Centre Back-to-Office Report, 1985

7/ World Bank, Irrigation Sub-Sector Review (1986 in preparation)

8/ W. Post: "Irrigation Development in Kenya", mimeo, 1982

9/ World Bank, Sector Memorandum, 1983.

10/ D. Kraatz, FAO Investment Centre, personal communication

11/ World Bank, adapted from the Gorgol Irrigation Project Staff Appraisal Report (1980)

12/ K. Lin, "Irrigation in Mauritius", in Blackie Ed., 1984

13/ Swamp development in Sierra Leone, FAO 1983 (mimeo)

14/ Government of Tanzania, National Food Strategy (1984)

15/ Mupawose: "Irrigation in Zimbabwe", in Blackie Ed., 1984

Table 18

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Contribution of Irrigated/Wetland Rice to Rice Production in SSA (1982)

| Country | Total Production | Upland | Wetland | Modern Irrigation | Irrigated Production as Percent of Total |
|---|---|---|---|---|---|
| | ..........'000 t.......... | | | | |
| Madagascar | 2,000 | 400 | 1,000 | 600 | 80 |
| Nigeria | 1,400 | 350 | 910 | 140 | 75 |
| Sierra Leone | 550 | 300 | 250 | 0 | 45 |
| Ivory Coast | 500 | 425 | 75 | 0 | 15 |
| Guinea | 275 | 180 | 95 | n.a. | 35 |
| Liberia | 241 | 229 | 12 | 0 | 5 |
| Zaire | 255 | 243 | 12 | 0 | 5 |
| Tanzania | 200 | 90 | 100 | 10 | 55 |
| Mali | 250 | 13 | 87 | 150 | 95 |
| Senegal | 100 | 25 | 65 | 10 | 75 |
| Ghana | 90 | 67 | 4 | 19 | 25 |
| Mozambique | 62 | 3 | 12 | 47 | 95 |
| Cameroon | 60 | 15 | 15 | 30 | 75 |
| Niger | 29 | 2 | 19 | 8 | 95 |
| Chad | 47 | 3 | 41 | 3 | 95 |
| Kenya | 43 | 11 | n.a. | 32 | 75 |
| Burkina Faso | 40 | 2 | 30 | 8 | 95 |
| Gambia | 35 | 2 | 29 | 4 | 95 |
| Guinea Bissau | 30 | 15 | 15 | 0 | 50 |
| Total | 6,207(a) | 2,375 | 2,771 | 1,061 | 62 |

Source: FAO

(a) Total production of rice in all SSA is 6.45 million tons.

Table 19

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Major Producer Countries for Irrigated Sugarcane in SSA
(1982)

| Country | Total Production | Rainfed | Irrigated | Irrigated Percent |
|---|---|---|---|---|
| | ................ | '000 t | ................ | |
| Mauritius | 6,500 | 5,525 | 975 | 15 |
| Kenya | 4,600 | 3,680 | 920 | 20 |
| Zimbabwe | 3,600 | 180 | 3,420 | 95 |
| Swaziland | 3,300 | 165 | 3,135 | 95 |
| Sudan | 2,500 | 0 | 2,500 | 100 |
| Ivory Coast | 2,400 | 120 | 2,280 | 95 |
| Malawi | 1,800 | 0 | 1,800 | 100 |
| Tanzania | 1,500 | 150 | 1,350 | 90 |
| Ethiopia | 1,400 | 70 | 1,330 | 95 |
| Nigeria | 1,200 | 960 | 240 | 20 |
| Zambia | 1,000 | 50 | 950 | 95 |
| Somalia | 600 | 0 | 600 | 100 |
| Sudan | 400 | 0 | 400 | 100 |
| Total | 30,800 (a) | 10,900 | 19,900 | 65 |

Source: FAO

(a) Total production of sugarcane in SSA in 1982 is estimated at 41 million tons. Most of the remainder is small-scale rainfed cane; hence the irrigated total of 19.9 million tons represents about 50% of total cane production.

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Madagascar: Lake Alaotra Irrigation Project

| Item | Original Appraisal Estimate | Actual/ Re-estimate | Remarks |
|---|---|---|---|
| General Project Data | | | |
| Type of irrigation | Surface diversion, gravity distribution, full control | Surface diversion, gravity distribution, full control | |
| Starting date | November 1970 | November 1970 | |
| Date physical components completed | December 1975 | January 1975 | |
| Closing date | June 1976 | June 1975 | |
| Development area (ha) | 10,000 | 10,000 | Plus about 1,800 ha dryland cropping. |
| Objectives/Project Benefits | | | |
| Number of direct beneficiaries (families) | 2,900 | 2,800 | |
| Number of settler families | 1,700 | did not take place | No funds were made available by the project for settlement infrastructure. |
| Incremental annual production at full development: | | | |
| - paddy (tons) | 25,900 | 24,500 | |
| Yields at full development: | | | |
| - paddy (kg/ha) | 3,350 | 3,000 | |
| - beans " | 1,000 | did not take place | |
| - wheat " | 2,000 | " " " | |
| Cropping Intensity (%) | 150 | 100 | Farmers who live at distance from the fields had no incentive to double crop. |
| ERR (%) | 11 | 22 | High rate of return because of increased paddy prices and reduced estimates of production without project during re-evolution. |
| Costs 1/ (US$ million) | | | |
| Total | 8.20 | 8.96 1/ | |
| Irrigation works ) Roads ) Buildings ) | 3.55 | 5.18 | |
| Equipment | 0.80 | 0.48 | |
| On-farm development | 1.01 | 1.53 | |
| Research, extension & training | 1.01 | 1.08 | |
| Technical assistance & studies | 0.64 | 0.69 | |
| Contingencies | 1.19 | - | |
| Total cost/ha (US$) | 820 (in 1970) | 896 (in 1976) | |
| Total cost/family (US$) | 2,828 (in 1970) | 3,200 (in 1976) | |

Source: World Bank Project Performance Audit Report No. 1622, - 8 June, 1977.

1/ Exchange rate at appraisal: US$ 1 = FMG 278 and average for the project period US$ 1 = FMG 245. The project was appraised in 1970 and completed in 1976.

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Mali : Riz Mopti Project

| Item | Original Appraisal Estimate | Actual/ Re-estimate | Remarks |
|---|---|---|---|
| **General Project Data** | | | |
| Type of irrigation | Controlled flood | Controlled flood | |
| Starting date | April 1972 | June 1972 | |
| Date physical components completed | June 1975 | February 1975 | |
| Closing date | May 1978 | September 1980 | |
| Development area (ha) | 31,100 | 26,100 | |
| **Objectives/Project Benefits** | | | |
| Number of direct beneficiaries (families) | 7,300 | 7,800 | |
| Incremental annual production at full development: | | | |
| - paddy (tons) | 35,000 | 29,400 | |
| Yields at full development: | | | |
| - average paddy (kg/ha) | 1,860 | 926 | Yields were lower due to limited adoption of improved cultivation techniques and wild rice infestation. |
| ERR (%) | 14 | 17 | Higher ERR because of inreased rice prices |
| **Costs 1/ (US$ million)** | | | |
| Total | 9.42 | 13.13 1/ | |
| Irrigation works | 3.21 | 5.54 | |
| Buildings | 0.65 | 1.10 | |
| Equipment | 0.93 | 0.93 | |
| On-farm development | - | 0.17 | |
| Research, extension and training | 0.45 | 0.17 | |
| Management and extension services | 1.72 | 4.51 | |
| Technical assistance & studies | 0.88 | 0.71 | |
| Contingencies | 1.58 | - | |
| Total cost/ha (US$) | 303 (in 1971) | 503 (in 1978) | |
| Total cost/family (US$) | 1,290 (in 1971) | 1,683 (in 1978) | |

Source: World Bank Project Performance Audit Report No. 3523 - 25 June, 1981.

1/ Exchange rate at appraisal: US$1 = MF 555.4 and average for the project period US$1 = MF 469.6. The project was appraised in 1971 and completion report prepared in 1978.

Table 21

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Cameroon : SEMRY I Rice Project

| Item | Original Appraisal Estimate | Actual/ Re-estimate | Remarks |
|---|---|---|---|
| **General Project Data** | | | |
| Type of irrigation | Pumped, surface distribution, full control | Pumped, surface distribution, full control | |
| Starting date | July 1972 | July 1972 | |
| Date physical components completed | June 1975 | July 1975 | |
| Closing date | June 1976 | June 1976 | |
| Development area (ha) | 4,300 | 4,075 | Plus an additional 725 ha elsewhere (Polder 8) |
| **Objectives/Project Benefits** | | | |
| Number of direct beneficiaries (families) | 2,800 | 2,870 | |
| Incremental annual production at full development: | | | |
| - wet season paddy (tons) | 11,460 | 18,335 | |
| - dry season paddy (tons) | 4,500 | 13,500 | |
| Yields at full development: | | | |
| - wet season paddy (kg/ha) | 3,000 | 4,500 | Yields are higher because of the general acceptance of transplanting by farmers. |
| - dry season paddy " | 3,000 | 4,500 | |
| Cropping Intensity (%) | 134 | 173 | |
| ERR (%) | 11 | 23 | High ERR due to increase in yields, remarkable rate of double cropping and higher paddy prices. |
| Costs 1/ (US$ million) | | 1/ | |
| Total | 7.40 | 9.26 | |
| Irrigation works | 2.49 | 3.55 | |
| Buildings | n.a. | 0.35 | |
| Equipment | 1.35 | 1.52 | |
| On-farm development | 0.28 | 1.35 | |
| Administration, overheads & mainten. | 1.33 | 0.42 | |
| Technical assistance & studies | 0.82 | 2.07 | |
| Contingencies | 1.13 | - | |
| Total cost/ha (US$) | 1,721 (in 1971) | 2,272 (in 1977) | |
| Total cost/family (US$) | 2,643 (in 1971) | 3,226 (in 1977) | |

Source: World Bank Project Performance Audit Report No. 2054 - 12 May, 1978.

1/ Exchange rate at appraisal: US$1 = CFAF 256 and average for the project period US$1 = 245. The project was appraised in 1971 and completed in 1975.

Table 22

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Madagascar : Morondava Irrigation and Rural Development Project

| Item | Original Appraisal Estimate | Actual/ Re-estimate | Remarks |
|---|---|---|---|
| **General Project Data** | | | |
| Type of irrigation | Surface diversion, gravity and sprinkler distribution, full control | Surface diversion, gravity distribution full control | |
| Starting date | September 1972 | April 1973 | Delayed because of uncertainty caused when the Government was overthrown in May 1972. |
| Date physical components completed | December 1978 | December 1981 | |
| Closing date | June 1979 | December 1981 | |
| Development area (ha) | 9,300 | 3,800 | |
| **Objectives/Project Benefits** | | | |
| Number of direct beneficiaries (families) | 3,500 | 4,745 | At completion, about 1,065 farm families in the project area and 3,680 outside have benefitted from project activities. |
| Number of settler families | 2,300 | n.a. 1/ | |
| Incremental annual production at full development: | | | The expected cotton production on state farms was insignificant due to poor performance of the State Corporation. Tobacco and groundnut production on state farms under sprinkler irrigation was deleted to reduce costs and did not materialize. |
| - paddy (tons) | 32,500 | 15,800 | |
| Yields at full development: | | | |
| - paddy (kg/ha) | 4,000 | 2,600 | Yields were low because of poor design of field canals, poor land levelling, lack of animal traction and farmers' lack of experience in rice cultivation. |
| Cropping Intensity Paddy (%) | 160 | 90 | |
| ERR (%) | 16 | negative to 0 | |
| Total Costs 1/ (US$ million) | 27 | 56 1/ | Cost over-runs are mainly due to re-design of the dam and the main canals, and inflation. |
| Total cost/ha (US$) | 2,903 (in 1971) | 14,737 (in 1983) | |
| Total cost/family (US$) | 7,714 (in 1971) | 11,802 (in 1983) | |

Source: World Bank Project Performance Audit Report No. 5403 - 28 December, 1984.

1/ Details are not provided in the PPAR.

Table 23

## STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

### Sudan : Rahad Irrigation Project

| Item | Original Appraisal Estimate | Actual/ Re-estimate | Remarks |
|---|---|---|---|
| **General Project Data** | | | |
| Type of irrigation | Pumped, surface distrib, full control | Pumped, surface distrib, full control | Detailed design after appraisal revealed heavy cost over-runs and the project was reappraised in 1975. |
| Starting date | August 1973 | November 1975 | |
| Date physical components completed | June 1978 | December 1982 | |
| Closing date | June 1979 | June 1983 | |
| Development area (ha) | 126,000 | 126,000 | |
| **Objectives/Project Benefits** | | | |
| Number of direct beneficiaries (fam.) | 160,000 | 140,000 | |
| Number of settler families | 13,700 | 14,242 | |
| Incremental annual production at full development: | | | |
| - cotton (tons) | 119,000 | 114,000 (average 1981/82 and 1982/83) | |
| - groundnuts " | 84,000 | 43,300 " " | |
| - sorghum " | not foreseen at appraisal | 37,370 " " | Sorghum was included by farmers being their main food crop, animal fodder, thatching material and means of payment to cotton pickers. |
| - vegetables " | n.a. | 43,365 " " | |
| Yields at full development: | | | |
| - cotton (kg/ha) | 2,020 | 2,278 " " | Yields improved because of better procurement prices and experience gained with new crops. |
| - groundnut " | 2,150 | 1,780 " " | |
| - sorghum " | n.a. | 2,780 " " | |
| - vegetables " | n.a. | 15,140 " " | |
| Cropping Intensity (%) | 85 | 83 | |
| ERR (%) | 13.5 | 20 | High ERR because of good agricultural performance, treatment of dam costs as sunk costs, higher prices & economic analyses carried out over 30 years instead of over 15 years. |
| **Costs** 1/ (US$ million) | | | |
| Total | 124.3 | 395.6 1/ | Cost over-run is due to delay in implementation as no detailed designs were available before appraisal. |
| Irrigation works | 54.2 | 164.6 | |
| Roads | 7.2 | 36.2 | The costs refer to the original appraisal of 1972 and there is a general cost over-run because of delayed implementation. |
| Buildings 2/ | 28.2 | 90.5 | |
| Equipment | 17.8 | 57.0 | |
| Research, extension & training | - | 1.6 | |
| Administration, overheads & mainten. | 2.6 | 9.4 | |
| Social amenities | 4.1 | 6.2 | |
| Settlement | 4.5 | 16.4 | |
| Technical assistance & studies | 5.7 | 13.7 | |
| Total cost/ha (US$) | 987 (in 1972) | 3,140 (in 1983) | |
| Total cost/family (US$) inc. labourers | 777 (in 1972) | 2,826 (in 1983) | |

Source: World Bank Project Performance Audit Report No. 5130, 13 June, 1984.

1/ Exchange rate at appraisal US$1 = LSd 2.5 and average for the project period US$1 = LSd 2.15.

2/ Consists of project buildings, services, utilities, processing and warehouses.

Table 25

## STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

### Cameroon : SEMRY II Rice Project

| Item | Original Appraisal Estimate | Actual/ Re-estimate | Remarks |
|---|---|---|---|
| **General Project Data** | | | |
| Type of irrigation | Reservoir, gravity distribution, full control | Reservoir, gravity distribution, full control | |
| Starting date | June 1978 | April 1978 | |
| Date physical components completed | December 1983 | June 1986 | Dike repair requirements have delayed the finalization of drainage, on-farm works and the settlement of new farmers, which is now expected to be completed by June 1986. |
| Closing date | September 1984 | Bank loan & credit fully disbursed & closed in Sept. 1984 but works would be completed in June 1986 | |
| Development area (ha) | 7,000 | 7,000 | |
| **Objectives/Project Benefits** | | | |
| Number of direct beneficiaries (settler families) | 7,000 | 7,500 | |
| Incremental annual production at full development: | | | |
| - paddy (tons) | 47,000 | 53,000 | |
| Yields at full development: | | | |
| - wet season paddy (kg/ha) | 4,000 | 4,500 | |
| - dry season paddy " | 4,700 | 5,500 | |
| Cropping Intensity (%) | 158 | 180 | |
| ERR (%) | 15 | 20 | Better ERR than that estimated at appraisal because of higher yields & cropping intensity which have more than offset the higher costs. |
| **Costs** 1/ (US$ million) | | | |
| Total | 55.50 | 68.80 1/ | Cost over-run due to dike repair and consequent delay. |
| Irrigation works | 16.73 | 22.18 | |
| Buildings | 5.78 | 8.31 | |
| Equipment | 12.80 | 13.33 | |
| Research, extension and training | 0.27 | 0.67 | |
| Administration, overheads & mainten. | 5.67 | 5.38 | |
| Social amenities | 0.62 | 0.84 | |
| Settlement | 0.53 | 1.87 | |
| Technical assistance & studies | 11.02 | 13.42 | |
| Other (fertilizer received for farmers, stocks & works outside the project area) | 2.08 | 2.80 | |
| Total cost/ha (US$) | 7,929 (in 1977) | 9,829 (in 1982) | |
| Total cost/family (US$) | 7,429 (in 1977) | 9,173 (in 1982) | |

Source: World Bank Project Performance Audit Report No. 5156 - 25 June, 1984.

1/ Costs are as of June 1982 and are converted from CFAF to US$ using the intervening year's average between appraisal and 1982 of US$1 = CFAF225. Exchange rate at appraisal (1977) was US$1 = CFAF 245. Total project costs are estimated to reach US$75 million when all works would be completed in June 1986.

Table 26

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Comparison Between Expected Goals, Benefits and Costs and Achievements at Project Completion

| | Lake Alaotra | Mopti | SEMRY I | Morondava | Rahad | SEMRY II |
|---|---|---|---|---|---|---|
| Development Area (ha) - expected | 10,000 | 31,100 | 4,300 | 9,300 | 126,000 | 7,000 |
| - actuel | 10,000 | 26,100 | 4,075 | 3,800 | 126,000 | 7,000 |
| Cropping Intensity (%) - expected | 150 | - | 134 | 160 | 85 | 158 |
| - actual | 100 | - | 173 | 90 | 83 | 180 |
| Incremental Production (tons) Paddy | | | | | | |
| - expected | 25,900 | 35,000 | 15,960 | 32,500 | - 1/ | 47,000 |
| - actual | 24,500 | 29,400 | 31,835 | 15,800 | - 1/ | 53,000 |
| Yields (kg/ha) Paddy - expected | 3,350 | 1,860 | 3,000 | 4,000 | - 1/ | 4,000 & 4,700 2/ |
| - actual | 3,000 | 926 | 4,500 | 2,600 | - 1/ | 4,500 & 5,500 2/ |
| Number of Beneficiaries - expected | 2,900 | 7,300 | 2,800 | 3,500 | 160,000 | 7,000 |
| - actual | 2,800 | 7,800 | 2,870 | 4,745 | 140,000 | 7,500 |
| Number of Settlers - expected | 1,700 | - | - | 2,300 | 13,700 | 7,000 |
| - actual | none | - | - | n.a. | 14,242 | 7,500 |
| ERR (%) - expected | 11 | 14 | 11 | 16 | 13.5 | 15 |
| - actual | 22 | 17 | 23 | negative to 0 | 20 | 20 |
| Costs (US$ million) - expected | 8.20 | 9.42 | 7.40 | 27.0 | 124.3 | 55.50 |
| - actual | 8.96 | 13.13 | 9.26 | 56.0 | 395.6 | 68.80 |
| Implementation Period (years) - expected | 5.5 | 6.0 | 4.0 | 5.0 | 6.0 | 6.0 |
| - actual | 4.5 | 8.0 | 4.0 | 8.5 | 7.5 | 8.0 |

1/ Expected production was 119,000 tons of cotton and 84,000 tons of groundnuts but achievements have been 114,000 tons of cotton, 43,300 tons of groundnut and 37,370 tons of sorghum. Yield expectations were 2,020 kg/ha for cotton and 2,150 for groundnut as opposed to actuals of 2,278 kg/ha and 1,780 kg/ha of sorghum respectively.

2/ Dry season and wet season paddy.

Table 27

## STUDY OF IRRIGATION IN AFRICA SOUTH OF SAHARA

### Cost Per Hectare

| Project | Total Costs Current Prices | Total Costs 1985 Prices | Irrigation Works 1/ Current Prices | Irrigation Works 1/ 1985 Prices | Adm. Overheads & Maintenance Current Prices | Adm. Overheads & Maintenance 1985 Prices | Technical Assistance Current Prices | Technical Assistance 1985 Prices | Other Current Prices | Other 1985 Prices |
|---|---|---|---|---|---|---|---|---|---|---|
| | (US$) | | | | | | | | | |
| Lake Alaotra (gravity - full irrigation) | | | | | | | | | | |
| Appraisal (1970) 3/ | 820 | 2,355 | 627 2/ | 1,801 | n.a. | n.a. | 75 | 215 | 118 | 339 |
| Completion (1976) | 896 | 1,250 | 719 2/ | 1,003 | n.a. | n.a. | 69 | 96 | 108 | 151 |
| Mopti (flood control) | | | | | | | | | | |
| Appraisal (1971) 3/ | 303 | 802 | 160 | 424 | 66 | 174 | 34 | 90 | 43 | 114 |
| Completion (1977) | 503 | 650 | 254 | 328 | 173 | 224 | 27 | 35 | 49 | 63 |
| First Semry (pump - full irrigation) | | | | | | | | | | |
| Appraisal (1971) 3/ | 1,721 | 4,560 | 1,131 | 2,997 | 365 | 967 | 225 | 596 | - | - |
| Completion (1977) | 2,272 | 2,930 | 1,575 | 2,031 | 103 | 133 | 508 | 655 | 86 | 111 |
| Morondava (gravity - full irrigation) | | | | | | | | | | |
| Appraisal (1971) | 2,903 | 7,690 | - | - | - | - | - | - | - | - |
| Completion (1983) | 14,737 | 15,030 | - | - | - | - | - | - | - | - |
| Rahad (pump - full irrigation) | | | | | | | | | | |
| Appraisal (1972) | 987 | 2,385 | 450 | 1,087 | 16 | 39 | 36 | 87 | 485 | 1,172 |
| Completion (1983) | 3,140 | 3,200 | 1,759 | 1,794 | 74 | 75 | 109 | 110 | 1,198 | 1,221 |
| Second Semry (gravity - full irrigation) | | | | | | | | | | |
| Appraisal (1977) | 7,929 | 10,224 | 4,219 | 5,440 | 810 | 1,044 | 1,574 | 2,030 | 1,326 | 1,710 |
| Completion (1982) | 9,829 | 9,600 | 5,073 | 4,955 | 769 | 751 | 1,917 | 1,872 | 2,070 | 2,022 |

1/ Includes irrigation works, on-farm development and equipment.
2/ Includes roads and buildings as they were not given separately in the PPAR.
3/ Contingencies have been pro-rated on the different cost items.

## STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

## IRRIGATION COSTS IN FRANCOPHONE AFRICA SOUTH OF THE SAHARA

### A. Introduction

1. This annex is based mainly on experience in Mali, and relies on documentary sources for other Sahelian countries. Evidently there are likely to be variations between countries which can only be confirmed by field visits. The figures given should not therefore be taken as definitive. The annex considers:

- the costs of building, operating and maintaining irrigation works in the Sahelian region;

- the reasons why these costs are so high;

- the possibilities of cutting costs while maintaining acceptable technical standards.

The presentation is divided into three parts covering the classification of irrigation types and construction costs; the costs of operation and maintenance, and suggestions for cost reduction. Findings are summarised in attached tables.

### B. Classification of Irrigation Types and Construction Costs

2. Six different types of irrigation system are discussed in this section. Ranging from the simplest to the most complicated they are:

- controlled flooding;

- swamp or lowland schemes (<u>bas fonds</u>);

- recession irrigation;

- groundwater systems;

- pressure irrigation systems;

- fully-controlled surface irrigation.

A summarised technical description giving the main characteristics of each is given in Table 1. Construction costs are summarised in Table 2 and approximate estimates of O & M costs are given in Table 3. It should be noted, however, that all construction cost estimates <u>exclude</u> major multipurpose infrastructure such as dams, as well as supporting items not directly required for irrigation such as major access roads. In the case of surface irrigation systems the cost of main supply canals are also excluded, because of the wide variations which are likely between sites. In many cases it will in practice be necessary to add to the costs derived here the costs of one or more of these associated items, before arriving at a total project cost.

## Controlled Flooding

3. There are several variations of controlled flood irrigation (see Table 1).

### Standard System

4. The standard system of controlled flooding comprises:

- flood protection of the irrigated area by a dyke along the river bank, with a connecting skirting dyke if necessary;
- an adjustable water intake with manually controlled or automatic gates; it may also serve to drain the area, or there may be a separate drainage outlet or outlets;
- a main canal, generally flat-bottomed, connecting the main intake to the various low points of the perimeter, with secondary channels to regulate the flooding of each of these basins;
- bunds to subdivide the land according to topography, separating areas of different water depth suited to different rice varieties.

5. The adjustable intake gives a better water regime than natural flooding but since the land is not levelled, flood depth nevertheless varies. Different rice varieties must therefore be used according to topography. The lowest planted level is the zone of floating rice which, growing with the flood, generally reaches a height of 1.30 m with possible maxima of 2.5 to 3 m. The next level, with a water depth of around 60 cm, is sown with traditional lowland varieties capable to tolerating some fluctuations in water level. Areas with an expected flood of 15 cm or less are normally left in reserve in the case of standard systems, due to the difficulties of judging whether they will, due to the micro-relief and annual flood variations, actually receive adequate water. Systems of this sort are normally designed to reach their full flood level with a 90% probability. In Mali they cover about 70,000 ha.

### Semi-Controlled Systems

6. In Mali, in particular, systems of the standard type may be left partially incomplete, to give semi-controlled flooding. This term covers all controlled-flood systems in which some of the full range of channels, submersible dykes or concrete structures are absent or built to a lower specification. Work is often done by non-governmental organizations with participation by the population, who may or may not receive food for their work. It is therefore impossible to establish a definite unit cost, although it usually seems to be less than US$400/ha.

Improving Water Supply

7. Many standard flood control systems in the Sahel have in recent years failed to fill sufficiently, because of reduced flood regimes due to declining rainfall. Attempts have been made (e.g. in Senegal) to guarantee water supply by pumping, but this has generally failed due to problems of management (when to start if the flood is late, pump maintenance, etc) and the low value of marginal yield gains in relation to pumping costs. Where possible, therefore, weirs have instead been built in the beds of tributaries to divert water into the flood plain of the main river instead of letting it escape down the principal channel.

Improving Water Control

8. Flood irrigation has two main limitations even with an adequate annual flood. First, yield tends to be restricted by variations in water level and the generally high average water depth in relation to the size of the rice plant, so that only traditional long-stemmed or floating varieties can be planted. Second, sowing is not possible until the ongoing rainy season has provided sufficient flood water. Two refinements are possible to partially counteract these drawbacks, without really changing the flooding system: sub-division of basins to give better depth control, and localised pre-flood irrigation.

9. To reduce water depth without excessive soil grading, the area can be divided into basins and sub-basins with bunds, until it is possible to use high-yielding short stemmed rice. Numerous case studies in Mali and Senegal show that this solution gives adequate returns, but only if an adequate flood is guaranteed - e.g. by a weir. Otherwise, the locally higher yields do not compensate for the loss in cropland due to bunding. Secondary basins may be created covering several dozen hectares and with level differences to 50 cm, or tertiary basins where the difference in level does not exceed 10 cm. Lastly, the tertiary basins can be graded to obtain, in effect, a fully-controlled conventional irrigation system, although one which can still only be planted once a year, during the rains.

10. Attempts to permit planting outside the flood period have been less successful. However pre-flood or supplementary irrigation of rice is practiced in northern Mali where low-horsepower mobile pumps are used to transfer water from channels to plots through hoses or pipes about 100 m long. The paddy fields, which are not graded, are irrigated by shifting the pipe from time to time. Although theoretical calculations indicate a good financial return from such refinements to controlled flooding and several hundred pumps have been sold in Mali, in practice they succeed only if the farmer has additional income as a trader or from a military pension to pay for repairs when these become necessary, or if he also uses the pump for an off-season irrigated crop such as vegetables or wheat. Proposals have been made elsewhere to use sprinkler irrigation or hand pumps for pre-irrigation or supplementary supply of controlled-flood systems, but these are still in the trial stage and are not expected to be financially viable.

11. The various improvements to controlled flooding indicated above can be combined. This may gradually lead towards a conventional system with gravity irrigation from a weir or supply from a pumping station, with only land levelling omitted. It must be accepted, however, that this may not always be easy. The need to build improved structures on new allignments, add costly pumped drainage, or greatly increase the dimensions of protection dykes (so that they can no longer be built from soil, by hand) may in some cases bring the cost of upgrading close to that of an entirely new scheme.

Costs of Controlled Flood Irrigation (See Table 2 for Summary)

12. In recently-completed projects standard systems have cost about US$1,000 per hectare, including studies (about US$200 per hectare) and supervision (4% of the total). The cost of concrete structures and earthworks (dykes and channels) is 20% and 80% respectively of construction costs. The division of earthwork costs between dykes and channels depends on the topography of the river bank: if it is high the dyke is not expensive, but the main channel through it becomes more expensive; if the bank is low, the reverse is true. The capital cost for semi-controlled systems, as already indicated, is hard to estimate but may be around US$400/ha.

13. Annual maintenance charges for standard or semi-controlled systems account for about one percent of investment value, i.e. US$4 to 10/ha. System operation (reading of flood scales, operation of gates) costs about US$0.5/ha/yr.

14. Weir construction adds about US$500/ha to the cost of controlled flood irrigation. Concrete works account for 90% of this figure and earthworks on protection dykes 10%. Annual upkeep is put at about 1% of the cost - US$5/ha. A pumping station, in contrast, would add about US$1,000/ha. Approximately a half of this would be for civil works and half for pumps to provide an output of about 3 l/sec/ha irrigated. Operating costs would be about US$0.01 per m3, assuming an average lift of 5m and an annual duty of 10,000 m3/ha. (6,000 m3 for flooding, 4,000 m3 for the rainy season).

15. Additional investment costs for internal bunding naturally vary with sub-basin size and therefore with the number of intermediate dykes and channels.

- Secondary installations (plots of several dozen hectares, average water depth 40 cm) have a total cost of about US$1,700/ha of which 20% is for concrete structures, excluding the weir.

- Tertiary installations (plots of 0.5 ha with an overall difference in level of 10 cm) have a total cost of about US$3,000/ha of which 20% is for concrete structures, again excluding the weir.

If they are properly designed, with bunds of compacted laterite and control structures with return walls, the annual maintenance cost of such networks should be about one percent of construction cost.

16. For pre-flood or supplementary irrigation of about 12 ha in Mali, investment costs are estimated as follows:

- Pump: US$250/ha (Lister) or US$105/ha (Indian type)

- Pipe (15 mm): US$15/ha (canvas hose ) or US$105/ha (galvanized)

Current operating and maintenance costs for the above equipment are as follows:

| | Pumping Cost (US$/m3) | Floating Rice ..........US$/ha/crop............ | Short Stemmed Rice |
|---|---|---|---|
| Lister pump and steel pipe | 0.02 | 395 | 840 |
| Indian pump and canvas hose | 0.016 | 325 | 695 |

## Swamp or Lowland Schemes (Bas fonds)

17. Schemes of this type channel rainfall runoff into low-lying areas (bas fonds) where hydromorphic soils retain the water either in the form of a surface flood or, after the rains end, as an elevated water table. This method is appropriate for rice cultivation where annual rainfall is about 900 to 1,400 mm and is practiced in Mali and Burkina Faso. There are three types of scheme of this sort in Burkina Faso.

Simple open type. Bunds are built along contour lines at height intervals of 15 cm. Water is let in at the top of the scheme and spreads downwards. When the upper plot is full, water runs into the next by overspill.

Semi-open type. Construction is similar, but with the addition of a 70 cm external bund which protects the scheme at peak flood.

Type with central channel. An additional central channel is also incorporated, which protects against heavier runoff and flooding.

The ability to cope with heavy rainfall is particularly important. Lowland schemes have been abandoned when they were damaged by runoff. For the same reason the size of the catchment area which feeds the perimeter needs to be limited; 30 km2 is considered a maximum in Burkina Faso.

18. In favourable settings and given a motivated population, existing traditional lowland schemes can be upgraded and expanded by adding a small dyke with a diversion structure and drainage channel as well as one or two intakes for supplementary irrigation. These improvments may permit the development of lowland areas of up to several hundred hectares, rather than the small bas fonds under simple systems.

19. Swamp or lowland schemes are usually built by local people led and advised by an extension service. Updated 1977 construction costs for Burkina Faso are US$200/ha for conventional lowlands and US$800/ha for improved lowland schemes (see Table 2). Prices in Mali would be lower, but no details are available. In theory, maintenance is paid for by the users but the annual cost of extension workers' visits may amount to 1 to 2% of the investment expenditure, i.e. US$2 to 8/ha/year.

## Recession Irrigation

20. In this case residual soil moisture from the receding flood is used to grow sown or transplanted upland foodcrops such as sorghum, maize, groundnuts or cowpeas. There are various systems.

Flood recession cultivation of sorghum sown in October in Mauritania, below small dams which are built to retain water long enough to saturate the soil. In Niger, similar crops are grown in the beds of some irrigation reservoirs as water levels decline.

Traditional flood recession cultivation of sorghum in the Senegal River Valley. This is also practised from October to January, and tens of thousands of hectares are planted on riverine alluvial land as soon as the water subsides. No work has been done to improve this crop - for instance by digging channels for improving water supply to the basins, or constructing dykes to avoid too rapid drainage. This system will eventually be eliminated by the regulating effects of the Manantali Dam, although for the first ten years the dam will be operated to create an artificial flood.

Mouskwari cultivation of transplanted sorghum in Cameroon, like that in Mauritania but without dams.

Flood recession cropping along the Niger River below its inland delta. This involves numerous existing or projected installations totalling tens of thousands of hectares and is very complex; in some cases it also involves floating rice and other crops, depending on local topography, water depth and timing of the flood.

Dams in the Dogon country, where onions are grown by using reservoir water which is distributed manually.

Details of some of these systems are given below.

21. Mauritanian Dams. Water is held to a depth of several metres behind an earth dam, with or without a concrete spillway. Typical characteristics are:

| | |
|---|---|
| - Reservoir area: | Tens to thousands of hectares |
| - Catchment area: | 5 to 500 km2 |
| - Maximum height: | 2 to 6 m |
| - Filling material: | Thousands to tens of thousands of m3 |
| - Water volume: | Hundreds of thousands to millions of m3 |

As such dams are usually built on force account with foreign technical assistance, their average cost is not known; it was estimated in 1976 at US$3 million for an irrigated area of 2,000 ha (US$1,500/ha) but this is probably an overestimate. Annual maintenance would be about 1% of construction cost.

22. Flood recession irrigation on the Niger River. In the region between the Inland Delta and Niamey sorghum is the main floodplain crop. It is sown or transplanted from February to May when the Niger subsides, grows on groundwater until July, then finishes growing under rainfall. It is harvested in late September or early October. Other floodplain crops such as groundnuts, maize and cowpeas are grown solely on residual water during the hot season from between January and May. In lake beds on the left bank of the Niger (Horo, Faguibine), soil capillarity is sufficient to allow other crops to be grown on higher ground above the level of sorghum, while parts of basins below sorghum are usually planted with floating rice.

23. Flood recession irrigation can be improved by building canals to speed the filling of the system, dykes to delay drainage (so that sorghum can establish more easily and larger areas can be sown, or to protect the maturing crop from returning floods), as well as by incorporating control structures or secondary canals to adjust water supply. However equitable distribution of floodplain land often raises social problems. Organisation

is in practice often left to the villagers themselves.

24. The civil works required for improved flood recession irrigation are similar to those for swamp or lowland schemes. In the Zone Lacustre of Senegal the average cost for 17 projects was about US$400/ha, including 6% for studies and supervision, with a range of US$110 to 1,200/ha. For eight schemes on the Niger between Timbouctou and Niamey average cost was US$1,000/ha, including studies and supervision. The cost difference is because the Timbouctou/Niamey schemes averaged 500 ha, versus 1,200 ha in the Zone Lacustre, and required higher protection dykes. Concrete structures represent 20 to 25% of costs and earthworks 75 to 80%. Technical specifications and costs are summarised in Tables 1 and 2, respectively.

25. Annual operation and maintenance costs for flood recession systems are estimated as follows:

| | Zone Lacustre | Timbouctou/Niamey |
|---|---|---|
| | .............US$/ha.............. | |
| Maintenance | 4.2 | 5.8 |
| Operation | 0.5 | 0.5 |
| Contingencies for non-cultivation | 1.3 | 1.7 |
| Total | 6.0 | 8.0 |

26. Dams in the Dogon area. Dams of the Dogon are built of masonry. Since they are located in a fractured sandstone area they pose many technical difficulties for water retention. Furthermore access is usually possible only by rocky tracks and water needed for construction may be 80 km away. Hence construction costs are high. Typical characteristics are:

| | |
|---|---|
| Height: | 3 to 6 m |
| Capacity: | tens to hundreds of thousands of m3 |
| Irrigable area: | 3 to 6 ha |
| Average cost: | US$25,000 plus 6% for studies and supervision, assuming masonry work with local participation. |

Water is used only for horticultural crops and is drawn by hand. Maintenance costs consist of renewal of waterproofing once every 10 years and, at about 0.5% of investment per year, or US$80/ha, are very low. They have so far been borne by the government.

## Groundwater Irrigation

27. Groundwater is more widespread than surface water in much of the Sahel, although it is at present exploited mainly for domestic and livestock purposes, from traditional wells with yields too low for irrigation. However improved drilling techniques have recently made it possible to find water in larger quantities and in formations that were once considered unproductive, so that great hopes now are pinned on groundwater development in the region.

28. Groundwater irrigation costs in Mali, using existing boreholes with an output of 7 to 14 m3/hr, were studied by AGRER in 1985. Design options examined were the use of solar energy,electrical generator, diesel engine or animal power for water lifting, and water distribution by concrete-lined channels or pipes (plastic lining was ruled out and prefabricated channels were not envisaged, although they would cost less). Table 4 compares the

systems and Table 5 gives some underlying technical assumptions. It should be noted that animal-operated pumps can irrigate only two hectares, even with four oxen, whereas diesel and electric pumps can cover larger areas. As a result the capital cost/ha for animal-powered pumps is, for lack of appropriately adapted designs, far above that for diesel or electric pumps. In the absence of an existing borehole well drilling costs would be about US$105/m, but since only about two-thirds of the boreholes in the area concerned were productive, actual cost would be US$160/m.

29. The investment costs in Table 4 reflect force account work and do not include technical assistance with system layout (although the latter may not always be necessary). Combining the figures, the average hectare cost of a new installation would be as shown below, although this might be reduced by up to one-third using simpler equipment and distribution systems.

| | US$/ha |
|---|---|
| - Drilling new borehole | 3,600 |
| - Animal-powered pump | 6,300 |
| - Diesel powered pump and motor | 2,500 |
| - Reservoir, 100 m3 | 3,000 |
| - Intermediate reservoir, 2 m3 | 1,300 |
| - PVC pipes | 800 |
| - Lined channels | 4,200 |
| Total per hectare with animal power | 19,200 |
| Total per hectare with diesel power | 15,400 |

The cost using a solar-powered pump, at almost US$34,000/ha, would clearly not be competitive with the above systems.

30. Variable operating costs of pumps calculated by AGRER are given in Table 4. To them must be added the maintenance costs for the distribution network (1% of total value, i.e. US$90/ha) and the depreciation of the borehole (assumed life 20 years, i.e. US$180/ha), a total of US$270/ha/year.

## Pressure Irrigation Systems

### Small-scale Sprinkler Networks

31. Small commercially-available sprinkler systems, suitable for individual holdings or village use, have the advantage that their low operating pressures and sprinkler spacing of about 12 m economise on pumping costs and reduce sensitivity to wind. Furthermore they are easy for inexperienced farmers to handle. A typical system consists of a motor, a pump, a fixed pipe which can be moved one or twice a year, and a series of 30 m hoses each fitted with three sprinklers. Operating 12 hours a day, six days a week, a typical system can irrigate 5.2 ha. Manometric pumping height is 38 m, requiring an 8.5 horsepower engine. Investment cost is about US$3,200/ha, including 10% for a stock of spare parts. Operation, maintenance and depreciation costs total about US$0.084/m3 of water distributed.

32. This kind of installation has been tried in Mali for supplementary irrigation of flooded rice in the Timbouctou area but was not profitable. It is used successfully in Ivory Coast, however, for bananas and pineapples.

## Large Sprinkler Networks

33. Large sprinkler networks are used for estate-grown sugarcane and have been tested for large-scale wheat growing at Sourou (Burkina Faso) and small-scale wheat growing at Diré (Mali). The network usually comprises a main pumping station supplying one or several main canals, and secondary pumping stations supplying one or more central pivots or moving booms.

34. A study made in Mali in 1980 on 500 ha blocks compared:

- central pivot (360.5 ha) supplemented by Rain Pacer booms with sprinklers (137.5 ha);
- high-pressure rolling sprinkler (540 ha);
- laterally-moving booms (Rain Pacers) (248 ha) and rolling sprinkler (260 ha).

Details are given below.

| Variant | Irrigated Area (ha) | Output (l/s) | Pressure at Network Entrance (bars) | Cost per Irrigated ha (US$) | Lift (m) |
|---|---|---|---|---|---|
| Central Pivot and Rain Pacers | 498 | 574 | 4.6 | 2,030 | 54 |
| Rolling Sprinkler | 540 | 620 | 11.1 | 2,840 | 120 |
| Rain Pacers and Rolling Sprinkler | 508 | 585 | 15.0 | 2,680 | 158 |

For the first variant, which has the cheapest distribution system, total hectare cost is as follows:

| | US$/ha |
|---|---|
| Network | 2,030 |
| Pumping station and pipes | 1,960 |
| Studies | 140 |
| Protective drains | 260 |
| Total | 4,390 |

However operating costs for this variant amounted to five times the cost of surface irrigation, even allowing for its 85 to 90% efficiency, instead of the 40 to 50% of surface irrigation.

## Localised Irrigation

35. Localised irrigation, little used up to now, is appropriate for fruit trees and other tree crops. A study in Benin (GERSAR-IRHO, 1985) produced the following findings for micro-sprinkler irrigation of oil palms:

| Investments | US$/ha |
|---|---|
| Pump and sprinkler system for 1 ha | 3,400 |
| Pump and sprinkler system for 5 to 8 ha | 2,100 |
| Borehole, plus pump and sprinkler system for 5 ha | 5,500 |

| Operating Costs | |
|---|---|
| Fixed costs | US$160 to 210/ha |
| Variable costs | US$0.03/m3 water |

## Fully-Controlled Surface Irrigation

36. For fully-controlled surface irrigation the following are needed:

- protection of the area against flooding;

- a supply network capable of delivering water to satisfy peak crop demand, which in Africa may imply a 24-hour nominal flow of 1 to 2 l/ha/sec for several days in succession;

- a drainage network capable of evacuating surface runoff and rainfall in about three days, at a flow of 1 to 3 l/ha/sec;

- levelled cropland surrounded by bunds at least 25 cm high for paddy and wheat, or cultivated in basins or on slopes for other crops;

- a separate water inlet and outlet for each plot.

Total cost will be much influenced by the factors below, which are likely to vary greatly between sites.

37. Source of Irrigation Water. The water source may be undeveloped, or an existing reservoir or diversion structure. Thus not only may the cost of the water source vary greatly, but it may consist of a multipurpose structure for electricity and urban water supply, of which irrigation is not the major product. Hence the cost to irrigation is not always easy to calculate. To these costs must be added the project-specific cost of transporting the water to the scheme via a main channel of varying and sometimes considerable length. In view of these great variations, the system costs developed below do not include any of these items.

38. Dyking. The dykes needed to protect the scheme against flooding will be determined by topography in relation to the level of the water course. The need is greatest for schemes in basins, while for river terrace development dykes may not be needed at all. Dyke cost also depends on the degree of safety desired. For instance, the terraces along the Senegal are subject to floods one year in ten but there is no plan for protection dykes, while schemes on the Niger are protected against hundred-year floods. Dyking costs therefore vary greatly, reaching as much as US$2,100/ha for some Niger schemes.

39. Land Levelling and Plot Size. Levelling costs depend to a great extent on the required plot size and intended irrigation practices. In general, overly large plots are to be avoided for the following reasons:

- Accurate levelling is difficult over a large plot and in any case the volume of earthwork per hectare increases.

- It is difficult to irrigate on large plots unless considerable base flows are provided.

- High flows often cannot be handled by peasants unfamiliar with irrigation. To provide smaller flows over a longer irrigation period is likely to reduce on-field efficiency and raise transmission losses in an earth distribution system.

- Deep levelling may expose infertile subsoil.

Some indicative levelling figures for land with an average 2% slope and a field length of 100 m parallel to the greatest slope are given below.

| | | |
|---|---|---|
| Plot size | 5,000 m2 | 2,000 m2 |
| Plot length | 50 m | 20 m |
| Maximum cut of excavation | 0.5 m | 0.2 m |
| Volume of excavated material | 1,300 m3 | 500 m3 |
| Flow needed (a) | 35 l/sec | 14 l/sec |

(a) Assuming a requirement of 1,000 m3/ha over eight hours at an average efficiency of 50%

The above figures demonstrate the cost advantage of small plots on a 2% slope. But small plots are not suitable for mechanized cropping and moreover the average slope greatly affects the cost advantage. Thus, levelling costs of schemes on river terraces in Mali with only a 0.1% slope are substantially less than those for basins in Niger, with a 1% slope. Finally, project authorities may save all levelling costs for very small plots, since this work can often be done by the farmers themselves.

40. In general, the following types of fully-controlled surface irrigation developments can be distinguished in Francophone West Africa:

| | |
|---|---|
| Individual developments | 1 to 10 ha |
| Village-level schemes | 10 to 50 ha |
| Medium-sized schemes | 50 to 500 ha |
| Large schemes | Over 500 ha and up to 50,000 ha (e.g. Office du Niger) |

Technical characteristics are summarised in Table 1, capital costs in Table 2 and O & M cost estimates are given in Table 3.

Individual Developments

41. Most individual surface irrigation developments in the countries studied in Francophone West Africa depend on low-lift pumping. They generally have a motorised pump, although a hand-operated or animal-powered pump may be used for plots under one hectare. Experience in Mali shows that motor pumps cost US$400/ha. To this must be added the substantial costs of fuel, maintenance and service. With appropriate motor pumps, however,

operating costs as low as US$0.005/m3 of pumped water may be obtained for a pumping lift of only one meter.

Village-level Schemes

42. For a Mauritanian project of 75 village schemes totalling 1,600 ha, or 21.3 ha on average, the costs, on semi-terrace land requiring only small protection dykes, were:

| | US$/ha |
|---|---|
| Earthwork by contractor | 720 |
| Materials | 460 |
| Motor pumps | 960 |
| Supervision of work | 970 |
| Total | 3,110 |

In Mali costs were put at US$2,160/ha without dykes, but with low government staff costs since the population was already familiar with irrigation. In the basin schemes of Gao Region, where dykes are needed and canals are concrete-lined, construction costs of village-level schemes are around US$3,300/ha.

43. Annual operating costs were estimated as follows in Mali, for a pump lift of 6 m.

| | |
|---|---|
| Fixed costs | US$19/ha |
| Variable costs | US$0.015/m3 water |

Figures are similar for Mauritania, except that pumping height is greater, giving larger variable costs. In Gao, however, fixed costs are about US$84/ha and variable costs are US$0.01 to 0.013/m3, for pump lifts of up to 5 m.

Medium-sized Schemes

44. Construction costs of medium-sized schemes are generally similar to those for large-scale schemes (see below), although with some minor diseconomies of scale. In Mali, however, the reverse is true. Costs of medium-sized schemes in the Niger basin are similar to those of village-level schemes and there is no effect of scale.

45. Two special examples of medium-sized schemes should be mentioned:

- A proposed project for three 200-ha schemes in Mauritania, which would be operated like a series of village schemes; pumps would supply a main channel that would feed a series of separate 20-ha networks. Average cost is estimated at US$6,800/ha of which US$4,000/ha represents the cost of a protection dyke and access tracks.

- The Lossa scheme in Niger, where farmers are supplied by individual conduits.

Large Schemes

46. The main feature of large schemes is that all main works are carried out by contractors or on force account with no farmer participation. Hence they generally have higher government costs than other forms of fully-controlled irrigation. Nevertheless costs can vary greatly. Furthermore there is little recent experience because few development activities are under way; present emphasis is more on the rehabilitation of existing large schemes. However some examples may be mentioned.

Schemes on river terraces at Diré in Mali. Here investment costs are US$4,800/ha (earth channels, scraping instead of full levelling), fixed operating costs are US$53/ha, and variable pumping cost is US$0.008/m3 for a 6 m lift.

Niger basins at Timbouctou. Investment cost is stated to be US$5,000/ha for systems with earth channels, no levelling, and a dyke costing US$950/ha, although these figures are undoubtedly underestimated. Fixed operating cost is quoted as US$63/ha plus variable costs of US$0.004/m3 of water pumped.

Niger basins at Gao (concrete-lined canals). Investment costs are estimated at US$6,300 to 7,400/ha without levelling, and operating costs are similar to those of the Niger basins at Timbouctou.

Other projects in Niger where land levelling is added to the above. In this case investment cost for irrigation works reaches US$8,400/ha.

C. Operating and Maintenance Costs (For summary see Table 3)

47. The International Commission on Irrigation and Drainage defines maintenance as keeping the irrigation and drainage system in good running order in line with original project objectives. It also includes minor improvements during normal maintenance work. Conceived in this way, maintenance makes for a very long working life of irrigation schemes with technical depreciation affecting only equipment with a fixed life (pumps) or civil engineering structures such as dams and boreholes that may become irreversibly silted up or clogged. This definition excludes major reconstruction due to neglected maintenance, which is a common need in Sub-Saharan Africa. Experience in Mali suggests that after ten years of neglect the cost of this sort of rehabilitation is roughly ten times the cost of adequate annual maintenance, as estimated in this section.

48. Sources of data on O & M costs are projects in Niger (ONAHA), Mali (Office du Niger, flood control basins), Senegal (SAED) and Cameroon (SEMRY). An attempt has been made to estimate the true costs of fully adequate O & M rather than quoting actual expenditures, since the latter often reflect current budgetary constraints under which maintenance is at present inadequate.

## Maintenance Costs

49. Quick methods for determining annual maintenance costs are based on percentages of construction costs. A more rigorous evaluation uses the length of dykes and canals and number of structures to evaluate the quantity of equipment, materials and labour needed, of which costs are then calculated. However the two methods often give similar results. Using the first approach, typical annual maintenance costs would be as follows:

| Structure | Economic Life | Annual Percent of Construction Cost | Of which, Percent Local Labour |
|---|---|---|---|
| Major dykes | | | |
| - with laterite | 40 years | 0.5 to 0.75 | 10 to 20 |
| - without laterite | 30 years | 1.0 to 1.50 | 10 to 20 |
| Submerged dykes | | | |
| - with laterite | 30 years | 1.5 | 20 to 30 |
| - without laterite | 20 years | 2.0 | 70 |
| Main canals or drains | 30 years | 1.0 | 70 |
| Concrete structures | 40 years | 0.6 | 5 |
| Main gates and sluices | 20 years | 2.0 | 0 |
| Medium control structures | 30 years | 1.0 | 5 |
| Secondary and tertiary networks | 30 years | 1 to 2 | 50 |

50. The following figures for annual maintenance costs, taken from various project reports, support the above table. The figures for Senegal are higher perhaps because soil characteristics are poor, and because installations and networks were not originally designed to minimise maintenance costs.

| | Annual Cost (US$/ha) | Percent of Construction Cost |
|---|---|---|
| Niger | | |
| Surface distribution system | 48 | 1 |
| Buried pipe system | 27 | 0.5 |
| Senegal | | |
| Surface distribution system | 63 | 2 |
| Mali | | |
| Surface distribution system | 42 | 1 |

51. In small areas such as village and individually-operated schemes with earth channels, repairs are generally made by the irrigators themselves. Government costs here consist mainly of inspections by personnel, which are in practice difficult to separate from agricultural extension costs. A figure of US$10 to 20/ha seems realistic.

52. Maintenance of levelling is also generally left to the farmers. However on large schemes scraping or land planing is sometimes repeated at a cost of US$40 to 60/ha every three to five years, i.e. at an average cost of about US$15/ha/year.

## Pumping Costs

53. Pumping costs depend on a wide variety of factors such as height of lift, energy source, pump and engine efficiency, intensity of equipment use, local fuel and servicing costs, location of the scheme and the quality of O & M. These factors are dealt with at length in standard publications - e.g. Pumps and Small Pumping Stations, SOGREAM (1978) Series: "Rural Techniques in Africa". Due to the huge variations between schemes it is not considered worthwhile to give such calculations here. Examples for various specific types of pumped system have already been given in the previous section and are summarised in Table 3.

54. However actual pumping costs are often much higher than calculated because unsuitable, low-output equipment has been chosen, (e.g. at Diré in Mali where the pumps have an efficiency of 30%) or due to inappropriate installations (e.g. at San in Mali, where closed-circuit engine cooling alone requires an installed power capacity of 100 kva). The costs of pumped drainage must also be included, where appropriate. The conventional assumption that drainage pumping costs are 10% of irrigation pumping costs for irrigation is seldom accurate.

## Water Management Costs

55. Water management costs are usually low in comparison with other elements of O & M, certainly less than US$10/ha/yr. They cover field maintenance staff (watermen), who are generally budgeted under the costs of pumping and maintenance, and supervisory staff who are generally counted among maintenance or extension personnel. As an example SEMRY, in northern Cameroon, provides one head waterman per primary channel (average 1,600 ha), one waterman per secondary channel (about 400 ha) and one assistant for every two or three irrigation "quarters" (total 100 or 150 ha).

## D. Reducing Costs and Improving Results

56. Irrigation development is costly in Francophone Africa for both external causes which are beyond the developer's control, and for internal causes that depend on the designer. However it must be realised that reducing investment costs often incurs increasing maintenance charges. If the result of reducing capital costs is a network of mediocre quality and higher O & M charges to the irrigator, productivity and financial returns will fall and farmers will be discouraged. Therefore, in reducing investment costs one must always consider the subsequent problems of maintenance. For instance the use of concrete-lined canals and laterite for dykes, although more costly, may ultimately be justified by a reduction of maintenance costs and consequently improved farmer incentives. Furthermore, with the present severe restrictions on recurrent expenditure budgets being faced by most

Sahelian countries, capital funds, derived from external loans or grants, may be easier to obtain than local funds for subsequent O & M of installations.

57. External causes of high investment costs include:

- The overvaluation of most African currencies, which inflates all costs in dollar terms.

- Difficult access to the landlocked African countries and to most irrigation perimeters. In Mali, for instance, cement costs 40 to 50% more at Gao than at Bamako. Poor roads in the Zone Lacustre add 15%, but the cost would be 25% higher than at Bamako due to the transport distance alone.

- Taxes, which unnecessarily raise certain costs - for instance a 15% wages tax in Mali, plus import duties and fuel taxes - and which are rarely waived.

- The lack of local manufacture of equipment and spares together with supply difficulties, make it necessary for projects to carry heavy stocks; when manufacturers make technical modifications considerable stocks of spares become obsolete, increasing operating costs.

- The lack of local equipment sales and service agents. For instance to obtain a pump adapted to the conditions of Mali, with an efficiency of 70% as against the 40% of locally-sold pumps, it is necessary to purchase in Europe.

- Shortage of skilled local personnel (mechanics, construction workers) and of small contractors, especially for earthworks.

- The use of tied external funds to build irrigation networks; this often involves some extra supervision and administration costs and, especially, the purchase of non-standard equipment requiring special maintenance and spare parts.

58. There are other physical causes in addition to distance.

- Major flood protection dykes are necessary for most rice perimeters. In many Asian countries, such dykes were built long ago and no longer appear as investment costs, whereas they often account for one-quarter of the cost of civil works in West Africa.

- The patchy distribution of irrigable soils and the uneven shape and topography of many African perimeters, which calls for complex water distribution and drainage networks with considerable levelling.

- The low population density, which sometimes requires associated investments for colonization and other social infrastructure.

- The reservoirs and dams which are essential to stabilise the erratic flows of West African rivers. Because of the predominantly flat local topography dams are usually long, low and expensive, reservoirs are shallow, and evaporation is high. Hence a large investment is required to store a usable volume of irrigation water.

- There are no abundant, shallow sources of groundwater suitable for localised irrigation or conjunctive use comparable to those of India or Pakistan. Maximum output of boreholes often is less than 5m3/hr and water often has to be pumped from 10 m depth or more.

- It is often necessary to include related investments for land clearing and access tracks, which increase total scheme costs compared with other countries.

- The climate is severe. The possibility of very intense rainfall and cyclic droughts require high safety coefficients in project design.

59. The external causes of high costs, if they are to be reduced at all, would mostly require government policy changes or will only come about as a product of overall industrialisation and further national economic development. Most of the physical causes are beyond human intervention altogether. However several of the internal causes of high costs could be reduced by the irrigation agencies themselves. Principal internal causes are as follows.

- Most studies are made by foreign consulting firms which are not subjected to adequate local control. This results in three kinds of extra cost. First, such studies usually cost about twice what they would if they could be made by local firms; hence they add an extra 2 to 4% to investment costs. Second, the consulting firm's reputation is at stake, so that often superfluous design precautions are taken to make sure that the structures concerned will last a long time. Exaggerated safety measures in civil engineering involve considerable extra costs and few of those in the irrigation agencies who order a job are technically competent to propose simpler standards to specialised foreign consulting firms. Third, foreign firms may have little local experience and do not always design structures in line with local resources. In Mali, for instance, 3 m wide hand-operated control gates with wooden frames can be manufactured locally. If 5 m wide gates are specified they have to be made in Europe, as well as the frames which must then be of metal, and they need a gantry to operate them. As control structures typically account for 20 to 25% of project cost a 20% saving on items such as these saves 4 to 5% of the total investment.

- Simplified initial designs could be adopted, even if they may need repair or upgrading after a year's operation. For example, it was noted in Mali that some parts of dykes had been weakened by wave action. However, rather than designing all dykes with full protection it was found preferable to build simple dykes and to protect in the following year only the parts that had been weakened. This method obviously requires prior agreement with the funding source that money will be kept available for subsequent upgrading, and that no one should criticise the builder of the dyke when a part is damaged in the first year.

- If local consulting firms are enlisted, the funding sources must, however, have confidence in them, help them with consultants' missions, and do away with certain useless controls.

- Common design standards could be agreed, and departure from these standards should have to be specifically justified by project planners. In this way costly over-designing could be reduced. Among the sources for this study, for instance, the following were noted, for projects designed for comparable ecological conditions:

    - Strickler coefficients varied from 25 to 40, sometimes for the same agency, resulting in very different channel sizes for a given duty;

    - irrigation duties for flood-irrigated rice ranged from 1.54 to 10 l/sec/ha;

    - drainage duties ranged from 0.68 to 17 l/sec/ha.

- Irrigation agencies could do more to standardise their equipment. To do so it would be necessary to overcome obstacles due to tied aid, plus the not infrequent local problems posed by agents or suppliers with special influence.

- Project designers should be required to draw up detailed manuals for irrigation scheme operation and maintenance at the design stage. This would focus the designers' thinking on maintenance needs, and perhaps cause them to adapt the project accordingly.

- There is no communication among countries on technical improvements for cutting costs. The following are examples from Mali which might with advantage be applied elsewhere in the region:

    - laterite coating of dykes, even though normally left uncompacted, provides an all-weather track and reduces maintenance cost;

    - very cheap types of prefabricated concrete channels have been developed;

    - masonry has been used for some structures instead of reinforced concrete, resulting in considerable savings;

    - drainage ditches are sown with bourgou, a plant which is regularly cut for fodder by the local population, thus ensuring free drain maintenance;

- Owing to currency overvaluation and low population density labour can be expensive in Africa. Nevertheless, to reduce dependence on imported equipment and fuel it may still be advisable to adopt more labour-intensive construction methods, as is done in India. At present such an approach is usually limited by a shortage of skilled supervisors and by disincentive labour regulations.

- Lastly, government costs could be lowered by greater participation of beneficiaries in construction and O & M. Improved security of tenure of irrigated land, under a revised legal framework, could be a major incentive towards improving farmers' participation.

60. A number of common actions involving government irrigation agencies, technical assistance organisations and international funding agencies could also help to reduce irrigation costs in the region and improve results. The following measures might be useful.

- International publication, on the basis of discussions between international consulting firms and their African counterparts, of irrigation manuals geared to African conditions, as well as a technical bulletin (the corresponding publications of ICID are inadequately distributed and too general to meet specific regional needs).

- On-the-spot verification of technical coefficients for irrigation in Africa.

- International seminars for African irrigation specialists, with field visits to show appropriate, low-cost technical approaches.

- More national and international taining on irrigation management, maintenance, and manpower use.

- Use of working experts with first-hand experience (irrigation engineers and agriculturalists of consulting firms, maintenance and service chiefs, etc.) as leaders and instructors for national and regional irrigation seminars, meetings and training courses.

- An examination of the possibilities for local manufacture in Africa of certain items of irrigation equipment (gates, pumps, etc.) and, especially, of spare parts.

- A review of African experience with sprinkler and drip irrigation, leading to an assessment of the circumstances and conditions in which expansion of these systems would be appropriate.

- Investigation of improved land levelling methods aimed to reduce levelling costs.

- A review of possible ways to stimulate irrigation development by private enterprises.

- A study of ways to boost local participation in development of small and large-scale irrigation schemes.

- The design of better systems of budgeting and cost control (especially separation of agricultural extension costs from scheme O & M budgets) to ensure more appropriate and timely budget allocations and help reduce the needs for later major rehabilitation.

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

General Characteristics of Irrigation Schemes in Francophone West Africa

| Type | Description of Works | Characteristics | Crops |
|---|---|---|---|
| **Controlled Flooding** | | | |
| Standard system | Simple protection dyke, main inlet, main and secondary canals, demarcation of irrigable areas. | Fills and drains with flood; maximum water depth 1.3 m (except Gao-Timbouctou 2.5 m) | Floating and long-stemmed rice |
| Improved system | Addition of submersible dyke with control structures and main canal control structures to above | Operation as above, but partial water control | Floating and long-stemmed rice |
| Weir | Concrete structure in main channel, with protection dykes | Ensures minimum flood level, as improvement on standard system | Rice |
| Semi-controlled system | Standard system with additional dykes, canals and control structures | As for standard system but with water depth limited to 0.50 due to weir; plots cover tens of hectares | Long-stemmed rice |
| Secured system | Standard system with additional dykes, canals and control structures | As for semi-controlled system but with water depth controlled to 15 cm; plots levelled, 1 to 10 ha | Short-stemmed rice |
| Supplementary pumping | Mobile pumps, Lister or Indian type (Where feasible weirs may instead be built on tributaries to divert flood-water from a higher level) | Provides pre-irrigation before main flood or supplements inadequate flood level | Rice |
| **Swamp or Lowland Schemes** | | | |
| Basic system | Earth bunds with or without additional protection bunds and central drainage channel | Retains natural runoff from small catchment areas | Rice |
| Improved systems | Small dam and some control structures, in addition to the above | Increases reliability, volume and control of water supply | Rice |
| **Flood Recession Irrigation** | | | |
| Mauritanian dam | Earth dam with concrete spillway | Cultivation on receding water level, after filling in rainy season | Sorghum |
| Niger flood recession | Protective dykes and shallow storage reservoirs; main and secondary canals, control structures, etc. | System fills from floods in October/December; cropping from January to September on receding water | Sorghum, groundnuts, cowpeas, etc. |
| Dogon dams | Masonry dams in rocky areas, sometimes with imported soil | Water hand-drawn from reservoir | Horticulture |

| Type | Description of Works | Characteristics | Crops |
|---|---|---|---|
| **Groundwater Irrigation** | | | |
| Animal pumping | Shallow borehole plus pump driven by oxen, supplying water to up to 2 ha | Conventional surface irrigation | Horticulture |
| Motorised pumping | Borehole plus diesel (rarely petrol or electric) pump supplying water to 3 or 4 hectares | Conventional surface irrigation | Horticulture |
| **Pressure Irrigation** | | | |
| Small-scale individual systems | Motorised pump plus small sprinkler network of 1 to 10 hectares. | Mobile sprinkler network; low pressure | Horticulture |
| Large-scale systems | Large motorised pump feeding central pivot, roller or Rain Pacer equipment | Estate, commercialised cultivation; high pressure | Sugarcane, wheat, etc. |
| Localised irrigation | Motorised pump plus small drip network or micro-sprinklers, generally supplied by borehole | Commercial tree crop cultivation | Citrus, dates, etc. |
| **Surface Irrigation** | | | |
| Individual developments | Motorised pump or (less often) surface diversion, plus 1 to 10 hectare irrigation network | Standard irrigated cultivation; distribution made by farmer; needs pump maintenance and external technical advice and organization | All crops |
| Village-level schemes | As above, but 10 to 50 hectare irrigation network either:<br>(a) without protective dyke<br>(b) divided into basins with protective dykes | Standard irrigated cultivation; distribution system usually made by villagers except for main canals, if in concrete, and any concrete control structures | All crops |
| Medium-sized schemes | As above, with pumps supplying a canal with branches to a series of sub-networks, each of about 20 hectares. Total area 50 to 500 ha | Sub-networks and on-farm works by farmer groups or individuals and the rest by government | All crops |
| Large schemes | Large pumping station supplying a concrete or earth network with primary, secondary and other canals and drainage system, possibly through secondary pumping stations; protection dykes needed for low-lying perimeters | All contruction, O & M by government except for on-farm works, which may sometimes be by farmers | All crops |

## STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

### Irrigation Schemes in Francophone Africa: Estimated Investment Costs
(US$/ha)

| Type | ...........Main Works........... | | | Pumps and Equipment | Borehole | Levelling and on-farm works | Total | Remarks |
|---|---|---|---|---|---|---|---|---|
| | Earthworks | Concrete Structures | Sub-Total | | | | | |
| **Controlled Flooding** | | | | | | | | |
| Standard system | 800 | 200 | 1,000 | - | - | - | 1,000 | Water depth 1.3 m |
| Improved system | 200 | 200 | 400 | - | - | - | 400 | " " |
| Weir | 50 | 450 | 500 | - | - | - | 500 | Add to costs as appropriate |
| Semi-controlled system | 1,350 | 350 | 1,700 | - | - | - | 1,700 | Water depth 50 cm |
| Secured system | 3,000 | 800 | 3,800 | - | - | - | 3,800 | Water depth 15 cm |
| Supplementary pumping | | | | | | | | |
| (a) Indian pump | - | - | - | 120 | - | - | 120 | Add to other costs as appropriate |
| (b) Lister pump | - | - | - | 350 | - | - | 350 | Add to other costs as appropriate |
| **Swamp or Lowland Schemes** | | | | | | | | |
| Basic | ? | ? | 200 | - | - | - | 200 | |
| Improved | ? | ? | 800 | - | - | - | 800 | |
| **Flood Recession Irrigation** | | | | | | | | |
| Mauritanian Dams | ? | ? | 1,500 (?) | - | - | - | 1,500 | Probably over-estimated |
| Niger flood recession | | | | | | | | |
| (a) Lake region | 320 | 80 | 400 | - | - | - | 400 | |
| (b) Central Niger | 800 | 200 | 1,000 | - | - | - | 1,000 | |
| Dogon dams | - | 15,000 | 15,000 | - | - | - | 15,000 | Horticultural crops |
| **Groundwater Irrigation** | | | | | | | | |
| Animal pumping | - | 9,300 | 9,300 | 6,300 | 3,600 | labour | 19,200 | Probably over-estimated |
| Motorised pumping | - | 9,300 | 9,300 | 2,500 | 3,600 | labour | 15,400 | " " |

| Type | ............Main Works............ Earthworks | Concrete Structures | Sub-Total | Pumps and Equipment | Borehole | Levelling and on-farm works | Total | Remarks |
|---|---|---|---|---|---|---|---|---|
| **Pressure Irrigation** | | | | | | | | |
| Small-scale | - | - | - | 3,200 | - | - | 3,200 | |
| Large-scale | 250 | 550 | 800 | 3,600 | - | - | 4,400 | Includes studies and protective drains |
| Localised irrigation | | | | | | | | |
| (a) 5 ha | - | - | - | 2,100 | 3,400 | - | 5,500 | Includes borehole |
| (b) 1 ha | - | - | - | 3,300 | 3,400 | - | 6,700 | " " |
| **Surface Irrigation** | | | | | | | | |
| Individual developments | - | - | - | 400 | - | labour | 400 | High extension costs |
| Village-level schemes | | | | | | | | |
| (a) River terraces | 1,000 | 700 | 1,700 | 1,500 | - | labour | 3,200 | Favourable sites |
| (b) Lowlands | - | - | 4,400 | 1,000 | - | 400 + labour | 5,800 | Favourable sites, earth canals |
| Medium-sized schemes | - | - | 5,000 | 600 | - | 1,200 | 6,800 | High dyke |
| Large schemes | | | | | | | | |
| (a) River terraces | 2,400 | 800 | 3,200 | 1,200 | - | 400 | 4,800 | Light levelling, favourable sites concrete-lined canals |
| (b) Lowlands | 4,600 | 1,200 | 5,800 | 1,000 | - | 600 + labour | 7,400 | " " " |
| | 4,600 | 1,200 | 5,800 | 1,000 | - | 1,600 | 8,400 | Complete levelling |

## STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

### Irrigation Schemes in Francophone West Africa: Estimated Annual Operation and Maintenance Costs
(US$/ha) (1)

| | ....Annual Fixed Costs.... | | .............Pumping Costs........... | | |
|---|---|---|---|---|---|
| | Percentage of Investment | Total (US$/ha/yr) | Manometric Height (2) (m) | US cents/m3 | Remarks |
| **Controlled Flooding** | | | | | |
| Standard system | 1 | 10 | - | - | Costs partially borne by farmers |
| Improved system | 1.5 | 6 | - | - | " " " |
| Weir | 1 | 5 | - | - | " " " |
| Semi-controlled system | 1 | 17 | - | - | " " " |
| Secured system | 1 | 38 | - | - | " " " |
| Supplementary pumping | | | | | |
| (a) Indian pump | - | - | 5 | 1.6 | |
| (b) Lister pump | - | - | 5 | 2.0 | |
| **Swamp or Lowland Schemes** | | | | | |
| Basic | 1 | 2 | - | - | Plus farmer's contribution to maintenance |
| Improved | 1 | 8 | - | - | " " " |
| **Flood Recession Irrigation** | | | | | |
| Mauritanian dams | 1 | 16 ? | - | - | Probably overestimated |
| Niger flood recession | | | | | |
| (a) Lake Region | 1 | 5 | - | - | |
| (b) Central Niger | 1 | 9 | - | - | |
| Dogon dams | 1 | 80 | - | - | |
| **Groundwater Irrigation** | | | | | |
| Animal pumping | - | 270 | 25 | 14 | Probably overestimated |
| Motorised pumping | - | 270 | 35 | 10 | " " |
| **Pressure Irrigation** | | | | | |
| Small-scale | - | - | 40 | 8.4 | |
| Large-scale | - | - | 70 | 7.4 | |
| Localised irrigation | - | 180 | | 3.0 | |
| **Surface Irrigation** | | | | | |
| Individual developments | - | - | 8 | 2.4 | Costs partially borne by farmers |
| Village-level schemes | | | | | |
| (a) River terraces | - | 19 | 10 | 1.5 | " " " |
| (b) Lowlands | - | 84 | 6 | 1.1 | " " " |
| Medium-sized schemes | - | see small-scale schemes | | | |
| Large schemes | | | | | |
| (a) River terraces | 1 | 53 | 9 | 0.8 | Includes limited labour contribution by farmers |
| (b) Lowlands | 1 | 63 | 4 | 0.4 | " " " |

(1) For lack of specific information the figures above are very approximate estimations.
(2) 5 to 10 m should be deducted from Manomatric Height to obtain the water level in the borehole.

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Comparison of Pumping Systems

| | Solar Energy | Electric Generator | Diesel Engine | Animal Traction |
|---|---|---|---|---|
| Advantages | Energy free, renewable and non-polluting<br>Maintenance and operating costs of photo-electric units are low<br>Little supervision needed | 1 Generator can operate several pumps<br>Low capital cost | Pumping up to 16 hr/day<br>Technically simple<br>Low fuel consumption | Renewable energy<br>Negligible foreign exchange cost<br>Simple equipment and requires little maintenance |
| Disadvantages | Very high capital cost<br>Operation only 9 to 10 hr/day<br>Output drops due to cloud or sandstorms<br>Technically sophisticated | Fuel consumption high<br>Maintenance difficult<br>Foreign exchange needed for operation<br>Requires continuous supervision | Engine needs regular maintenance<br>Requires continuous supervision<br>Foreign exchange needed for operation | Pumping limited to 10 to 12 hr/day<br>Requires continuous supervision<br>Pumping depth limited |
| Investment to be amortized over 10 years (US$/ha) | 21,000 | 4,400 | 4,500 | 6,500 |
| Operating cost, without depreciation (US$/ha/yr) | 340 | 1,315 | 812 | 524 |

STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

Small-Scale Irrigation: Comparison of Pump Systems for Groundwater at Different Depths

| Output (m3/h) | TMH (m) (1) | Irrigated Area (ha) | Pumping System | Capital Cost (2) (US$) | Estimated Cost per m3 Water (3) (US cents) |
|---|---|---|---|---|---|
| 6 - 8 | 20 - 25 | 0.6 - 0.7 | Animal Traction, 2 oxen | 4,200 | 16.0 |
| 9 - 11 | 25 - 30 | 1.7 - 2.0 | Animal Traction, 4 oxen | 13,000 | 14.0 |
| 12 - 14 | 30 - 35 | 2.8 - 3.2 | Diesel pump, 5 hp | 7,400 | 9.5 |
| 12 - 14 | 45 - 50 | 2.8 - 3.2 | Diesel pump, 8 hp | 7,960 | 11.5 |

(1) 5 to 10 m should be deducted from TMH (Total Manometric Height) to obtain the water level in the borehole.

(2) Capital cost covers purchase price, without taxes, transport of equipment to the irrigation site or assembly.

(3) The cost per cubic metre of pumped water covers operating cost, assuming 2,000 - 2,200 hr pumping/yr, amortaization of capital costs and pump oeprators' wages. Costs of borehole amortization and use of the irrigation network are not included.

## STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

## THE ECONOMICS OF IRRIGATION INVESTMENTS

1. This annex examines the implications for economic returns of some typical phasing patterns for investment in construction of irrigation schemes and the subsequent build-up in production. It aims to indicate the levels or values of production that are necessary to get specified economic returns from different levels of investment. Three typical scenarios have been prepared for the time scale of project construction and the buildup of output. Scenarios 1 and 2 represent medium to large-scale schemes and 3 refers to small-scale schemes.

2. Scenario 1 represents projects as they are often planned, where construction is phased over five years and production reaches full development by year 8. Scenario 2 represents projects as they more often are in reality, with investment spread over eight years and production reaching its maximum in year 12. Scenario 3 assumes a one-year investment typical of a small-scale groundwater project and full production in year 3. The assumed annual percentages of investment and production build up of the three scenarios are indicated below.

| | Project Years | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12-30 |
| | (%) | | | | | | | | | | | |
| **Scenario 1** | | | | | | | | | | | | |
| Investment | 5 | 15 | 25 | 35 | 20 | - | - | - | - | - | - | - |
| Production | - | - | 10 | 20 | 35 | 50 | 70 | 100 | 100 | 100 | 100 | 100 |
| **Scenario 2** | | | | | | | | | | | | |
| Investment | 5 | 5 | 10 | 15 | 15 | 20 | 20 | 10 | - | - | - | - |
| Production | - | - | - | 10 | 20 | 30 | 45 | 55 | 75 | 85 | 95 | 100 |
| **Scenario 3** | | | | | | | | | | | | |
| Investment | 100 | - | - | - | - | - | - | - | - | - | - | - |
| Production | 30 | 65 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

3. The net annual values of incremental production needed at full development to generate economic rates of return of 12% and 7% were then calculated, as a proportion of the total investment cost for each scenario. The results are given below.

Net Annual Benefit Required at Full Development,
as Proportion of Capital Cost

| Scenario | For ERR of 12% | For ERR of 7% |
|---|---|---|
| 1 | 0.152 | 0.094 |
| 2 | 0.152 | 0.101 |
| 3 | 0.125 | 0.082 |

It is significant that when both costs and benefits are delayed, as in Scenario 2, there is no great difference in economic results from Scenario 1: the required benefits are similar, if not identical. This does not mean, however, that both Scenarios are equally acceptable. Scenario 2 will take longer to contribute to the economy, which in a country facing increasing food shortage could be of great national importance. The longer construction period would also give greater risks of cost increases, which would be of importance for national expenditure plans.

4. From the above proportions it is possible to calculate the level of incremental production which must be obtained for a given investment to achieve the desired ERR, or vice versa. For example, if a project is known to produce a net increment equivalent to three tons of milled rice per hectare per year with a value at current prices of US$666, this net increment would justify a total investment of US$4,382 per hectare at a 12% ERR under Scenarios 1 or 2 and US$5,328 for Scenario 3.

5. In the tables below the factors given above have been related to tonnages of four of the major irrigated crops - rice, maize, sugarcane and cotton - for economic rates of return of 12% or 7%. It is important to note that the tonnages shown are in fact likely to be under estimates, since they take no account of the need to cover, in addition, the on-farm crop production costs as well as the operating and maintenance costs of the irrigation system.

Net Incremental Value of Production Required to Achieve an ERR of 12%

| Investment Cost | Net value of(a) Incremental Production | Paddy(b) Equivalent | Maize(c) Equivalent | Sugarcane(d) Equivalent | Seed Cotton Equivalent(e) |
|---|---|---|---|---|---|
| .........US$/ha........ | | .....................t/ha.......................... | | | |
| Scenarios 1 and 2 | | | | | |
| 15,000 | 2,280 | 15.1 | 19.0 | 293 | 4.6 |
| 12,000 | 1,824 | 12.1 | 15.2 | 234 | 3.6 |
| 10,000 | 1,520 | 10.1 | 12.7 | 195 | 3.0 |
| 8,000 | 1,216 | 8.1 | 10.1 | 156 | 2.4 |
| 6,000 | 912 | 6.0 | 7.6 | 117 | 1.8 |
| 4,000 | 608 | 4.0 | 5.1 | 78 | 1.2 |
| 2,000 | 304 | 2.0 | 2.5 | 39 | 0.6 |
| 1,000 | 152 | 1.0 | 1.3 | 20 | 0.3 |
| Scenario 3 | | | | | |
| 15,000 | 1,875 | 12.4 | 15.6 | 241 | 3.7 |
| 12,000 | 1,500 | 9.9 | 12.5 | 193 | 3.0 |
| 10,000 | 1,250 | 8.3 | 10.0 | 161 | 2.5 |
| 8,000 | 1,000 | 6.6 | 8.3 | 128 | 2.0 |
| 6,000 | 750 | 5.0 | 6.3 | 96 | 1.5 |
| 4,000 | 500 | 3.3 | 4.2 | 64 | 1.0 |
| 2,000 | 250 | 1.7 | 2.1 | 32 | 0.5 |
| 1,000 | 125 | 0.8 | 1.0 | 16 | 0.3 |

(a) After on-farm and scheme O & M costs have been deducted.
(b) At US$222/ton; milled rice yield 68%.
(c) At US$120/ton.
(d) At US$82/ton; sugar extraction 9.5%.
(e) At US$1,520/ton; lint yield 33%.

Net Incremental Value of Production Required to Achieve an ERR of 7%

| Investment Cost | Net value of(a) Incremental Production | Paddy(b) Equivalent | Maize(c) Equivalent | Sugarcane(d) Equivalent | Seed Cotton Equivalent(e) |
|---|---|---|---|---|---|
| .......US$/ha.......... | | ......................t/ha...................... | | | |
| **Scenario 1** | | | | | |
| 15,000 | 1,410 | 9.3 | 11.8 | 181 | 2.8 |
| 12,000 | 1,128 | 7.5 | 9.4 | 145 | 2.2 |
| 10,000 | 940 | 6.2 | 7.8 | 121 | 1.9 |
| 8,000 | 752 | 5.0 | 6.3 | 97 | 1.5 |
| 6,000 | 564 | 3.7 | 4.7 | 72 | 1.1 |
| 4,000 | 376 | 2.5 | 3.1 | 48 | 0.8 |
| 2,000 | 188 | 1.3 | 1.6 | 24 | 0.4 |
| 1,000 | 94 | 0.6 | 0.8 | 12 | 0.2 |
| **Scenario 2** | | | | | |
| 15,000 | 1,515 | 10.0 | 12.6 | 195 | 3.0 |
| 12,000 | 1,212 | 8.0 | 10.1 | 156 | 2.4 |
| 10,000 | 1,010 | 6.7 | 8.4 | 130 | 2.0 |
| 8,000 | 808 | 5.4 | 6.7 | 104 | 1.6 |
| 6,000 | 606 | 4.0 | 5.0 | 78 | 1.2 |
| 4,000 | 404 | 2.7 | 3.4 | 52 | 0.8 |
| 2,000 | 202 | 1.3 | 1.7 | 26 | 0.4 |
| 1,000 | 101 | 0.7 | 0.8 | 13 | 0.2 |
| **Scenario 3** | | | | | |
| 15,000 | 1,230 | 8.2 | 10.2 | 158 | 2.5 |
| 12,000 | 984 | 6.5 | 8.2 | 126 | 2.0 |
| 10,000 | 820 | 5.4 | 6.8 | 105 | 1.6 |
| 8,000 | 656 | 4.3 | 5.5 | 84 | 1.3 |
| 6,000 | 492 | 3.3 | 4.1 | 63 | 1.0 |
| 4,000 | 328 | 2.2 | 2.7 | 42 | 0.7 |
| 2,000 | 164 | 1.1 | 1.4 | 21 | 0.3 |
| 1,000 | 82 | 0.5 | 0.7 | 11 | 0.2 |

(a) After on-farm and scheme O & M costs have been deducted.
(b) At US$222/ton; milled rice yield 68%.
(c) At US$120/ton.
(d) At US$82/ton sugar; extraction 9.5%.
(e) At US$1,520/ton; lint yield 33%.

6. Evidently net returns of US$300 to US$400/ha/year, which are the sorts of values currently achieved from rice, maize, sugarcane or cotton on some of the better small-farmer irrigation projects in SSA, can support an investment cost of no more than about US$2,500/ha at a conventional opportunity cost for capital of 12%. Even if, because of additional social benefits, a return of no more than 7% is demanded, the maximum supportable cost is only about US$4,000/ha.

7. Reversing the procedure it is possible to calculate the capital costs supportable at somewhat higher levels of output which might be attainable on average on government irrigation projects in the future. The following assumptions can be made on production. They give net annual output values of US$550 to 750/ha/year.

| Crops | Yield (t/ha/crop) | Cropping Intensity (%) | Production Costs (% of production value) |
|---|---|---|---|
| Paddy | 3.5 | 150 | 30 |
| Maize | 3.5 | 150 | 15 |
| Sugarcane | 100.0 | 100 | 20 |
| Seed cotton | 2.5 | 100 | 40 |

8. On these assumptions, the supportable levels of investment for an ERR of 12% or 7% are shown below.

| | Paddy | Maize | Sugarcane | Seed Cotton |
|---|---|---|---|---|
| Gross production (t/ha/yr) | 5.3 | 5.3 | 100 | 2.5 |
| Net production (t/ha/yr) | 3.7 | 4.5 | 80 | 1.5 |
| Value of net production (US$/ha/yr) | 560 | 540 | 623 | 752 |
| Supportable investment at an ERR of 12% (US$/ha) | | | | |
| - Scenarios 1 and 2 | 3,684 | 3,553 | 4,079 | 4,934 |
| - Scenario 3 | 4,480 | 4,320 | 4,960 | 6,000 |
| Supportable investment at an ERR of 7% (US$/ha) | | | | |
| - Scenario 1 | 5,957 | 5,745 | 6,628 | 8,000 |
| - Scenario 2 | 5,545 | 5,347 | 6,168 | 7,446 |
| - Scenario 3 | 6,829 | 6,585 | 7,561 | 9,146 |

9. The implication of these results is that, even at the better present levels of production efficiency, none of the crops is likely to generate an adequate economic return at investment costs for the irrigation system of more than US$6,000 per hectare. For maize and paddy investment beyond US$4,500 per hectare would be unprofitable. Projects with higher construction costs would require either levels of efficiency which have not so far been obtained, or the addition to the cropping pattern of some higher value items - for instance vegetable crops.

10. Clearly in an analysis intended to illustrate in a quick manner the relationship between expected output and maximum investments several simplistic assumptions have been made. For example no residual crop values have been included, processing costs of crops have been assumed to be covered by their by-products, and current world prices have been used instead of medium or long-term forecasts. These details do not undermine the validity of this form of analysis, although it is clear that in practice all values need to be based on actual conditions of specific projects.

11. The important point, however, is that a simple initial analysis of this sort can allow planners to consider different project approaches and technologies at the preparatory stage, when realistic assessment needs to be combined with all the imagination possible. Preliminary assessments can be made of options such as increasing the cropped area through supplementary irrigation, increasing irrigation intensity, selecting different designs or production technology, or the choice of different crops.

# STUDY OF IRRIGATION IN AFRICA SOUTH OF THE SAHARA

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